

Investigation of Earthquake Induced Changes in the Industrial Performance of Kahramanmaraş Using Gray Relational Analysis

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Abstract

The aim of this study is to analyze the industrial and economic vulnerability of Kahramanmaraş after the February 6, 2023 Kahramanmaraş earthquakes within the framework of a multi-criteria decision-making approach. This study uses criteria such as the number of newly established companies, the number of closed companies, exports, imports, employment, and electricity consumption; the pre-earthquake period, the earthquake year, and the post-earthquake recovery process are evaluated comparatively. Grey Relational Analysis (GRA) method was used in this research.

The findings of the study indicate that significant declines were observed in indicators such as exports, employment, and electricity consumption in 2023 coinciding with the earthquake period. According to the analysis results, 2022 was identified as the year with the highest performance, whereas 2023 was determined to be the year with the lowest performance level. In 2024 and 2025, the increases observed especially in employment and the number of newly established companies reveal that the industry has entered a recovery process. However, it was determined that the export, import, and electricity consumption indicators have not yet reached pre-earthquake levels. In conclusion, this study contributes to the evaluation of post-disaster regional industrial performance and provides data-driven insights for policymakers and decision-makers.

Key Words: Disaster Economics, Economic Vulnerability, Industrial Performance, Multi-Criteria Decision Making, Grey Relational Analysis

Jel Codes: D81, L60, Q54, R11

Kahramanmaraş Sanayi Performansındaki Deprem Kaynaklı Değişimlerin Gri İlişkisel Analiz ile İncelenmesi

Öz

Bu çalışmanın amacı, 6 Şubat 2023 Kahramanmaraş depremleri sonrasında Kahramanmaraş'ın sanayi ve ekonomik kırılganlığını çok kriterli karar verme yaklaşımı çerçevesinde analiz etmektir. Çalışmada yeni kurulan şirket sayısı, kapanan şirket sayısı, ihracat, ithalat, istihdam ve elektrik tüketimi gibi kriterler kullanılarak deprem öncesi dönem, depremin gerçekleştiği yıl ve deprem sonrası toparlanma süreci karşılaştırmalı olarak değerlendirilmiştir. Araştırmada Gri İlişkisel Analiz (GİA) yöntemi kullanılmıştır.

Çalışmanın bulguları, depremin etkisiyle 2023 yılında ihracat, istihdam ve elektrik tüketimi gibi göstergelerde önemli düşüşlerin meydana geldiğini göstermektedir. Analiz sonuçlarına göre, 2022 yılı en yüksek performansın sergilendiği yıl, 2023 yılı ise en düşük performans düzeyinin görüldüğü yıl olarak belirlenmiştir. 2024 ve 2025 yıllarında özellikle istihdam ve yeni kurulan şirket sayısında gözlenen artışlar, sanayi sektörünün bir toparlanma sürecine girdiğini ortaya koymaktadır. Bununla birlikte, ihracat, ithalat ve elektrik tüketimi göstergelerinin henüz deprem öncesi seviyelere ulaşmadığı tespit edilmiştir. Bu çalışma, afet sonrası bölgesel sanayi performansının değerlendirilmesine katkı sağlamakta ve politika yapıcılar ile karar vericilere veri temelli çıkarımlar sunmaktadır.

Anahtar Kelimeler: Afet Ekonomisi, Ekonomik Kırılganlık, Sanayi Performansı, Çok Kriterli Karar Verme, Gri İlişkisel Analiz

Jel Kodları: D81, L60, Q54, R11

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1. Introduction

The economy is vital for a country's development and prosperity. A country's economic strength directly impacts not only its domestic economic stability but also its global competitiveness, social welfare, and position in international trade. Economic metrics such as economic growth, employment rates, foreign trade volume, current account balance and inflation are key indicators that play a critical role in assessing a country's economic health. Fluctuations in these metrics often become more pronounced following unexpected events such as natural disasters (Tüfenk, 2024: 132). Disasters have multifaceted impacts on societies, causing loss of life and injury, as well as increasing population mobility, disrupting social order, damaging human and natural resources, and resulting in significant economic losses (Markhvida and Baker, 2023: 914). Earthquakes are considered one of the most destructive natural disasters (Brown et al., 2015; Mao et al., 2020: 1).

The major earthquakes that have occurred in Turkey in the last century are noteworthy not only for the loss of life but also for the devastation they have caused to the economic system. Disruptions in the industrial, agricultural, transportation and service sectors, in particular, have led to disruptions in the production chain and hampered regional development goals (Orçun et al., 2026: 48). The 2023 Kahramanmaraş earthquakes are considered one of the biggest disasters of the Republic era, and are regarded as among the most destructive and widespread tremors not only on a national scale but also globally. This disaster affected a total of 11 provinces, impacting a vast geographical area representing approximately 15% of Turkey's land surface (Bardakçı and Demirtaş, 2023: 186). Disasters can disrupt the operation of businesses through damage to non-structural elements and disruptions in operational processes (Kajitani and Tatano, 2014: 16); this can lead to serious economic losses (The World Bank, 2020).

Of the country's total exports amounting to 254.2 billion USD in 2022, 21.9 billion USD, corresponding to 8.6%, was generated by the provinces located in the earthquake-affected region. In 2021, the share of the manufacturing industry in the regional provinces within Turkey's Gross Domestic Product (GDP) was 11.5%. The sectors with exports exceeding 300 million USD in the region include chemicals, textiles and food in Adana; chemicals, food, textiles, machinery and furniture in Gaziantep; iron and steel and fresh fruit in Hatay and Osmaniye; and steel, textiles in Kahramanmaraş. This overall picture demonstrates that the export and production structures of the regional provinces are shaped on the basis of sectoral concentration and, therefore, exhibit varying levels of vulnerability to external shocks. In this context, examining the export performance specifically in Kahramanmaraş is crucial in order to reveal the concrete implications of this structure (Ministry of Industry and Technology of the Republic of Turkey, 2023: 50).

Indeed, considering the province's sectoral specialization and production capacity, it is assessed that the changes experienced in the post-earthquake period can be observed more clearly. An examination of Kahramanmaraş's export performance reveals that exports, which amounted to 120,036 thousand USD in 2022, declined to 94,445 thousand USD in 2023. However, in the following period, they exhibited a recovery trend and reached 102,507 thousand USD in 2025. (The data in question are based on statistics published in November of each year) (KMTSO, 2026). In this context, Kahramanmaraş attracts attention both as the epicenter of the earthquakes and as a province possessing significant production capacity in sectors such as textiles, yarn, metal and food. The concentration of the provincial economy in specific sectors may lead to industrial economic vulnerabilities becoming more pronounced in the post-disaster period. Factors such as disruptions in production processes, suspension of business operations, capacity reductions, job losses and problems arising within the supply chain constitute the primary elements that increase the vulnerability of the regional economy. Therefore, the case of Kahramanmaraş stands out as an important field of research in the examination of post-earthquake industrial economic vulnerability.

The existing literature on the subject includes numerous studies examining the changes occurring in the economic structures of countries, regions, cities and businesses following various disasters. Particularly following the 2023 Kahramanmaraş earthquakes, various studies have been conducted using different evaluation criteria related to the economic, social and sectoral structure of the region. The aim of this study is to analyze the industrial economic vulnerability of the province following the Kahramanmaraş earthquakes that occurred in 2023 within the framework of multi-criteria decision making approaches.

In this context, the Grey Relational Analysis (GRA) method, which enables the holistic evaluation of different economic indicators, was employed in the study. The originality of the study lies in its comparative evaluation of the pre- and post-earthquake performance of Kahramanmaraş's industrial sector by jointly examining different economic indicators such as the numbers of newly established companies and closed companies, exports, imports, employment and electricity consumption. Furthermore, this study contributes to the literature by revealing the multidimensional effects of disasters on the regional industrial structure. Through the findings obtained, the study aims to provide data driven evaluations and strategic implications for policymakers, local administrators and decision makers. This study consists of five sections. Following the introduction, the second section presents the literature review related to the subject, the third section explains the dataset and methodology, the fourth section presents the analysis findings, and the final section includes the conclusion and discussion based on the findings obtained.

2. Literature Review

The effects of natural disasters on economic systems generate multidimensional consequences such as production losses, employment contraction, disruptions in foreign trade, business closures and financial vulnerabilities. Therefore, the effects of disasters on the industrial economy have been examined in the literature at different scales, across various sectors and through diverse methodologies. Existing studies can generally be categorized into five main groups: (i) firm financial performance, (ii) foreign trade and macroeconomic effects, (iii) industrial production, employment and regional recovery, (iv) international comparative studies on industrial resilience, and (v) post-disaster business recovery models.

The first group of studies has focused on the effects of the February 6, 2023 Kahramanmaraş earthquakes on the financial performance of businesses. Akgemci (2023) identified increases in the liquidity and return on assets ratios of firms operating in the construction sector, indicating a partial post-earthquake recovery. Similarly, Akpınar and Karyağdı (2025) determined that the majority of firms operating in the construction and cement sectors experienced improvements in financial performance. In contrast, Orçun et al. (2026) revealed a general decline in the performance of companies operating in the textile, apparel and leather sectors, while emphasizing the growing importance of liquidity and cash management. When these studies are evaluated together, it can be understood that post-earthquake recovery differs across sectors and that sectors associated with reconstruction processes tend to recover more rapidly.

The second group of studies examined the effects of earthquakes on foreign trade and macroeconomic indicators. Erdoğan (2025) analyzed the export performance of the 11 provinces affected by the earthquake and demonstrated that industrial electricity consumption had a positive effect on exports. Tanrıverdi (2025) determined that the export performance of firms in the earthquake region was negatively affected by 6.85% in the medium term. Bardakçı and Demirtaş (2023), as well as Tüfenk (2024), stated that the earthquakes led to declines in Turkey's exports and imports, disruptions in supply chains and economic slowdown.

The third group of studies focused on post-earthquake industrial production, labor markets and regional recovery processes. Şekkeli et al. (2026) stated that labor losses, capacity reductions and financial vulnerabilities increased in the Kahramanmaraş textile sector. Türkcan (2025) revealed that production and employment losses negatively affected the regional economy. Boz (2025) demonstrated that serious deteriorations occurred in the labor market in Hatay province. Engin and Özdemir (2024) emphasized that migration movements affected the regional economic structure. On the other hand, Kızıltoprak (2026) determined that Kahramanmaraş recovered more rapidly than Hatay in certain indicators. These studies reveal that post-earthquake economic recovery occurs at different rates across provinces.

The international literature on this subject also provides important evidence. Liu et al. (2021; 2024) modeled production capacity losses and recovery processes in industrial sectors following the Kumamoto earthquakes in Japan and emphasized the critical role of energy and infrastructure services. Liu et al. (2023) demonstrated that the manufacturing sector recovered more slowly than non-manufacturing sectors. Zhao et al. (2025) stated that indirect industrial losses in the Wenchuan earthquake were considerably higher than direct losses. On the other hand, Mohan et al. (2023)

demonstrated that certain disasters may lead to technological renewal and productivity increases. These findings indicate that industrial resilience depends not only on physical damage but also on infrastructure, energy systems and sectoral structure.

Recent studies have addressed post-disaster recovery processes and the spatial impacts on businesses. Li and Hong (2019) determined that business recovery following the Lushan earthquake exhibited spatial clustering and that neighboring businesses influenced one another. Mao et al. (2020) revealed that the duration of business closures across different sectors varied depending on disruptions in infrastructure, logistics and labor supply. Markhvida and Baker (2023) analyzed direct and indirect economic losses associated with earthquakes through a holistic model. These studies demonstrate that business recovery is a complex process characterized by spatial and sectoral interdependencies.

An examination of the existing literature reveals that most studies primarily focus on firm financial performance, foreign trade effects or single-sector analyses. However, studies that holistically measure the vulnerability of the post-earthquake industrial economy through multidimensional indicators such as company openings and closures, exports, imports, employment and electricity consumption remain limited. Furthermore, empirical research specifically evaluating the industrial economy of Kahramanmaraş through multi-criteria decision making methods is quite scarce. In this context, the present study makes an original contribution to the literature by measuring the vulnerability level of Kahramanmaraş's post-earthquake industrial economy using the grey relational analysis method.

3. Methodology

3.1. Scope of the Research and Dataset

This study aims to analyze the post-earthquake industrial economic vulnerability of Kahramanmaraş. In this regard, the main indicators representing the province's industrial and economic structure were taken into consideration. The criteria used in this research consisted of the number of newly established companies, the number of closed companies, exports, imports, employment and electricity consumption. These indicators enable a holistic evaluation of the continuity of economic activities, production capacity and industrial performance in the region. In addition, the study comparatively examines the pre-earthquake period, the year in which the earthquake occurred and the post-earthquake recovery process in order to reveal the changes in economic indicators. Within this framework, the grey relational analysis method was used to evaluate the relationships among these indicators, and the dimensions and indicators associated with economic vulnerability in the post-earthquake period were identified in the post-earthquake period.

The criteria used in the study were selected from the economic indicators included in the monthly economic bulletins published by the Kahramanmaraş Chamber of Commerce and Industry. However, due to the inability to obtain regular and comparable data for certain indicators across different years, six criteria for which data continuity could be ensured were included in the analysis. An examination of the existing literature indicates that a significant portion of the criteria employed in this research has previously been used in studies on disaster economics, regional vulnerability and industrial performance. Among these, the indicators of exports, imports, employment and electricity consumption were utilized in the studies conducted by Bardakçı and Demirtaş (2023), Tüfenk (2024), Erdoğan (2025) and Tanrıverdi (2025). When evaluated specifically in terms of the employment criterion, Türkcan (2025), Boz (2025) and Şekkeli et al. (2026) stated that labor losses, employment contraction and declines in production capacity constitute some of the most important indicators of the post-earthquake economic structure. Furthermore, evaluations related to industrial production and energy consumption are also emphasized in the studies conducted by Liu et al. (2023), which highlight the critical role of energy and infrastructure services in industrial recovery. Li and Hong (2019) and Mao et al. (2020) examined post-disaster economic recovery through business reopening processes and closure durations. In this context, the criteria of newly established and closed companies used in the study contribute to measuring regional economic dynamism and business resilience. Therefore, the criteria preferred in this study are supported by the literature not only in terms of data accessibility but also in terms of their capacity to represent post-disaster economic vulnerability, industrial performance, production capacity, foreign trade and labor markets. In this respect, the research brings together indicators that have been addressed separately in different studies within a holistic framework and evaluates the economic performance of Kahramanmaraş's industrial sector in a multidimensional manner across the pre-earthquake period, the earthquake year and the post-earthquake period.

The data used in the study were obtained from secondary data sources reflecting the general economic outlook of Kahramanmaraş's industrial sector. In this context, the data were compiled from publicly available sources published by the Kahramanmaraş Chamber of Commerce and Industry and the Social Security Institution (SSI).

In order to ensure comparability across years during the construction of the dataset, only the first ten months (January-October) of each year were included in the analysis. The primary reason for this approach was the inability to regularly access post-October data for certain years and the intention to preserve data integrity. Through this approach, a homogeneous and comparable data structure was established for all periods included in the analysis.

The significance of this study emerges from several key aspects. First, while a substantial portion of the studies in the disaster and economics literature focus on macro-level analyses, this study provides a detailed examination at the provincial level. In this respect, this study contributes to addressing the lack of regional analyses in the literature. Second, the use of Grey Relational Analysis, one of the multi-criteria decision making methods, in measuring post-disaster economic vulnerability offers a methodological contribution by demonstrating the applicability of the method in this field. Particularly in post-disaster processes characterized by data limitations and high levels of uncertainty, the use of such methods enables the achievement of more reliable and meaningful results.

3.2. Research Method: Grey Relational Analysis

In this study, the Grey Relational Analysis (GRA) technique, one of the multi-criteria decision making methods, was employed. Based on grey system theory, this method enables the analysis of relationships among alternatives, particularly in situations characterized by uncertainty and incomplete information.

The grey relational analysis method was preferred because it allows the comparison of criteria with different measurement units and produces effective results with small datasets. Since data deficiencies and irregularities are frequently encountered in post-disaster periods, this method constitutes an appropriate analytical tool for the purpose of the study. Furthermore, GRA identifies the degree of relationships among criteria and reveals which indicators are more influential on economic vulnerability. The grey relational analysis method is implemented through specific stages, and the process consists of the following steps.

3.2.1. Preparation of the Dataset and Construction of the Decision Matrix

A total of m criteria to be compared within the scope of the decision problem are determined. The criteria are defined as shown in Equation (1).

$$x_i = (x_i(1), \dots, x_i(n)), \quad i = 1, 2, \dots, m \text{ and } j = 1, 2, \dots, n \quad (1)$$

While x_i represents the alternatives, $x_i(j)$ denotes the performance values of the alternatives with respect to each criterion. The decision matrix is constructed as expressed in Equation (2) (Yıldırım & Önder, 2015: 233).

$$X = \begin{bmatrix} x_1(1) & x_1(2) & \cdots & x_1(n) \\ x_2(1) & x_2(2) & \cdots & x_2(n) \\ \vdots & \vdots & \ddots & \vdots \\ x_m(1) & x_m(2) & \cdots & x_m(n) \end{bmatrix} \quad (2)$$

3.2.2. Construction of the Reference Series and the Comparison Matrix

The reference series determined for comparing the criteria in the decision matrix is formulated as shown in Equation (3). In the formula $x_0(j)$, represents the most appropriate value among the normalized values of the j . criterion. This series expresses the optimal value of each criterion included in the decision matrix (Özbek, 2017: 144).

(3)

$$X_0 = (x_0(j)), \quad \text{and} \quad j=1,2, \dots, n$$

3.2.3. Normalization of the Decision Matrix

The difficulties associated with evaluating indicators of different dimensions necessitate the standardization of the data. This process is carried out with the help of Equations (4), (5) and (6) (Peker and Baki, 2011: 8).

$$x_i(j) = [x_i(j) - \min x_i(j)] / [\max x_i(j) - \min x_i(j)] \quad (4)$$

$$x_i(k) = [\max x_i(j) - \min x_i(j)] / [\max x_i(j) - \min x_i(j)] \quad (5)$$

$$x_i(j) = 1 - |x_i(j) - u_i| / |x_i(j) - u_i| \quad (6)$$

Equation (4) represents the benefit criteria, Equation (5) represents the cost criteria and Equation (6) demonstrates the standardization of these criteria by transforming them into optimal values.

3.2.4. Construction of the Absolute Difference Matrix

The value of the absolute difference between x_0 and x_i , denoted as $\Delta_{0i}(j)$, is obtained with the help of Equation (7) (Yıldırım & Önder, 2015: 234).

$$\Delta_{0i} = |x_0(j) - x_i(j)| \quad i=1,2, \dots, m \quad j=1,2, \dots, n \quad (7)$$

$$\Delta_{0i} = \begin{bmatrix} \Delta_{01}(1) & \Delta_{01}(2) & \dots & \Delta_{01}(n) \\ \Delta_{02}(1) & \Delta_{02}(2) & \dots & \Delta_{02}(n) \\ \vdots & \vdots & \ddots & \vdots \\ \Delta_{0m}(1) & \Delta_{0m}(2) & \dots & \Delta_{0m}(n) \end{bmatrix}$$

3.2.5. Construction of the Grey Relational Coefficient Matrix

The Grey Relational Coefficient Matrix is calculated using Equations (8) and (9).

$$\gamma_{0i}(j) = \frac{\Delta_{\min} + \zeta \Delta_{\max}}{\Delta_{0i}(j) + \zeta \Delta_{\max}} \quad (8)$$

$$\Delta_{\max} = \max_i \max_j \Delta_{0i}(j) \quad \Delta_{\min} = \min_i \min_j \Delta_{0i}(j) \quad (9)$$

The parameter ζ included in Equation (8) is the distinguishing coefficient, which takes values within the range of $0 \leq \zeta \leq 1$. In the literature, the value of $\zeta = 0,5$ is generally used as the distinguishing coefficient (Peker and Baki, 2011: 9).

3.2.6. Calculation of Grey Relational Grades

In order to construct the relational matrix, the grey relational grades corresponding to each difference dataset are calculated. Equation (10) represents the grey relational grade of the i -th series and the case in which the criteria are equally weighted.

$$\Gamma_{0i} = \frac{1}{n} \sum_{j=1}^n Y_{0i}(j) \quad i=1,2, \dots, m \quad (10)$$

In Equation (11), $w_i(j)$ represents the weight of the j -th criterion and expresses the case in which the criteria have different levels of importance.

$$\Gamma_{0i} = \sum_{j=1}^n [w(j) \cdot Y_{0i}(j)] \quad i=1,2, \dots, m \quad (11)$$

After the grey relational grades are calculated, they are ranked from highest to lowest in order to demonstrate their geometric similarity to the reference series. The alternative with the highest grey relational grade is considered the most appropriate option for the decision problem.

3.3. Limitations of the Study

The study has certain limitations. First, the dataset covers only the first ten months of each year, which restricts the ability to conduct a full-year evaluation. In addition, the method employed allows for relative assessments based on the available data, rather than directly measuring absolute economic impacts.

4. Findings

Based on the determined criteria, the decision matrix was constructed and the data related to the criteria to be used in the analysis were organized. In order to make the data with different measurement units comparable, a normalization process was performed. The reference series was determined, and grey relational coefficients were calculated for each criterion. Using the obtained coefficients, grey relational grades were computed and the relative importance levels of the criteria were identified. As a result of this process, the industrial economic vulnerability level of Kahramanmaraş was comparatively evaluated across the examined periods.

In this study, data analysis and calculations were carried out using Python, an open-source programming language. The Python programming language was preferred due to the flexibility and speed it provides in data processing, analysis and mathematical modeling. Throughout the analysis process, all analytical procedures, including data organization, normalization and the calculation of grey relational coefficients, were conducted within the Python environment. This section presents the findings obtained as a result of the analyses carried out within the scope of the research.

4.1. Preparation of the Dataset and Construction of the Decision Matrix

A comprehensive literature review on the measurement of industrial performance was conducted, and six evaluation criteria and five years were identified for analysis. The evaluation criteria consist of newly established companies, closed companies, exports, imports, employment and electricity consumption. Data covering the first ten months (January-October) of each year were used in the analysis. The reason for this preference is that the data for the last two months of some years could not be accessed. Since the common accessible data for all years covered the January-October period, the first ten months were selected. The determined years are presented in Table 1, while the evaluation criteria are provided in Table 2.

Table 1. Evaluated Years

Years
2021
2022
2023 (Year of the February 6 Earthquake)
2024
2025

Table 2. Evaluation Criteria

Criterion Code	Definition of the Criterion
K1	Newly Established Companies
K2	Closed Companies
K3	Exports (*1000 Dollar)
K4	Imports (*1000 Dollar)
K5	Employment
K6	Electricity Consumption (MWh)

Table 3 presents the decision matrix related to the industrial performance of Kahramanmaraş. Among the criteria used in the study, the number of closed companies was evaluated as a cost-oriented (min) criterion, whereas the remaining criteria were considered benefit-oriented (max) criteria. The main reason for this classification is that increases in the number of newly established companies, exports, imports, employment and electricity consumption are associated with the revitalization of industrial activities, growth in production capacity and strengthening of economic performance. In contrast, an increase in the number of closed companies indicates the inability of businesses to sustain their operations, economic contraction and increased regional vulnerability, and was therefore regarded as a negative indicator. Consequently, lower values for the number of closed companies were considered more favorable in the analysis process, and the criterion was incorporated into the model as a cost-oriented criterion.

Table 3. Decision Matrix of the Kahramanmaraş Industrial Sector

	Max	Min	Max	Max	Max	Max
	K1	K2	K3	K4	K5	K6
2021	709	151	1.113.587	752.868	171.476	1.375.811
2022	783	149	1.230.970	1.477.532	175.714	1.461.948
2023	709	94	837.361	1.034.461	164.117	733.174
2024	826	126	921.815	983.702	180.067	876.893
2025	861	164	1.068.216	1.044.187	206.612	896.312

4.2. Construction of the Reference Series and the Comparison Matrix

The reference series was determined by considering the highest performance values for each criterion among the alternatives. The decision matrix with the constructed reference series is presented in Table 4.

Table 4. Decision Matrix with the Reference Series Added

	Max	Min	Max	Max	Max	Max
	K1	K2	K3	K4	K5	K6
Reference Series	861	94	1.230.970	1.477.532	206.612	1.461.948
2021	709	151	1.113.587	752.868	171.476	1.375.811
2022	783	149	1.230.970	1.477.532	175.714	1.461.948
2023	709	94	837.361	1.034.461	164.117	733.174
2024	826	126	921.815	983.702	180.067	876.893
2025	861	164	1.068.216	1.044.187	206.612	896.312

4.3. Normalization of the Decision Matrix and Construction of the Normalization Matrix

Following the construction of the reference series and its inclusion in the dataset, a normalization process was applied in order to make the alternatives comparable and eliminate the effects of different measurement units.

Table 5. Normalized Decision Matrix

	Max	Min	Max	Max	Max	Max
	K1	K2	K3	K4	K5	K6
Reference Series	1,000	1,000	1,000	1,000	1,000	1,000
2021	0.000000	0.185714	0.701778	0.000000	0.173173	0.881806
2022	0.486842	0.214286	1.000000	1.000000	0.272903	1.000000
2023	0.000000	1.000000	0.000000	0.388584	0.000000	0.000000
2024	0.769737	0.542857	0.214563	0.318539	0.375338	0.197207
2025	1.000000	0.000000	0.586508	0.402006	1.000000	0.223853

The normalized decision matrix for the five years is presented in Table 5. In this process, minimum oriented criteria were treated as cost criteria, whereas maximum oriented criteria were considered benefit criteria.

4.4. Construction of the Absolute Difference Matrix

In this step, the absolute differences between the normalized reference series and the normalized values of the alternatives were determined. These calculations were performed using Equation (7), and the results are presented in Table 6.

Table 6. Absolute Difference Matrix

	K1	K2	K3	K4	K5	K6
2021	1.000000	0.814286	0.298222	1.000000	0.826827	0.118194
2022	0.513158	0.785714	0.000000	0.000000	0.727097	0.000000
2023	1.000000	0.000000	1.000000	0.611416	1.000000	1.000000
2024	0.230263	0.457143	0.785437	0.681461	0.624662	0.802793
2025	0.000000	1.000000	0.413492	0.597994	0.000000	0.776147

4.5. Construction of the Grey Relational Coefficient Matrix

In order to transform all criteria into grey relational coefficients, Table 7 was constructed using Equations (8) and (9) with $\zeta = 0,5$.

Table 7. Grey Relational Coefficient Matrix

	K1	K2	K3	K4	K5	K6
2021	0.333333	0.380435	0.626392	0.333333	0.376839	0.808807
2022	0.493506	0.388889	1.000000	1.000000	0.407466	1.000000
2023	0.333333	1.000000	0.333333	0.449877	0.333333	0.333333
2024	0.684685	0.522388	0.388973	0.423205	0.444578	0.383791
2025	1.000000	0.333333	0.547350	0.455376	1.000000	0.391804

4.6. Determination of Grey Relational Grades

The grey relational grades were calculated using the grey relational coefficients, and the years were subsequently ranked according to their performance. In the evaluation of the grey relational coefficient matrix, two approaches are generally adopted; assigning equal weights or different weights to the criteria. In this study, the assumption that all criteria have equal weights was adopted. Rather than prioritizing a specific economic dimension, an equal weighting approach was adopted to provide a multidimensional and balanced assessment of industrial performance. In addition, based on expert opinions, it was determined that the importance levels of the criteria were quite similar and that each

criterion played an important role in evaluating industrial performance. Therefore, equal weights were assigned to all criteria in order to avoid introducing unnecessary subjectivity into the results by prioritizing any criterion over the others.

Table 8. Performance Ranking of the Years

Year	K1	K2	K3	K4	K5	K6	Γ_{i0i}	Ranking
2022	0,494	0,389	1,000	1,000	0,407	1,000	0,715	1
2025	1,000	0,333	0,547	0,455	1,000	0,392	0,621	2
2021	0,333	0,380	0,626	0,333	0,377	0,809	0,477	3
2024	0,685	0,522	0,389	0,423	0,445	0,384	0,475	4
2023	0,333	1,000	0,333	0,450	0,333	0,333	0,464	5

In the K1 (Newly Established Companies) and K5 (Employment) criteria, the highest values over the years were observed in 2025, whereas the lowest values belonged to 2023. According to the K3 (Exports) and K6 (Electricity Consumption) criteria, the highest values were recorded in 2022, while the lowest values occurred in 2023. One of the most noteworthy criteria in this context is K2 (Closed Companies). The highest number of closed companies was recorded in 2025, while the lowest number was observed in 2023.

The findings obtained indicate that the industrial sector of Kahramanmaraş reached its highest performance level in 2022, experienced a significant performance decline during the earthquake year that occurred in 2023, and entered a gradual recovery process during the 2024-2025 period.

Table 9. Sensitivity Analysis of Grey Relational Rankings

Scenario	1st	2nd	3rd	4th	5th
Equal weights	2022	2025	2021	2024	2023
Trade & energy emphasis	2022	2025	2021	2024	2023
Business & employment emphasis	2022	2025	2024	2023	2021

As presented in Table 9, the robustness analysis was conducted under two alternative weighting scenarios. In the first scenario, greater weights were assigned to exports and electricity consumption, whereas the second scenario assigned greater weights to newly established companies, closed companies, and employment. The results show that 2022 remained the highest-performing year and 2025 maintained its second position under both alternative weighting scenarios. Although minor changes were observed in the ranking of the remaining years, the overall ranking pattern remained largely stable. These findings indicate that the main results are robust and are not substantially sensitive to changes in the criterion weights.

5. Conclusion And Discussion

Overall, the findings indicate that the industrial sector of Kahramanmaraş experienced a significant disruption and subsequent recovery process during the examined period. The fact that the highest values in the criteria of newly established companies (K1) and employment (K5) were observed in 2025, while the lowest values occurred in 2023, indicates that post-earthquake economic activities and entrepreneurial dynamics weakened substantially but subsequently showed signs of recovery in the following period. These findings suggest a recovery in entrepreneurial activity and the labor market. Similarly, the highest values in the export (K3) and electricity consumption (K6) criteria were recorded in 2022, whereas the lowest values occurred in 2023, indicating that the earthquake year coincided with a strong contraction in production capacity and foreign trade indicators on production capacity and

foreign trade. In particular, the decline in electricity consumption stands out as one of the most concrete indicators of the disruption in industrial production. On the other hand, the closed companies criterion (K2) constitutes an indicator that should be interpreted carefully. The closed companies criterion (K2) should be interpreted cautiously. The number of closed companies was lowest in 2023 and reached its highest level in 2025. Therefore, this indicator does not provide a straightforward pattern of post-earthquake deterioration and may reflect administrative, sectoral and temporal factors. However, in post-disaster periods, delays in administrative closure procedures or the inability of actual business closures to be immediately reflected in official records should also be taken into consideration when interpreting this indicator.

The overall performance ranking also supports these findings. While 2022 stands out as the year with the highest performance, 2023 exhibits the lowest performance level. The improvement observed in 2024 and particularly in 2025 indicates that the industrial sector has entered a restructuring process and that a significant recovery has occurred, especially in employment and company establishment indicators. However, the fact that foreign trade and production indicators have not yet returned to their 2022 levels demonstrates that the recovery process remains incomplete.

In conclusion, the industrial sector of Kahramanmaraş experienced a multidimensional contraction coinciding with the effects of the 2023 earthquakes. However, in the following years, it entered a gradual recovery process, particularly through public support mechanisms, reconstruction activities and economic adaptation processes. While this situation demonstrates the existence of resilience capacity within the regional economy, it also indicates the necessity of strengthening production infrastructure, increasing foreign trade capacity and developing risk management policies that ensure the continuity of industrial activities in order to achieve sustainable recovery.

The contraction observed in 2023 may reflect not only production losses but also multidimensional factors such as labor losses, migration movements, logistics disruptions and difficulties in accessing finance. The parallel movement between electricity consumption and exports suggests an association between industrial production and foreign trade. Similarly, the positive directional change between the increase in employment and the number of newly established companies reveals that economic recovery has been supported by business dynamics at the micro level. The sharper decline in electricity consumption compared with the other variables suggests substantial disruption to industrial activities. This finding suggests that electricity consumption may serve as a potentially useful indicator for monitoring industrial disruptions in post-disaster contexts.

The recovery observed in 2024 and 2025 demonstrates that the industrial sector of Kahramanmaraş possesses a certain level of economic resilience capacity against shocks. This situation can be explained through the concept of “economic resilience,” which refers to the ability of regional economies to adapt and restructure in the aftermath of crises.

The findings obtained from the study reveal results that are consistent with many studies in the literature. In particular, the declines observed in exports, employment and electricity consumption in 2023 correspond with the findings of foreign trade contraction, production losses, and economic slowdown reported by Erdoğan (2025), Tanrıverdi (2025), Bardakçı and Demirtaş (2023) and Tüfenk (2024). Similarly, the results regarding labor losses, declines in production capacity and increasing economic vulnerability are parallel to the findings reported by Şekkeli et al. (2026), Türkcan (2025) and Boz (2025). Furthermore, the identification of a parallel movement between electricity consumption and exports supports the relationship among energy, production capacity and foreign trade emphasized in the studies conducted by Erdoğan (2025) and Liu et al. (2021; 2024).

The Grey Relational Analysis method enabled a holistic evaluation of regional economic performance by allowing data measured on different scales to be made comparable within the context of multi-criteria decision making problems. For future studies, it is recommended to conduct more detailed sector based analyses at the provincial level and to perform comparative evaluations using different multi-criteria decision making methods.

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