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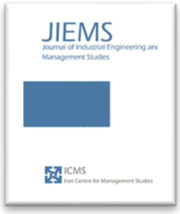

Evaluation of key cement production industries based on sustainable development factors with a combined approach of Fuzzy (AHP-VIKOR)

Mehdi Ajalli [1*]

[1] Department of Management, Faculty of Management and Accounting, Bu-Ali Sina University, Hamedan, Iran.

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Abstract

In recent decades, the world has focused on a new concept that emphasizes the effective protection of the environment and careful use of natural resources; these emphases bring the goals of sustainable economic, environmental and social growth. Sustainable development (SD) means the development and progress of the current generation while preserving resources for the development of the future generation. The main purpose of this research is evaluation of key cement production industries based on SD factors with a combined approach of FAHP-FVIKOR. The statistical population includes 55 experts and specialists familiar with the concept of SD in 5 key industries of Iran's cement industry. Due to the limited community and lack of access to them, the opinions of 33people were finally used. The research method was practical in terms of its purpose, and it was a descriptive survey type using two questionnaires in terms of the data collection method. For this purpose, to evaluate the importance of three key factors in SD, FAHP (Analytic Hierarchy Process) approach was used and the weight of the factors was calculated. The results showed that the economic sustainability factor is more important than the environmental and social sustainability factors. Next, in order to evaluate the mentioned 5 industries based on SD factors, the fuzzy VIKOR (VlseKriter ijumskaOptimizacija I KompromisnoResenje) technique was used and the final ranking of the industries was extracted. The present research is the first applied research in the field of evaluating the SD factors of the country's cement industry and ranking the key cement industries with multi-criteria decision-making techniques; So that its results can be used in the evaluation of other cement production industries and related industries of the country.

Keywords: SD, cement production, environmental sustainability, economic sustainability, social sustainability.

Paper Type: Original Research

1. Introduction

Sustainability is defined as: "the ability to remain or survive in the long term and use natural products and energy in a way that does not harm the environment", "a process through which new ways of working, improving performance and continuous improvement in a field certain, maintained for a suitable period", "use of vital resources so that they are available for an indefinite period of time", "a level of production that does not threaten the living conditions of future generations", "the ability to meet the needs of the present without harm Bringing the ability of future generations to meet their needs" is defined as "innovations that have a positive impact on the environment through changing the organization's value creation system or significantly reduce its negative effects on the environment or society" (Asheghi-Oskooee & Gharbanizadeh, 2020). In a comprehensive study, Sajjadi (2022) has mentioned 17 main goals of sustainable development: 1. Ending poverty in all its forms and everywhere. 2. Ending hunger, realizing food security, better nutrition and developing sustainable agriculture. 3. Ensuring a healthy life and promoting well-being for everyone and at all ages. 4. Ensuring quality, equal and inclusive education and promoting lifelong learning opportunities for all. 5. Achieving gender equality and empowering all women and girls. 6. Ensuring access to water and sustainable management of water and sanitation for all. 7. Ensuring access to affordable, reliable, sustainable and new energy sources. 8. Promoting permanent, comprehensive and sustainable economic growth, full and productive employment and employment Honorable for everyone. 9. Creating resilient infrastructure, promoting sustainable and inclusive industrialization and promoting innovation. 10. Reducing inequality within and between countries. 11. Transforming cities and human settlements into inclusive, safe, resilient and sustainable places. 12: Guaranteeing sustainable patterns of production and consumption. 13. Immediate action to face climate change and its effects. 14. Protection and sustainable use of oceans, seas and marine resources for sustainable development. 15. Protection, restoration and promotion of sustainable use of terrestrial ecosystems,

*Corresponding Author: m.ajalli@basu.ac.ir

sustainable management of forests, combating desertification and stopping and changing the procedure of land destruction (or erosion) and preventing the destruction of biodiversity. 16. Promoting peaceful and inclusive societies to achieve sustainable development, establishing access to justice for all and creating efficient, responsive and inclusive social institutions at all levels. 17. Strengthening executive tools and revitalizing global partnership to achieve sustainable development. In September 2015, with the consensus of 193 member countries at the United Nations meeting in New York, the Sustainable Development Goals (SDGs) in the Global Agenda for Sustainability for 2030 were set with 17 goals and 169 targets (Astha et al., 2021). SD is the general policy of the United Nations for inclusive growth. From the last quarter of the 20th century to the current decade, the effects of environmental degradation and ecosystem challenges have been recognized globally. Globally, people agree that the pursuit of social and economic progress is accompanied by environmental challenges and the degradation of the planet's ecosystem. This means that environmentally friendly and humanitarian methods should be used. SD is defined as a development that optimally meets the needs of the current generation (social, economic and environmental development needs) without compromising the capacity of future generations (Ogbonna, 2022). Meanwhile, the SD of the cement industry has a key impact on the national economy and the development of other sectors of the society, such as the construction of roads, sea docks, railways, airports, transportation terminals, construction of dams, etc. Cement is a vital construction material, but its production is a major contributor to greenhouse gas emissions and other environmental problems. The cement industry is aware of its environmental impact and is trying to create new and more sustainable ways to produce cement. As one of the basic industries, the cement industry plays an essential role in the development of the economic and social infrastructure of any country, and today this industry is considered as one of the most important, fast-moving and influential industries in the development and industrial growth of countries. The emission rate of heat and greenhouse gases and gases such as CO2 and SO2 and the like from the chimney of cement factories is very high and it is known as one of the energy-intensive industries with high pollution. The share of energy used to produce one ton of cement is estimated at 25-30%. The cement industry consumes about 4% of the country's electricity, about 11% of the industry's share, and about 3.4% of the country's gas. It is estimated that in the horizon of 2026, cement production will increase to about twice the current amount, and it needs to be re-examined on the consumption of energy and raw materials of cement industries. In the future, cement industries will have to comply with more limited standards and need much more stability in their properties because the clinker content in mixed cements will be less. In the future, concrete binders will be more compatible with complex chemical additives and their applications will lead to more durable concrete instead of stronger concrete (Monammi, 2018). By referring to the history of previous studies, it was found that there has been no research related to the evaluation of SD factors in the cement industry. In addition, in previous researches, MCDM combined techniques have not been used in order to evaluate SD factors and also to rank industries based on factors. Ajalli et al., (2019a) proposed a hybrid FSIR-TOPSIS approach for selecting of manufacturing levers. So dealing with the selected manufacturing levers and promoting them, an organization makes customers satisfied with the least cost and time. Astha et al., (2021) evaluated the critical success factors of SD by using interpretive structural modeling approach. They found that cost, environmental protection, and public awareness are the foundations of long-term building sustainability. Also, construction technology, budget and availability, and governmental and political support are elements that have a smaller but still significant impact on the face of sustainable buildings. Ozili (2022) has described sustainability research and SD around the world in research. Existing empirical research has shown that integrating sustainability or SD concerns into business or environmental management brings positive benefits. Ogbonna (2022) investigated the success factors for SD in the economic growth and development of Nigeria. The findings show that stakeholders have a great impact on the success of SD efforts in Nigeria. Also, SD policy implementation and adaptation may take decades, but when incorporated into the overall economic sectors, organizational operations, and corporate social responsibilities, as well as the majority of relevant population, social, and economic activities, the sustainability effects environmental, will be deep. Ayough et al. (2022) proposed a new interactive method based on multi-criteria preference degree functions for solar power plant site selection. This study renders a new approach that redefines the linear relations of Interactive Simple Additive Weighting (ISAW) by multi-criteria preference degree functions of Preference Ranking Organization Method for Enrichment Evaluation (PROMETHEE). In the proposed approach, an initial order of alternatives is gradually improved by swapping the order of a pair of alternatives until the decision-maker becomes satisfied. To validate the proposed method, we consider a case study of site selection for solar farms. Ayough et al. (2023) presented a new integrated approach based on base-criterion and utility additive methods and its application to the supplier selection problem. A numerical example and a real case in the electronics industry have been presented to corroborate the applicability and effectiveness of the BCUA model. Sensitivity analysis and a comparative analysis of the proposed method are discussed in comparison to already existing MCDM methods, including the Fully Consistency Method (FUCOM), Ordinal Priority Approach (OPA), Level Based Weight Assignment (LBWA), and Defining Interrelationships Between Ranked Criteria (DIBR). These analyses indicate that the criteria weights and alternative rankings are robust to changing the parameters δ and λ. In addition to selecting the most suitable supplier, the model presented here can also be used in any decision-making problem with multiple attributes and alternatives, particularly when decision-makers are faced with many alternatives. Sharifjon et al., (2024) did a comprehensive analysis on the influencing factors of SD in Eco-tourism settlements. The findings show that the following strategies are more effective in promoting SD for policymakers and stakeholders involved in the development of national parks and ecotourism settlements in Tajikistan and Uzbekistan: encouraging the active participation of local authorities and the population, providing high-quality services to tourists, and protecting the environment. Ajalli et al., (2024) used a hybrid approach (CFA-SWARA-MOORA) in order to MODELING and evaluate the of determining factors in the assessment of sustainability and resilience of the supply chain in Iran rubber industry. The output of this approach showed that all the identified factors have a positive effect on the evaluation of suppliers. Then, by using the SWARA technique and using the opinions of 40 industry experts, the weight of the factors was calculated. The output of this technique showed that the third factor of supply chain sustainability, (S3: Strategy, support and commitment of company managers) with the highest weight is ranked first in terms of importance. Also, the 7th factor of sustainability (S7: Green warehouse) with the least weight in terms of importance in the integrated performance evaluation system of suppliers was placed in the 16th ranks. At the end of the research, 7 rubber industry suppliers were evaluated using the opinions of 40 experts and using MOORA's technique. The final result of this technique showed that the fifth supplier is ranked first, and the fourth supplier is ranked last. In this way, an integrated and comprehensive approach was proposed in order to measure and evaluate the suppliers of the rubber industry in Iran. In order to research the goals of SD of the cement industry, it is necessary to evaluate the key industries of Iran's cement production based on the key factors of SD. The present research has been carried out with the understanding of the necessity of evaluating cement production industries due to environmental effects and severe pollution. One of the main innovations of this research is the evaluation of SD factors and the ranking of cement production industries with multi-criteria decision-making techniques, which has not been addressed in previous researches. Therefore, the main research questions are proposed as follows:

1. How is the importance of SD factors in the country's cement production industry?

2. What is the ranking of the country's key cement production industries based on agreement with SD factors?

What solutions can be offered in order to solve the challenges of SD of the country's cement production industry?

2. Literature Review

2.1. Opportunities and challenges of sustainable cement production

There are a number of opportunities for sustainable cement production. One of the promising approaches is the use of alternative fuels and raw materials. For example, cement manufacturers can use waste biomass such as wood chips and agricultural residues to fuel their kilns. They can also use alternative raw materials such as fly ash and slag to produce cement clinker. Another promising approach is the use of carbon capture and storage (CCS) technology. CCS technology collects CO2 emissions from cement production and stores them underground. This technology can help reduce the greenhouse gas footprint of cement production. Finally, the cement industry is also developing new cement chemicals that require less energy to produce and produce fewer greenhouse gases. An example is geo-polymer cement, which is made from fly ash and other industrial byproducts. One of the biggest challenges in sustainable cement production is the high energy (electricity and gas) demand in this process. Cement is made by heating limestone and other minerals to very high temperatures. This process requires a lot of energy, which is often produced from fossil fuels. Another challenge is the use of limestone in cement production. Limestone is the main source of CO2 emissions during warming. The cement industry is trying to reduce its reliance on limestone, but it is a complex challenge. The cement industry in Iran is in the second rank after power plants in terms of gas consumption. According to preliminary calculations, 115 cubic meters of natural gas and 120 kilowatts of electricity are consumed on average in the country to produce each ton of cement. Every year in the winter season, when the weather gets cold, the cement companies' gas is cut off. Diesel fuel is always presented as an alternative fuel in this industry and has many harmful environmental effects. In the current situation, the consumption of electricity and gas in the country's cement factories should be reduced by 25% of electricity and 35% of gas, respectively, according to international standards and models, in order to reach at least conventional energy consumption. The second challenge related to cement companies is the exchange rate change and as a result inflation issues, which causes the companies' working capital to face problems. This issue has a greater impact especially on companies that are a subset of institutions and usually share 100% of their profits and causes a decrease in working capital. The third challenge that exists in cement companies is the lack of reconstruction and modernization of production lines, their development and updating. These risks have caused this industry not to be welcomed by investors; As a result, not attracting investors is another problem in this industry. When the production units are depreciated, the production lines must be replaced and renovated. But due to the growth of the exchange rate, the cost of renovation and reconstruction has gone up; As a result, companies cannot improve their production lines. In the meantime, one of the problems of this industry in terms of management is its short duration. This causes the appointed managers to have a short-term view, and because the managers know that they are in this position for a short time, as a result, they do not have a long-term view to think about fixing problems such as depreciation of production lines. Therefore, problems are transferred from one manager to another (Boad, 2023).

2.2. SD Factors & hierarchical model of research

Sustainability in a holistic view consists of three basic components (Ogbonna, 2022).

- Economics: Economics describes the available resources and how these resources are organized to meet human needs and goals. Economic factors have many meanings in relation to environmental effects and social factors.

- Society: In this sense, society means a set of human interactions and how they are organized. Humans are perfected to be completely dependent on society. Therefore, the sustainability of societies is an important condition for gathering human needs. Community-based criteria are important for sustainability because they define the current characteristics of life and can be a major component of the legacy of future generations.

- Environment: The environment also surrounds humans and supports their livelihoods and limits their activities according to basic physical laws. Environmental factors affect current well-being and determine the legacy of future generations.

- To achieve sustainability, factors of economic, social and environmental sustainability must be in balance and harmony with each other. These three main pillars can be defined as follows (Stephanie, 2024):

- Environmental sustainability means that we live with the help of our natural resources, and for environmental sustainability, we must learn to consume our natural resources such as fuel, land, water, etc. at a sustainable rate. Some resources are more abundant than others, but we must consider the damage to the environment caused by the indiscriminate extraction of these materials and be able to consume resources within the framework of economic principles. We must strive to reach the goal of zero carbon production and then go further and finally achieve a clean climate. Environmental sustainability should not be confused with complete sustainability, because this factor is along with economic and social factors that lead to sustainability.

- Economic sustainability requires that a business or country use its resources effectively and responsibly so that it can operate in a sustainable manner to continuously generate profits. Without profit, a business cannot sustain its activities. But without responsible behavior and optimal use of resources, a company will not be able to maintain its activities in the long run.

- Social sustainability is the ability of society or any social system to continuously achieve good social welfare, equity and justice. Achieving social sustainability ensures that the social welfare of a country, an organization or a society can be maintained in the long term.

- Finally, the relationship between the principles will be as follows (Safdie, 2024):
- Social + Environmental sustainability = bearable
- Economic + Environmental sustainability = viable
- Economic + Social sustainability = equitable
- But we can achieve real sustainability only by creating economic + social + environmental balance.

In Figure 1, the principles of SD are presented:

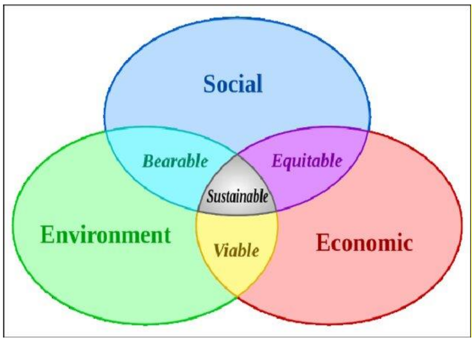

Figure 1. the principles of SD

In this research, the evaluation and ranking of 5 major key industries of the cement industry of the country is done using the fuzzy VIKOR technique. In order to achieve this goal, it is necessary to first evaluate the factors of SD (environmental factors, economic factors, social factors) in the cement industry and calculate the weight of these factors (as decision criteria in the ranking of industries). Hierarchical model of criteria and industries is shown in Figure 2:

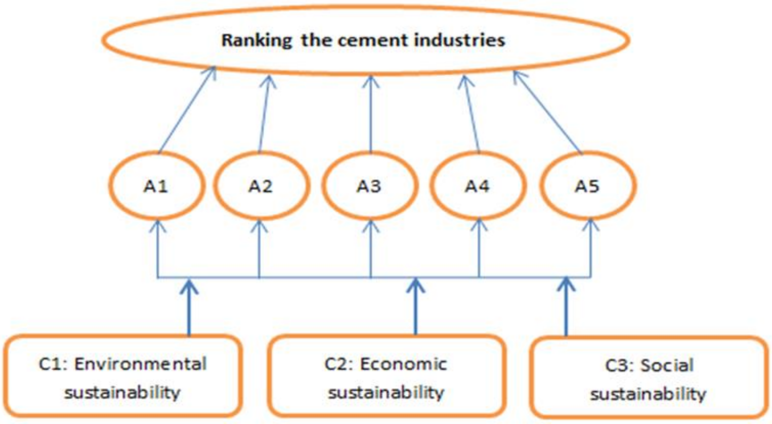

Figure 2. Hierarchical model of criteria and industries

3. Methodology

3.1. FAHP

The Analytic Hierarchy Process is a tool utilized by many researchers worldwide. It is a decision making process which helps to set priorities when a quantitative and qualitative aspect is being considered in an equation. Many find it very practical and flexible to use (Saaty, 2016). This process works by minimizing complex evaluation criteria into a series of one to one comparisons. However, due to lack of certainty on information and difficulty evaluating strength of preferences, decision makers are unable to set the exact numerical values when conducting the test. Therefore, AHP plays a key role in solving this issue; it enables the users to deal with vagueness and uncertainty in the decision process (Saaty, 2008). FAHP uses fuzzy set theory to express the uncertain comparison judgments as a fuzzy numbers. The main steps of FAHP are as follows (Ajalli et al., 2017):

Step1: Structuring decision hierarchy, Similar to conventional AHP, the first step is to break down the complex decision making problem into a hierarchical structure.

Step2: Determination of Fuzzy Pair-wise Matrix as follows:

	C_1	C_2	...	C_n
C_1	(1,1,1)	$(a_{12}^l, a_{12}^m, a_{12}^u)$	...	$(a_{1n}^l, a_{1n}^m, a_{1n}^u)$
C_2	$(a_{21}^l, a_{21}^m, a_{21}^u)$	(1,1,1)	...	$(a_{2n}^l, a_{2n}^m, a_{2n}^u)$
$\vdots$			$\vdots$	$\vdots$
C_m	$(a_{m1}^l, a_{m1}^m, a_{m1}^u)$	$(a_{m2}^l, a_{m2}^m, a_{m2}^u)$	...	(1,1,1)

That: $\left(a_{ij}^l, a_{ij}^m, a_{ij}^u\right) = \left(\frac{1}{a_{ji}^u}, \frac{1}{a_{ji}^m}, \frac{1}{a_{ji}^l}\right)$

Consider a prioritization problem at a level with n elements, where pair-wise comparison judgments are represented by fuzzy triangular numbers $\tilde{a}_{ij} = (l_{ij}, m_{ij}, u_{ij})$. As in the conventional AHP, each set of comparisons for a level requires $\frac{n(n-1)}{2}$judgments, which are further used to construct a positive fuzzy reciprocal comparison matrix $\tilde{A} = \tilde{a}_{ij}$ such that:

$$\begin{bmatrix} \tilde{a}_{11} & \cdots & \tilde{a}_{1n} \\ \vdots & \ddots & \vdots \\ \tilde{a}_{m1} & \cdots & \tilde{a}_{mn} \end{bmatrix}$$

Step3: Determination of composed Fuzzy column Matrix as:

	C_1	C_2	...	C_n	$\tilde{s}_i$
C_1	(1,1,1)	$(a^l_{12}, a^m_{12}, a^u_{12})$	...	$(a^l_{1n}, a^m_{1n}, a^u_{1n})$	$\tilde{s}_1 = (s^l_1, s^m_1, s^u_1)$
C_2	$(a^l_{21}, a^m_{21}, a^u_{21})$	(1,1,1)	...	$(a^l_{2n}, a^m_{2n}, a^u_{2n})$	$\tilde{s}_1 = (s^l_1, s^m_1, s^u_1)$
⋮			⋮	⋮	⋮
C_m	$(a^l_{m1}, a^m_{m1}, a^u_{m1})$	$(a^l_{m2}, a^m_{m2}, a^u_{m2})$	...	(1,1,1)	$\tilde{s}_m = (s^l_m, s^m_m, s^u_m)$

Step4: Determination of composed Crisp column Matrix based on value degree as:

	C_1	C_2	...	C_n	$\tilde{s}_i$	s_i
C_1	(1,1,1)	$(a^l_{12}, a^m_{12}, a^u_{12})$	...	$(a^l_{1n}, a^m_{1n}, a^u_{1n})$	$\tilde{s}_1 = (s^l_1, s^m_1, s^u_1)$	s_1
C_2	$(a^l_{21}, a^m_{21}, a^u_{21})$	(1,1,1)	...	$(a^l_{2n}, a^m_{2n}, a^u_{2n})$	$\tilde{s}_1 = (s^l_1, s^m_1, s^u_1)$	s_2
⋮			⋮	⋮	⋮	...
C_m	$(a^l_{m1}, a^m_{m1}, a^u_{m1})$	$(a^l_{m2}, a^m_{m2}, a^u_{m2})$	...	(1,1,1)	$\tilde{s}_m = (s^l_m, s^m_m, s^u_m)$	s_m

With

VL:(0,0.5,2); L:(1,2,3); ML:(2,3.5,4); M:(4,5,6); MH (5,6.5,8); H:(7,8,9); VH (8,9.5,10)

$$V(\tilde{A} > \tilde{B}) = \begin{cases} 1 & ; \quad a_m \geq b_m \\ \frac{b_l - a_u}{(a_m - a_u) - (b_m - b_l)} & ; els \end{cases}$$

$V(\tilde{A} > \tilde{B}, \tilde{C}, \tilde{D}, \ldots)$=Min$\{V(\tilde{A} > \tilde{B}), V(\tilde{A} > \tilde{C}), V(\tilde{A} > \tilde{D}), \ldots\} = \alpha$

$V(\tilde{B} > \tilde{A}, \tilde{C}, \tilde{D}, \ldots)$=Min$\{V(\tilde{B} > \tilde{A}), V(\tilde{B} > \tilde{C}), V(\tilde{B} > \tilde{D}), \ldots\} = \beta$

$V(\tilde{C} > \tilde{A}, \tilde{B}, \tilde{D}, \ldots)$=Min$\{V(\tilde{C} > \tilde{A}), V(\tilde{C} > \tilde{B}), V(\tilde{C} > \tilde{D}), \ldots\} = \gamma$

$V(\tilde{D} > \tilde{A}, \tilde{B}, \tilde{C}, \ldots)$=Min$\{V(\tilde{D} > \tilde{A}), V(\tilde{D} > \tilde{B}), V(\tilde{D} > \tilde{C}), \ldots\} = \lambda$

That: $s_1 = s_A = \frac{\alpha}{\alpha+\beta+\gamma+\lambda}$, $s_2 = s_B = \frac{\beta}{\alpha+\beta+\gamma+\lambda}$, $s_3 = s_C = \frac{\gamma}{\alpha+\beta+\gamma+\lambda}$, $s_4 = s_D = \frac{\lambda}{\alpha+\beta+\gamma+\lambda}$

Step5: Consistency check and deriving priorities and Weighting & Ranking. This step checks for consistency and extracts the priorities from the pair-wise comparison matrices. In existing fuzzy AHP methods, only a few past studies have addressed the issue of checking for inconsistencies in pair-wise comparison matrices. According to Buckley (1985), a fuzzy comparison matrix A ̃=a ̃_ijisconsistent ifa ̃_ik⊗a ̃_kj≈a ̃_ij where i,j,k=1,2,…,n and⊗isfuzzy multiplication, and ≈ denotes fuzzy equal to. Oncethe pair-wise comparison matrix,A ̃, passes the consistencycheck, fuzzy priorities w ̃_ican be calculated with conventional fuzzy AHP methods. Then, the priority vector 〖(w_1,w_2,…,w_n)〗^Tcan be obtained from the comparisonmatrix by applying a prioritization method. Briefly, stages of Consistency check are as below (Ajalli et al., 2017):

Stage1: deviation the fuzzy triangular matrix to tow matrix as;

1. Interval numbers of triangular judgments: $A^m = [a_{ijm}]$
2. Geometric average of upper and low limits of triangular numbers: $A^g = \sqrt{a_{iju} a_{ijl}}$

Stage2: Calculating of weight vector for each matrix using saaty's method as equations (1), (2):

$$W_i^m = \frac{1}{n} \sum_{j=1}^{n} \frac{a_{ijm}}{\sum_{i=1}^{n} a_{ijm}}; \quad W^m = [W_i^m] \quad (1)$$

$$W_i^g = \frac{1}{n} \sum_{j=1}^{n} \frac{\sqrt{a_{iju} a_{ijl}}}{\sum_{i=1}^{n} \sqrt{a_{iju} a_{ijl}}}; \quad W^g = [W_i^g] \quad (2)$$

Stage3: Calculating the biggest of specific amount for each matrix as equations (3), (4):

$$\lambda_{max}^{m} = \frac{1}{n}\sum_{i=1}^{n}\sum_{j=1}^{n} a_{ijm}\left(\frac{W_j^m}{W_i^m}\right) \quad (3)$$

$$\lambda_{max}^{g} = \frac{1}{n}\sum_{i=1}^{n}\sum_{j=1}^{n}\sqrt{a_{iju}a_{ijl}}\left(\frac{W_j^g}{W_i^g}\right) \quad (4)$$

Stage4: Calculating of consistency index using the equation (5), (6):

$$CI^{m}=\frac{(\lambda_{max}^{m}-n)}{n-1}, \quad (5)$$

$$CI^{g}=\frac{(\lambda_{max}^{g}-n)}{n-1} \quad (6)$$

Stage5: Calculating of consistency rate using the equations (7), (8):

$$CR^{m}=\frac{CI^{m}}{RI^{m}}, \quad (7)$$

$$CR^{g}=\frac{CI^{g}}{RI^{g}} \quad (8)$$

If both of indexes were less of 0.10, then fuzzy matrix is consistent, and if they were most of 0.10, then decision makers should revise the prioritization, and if one of these indexes were most of 0.10, then decision makers should revise the interval amounts of triangular judgments (Buckley, 1985).

3.2. FVIKOR

The VIKOR method is a compromise MADM method, developed by Opricovic (1998) and Opricovic et al., (2002), Opricovic & Tzeng (2007) started from the Lp-metric as equation 9 (Ajalli & Asgharizadeh, 2016a):

$$L_{p_i} = \left\{\sum_{j=1}^{n}\left[\frac{w_j\left(F_j^* - F_{ij}\right)}{\left(F_j^* - F_j^-\right)}\right]^p\right\}^{\frac{1}{p}} \quad 1 \le p \le +\infty\ ;\ i = 1, 2, \ldots, I. \quad (9)$$

The VIKOR method can provide a maximum ''group utility'' for the "majority'' and a minimum of an individual regret for the ''opponent''.

The Fuzzy VIKOR stepwise procedure is as follows (Ajalli et al., 2019b):

Step1. Construct Fuzzy Decision Matrix by consider to the scores of each industry as fuzzy in each criteria as table 1:

Table 1. Fuzzy decision matrix

Fuzzy DM	C_1	…	C_n
A_1	(l, m, u)	…	(l, m, u)
⋮	⋮		⋮
A_m			
W_j	(l, m, u)		(l, m, u)

To convert the fuzzy linguistic variables to fuzzy number can use the table 2:

Table 2. Linguistic variables for paired comparison criteria

Equal important	1	1	1
Weakly more important	1	3	5
More important	3	5	7
Strongly more important	5	7	9
Absolutely more important	7	9	11

Step2: Determine the Best and Worst values in each column and finally subtract them as figure 3:

uzzy DM	C_1	…	C_n
A_1	(l,m,u)	…	(l,m,u)
⋮	⋮		⋮
A_m			
W_j	(l,m,u)		(l,m,u)
F^*			
F^-			
$F_j^* - F_j^-$			

Figure 3. The best and worst values in each column and subtract them

For all the attribute functions the best value was F_j^* and the worst value was F_j^-, that is, for attribute J=1-n, it gets formulas as below:

$$F_j^* = \max F_{ij} \ , i = 1, 2, \ldots, m$$

$$F_j^- = \min F_{ij} \ , i = 1, 2, \ldots, m$$

$$F_j^* - F_j^-$$

Where F_j^* the positive ideal solution for the criteria is, F_j^- is the negative ideal solution for the jth criteria. If one associates all F_j^*, one will have the optimal combination, which gets the highest scores, the same as F_j^-.

Step3. Calculate Weighted Normalized Fuzzy Decision Matrix using the equations (10), (11) and as Table 3:

$$0 \le x_{ij}^N = \frac{F_j^* - x_{ij}}{F_j^* - F_j^-} \le 1 \quad (10)$$

$$m_{ij} = x_{ij}^N \times W_j \quad (11)$$

Table 3. Weighted Normalized Fuzzy DM

Weighted Normalized Fuzzy DM	C_1	…	C_n
A_1	$m_{11} = (l,m,u)$	…	$m_{1n} = ((l,m,u)$
⋮	⋮		⋮
A_m	$m_{m1} = (l,m,u)$		$m_{mn} = (l,m,u)$

Step 4. Compute the distance of alternatives to ideal solution (Calculating S, R) as table 4:

Table 4. Calculating S, R

Weighted Normalized Fuzzy DM	C_1	…	C_n	$0 \le S_i$	$0 \le R_i \le 1$
A_1	$m_{11} = (l,m,u)$	…	$m_{1n} = ((l,m,u)$	$S_i = \sum_{j=1}^{n} m_{ij}$	$R_i = Max_{j=1}^{n}(m_{ij})$
⋮	⋮		⋮	⋮	⋮
A_m	$m_{m1} = (l,m,u)$		$m_{mn} = (l,m,u)$	$\sum m_{mj}$	$Max(m_{mj})$

This step is to calculate the distance from each alternative to the positive ideal solution and then get the sum to obtain the final value according to formulas (12), (13) as below:

$$S_i = \sum_{j=1}^{n} w_j \left(F_j^* - F_{ij}\right) / \left(F_j^* - F_j^-\right) \tag{12}$$

$$R_i = \max{}_j \left[w_j \left(F_j^* - F_{ij}\right) / \left(F_j^* - F_j^-\right) \right] \tag{13}$$

Where Si represents the distance rate of the alternative to the positive ideal solution (best combination), Ri represents the distance rate of the alternative to the negative ideal solution (worst combination). The excellence ranking will be based on Si values and the worst rankings will be based on Ri values. In other words, Si , Ri indicate L1i and L*i of Lp- metric respectively.

Step 5. Calculate (– ,+," − "   −   " + ") as below:

$$\text{Negative } (-) = Max\ all\ of\ numbers\ in\ each\ column\ of\ S\ Matrix$$

$$Positive\ (+) = Min\ all\ of\ numbers\ in\ each\ column\ of\ S\ Matrix$$

$$\text{Negative} - Positive = (-) - (+)$$

Step6. Calculate the Fuzzy VIKOR values Qi for i=1, 2,…, m, which are defined as equation (14):

$$Q_i = v\left[\frac{S_i - S^*}{S^- - S^*}\right] + (1-v)\left[\frac{R_i - R^*}{R^- - R^*}\right] \tag{14}$$

Where $S^- = \max_i S_i$, $S^* = \min_i S_i$, $R^- = \max_i R_i$, $R^* = \min_i R_i$ and v is the weight of the strategy of "the majority of criteria'' (or ''the maximum group utility''). $\left[\left(S - S^*\right)/\left(S^- - S^*\right)\right]$ Represents the distance rate from the positive ideal solution of the alternative's achievements In other words, the majority agrees to use the rate of the $\left[\left(R - R^*\right)/\left(R^- - R^*\right)\right]$ Represents the distance rate from the negative ideal solution of the alternative; this means the majority disagree with the rate of the alternative. Thus, when the v is larger (> 0.5), the index of Qi will tend to majority agreement; when v is less (< 0.5), the index Qi will indicate majority negative attitude; in general, v = 0.5, i.e. compromise attitude of evaluation experts.

Step 7. Defuzzification and ranking the alternatives by Qi values

According to the Qi values calculated by step6, it can rank the alternatives and to make suitable decision.

4. Findings

4.1. Evaluation of SD factors using FAHP

The final output of steps 1 to 3 is given in table 5:

Table 5. composed Fuzzy column Matrix

		Si	
C1	0.13	0.34	0.68
C2	0.25	0.50	0.91
C3	0.09	0.17	0.53

Finally, the output of step 4 is presented in table 6 :

Table 6. composed Crisp column Matrix & weight of factors

	C1	C2	C3
C1: Environmental sustainability	1	1	0.707379
C2 C2: Economic sustainability	0.730429	1	0.465418
C3 C3: Social sustainability	1	1	1
V(Ci>C1,C2,C3,C4)	0.730429	1	0.465418
Weight	0.332641	0.455405	0.211954

According to the output of the Excel software, the consistency index & consistency rate of the criteria are both less than 0.10, so the decision matrices of the experts have good compatibility. As can be seen in the table above, the second factor (Economic sustainability) with the highest weight is ranked first, and the first and third factors (Environmental sustainability & Social sustainability) are ranked next. The extracted weights of these factors are considered as the input of the FVIKOR technique to evaluate the key cement industries.

4.2. Ranking of Industries using FVIKOR

In this section, the evaluation and ranking of key cement production industries are done using the steps of the FVIKOR technique.

Step 1: The final geometric fuzzy decision matrix to rank the five industries is as table 7:

Table 7. The final geometric fuzzy decision matrix

DM		C1			C2			C3	
A1	1	2	3	3	3.5	3.7	2	4	6
A2	1	2	4	2	3	4	1	5	7
A3	2	3	5	2	3.5	4.5	2	3.5	4.5
A4	2	3	4	1	3	4.6	1	4	5
A5	5	6	7	2	3	6	3	4	5
Wj	0.332641	0.332641	0.332641	0.455405	0.455405	0.455405	0.211954	0.211954	0.211954

Which fuzzy weights are obtained from FAHP technique and consider as input to Fuzzy VIKOR method.

Step 2: The Best and worst values in each column are presented as table 8:

Table 8. The Best and worst values in each column

F*	5	6	7	3	3.5	6	3	5	7	
F-	1	2	3	1	3	3.7	1	3.5	4.5	
F*-F-	2	4	6	-0.7	0.5	5	-1.5	1.5	6	Min= -1.5
(F*-F-)N	3.51	5.51	7.51	0.81	2.01	6.51	0.01	3.01	7.51	

Step 3: The weights normalized fuzzy decision matrix is calculated as table 9:

Table 9. The weights normalized fuzzy decision matrix

NDM		C1			C2			C3		
A1	0.09	0.24	0.57	-0.05	0.00	1.69	-0.08	0.07	105.98	
A2	0.04	0.24	0.57	-0.07	0.11	2.25	-0.11	0.00	127.17	
A3	0.00	0.18	0.47	-0.10	0.00	2.25	-0.04	0.11	105.98	
A4	0.04	0.18	0.47	-0.11	0.11	2.81	-0.06	0.07	127.17	
A5	-0.09	0.00	0.19	-0.21	0.11	2.25	-0.06	0.07	84.78	Min all of numbers = -0.21

Step 4: The distance of alternatives to ideal solution matrix is calculated as table 10:

Table 10. Calculated S, R

	S			R	
0.58	0.94	108.86	0.30	0.45	106.19
0.49	0.98	130.62	0.25	0.45	127.38
0.48	0.92	109.33	0.21	0.39	106.19
0.51	0.99	131.09	0.25	0.39	127.38
0.27	0.81	87.85	0.15	0.32	84.99

Step5: (–, +, "−" − "+") are as table 11:

- Negative (−) =$Max\ all\ of\ numbers\ in\ each\ column\ of\ S\ Matrix$
- $Positive$ (+) =$Min\ all\ of\ numbers\ in\ each\ column\ of\ R\ Matrix$
- Negative−$Positive$=(−)−(+)

Table 11. Calculated (– , +, "−" – "+")

	S	R					
A1	0.58	0.94	108.86	0.30	0.45	106.19	
A2	0.49	0.98	130.62	0.25	0.45	127.38	
A3	0.48	0.92	109.33	0.21	0.39	106.19	
A4	0.51	0.99	131.09	0.25	0.39	127.38	
A5	0.27	0.81	87.85	0.15	0.32	84.99	
-	0.58	0.99	131.09	0.30	0.45	127.38	
+	0.27	0.81	87.85	0.15	0.32	84.99	
- - +	-87.27	0.18	87.27	-84.69	0.13	84.69	Min = -87.27
- - + N	0.01	87.46	174.54	0.01	84.83	169.40	

Step 6: The Fuzzy VIKOR values Qi for i=1, 2,…, m, is calculated as table 12:

Table 12. The Fuzzy VIKOR values Qi

		Q	
A1	-0.5000	0.0015	10731.0322
A2	-0.5004	0.0017	12878.6836
A3	-0.5005	0.0010	10754.4051
A4	-0.5003	0.0014	12902.0566
A5	-0.5013	0.0000	8620.6497

Step 7: The Defuzzification and Ranking the industries by Qi values are as table 13:

Table 13. the final ranking of industries

Industries	Defuzzification	Rank
A1	1788.423	4
A2	2146.365	2
A3	1792.318	3
A4	2150.260	1
A5	1436.691	5

As can be seen in the above table, the fourth key industry is ranked first in terms of agreement with SD factors. Also, the fifth key industry was ranked last.

5. Conclusions

Cement is one of the main suppliers of the basic needs of structural activities. On the one hand, it is considered one of the main materials in the building sector, and on the other hand, it plays a decisive role in the implementation of construction and infrastructure projects, road construction, dam construction, canalization and concrete surfaces (instead of asphalt). In this sense, the rate of cement directly affects the finished rate of many projects; Changes and fluctuations in this industry, including production, consumption and price changes, will immediately reflect on related industries. The concept of SD was used in the early 1970s in relation to the environment and development. SD is a process that provides human needs and desirable futures for the human society due to the limited non-renewable resources necessary for the survival of the future generation, and it is an ongoing problem (Sajjadi, 2022). Regarding the factors of SD and solving the sustainability challenges of the cement production industry, the following are discussed:

Economic factors: The trend of energy consumption in cement factories is much higher than the global values, and the continuation of this situation imposes a lot of costs on cement factories, and with the updating of the rates of global carriers in the coming years, this industry will be unable to continue the production process, and unfortunately, in addition to the unemployment of thousands people will impose heavy consequences on the civil and construction sectors of the country. Iran's cement and concrete industry has no choice but to move towards SD and must be ready to face these fundamental changes to achieve this goal. Concrete will certainly be more durable in the future and will be developed to meet social and economic needs with minimal environmental effects. As one of the basic industries, cement plays an essential role in providing the country's economic infrastructure, so that there is a high correlation between the economic growth process and per capita consumption of cement in each country. This industry has always been developing in our country, so that based on the strategic plan published by the Ministry of Industry, Mining and Trade in 2015, the cement industry was introduced as one of the 7 strategic industries of the country, which plays the largest role in indicators such as the share It has added value, job creation, export, market share, relative advantage and supply chain (as raw materials or final goods) and the level of knowledge and technology that is relied on in the process of industrial development.

Environmental factors: The cement industry is one of the industries with high strategic importance in the development of human societies, which has high pollution in the environment and it is necessary to think about its serious damages. In the last decade, cement production in Iran has more than doubled, and at the same time, the emission of greenhouse gases and the consumption of fossil fuels and electric energy have doubled.

Social factors: Neglecting social factors during the development process puts the effectiveness of various development programs at serious risk. Because social development strategies aim to improve the quality of human life and emphasize cultural, welfare and psychological needs and the need for adaptability and growth in society's needs. In this context, cement production industries should pay attention to the continuous establishment of social welfare and justice and equality. In this situation, the future generations will have the same and more access to social resources than the current generation.

Also, based on the report of the Research Center of Islamic parlimant of Iran, the following solutions are suggested for the challenges of the cement industry:

- The cooperation of the Ministry of Energy with the Ministry of Industry and specialized associations of the cement industry to manage electricity consumption in this industry through the voluntary closure of cement companies (to carry out repairs) in the summer season and to prevent the product supply from being affected in the market by considering incentives Suitable for manufacturers.
- Revision of the electricity supply plan and the activity of cement factories based on the technical specifications of the equipment and machines so that they can operate with a percentage of demand (at least 70%) and not face the problem of supplying clinker for cement production and supply to the domestic market. . The current plan announced by the Ministry of Energy to supply electricity to cement producing companies is unprofessional and has led to the stoppage of production.
- The Ministry of Industry should play a regulatory role in regulating the cement market. It means to put an end to mandatory pricing and oblige all producers to supply a certain amount of cement weekly in the commodity exchange. This issue, while clarifying supply and demand, will eliminate the role of middlemen in the trade of this product, and real consumers and distributors can buy cement directly from the commodity exchange.
- Activation of the export ring of the commodity exchange for the export of cement and clinker in order to prevent negative competition and dumping and make export transactions transparent.
- Supervision of the Ministry of Industry on the warehouses of cement producers and distributors through the comprehensive system of warehouses to prevent possible hoarding of cement and clinker.
- Gradual correction of electricity and gas prices during a five-year plan with the aim of creating mobility in cement production factories to improve technology and renovation, some of which are 70 years old.
- Considering the production of cement in excess of domestic needs and the limited export markets, it is necessary to review cement plans with physical progress of less than 40%, so that if necessary, they can be stopped or their location changed.
- Any policies and planning for the cement industry should be done in consultation with manufacturers and related specialized associations and economic organizations.
- The distribution cooperatives of cement and building materials should be supported to buy cement from the commodity exchange so that the hands of brokers and middlemen are shortened from the cement market.

Also, the following scientific suggestions are provided for future research:

- Other key influential industries of cement production have been considered and the statistical community of the research has been developed and more reliable and community results have been obtained.
- Researchers can conduct a more comprehensive review of the indicators related to the key factors of SD and provide an interpretive structural model of the factors.
- Researchers can examine the relationship between the factors of SD and identify the influential and influential factors and determine the intensity of the relationship between the factors.
- Researchers can use other weighting techniques (including SWARA, BWM, etc.) and compare with the results of the present study.
- Researchers can take advantage of other ranking techniques (including SIMILARITY, WASPAS, ARAS, COPRAS, MOORA, etc.) and evaluate cement production industries and compare with the results of this research.

One of the limitations of the present research is the lack of easy access to specialists and experts and the unwillingness of some of them to complete the questionnaires. Also, the lack of familiarity with the implementation techniques of the research added to the difficulty of completing the questionnaire, which took a lot of time from the researcher regarding the description of the techniques and how to complete the questionnaires by the experts. So, the main limitations of the research were the lack of consolidation of key cement production industries in one region and the limitations of access to experts in those industries.

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