The evaluation of the effects of the COVID-19 pandemic on the Turkish manufacturing sector using AHP-TOPSIS methods

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Abstract

Purpose – The purpose of this study is to evaluate the effects of COVID-19 on the Turkish manufacturing sector by using analytical hierarchy process (AHP) and Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) methods on a sectoral basis. In this way, the sectors that had the highest negative effects of COVID-19 will be determined. Thanks to the findings to be obtained as a result of this study, it will be possible for decision-makers to develop strategies that may differ on a sectoral basis at the point of combating the pandemic.

Design/methodology/approach – The negative effects of COVID-19 were revealed by a large literature search. The importance levels of the factors determined within the scope of finance, supply, production and workforce were determined by the AHP method. Then, the TOPSIS method was used to determine which sectors were more affected by the COVID-19 pandemic, based on these factors.

Findings – The findings of this study obtained reveal that the most important negative effect of COVID-19 was on businesses in terms of reduced sales caused by domestic sales and export. Again, the findings show that the sector most affected by COVID-19 is automotive, which shows that the least affected sector is the pharmaceutical and medical equipment sector.

Practical implications – Primary data was used to determine the criteria weight. Therefore, there is a possibility that the answers are not objectively evaluated. The findings are limited to the criteria that was used, the views of the professionals and AHP-TOPSIS methods. Studies that use more criteria and different decision-making methods can have different results.

Originality/value – The manufacturing sector is at the forefront of the sectors affected by the global bottleneck caused by COVID-19. In this study, the effects of the COVID-19 pandemic on the Turkish manufacturing sector are discussed on a sectoral basis. Studies in the literature have revealed that the effects of pandemics such as COVID-19 vary between sectors. For this reason, it is important to evaluate the effects of COVID-19 from a sectoral perspective. Thanks to this study, it is thought that it will be possible to take measures that may differ between sectors to combat the negative effects of COVID-19.

Keywords COVID-19, Manufacturing sector, Multi-criteria decision-making, TOPSIS, AHP

Paper type Research paper

1. Introduction

COVID-19 has entered our lives as a pandemic that has affected the whole world. This pandemic, which caused the death of many people, has significantly limited both social life and business life with the fear and pressure on society (Luthi, 2020; Wang *et al.*, 2020). Like the pandemics experienced to date, the COVID-19 pandemic has had devastating effects on not only human health but also the economy, tourism, manufacturing, education and public activities (Goyal, 2020; Nicola *et al.*, 2020). In this process, consumer and producer confidence indices fell sharply; the government's budget revenues decreased and their expenditures increased; and unemployment rates increased. In this context, the worldwide spread of the COVID-19 pandemic affected production, supply chains and consumption, while sharply narrowing the economic activities in the world and bringing some sectors to a standstill (Harris *et al.*, 2020).

This pandemic, which has a devastating effect on the slowdown in economic activities, firm productivity and profitability, has caused the biggest global economic crisis since

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the Great Depression in the early 1930s (World Bank, 2020). The COVID-19 pandemic, which emerged in the city of Wuhan, China, has caused a huge economic collapse around the world. For example, the gross domestic product in the USA decreased by 1.3% in the first quarter of 2020 and by 9.5% in the second quarter of 2020 (OECD, 2020).

Quarantine measures taken especially in the fight against the pandemic, on the one hand, reduced the risk of transmission of the pandemic; on the other hand, it threatened many sectors on a global scale (Alon, 2020; Ozili and Arun, 2020). Situations such as the contraction or cessation of economic activities, reductions in labor supply and consumption and disruption of supply chains have deeply affected many sectors, especially manufacturing (Haleem *et al.*, 2020; Hughes *et al.*, 2020). Firms in this sector are experiencing a sharp decline in their income and performance because of both the disruption in the supply chain and declining personal consumption (Hassan *et al.*, 2020). These negativities caused a record decline in industrial production throughout the world. The negative consequences of the COVID-19 pandemic have affected many sectors. Restricting the free movement of their commodities by governments puts a lot of pressure on businesses, while it causes difficulties in raw material transfers and a serious shortage of supply. This situation creates risks such as not being able to meet the demand and rising prices (Butt, 2021). For example, Airbus Chief Executive Guillaume Faury stated that the aircraft manufacturing industry is experiencing the most severe crisis in its history (Rapaccini *et al.*, 2020).

Spreading as a result of human interactions, COVID-19 presents a very high risk of spread in industrial establishments that have a high human density. The coexistence of employees, both on the production line and in other common areas, increases the rate of spread of the pandemic and threatens business activities. However, to reduce the spread of the pandemic, there are situations such as the fact that the enterprises producing raw materials have to stop their activities or reduce their capacity and the borders of the country are closed. This situation eliminates the continuity of raw material supply and causes the disappearance of contracts between enterprises (Deloitte, 2020).

The Turkish manufacturing sector was also greatly affected by the crisis created by the COVID-19 pandemic that swept the world. The effects of the COVID-19 pandemic are undoubtedly seen in the production of industrial products such as automotive, textile, food, electronics, machinery and furniture, which constitute approximately 58% of Turkey's total exports (Dudaroglu, 2020). The manufacturing sector is one of the sectors most exposed to the problems created by the COVID-19 pandemic. According to TUIK data, Turkey's manufacturing industry usage volume decreased by 18% during the pandemic process. When examined from a sectoral point of view, the automotive sector is the leading sector of the Turkish economy when spare parts production is also taken into account. Because of the interruptions and slowdowns in supply processes, the sudden decline in the EU market, which is the most important export market, and order cancellations, the Turkish automotive industry has entered into a major crisis. There are business and turnover losses in the sector, where most companies take a break from their investments (Yenigun, 2020). The textile sector is another sector in which Turkey has a competitive power on a global scale. Especially the fact that China, which is at the center of the pandemic, has great problems in delivering its products to the European market under quarantine conditions has paved the way for the demand here to shift to Turkey. Therefore, it is expected that the textile industry will be among the sectors that slightly soften the negative effects of the pandemic process (SilkRoad Development Agency, 2020). The processed food sector is also one of the sectors least affected by the COVID-19 pandemic. The sector, which did not experience any contraction in demand during the pandemic process, has managed to adapt quickly to changing conditions thanks to the right strategies (Keyder *et al.*, 2020). Companies operating in the white goods-electronics sector, which have large-scale cooperation with European Union countries, had to stop or slow down their activities because of the rapid spread of the pandemic in Europe and the contraction in demand. However, the problems experienced in the supply chain and liquidity problems cause the crisis in the white goods-electronics sector to deepen. On the other hand, thanks to the important measures taken based on the sector, the negative effects of the pandemic were tried to be minimized. It is aimed that the white goods sector will survive the process with the least damage, thanks to measures such as planned reduction of production according to decreasing demands, bringing forward periodic stops in the production process, developing new strategies for stocking critical raw materials and making supply chains alternative (www.turkbesd.org, 2021). Crick and Crick (2020) stated that strong collaborations can be an effective marketing strategy for businesses and their stakeholders in the pandemic processes, as a result of their study in which they investigated the effects of business cooperation strategies in combating the COVID-19 pandemic. In addition, at this point, it was stated that businesses should be careful when choosing businesses to cooperate with, so that they do not adversely affect their performance. The chemical industry, which produces raw materials and intermediate goods for industry, is one of the sectors least affected by the COVID-19 pandemic. It is possible to say that the effective crisis management experience of the enterprises operating in this sector is important at this point. The chemical industry, which feeds many sectors and plays a leading indicator for the direction of economic activity, achieved an average growth of 8.5% in the September–November 2019 period. In this period, the general manufacturing industry index figures were realized as – 4.3% and 4.0%. In this context, it is possible to say that the sector has shown a better resistance and performance than the general average of the manufacturing industry. It is also possible to say that the turnover in the sector has followed a strong course in recent years (Bilirgen, 2020). Another factor least affected by the COVID-19 pandemic is the pharmaceutical and medical equipment sector. There is no problem in terms of sustainability in this sector, where demand is constantly increasing during the pandemic period. Especially in the pharmaceutical and medical equipment sector, the correct management of the pandemic and the reduction of its negative effects are possible thanks to accurate demand forecasting and determination of the number of infected patients. For this reason, medical equipment supply will enable accurate inventory management, thanks to the rapid, dynamic and

coordinated structure of the sector (Hossain *et al.*, 2022). The size of the global pharmaceutical industry at the end of 2019 is around US$1.3tn. This is expected to increase to US$1.5tn between 2020 and 2023. The situation of the sector in Turkey is also similar to the global structure. Turkey's geopolitical position creates the opportunity to diversify its export markets and constitutes an important power in making Turkey a regional pharmaceutical production base (Orhan, 2020).

The COVID-19 pandemic has brought with it risks and instabilities that prevent globally interconnected businesses from achieving their long-term goals. The negative effects of the pandemic expose disruptions to resource flow, leading to massive supply chain failures that halt production and service delivery. For this reason, it is very important for enterprises to develop a robust and agile supply chain against disruptions, dominated by high R&D coordination, integrated production processes and advanced business relations (Hossain *et al.*, 2022).

While research in recent years indicates that the COVID-19 pandemic is a catalyst that allows businesses to reconsider their business plans; it also states that short-term actions can be implemented to respond to the negative effects of the COVID-19 outbreak or reduce its spread and ensure business continuity (Rizou *et al.*, 2020; Mollenkopf *et al.*, 2020). For example Ivanov (2020) states that businesses should coach their employees on COVID-19 symptoms. In addition, Butt (2021) emphasized that businesses can continue their production during the pandemic process by adopting digital technologies, sharing new and updated information with existing and new suppliers thanks to strong automation and managing workforce diversity well. He stated that administrative measures based on the theory of social change will also be successful in eliminating the problems caused by the COVID-19 pandemic. At this point, the necessity of measures such as the development of in-house data analytics, the dissemination of e-commerce, the adoption of agile and proactive strategies, the strengthening and promotion of relationship orientation are very important in the struggle. In addition, the establishment of a central command center and providing trainings to increase the motivation of employees and to eliminate situations such as stress, anxiety and demoralization make it easier for businesses to cope with the difficulties of the pandemic process (Mora Cortez and Johnston, 2020).

In this study, the effects of the COVID-19 pandemic on the Turkish manufacturing sector are discussed on a sectoral basis. Loayza *et al.* (2012) revealed in their research that the effects of pandemic such as COVID-19 show differences between sectors. For this reason, it is important to evaluate the effects of COVID-19 from a sectoral perspective. This situation constitutes one of the strengths of the study. In this context, six criteria obtained as a result of wide literature research and expert opinions are weighted with the analytical hierarchy process (AHP) method. Then, the effects of these criteria on the determined sectors are revealed with the Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) method. In the second part of the study, previous studies on the subject are mentioned. Then, in the third section, the methods used in the study are explained, and in the fourth section, the criteria used in the research and the results of the analysis are given. In the last part, the findings are interpreted and various suggestions are made.

1.1 Motivation of research

The negative effects of the COVID-19 pandemic on a global scale are particularly felt in the manufacturing sector. In developing countries such as Turkey, the damage caused by these negative effects may be even deeper. Therefore, it is possible to compensate this damage quickly with precise and fast solutions. It is possible to say that the negative effects of the COVID-19 pandemic vary on a sectoral basis. At this point, the development of fast and definitive solution proposals against the negative effects of the pandemic can only be possible with sectoral assessments.

Comprehensive literature research shows that there are many studies on the COVID-19 pandemic. In addition to the studies carried out on a global scale, it is also possible to say that there are some studies made specifically for Turkey. However, it is very difficult to come across studies in which the subject is handled holistically by using multi-criteria decision-making (MCDM) methods on a sectoral basis, especially in the Turkish manufacturing industry. Existing studies in the literature have addressed the issue in general. In addition, the criteria regarding the negative effects of the pandemic process, which is quite complex in the literature, make it very difficult for decision-makers to take decisions on the subject. From this point of view, it is possible to say that the study is important in terms of literature. From this point of view, the negative effects of the pandemic will be determined according to their importance levels and the sectors that are most and least affected by these negative effects will be revealed. Thanks to the findings to be obtained as a result of the study, it will be possible for decision-makers to develop strategies that may differ on a sectoral basis at the point of combating the pandemic.

From this point of view, the study shows that the COVID-19 pandemic:

- What are the negative effects on the Turkish manufacturing industry?
- What is the significance level of adverse effects?
- What are the most and least affected sectors in the Turkish manufacturing industry?

designed in the framework.

2. Literature review

In this part of the study, studies dealing with the effects of COVID-19 on the manufacturing sector are mentioned. In addition, some studies using MCDM methods used in the research are also included.

The survey method was used in the study that was conducted by KPMG Turkey Consultancy to determine the sectoral effects of COVID-19. As a result of the study, it was concluded that the negative effects of COVID-19 have sectoral differences (KPMG, 2020). Lu *et al.* (2021) investigated the impact of the COVID-19 crisis on small- and medium-sized enterprises operating in different sectors. As a result of the research, it was concluded that COVID-19 has different sectoral effects and that the service sector is less affected by the crisis than the manufacturing sector. Harris *et al.* (2020) researched the COVID-19 crisis in the manufacturing sector in the UK. As a result of the research, they emphasized that the results of the COVID-19 pandemic should be evaluated by

making a sectoral distinction. The findings showed that the textile, leather products, machinery and electronics sectors were most affected by the COVID-19 pandemic in the UK. It was concluded that the sectors least affected by the pandemic were pharmaceuticals, chemicals, processed food and mining. Rapaccini *et al.* (2020) investigated the effects of COVID-19 on the Italian manufacturing sector in their research. Research findings indicated that the manufacturing sector should turn to digitalization eliminate the effects of COVID-19. The effects of COVID-19 on the global manufacturing sector were investigated by Orion Market Research (2020). In the presented report, it was stated that the COVID-19 pandemic had significant effects in the automotive, food, chemistry, electrical-electronics, pharmaceutical and medical equipment sectors. It was stated that many companies in these sectors were closed because of reasons such as supply problems, production stoppage and low demand, and new product development activities were stopped. Li (2021), in his study, revealed the organizational effects of COVID-19 on businesses operating in the manufacturing sector. The findings show that COVID-19 weakens organizational relationships and reduces business performance. Dubey *et al.* (2021) conducted a study that deals with supplier management and artificial intelligence-supported supply chain analytics capabilities of enterprises as basic dynamics within the scope of business-to-business cooperation. As a result of the study, it was revealed that supplier management increased the operational and financial success of enterprises under the mediation effect of artificial intelligence supported supply chain analytics at the point of coping with the negative effects of pandemic processes. Hu (2022) conducted a research to reveal the struggle of the personal protective equipment industry in Italy with the problems of supply chain and business relations that deteriorated during the COVID-19 process. As a result of the research, it has been seen that digital technologies and relationships enhance existing assets and capabilities that create new customer value during the COVID-19 pandemic. It has been concluded that these technologies enable business relations to be strengthened by sharing current information and training between businesses.

In the literature research, it was seen that the studies in which the subject was handled using MCDM were quite limited. This situation is considered to be very important in terms of the original value of the study.

When the existing studies in the literature about the AHP-TOPSIS methods used in the study were examined, it was seen that this method has widespread use in solving many different problems. Amiri (2010) carried out an application with the help of AHP-TOPSIS methods to develop oil fields. Again, Zare *et al.* (2015) used the AHP-TOPSIS method for electricity supply chain analysis. Beikkhakhian *et al.* (2015) evaluated the agile supplier selection criteria by using the AHP-TOPSIS methods together and ranked the suppliers in this respect. Sindhu *et al.* (2017) carried out feasibility studies for the establishment of solar farms using AHP-TOPSIS methods. Sennaroglu and Varlik Celebi (2018) used AHP-TOPSIS methods for military airport location selection. Kumar *et al.* (2021), using AHP and TOPSIS methods, presented a solution proposal for the problem of choosing optimum design parameters to increase the performance of nanomaterials.

3. Method

3.1 Analytical hierarchy process method

AHP, one of the MCDM approaches, was developed by Saaty in 1977. AHP is an approach based on matrices that reflect pairwise comparisons of decision-makers. Because of the simplicity of mathematical calculations, AHP is a method frequently preferred by researchers in terms of understanding and reaching solutions. Key components of the AHP structure include hierarchical structuring, weighting and consistency. AHP proposes an appropriate measure to test the consistency of a binary matrix (Harker, 1987; Saaty and Vargas, 2001; Uludag and Dogan, 2021).

Weights were determined in this decision-making problem using the AHP method, and to reach the final result, the opinion of an expert group of five people (D1, D2, D3, D4 and D5) consisting of academicians and sector representatives was consulted. The arithmetic averages were taken by taking the opinions of the decision-makers. The scale in Table 1 was used for pairwise criterion comparisons.

Within the scope of AHP, the mathematical method steps are as follows:a_1, a_2, a_3, …, a_n are the decision criteria; w_1, w_2, w_3 and w_n are the weights of the criteria; including $i, j = 1, 2, \ldots, n$ ve $\forall i, j \in A$, the pairwise comparison matrix represented by A is as in equation (1.1).

Table 1 Severity scale

Importance level	Definition	Explanation
1	Equally important	Both activities contribute equally to the purpose
3	Moderately important	Experience and judgment strongly favor one activity over another
5	Strongly important	Experience and judgment strongly favor one activity over another
7	Very strongly important	Activity is strongly preferred The dominance of the activity has been proven in practice
9	Absolutely important	It has the highest possible degree of evidence that makes one activity preferable over another
2, 4, 6, 8 mutual values	Intermediate values	i. activity j. if the activity took one of the above values when compared; j. the activity takes the inverse value when compared to activity i
Justifications	Ratios because of scale	If consistency was enforced by obtaining *n* numeric values to expand the matrix

Source: Saaty (1990)

$$A = \begin{bmatrix} a_{11} & \dots & a_{1j} & \dots & a_{1n} \\ \vdots & & \vdots & & \vdots \\ a_{i1} & \dots & a_{ij} & \dots & a_{in} \\ \vdots & & \vdots & & \vdots \\ a_{n1} & \cdots & a_{nj} & \dots & a_{nn} \end{bmatrix} = \begin{bmatrix} a_{11} & \dots & a_{1j} & \dots & a_{1n} \\ \vdots & & \vdots & & \vdots \\ 1/a_{1j} & \dots & a_{ij} & \dots & a_{in} \\ \vdots & & \vdots & & \vdots \\ 1/a_{1n} & \dots & 1/a_{in} & \dots & a_{nn} \end{bmatrix}, \quad i,j = 1, \dots, n. \tag{1.1}$$

The main problem in the AHP is calculating the value $a_{ij} \cong w_i/w_j$. The weight matrix represented by W is shown in equation (1.2).

$$W = \begin{array}{c} \\ w_1 \\ \vdots \\ w_i \\ \vdots \\ w_n \end{array} \begin{array}{c} \begin{array}{ccccc} w_1 & \dots & w_j & \dots & w_n \end{array} \\ \begin{bmatrix} w_1/w_1 & \dots & w_1/w_j & \dots & w_1/w_n \\ \vdots & & \vdots & & \vdots \\ w_i/w_1 & \dots & w_i/w_j & \dots & w_i/w_n \\ \vdots & & \vdots & & \vdots \\ w_n/w_1 & \dots & w_n/w_j & \dots & w_n/w_n \end{bmatrix} \end{array} \tag{1.2}$$

The product of the comparison matrix by the weight vector W is equal to the product of the eigenvalue n of A and the weight vector W. If the eigenvalue of A is n, then w is the eigenvector associated with it. This situation is shown in equation (1.3).

$$\begin{array}{c} \\ A_1 \\ \vdots \\ A_i \\ \vdots \\ A_n \end{array} \begin{array}{c} \begin{array}{ccccc} A_1 & \dots & A_j & \dots & A_n \end{array} \\ \begin{bmatrix} w_1/w_1 & \dots & w_1/w_j & \dots & w_1/w_n \\ \vdots & & \vdots & & \vdots \\ w_i/w_1 & \dots & w_i/w_j & \dots & w_i/w_j \\ \vdots & & \vdots & & \vdots \\ w_n/w_1 & \dots & w_n/w_j & \dots & w_n/w_n \end{bmatrix} \end{array} \begin{bmatrix} w_1 \\ \vdots \\ w_i \\ \vdots \\ w_n \end{bmatrix} = n \begin{bmatrix} w_1 \\ \vdots \\ w_i \\ \vdots \\ w_n \end{bmatrix}, (i,j = 1,2, \dots, n). \tag{1.3}$$

According to the AHP method, it is known that it not only provides an advantage for the solution shown in equation (1.3) but also increases the need for broader thinking. It is $a_{ij} = w_i/w_j$ with $i, j = 1, 2, \dots, n$ in $A = (a_{ij})$. The matrix A has positive inputs all around, providing the equality of $a_{ij} = 1/a_{ij}$ because of the inverse principle. It is a matrix that is consistent because of the equality of $i, j, k = 1, 2, \dots, n$, while $a_{jk} = a_{ik}/a_{ij}$. The formula shown in equation (1.4) is used to calculate the eigenvector W; that is, the Perron vector of matrix A is calculated (Uludag and Dogan, 2021).

$$Aw = \lambda_{max} w, \; w_i = \frac{\sum_j^n a_{ij} \; w_j}{\lambda_{max}} \; (\forall i = 1, 2, \dots, n) \tag{1.4}$$

After calculating the W eigenvector, it is necessary to determine whether the matrix A is consistent. The consistency of the matrix is calculated at the end of the process. According to the AHP method, the inconsistency in the A matrix must be caught by the criterion of $\lambda_{max} - n$ and matrix A must provide the equality of $\lambda_{max} = n$ to be consistent. Therefore, in matrix A with positive and inverse inputs, $\lambda_{max} \geq n$. As the next step in the method, two criteria are used, namely, the consistency index (CI) shown in equation (1.5) and the consistency ratio (CR) shown in equation (1.6).

$$CI = \frac{(\lambda_{max} - n)}{n - 1} \tag{1.5}$$

$$CR = CI/RI \tag{1.6}$$

Random consistency index (RI) values are used to calculate the CR shown in equation (1.6). These values are shown in Table 2.

As the number of criteria used in the study is six, the corresponding value (1.25) in Table 2 was used as the value. The CR being 0.10 or less than 0.10 indicates that the judgments are consistent. Otherwise, decision-makers need to renew pairwise comparisons (Vargas, 1997; Oreski, 2012).

3.2 Technique for order preference by similarity to ideal solution method

In the TOPSIS approach, the aim is to present a suggestion for the solution of the problem by choosing the solution alternative according to the idea of the closest distance from the positive ideal solution and the farthest distance from the negative ideal solution, within the scope of the problem to be decided. The solution process is considered to be shorter than the Electre method. According to the application of the method, the best criteria that can be obtained is positive ideal solution, and the negative ideal solution is expressed as the combination of the worst criteria (Wang *et al.*, 2009). The TOPSIS method includes a solution process consisting of six steps (Karami and Johansson, 2014). The first step is shown in equation (2.1):

Creating the decision matrix (A)

$$A_{ij} \begin{bmatrix} a_{11} & a_{12} & \dots & a_{1n} \\ a_{21} & a_{22} & \dots & a_{2n} \\ \vdots & \vdots & \dots & \vdots \\ a_{m1} & a_{m2} & \dots & a_{mn} \end{bmatrix} \tag{2.1}$$

In the first step, the decision matrix is created with the help of decision-makers. In the rows of the decision matrix, there are

Table 2 Random index

n	1	2	3	4	5	6	7	8	9	10
RI	0	0	0.52	0.89	1.11	1.25	1.40	1.45	1.45	1.49

decision alternatives, and in the columns, the criteria to be used in the problem. The second step is shown in equation (2.2):

Generating the normalized decision matrix (R)

$$r_{ij}=\frac{a_{ij}}{\sqrt{\sum_{k=1}^{m} a_{kj}^{2}}}\ (\mathrm{i}=1,2,\ldots,\mathrm{m}\ \mathrm{ve}\ \mathrm{j}=1,2,\ldots,\mathrm{n}) \qquad (2.2)$$

The normalized decision matrix is created using the elements of the A matrix with the help of the equation (2.2). The purpose of the normalization process is to bring the data to a standard value between 0 and 1, even though they may be from different units. The third step is shown in equation (2.3):

Creating the weighted standard decision matrix (V)

$$V_{ij}=\begin{bmatrix} w_1 r_{11} & w_2 r_{12} & \ldots & w_n r_{1n} \\ w_1 r_{21} & w_2 r_{22} & \ldots & w_n r_{2n} \\ \vdots & \vdots & \ldots & \vdots \\ w_1 r_{m1} & w_2 r_{m2} & \ldots & w_n r_{mn} \end{bmatrix} \qquad (2.3)$$

In this step of the method, the normalized decision matrix is multiplied by the importance coefficients of the criteria (w_j) and weighting is performed. The point to note here is that the sum of the (w_j) values gives the number 1. And then the next step is shown in equation (2.4):

Creating ideal (A+) and negative ideal (A−) solutions

$$A^{+}=\left\{\left(\max_i v_{ij} | j\in \mathcal{J}\right),\left(\min_i v_{ij} | j\in \mathcal{J}'\right)\right\} \qquad (2.4)$$

$$A^{-}=\left\{\left(\min_i v_{ij} | j\in \mathcal{J}\right),\left(\max_i v_{ij} | j\in \mathcal{J}'\right)\right\}$$

At this stage, the weighted normalized positive ideal solution (A^{+}) and the alternatives for each evaluation criterion are calculated as the weighted normalized negative ideal solution (A^{-}) value that is desired to diverge. The next step is shown in equation (2.5):

Calculation of separation measures

$$S_i^{*}=\sqrt{\sum_{j=1}^{n}\left(v_{ij}-v_j^{*}\right)^2}\ S_i^{-}=\sqrt{\sum_{j=1}^{n}\left(v_{ij}-v_j^{-}\right)^2} \qquad (2.5)$$

In this step, the distances of each alternative to these values are calculated for each evaluation criterion according to equation (2.5). The distance between the positive ideal solution value and the negative ideal solution value is calculated. And last step is shown in equation (2.6):

Calculating relative closeness to the ideal solution

$$C_i^{*}=\frac{S_i^{-}}{S_i^{-}+S_i^{*}} \qquad (2.6)$$

In the last step, the closeness coefficient of each alternative is calculated. The alternatives are then ranked according to these values. The alternative with a closeness coefficient value equal to or closest to 1 is ranked higher than the others.

4. Practice case study

In this part of the study, first, the criteria that negatively affect the Turkish manufacturing sector during the COVID-19 pandemic are determined. For this purpose, very extensive literature research was carried out, and the criteria to be used in the study and five alternative sectors were determined by consulting expert opinions. Accordingly, textile, pharmaceutical and medical equipment, automotive, processed food, white goods and electronics sectors have created alternatives to be used in the study. The criteria to be used in the study are presented in Table 3.

After determining the factors to be used in the study, a five-person decision-maker group consisting of academicians and sector representatives was formed. Experts have been preferred because of their extensive evaluation and experience in their fields of study. The experts were interviewed face to face with the help of a formatted form. It was included in the scope of the study by taking their evaluations on the subject. It was given importance that the experts forming the decision-maker group should be in senior management positions. Here, decision-makers were asked to compare these factors and evaluate them with a score between 0 and 10. The factors used in the study were coded as follows: automotive (A), white goods and electronics (WGE), textile (T), processed food (PF) and medicine and medical equipment (MME). The factors to be used in the study were coded as follows: decreases in domestic and export sales (DDES), supply chain bottlenecks (SCB), fluctuations in credit markets (FCM), increase in production costs (IPC), increasing workforce problems (IWP) and slowing down or stopping of production (SSP).

5. Findings

In the study, the AHP weighting model was applied during the creation of the weighted standard decision matrix. This method makes the order of importance of the factors with the actual values of the data forming the decision matrix. By calculating the weights of the factors with the AHP method, then with the TOPSIS method, which is the second stage of the application, it will be evaluated which sector is most affected by the factors.

Findings related to the AHP method are given as follows (Table 4):

A matrix was formed as a result of the scores obtained from the decision-makers according to the AHP method. In the matrix created, each opinion was evaluated in line with the opinions of the decision-makers (for the matrix formed by the opinions of a five-person expert group consisting of academicians and sector representatives), and its arithmetic average was taken. The final table created is expressed as the decision matrix [equation (1.1)] (Table 5).

In equation (1.2), the values are normalized with the decision matrix (A) based on expert opinions. Weights were calculated from the values on the normalized decision matrix (Table 6).

The ratios of the obtained criteria to the total number of criteria are used to calculate the averages of the weighted values. The mean value also denotes the value of λ. The CI value is calculated by using the λmax value, and the RI values are calculated with the calculated value. Thus, the CR and CI are calculated [equation (1.3)].

Table 3 Criteria affecting Turkey's manufacturing sector in the COVID-19 pandemic

No.	References	Criteria	Explanation
1	Lu *et al.* (2021), KPMG (2020), Harris *et al.* (2020), Chen *et al.* (2020), Aduhene and Osei-Assibey (2021), Tayar *et al.* (2020), Tekoglu (2020) and Temir (2020)	Decreases in domestic and export sales	COVID-19 seriously threatens global trade. The disruptions experienced in the traditional supply chain because of the pandemic and the shock in the supply–demand balance have narrowed the volume of both domestic and export-based sales. According to the data of the Ministry of Commerce for March 2020, the export figures decreased by 17.8% and the foreign trade volume decreased by 6.7% compared to the same period of the previous year
2		Supply chain bottlenecks	The possible effects of the COVID-19 pandemic on supply chains can be expressed as follows: raw material delays and cancellations, production stoppage, the slowdown in logistics activities, delays in shipments, increase in logistics costs and difficulties in payments
3		Fluctuations in credit markets	COVID-19 continues to affect global markets with liquidity shortages and currency pressure in financial markets. In addition to the volatile and uncertain market conditions of developing countries such as Turkey, they have come to struggle with factors such as increasing financing needs, high funding costs, increasing foreign capital outflows and uncertain investor behavior
4		Increasing workforce problems	The contraction in business volume caused by COVID-19 has led to an increase in workforce losses. In this process, employees are faced with risks such as losing their jobs, taking unpaid leave and decreasing their weekly working hours. However, the increase in health problems caused by the impact of COVID-19 and the resulting increased absenteeism and losses in the workforce have paved the way for the emergence of important problems
5		Increase in production costs	The fluctuation of prices because of the pandemic, the transition to new suppliers, the slowdown in production, the slowdown in logistics activities, the increased stock costs and the costs of productivity losses cause production costs to increase. According to the results of a study published by KPMG, it has been concluded that approximately 60% of the enterprises in Turkey have increased their production costs
6		Slowing down or stopping production	Supply problems, supply-demand irregularities, price fluctuations, increased order cancellations and the uncertainties caused by these during the COVID-19 process cause production to slow down or stop, decrease production quality and the demand for the produced goods

According to the formulas expressed by equation (1.5) and equation (1.6), CI and CR criteria were calculated. The value obtained in the study was determined as a value in the appropriate range in terms of forming the basis for the method to be considered as a hybrid. It is appropriate to use AHP-weighted criteria in the TOPSIS method, and their consistency supports this statement. The criteria weights determined by the AHP method are given in Table 7.

Findings regarding the TOPSIS method are given as follows.

The normalized decision matrix is given in Table 8.

After calculating the criteria weights with the AHP method, according to the relevant formula [equation (2.3)], the weighted standard decision matrix was created by multiplying the weights of each criterion with the values in the normalized decision matrix (Table 9).

Ideal positive (A+) and ideal negative (A−) solution sets are created by using equation (2.4). For the ideal positive solution set, the largest value in each column is taken in the weighted normalized decision matrix, while the smallest value in each column is chosen for the ideal negative solution set. The ideal

Table 4 Decision matrix (A)

	DDES	SCB	FCM	IPC	SSP	IWP
DDES	1.00	4.80	4.40	4.60	3.20	4.60
SCB	0.39	1.00	4.40	7.00	5.20	4.40
FCM	0.25	0.28	1.00	6.00	4.20	5.80
IPC	0.26	0.15	0.18	1.00	5.20	4.20
SSP	0.36	0.28	0.32	0.28	1.00	5.20
IWP	0.27	1.21	0.19	0.29	0.21	1.00

Table 5 Normalized decision matrix (Na)

	DDES	SCB	FCM	IPC	SSP	IWP	w
DDES	0.3953	0.6218	0.4194	0.2400	0.1683	0.1825	0.3378
SCB	0.1542	0.1295	0.4194	0.3652	0.2735	0.1746	0.2527
FCM	0.0988	0.0363	0.0953	0.3130	0.2209	0.2302	0.1657
IPC	0.1028	0.0194	0.0172	0.0522	0.2735	0.1667	0.1052
SSP	0.1423	0.0363	0.0305	0.0146	0.0526	0.2063	0.0804
IWP	0.1067	0.1567	0.0181	0.0151	0.0110	0.0397	0.0579

Table 6 Calculation of priorities vector for criteria

	DDES	SCB	FCM	IPC	SSP	IWP	aw
DDES	0.3953	0.6218	0.4194	0.2400	0.1683	0.1825	9.7323
SCB	0.1542	0.1295	0.4194	0.3652	0.2735	0.1746	9.9861
FCM	0.0988	0.0363	0.0953	0.3130	0.2209	0.2302	9.8123
IPC	0.1028	0.0194	0.0172	0.0522	0.2735	0.1667	8.7603
SSP	0.1423	0.0363	0.0305	0.0146	0.0526	0.2063	8.1611
IWP	0.1067	0.1567	0.0181	0.0151	0.0110	0.0397	9.2197

Table 7 Weights of criteria calculated by AHP method

	DDES	SCB	FCM	IPC	SSP	IWP
Weight	0.3378	0.2527	0.1657	0.1052	0.0804	0,0579

Table 8 Normalized decision matrix (R)

	DDES	SCB	FCM	IPC	SSP	IWP
MME	0.5754	0.5582	0.5573	0.5230	0.6523	0.6040
WGE	0.4028	0.3101	0.4458	0.4576	0.4566	0.4027
T	0.4603	0.4961	0.3901	0.3922	0.3262	0.5369
PF	0.4603	0.5582	0.5573	0.3922	0.3262	0.2685
A	0.2877	0.1861	0.1672	0.4576	0.3914	0.3356

Table 9 Weighted normalized decision matrix (V)

	DDES	SCB	FCM	IPC	SSP	IWP
MME	0.1944	0.1411	0.0924	0.0551	0.0525	0.0350
WGE	0.1361	0.0784	0.0739	0.0482	0.0367	0.0233
T	0.1555	0.1254	0.0647	0.0413	0.0262	0.0311
PF	0.1555	0.1411	0.0924	0.0413	0.0262	0.0155
A	0.0972	0.0470	0.0277	0.0482	0.0315	0.0194

positive and negative values formed as a result of these processes are formed as shown in Table 10.

Then, the deviations of each decision point from the positive ideal solution and negative ideal solution points are calculated. In this direction, the positive ideal discrimination (S+) and negative ideal discrimination (S−) values of each decision point were calculated [equation (2.5)] (Table 11).

In the last step, the closeness coefficient of each alternative is calculated, and the alternatives are ranked according to these values. The alternative with a closeness coefficient value equal to or closest to 1 is ranked higher than the others. In this way, according to the findings obtained with the TOPSIS method, the decision-maker is informed about which alternative is in the top row, and it helps to make a decision. The relative closeness (C+) of each decision point to the ideal solution was calculated as follows. After the calculation of the relative closeness to the ideal solution, which is the last step of the method, the C+ values found are arranged from the largest to the smallest, and the performance rankings of renewable energy sources are determined [equation (2.6)] (Table 12).

With this calculation, which is the last step of the TOPSIS method, while the C+ value is the sector most affected by COVID-19, the sector with the lowest C+ value is the sector least affected by COVID-19. According to this, the sector most affected by the negative effects of COVID-19 is automotive; the least affected sector is the pharmaceutical and medical equipment sector.

6. Conclusion

In this study, the effects of the COVID-19 pandemic process on the Turkish manufacturing sector were evaluated using AHP and TOPSIS methods. For this purpose, six criteria that were negatively affecting the manufacturing sector in the

Table 10 Determination of ideal (A+) and negative ideal (A−) solution

A+	0.1944	0.1411	0.0924	0.0551	0.0525	0.0350
A−	0.0972	0.0470	0.0277	0.0413	0.0262	0.0155

Table 11 Calculation of distance measures between alternatives

No.	Sector	S+	S−
1	MME	0.00000	0.154049
2	WGE	0.09003	0.069611
3	T	0.05847	0.105598
4	PF	0.05261	0.128169
5	A	0.15233	0.009487

Table 12 Calculating relative closeness to the ideal solution

No.	Sector	C+	Sira
1	MME	0	5
2	WGE	0.563953	2
3	T	0.356371	3
4	PF	0.291007	4
5	A	0.941371	1

COVID-19 pandemic, as well as five alternative sectors were determined as a result of wide literature research and expert opinions. The purpose of the study was to determine the negative effects of the COVID-19 pandemic on the manufacturing sector according to the level of importance and to reveal which sectors these criteria have more impact on. As a result of the implementation, it is expected to contribute to taking measures with sectoral differences against the negative effects of the COVID-19 pandemic and to get out of this pandemic with the least damage.

As a result of the AHP analysis carried out to determine the factor weights within the scope of the application, it is possible to say that the most important negative effect of COVID-19 on the manufacturing sector is the "decreases in domestic and export-based sales." This factor was followed by "bottlenecks in the supply chain," "fluctuations in credit markets," "increase in production costs," "slow down or stoppage of production" and "increasing labor problems."

After the results of the most important negative effects of COVID-19 on the manufacturing sector, TOPSIS analysis was carried out to determine the manufacturing sectors that were most affected by the factors whose weights were determined within the scope of the research. Findings obtained as a result of the analysis reveal that the automotive sector is the sector most negatively affected by the COVID-19 pandemic. The automotive sector was followed by white goods and electronics, textile, processed food, medicine and medical equipment sectors. It was concluded that the sector that was least adversely affected by COVID-19 in Turkey was the medicine-medical equipment sector.

7. Discussions

7.1 Implications for theory

The results obtained as a result of the application are in line with the literature data. In the large-scale survey conducted by KPMG Turkey Strategy and Operations Consultancy in 2020 to investigate the effects of COVID-19 on the business world, it has been stated that decreases in sales, access to finance and liquidity problems, problems in the supply chain and increasing production costs are the biggest effects of COVID-19 on businesses (KPMG, 2020). Again, in the report published by Allianz Research (2020), it was stated that reductions in sales, liquidity problems and decreased profitability with increasing costs are among the most important effects of COVID-19. Kutluay Tutar *et al.* (2021) stated, as a result of the research in which they examined the sectoral effects of COVID-19 in Turkey, that the negative effects such as demand and sales declines, disruptions in the supply chain and financial fluctuations occurred because of some measures implemented because of the pandemic.

The findings obtained as a result of the analyzes in which the effects of the COVID-19 pandemic on the Turkish manufacturing industry were examined from a sectoral perspective are similar to the results of previous studies. In the study conducted by KPMG (2020) using the survey method and evaluating the effects of COVID-19 in terms of the business world, it was concluded that the manufacturing sector in Turkey that was least affected by COVID-19 was the medicine and medical equipment sector. According to Allianz Research (2020), it was stated that the sector that would be most negatively affected by the COVID-19 pandemic was the automotive sector. In the same research, it was emphasized that after the automotive industry, the white goods and electronics industries were other sectors most affected by COVID-19, especially because of the deterioration in the supply–demand balance.

Despite the fact that the signs of the COVID-19 pandemic in the Turkish automotive sector were felt later than the rest of the world, a rapid decline was observed in the sector. Especially the global chip problems and supply and logistics problems have caused a great recession in the sector (Kutluay Tutar *et al.*, 2021). Sudden demand drops in the European market, increasing order cancellations and problems in logistics processes because of border crossings are among the biggest problems experienced especially in the export-oriented automotive sector. Again, the fact that the parts supplied from Europe for use in production cannot be supplied because the relevant factories have stopped or slowed down their production is also an important problem affecting the automotive industry in our country (Allianz Research, 2020).

The white goods and electronics sectors in Turkey are also among the sectors most negatively affected by the COVID-19 pandemic. Turkish manufacturers, who have a very large trade volume with the European Union, experienced a major crisis because of the decreasing demand because of the rapid spread of the pandemic in Europe. According to TURKBESD data, there was a 6% contraction in exports in the first nine months of 2020 (Izmir Chamber of Commerce, 2021).

The textile industry in Turkey, which produces mainly depending on imported inputs, supplies a significant part of the cotton used as raw material from several countries. With the COVID-19 pandemic, significant decreases were experienced in the import of this input. In the first quarter of 2020, import figures decreased by 18% compared to the same period of the previous year. In addition, order cancellations and supply problems caused contractions in the textile sector (Eastern Mediterranean Development Agency, 2020). However, in this process, the demand for overalls, masks, surgical gowns, body bags, bonnets and so on. Businesses that can switch to the production of protective clothing have had the opportunity to minimize the negative effects of COVID-19. Again, during the pandemic period, businesses in Europe turned their routes to Turkey because of supply problems in China, which also contributed to minimizing the negative effects of the pandemic (Middle Black Sea Development Agency, 2020).

The COVID-19 outbreak has revealed that pharmaceuticals and medical devices are of strategic importance at least as much as the defense industry in the following periods. According to the Pharmaceutical Industry Report published by the Republic of Turkey Ministry of Industry and Technology (2020a, 2020b), steps were taken in the COVID-19 pandemic toward the production of ventilators, disinfectants and protective equipment, and the average production index of basic pharmaceutical products and related materials grew by approximately 19% in 2019 compared to the previous year. Especially in this period, increasing production volume with increasing demands and increasing employment opportunities paved the way for this sector to be the sector that was least

adversely affected by the pandemic process (Kutluay Tutar *et al.*, 2021).

The food sector was one of the sectors least affected by the COVID-19 crisis, and the sales volume of food, beverages and tobacco throughout the country increased compared to the same month of the previous year. However, although the demand decreased in some sub-sectors because of the closure of businesses such as restaurants and cafes, it is possible to say that the sector did not have a demand problem in general (Middle Black Sea Development Agency, 2020).

7.2 Managerial implications

Our study has some managerial implications. Trying to reduce the negative effects of the COVID-19 pandemic also creates important problems in the business processes of businesses. Managers can take different actions to minimize the negative effects of the pandemic. At this point, the success of the actions to be taken will be possible thanks to the well-known negative effects of the COVID-19 pandemic threatening businesses and their impact levels. Businesses aim to overcome important problems such as the decline in sales caused by the pandemic, disruptions in the supply chain, financial fluctuations, slowdown in production and cost increases. In this direction, it is of great importance to take measures such as developing business-to-business marketing strategies, increasing the level of high trust and application of digital technologies, making agile and flexible supplier relations dominant and raising awareness of the personnel on this issue.

Considering that the negative effects of the pandemic differ between sectors, revealing the level of impact of these negativities in different sectors will allow the strategies to be developed by the managers in the fight against COVID-19 to be based on sectoral differences and more accurate data. It is also recommended for all sectors to simulate the possible effects of the COVID-19 pandemic. In this way, it will be able to better manage the possible difficulties that the pandemic will present in the future.

7.3 Recommendations

As a result of this study, in which the effects of COVID-19 on the Turkish manufacturing sector were evaluated on a sectoral basis, the factors of COVID-19 that negatively affected businesses were determined according to the level of importance. Then, the sectors most affected by these factors were revealed. Thanks to the findings, it is thought that it will be possible to take measures that may differ between sectors at the point of combating the negative effects of COVID-19. It is suggested to the authors that this study, which is thought to be an important source for future studies on the subject, should be done by using different MCDM methods.

It is emphasized that the results of the data analysis contribute to the attention of the government and the public to the incidence of COVID-19; therefore, it also contains up-to-date information. Likewise, it is hoped that it can be a reference in raising public awareness about the quality of health, the problems of their economic income and the industrial world itself. In terms of all stakeholders in the society, the importance and implications of the issue are so important that they cannot be ignored for future studies.

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Further reading

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