Istanbul Medipol University

School of Engineering and Natural Sciences

Graduation Project

2024-2025

PROJECT TITLE
Developing a Sustainability Index Using Fuzzy Cognitive Maps
PROJECT ADVISOR
Assoc. Prof. Dr. Melis Almula Karadayı
TEAM MEMBERS
Berna KOTAN (Leader) Büşra SAPAN Emre Hakan ÖZCAN Şüheda YARDIM

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Project Code:

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Developing a Sustainability Index Using Fuzzy Cognitive Maps

Project Advisor:

Assoc. Prof. Dr. Melis Almula KARADAYI

Project Team Members:

Berna KOTAN (Leader)
Büşra SAPAN
Emre Hakan ÖZCAN
Şüheda YARDIM

Sponsor Company (if any):

BUDGET (TL)	PROPOSED	CONSENTED
IMU FUNDING	-	
SPONSOR COMPANY FUNDING	9000	
TOTAL	9000	

PROJECT PLAN	PROPOSED	CONSENTED
PROJECT PLAN Duration in Weeks	28 Weeks	28 Weeks
STARTING DATE	10.10.2024	

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PROJECT OVERVIEW/SUMMARY/ABSTRACT

In today's world, with rapidly depleting natural resources and increasing environmental problems, sustainability has become a priority for all sectors. Organizations should protect the resources of future generations while meeting today's needs. In this context, in addition to striving to achieve their financial targets, companies should also adopt the sustainability approach called corporate sustainability and consider the environmental and social impacts of their business. Developing a sustainability index within the framework of this idea is important as a long-term strategy as it allows businesses to comprehensively evaluate their sustainability performance. Therefore, in this project, it is aimed to develop a sustainability index and contribute to businesses to evaluate themselves.

As a result of the researches conducted, there is no study that addresses both Sustainable Development Goals (SDGs) and Environmental, Social and Corporate Governance (ESG) as two aspects in sustainability studies. In order to address this gap, this project aims to develop a comprehensive sustainability index that is SDG and ESG compatible by using the Fuzzy Cognitive Maps (FCM) method. Some of the reasons for using this method are its ability to work with incomplete or uncertain information, its flexibility to easily add new variables to the system, and its easily integrable and dynamic structure.

The main objectives of the project are to develop an index that is compatible with the SDG and ESG frameworks, to model the interactions between ESG factors, and to adapt the index to different sectors and regions. It is also envisaged that this index will contribute to the corporate and environmental sustainability policies in Türkiye's 12th Development Plan.

The study started with identifying sustainability criteria in line with the SDG and ESG frameworks and then four expert opinions from different sectors were consulted to analyze the impacts of these criteria on each other. The linguistic data obtained from the experts were converted into weight matrices and an impact weight matrices were created for both FMCG and textile sector in line with that data. A sustainability index was created using this weight matrices and the FCM method.

As a result, it is thought that this project will be an important step towards eliminating the existing gaps in the literature on sustainability and it is aimed to create a perspective for sustainability studies to be carried out both in Türkiye and in the world.

Keywords: Sustainability, Fuzzy Cognitive Mapping (FCM), Sustainable Development Goals (SDGs), Environmental, Social, and Governance (ESG)

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1. OBJECTIVE OF THE PROJECT

The rapid consumption of resources with industrialization over the years has brought institutions and people closer to the concept of sustainability. In the Our Common Future/Brundtland Report prepared by the World Commission on Environment and Development (WCED) in 1987, sustainable development is defined as: 'Development that meets the needs of the present without compromising the ability of future generations to meet their needs'. [4] Within the framework of this perspective, the United Nations has established the SDGs consisting of 17 goals. While setting these goals, it is aimed to achieve global sustainable development by 2030. In addition, these goals are also mentioned in Türkiye's 12th Development Plan, which was published in November 2023 and covers the period between 2024-2028. In the published plan, it is clearly stated that one of the main objectives is to increase the effectiveness of coordination, monitoring and review processes by ensuring that the SDGs are carried out with a participatory approach. [23]. The approach of companies to the concept of sustainability is corporate sustainability. Corporate sustainability means that businesses should take into account the economic, environmental and social impacts that occur while striving to achieve their financial goals. In other words, corporate sustainability is an approach that aims to provide value to organizations in the long term by evaluating and managing opportunities arising from economic, environmental and social developments and preventing risks. [16]

The aim of this project is to provide companies with a new perspective by developing a comprehensive sustainability index in line with the United Nations SDG and ESG frameworks using FCMs. In addition, given the 12th Development Plan's emphasis on green transformation and environmental sustainability, the sustainability index to be developed in our project will be a tool that will directly contribute to the environmental and social sustainability goals of this plan.

Sustainability has become a global priority in line with international commitments such as the United Nations' 2030 Agenda for Sustainable Development and increasing ESGs. However, many organizations struggle to accurately measure and manage their sustainability contributions by integrating the interrelated aspects of SDG and ESG elements. Existing measurement tools lack the capacity to account for the complexity of sustainability drivers and their interdependencies. As a new approach, FCM is used to model the complex relationships between various sustainability indicators established under the Sustainable Development and ESG Goals. FCMs offer a promising solution to this problem with their ability to model complex systems where variables interact in non-linear and uncertain ways. Taking into account the multidimensional nature of sustainability measurements, this project will use FCMs to

develop a dynamic sustainability index, providing decision makers with an effective tool for strategic planning and performance assessment.

The developed index will serve as a tool for organizations to assess their own sustainability performance. Through these assessments, companies will be able to compare their performance with other existing organizations and take action accordingly. Furthermore, the index is intended to be adaptable to reflect the specific sustainability goals and challenges of different sectors and regions.

As a result, the overall objectives of the project are listed below:
- To develop a sustainability index framework in line with SDGs and ESG criteria.
- To model the interactions between sustainability factors in the ESG dimensions using the FCM method
- Develop an easy-to-use sustainability index that enables organizations and policy makers to monitor and assess sustainability performance.

2. LITERATURE REVIEW

When the literature is searched, it is seen that various Multi-Criteria Decision Making (MCDM) methods, which are defined as MCDM techniques, are frequently used while creating an index. The studies conducted with methods such as AHP, ARAS, MOOSRA, COPRAS and TOPSIS are listed below. In addition, studies on FCM method, which is the method to be used in the project, are also included.

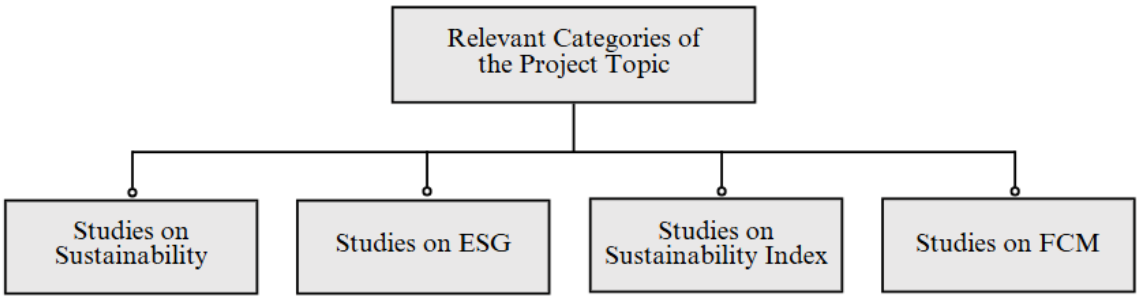

Figure 1. Classification of Project Topics

2.1. Studies on Sustainability

In their study, Ömürbek, Aksoy and Akçakanat (2017) analysed the sustainability performance of large-scale banks according to their asset size and used MCDM methods such as ARAS, MOOSRA and COPRAS to determine this performance. Three criteria were determined for the sustainable performance analysis of banks. As a result, the high values of the criteria used as social factor necessitated the consideration of this factor. [20]

In their study, Yalçın and Karakaş (2019) evaluated the corporate sustainability performance of a company operating in the energy sector. In order to make this evaluation, they used CRITIC and EDAS methods, which are MCDM methods. Considering this evaluation, it was observed that the company did not exhibit a stable behaviour in terms of corporate sustainability performance between 2010-2018. After 2018, it can be said that there is an increase in its performance. [16]

In their study, Obipi and Okeah (2023) have focussed their work on Sustainable Development Goals and the implementation of these SDGs. The aim of the study is to examine the importance of these objectives and the difficulty of their implementation. It also examines the contribution of management scientists to the challenge of implementing these goals. As a result, this paper facilitates the implementation of SDGs in combination with rethinking.[18]

2.2. Studies on ESG

In their study, Yang, Zuo, Li and Guo (2024) examine the role of Green Technological Innovations (GTI) in improving ESG performance to support sustainable development in the manufacturing sector. The study analyses the effects of GTI through internal and external mechanisms. As a result, with the regulations and improvements made, companies increase ESG performance and promote sustainable development. [29]

Vu (2024) examined how companies' ESG performance affects their sensitivity to social sustainability issues. The study shows that companies that are less sensitive to sustainability issues have better ESG performance. The “Sustainability Beta” (βSC) measure was developed to measure the sensitivity of companies. As a result, the study shows that companies can reduce their financial risks by positively affecting investor perceptions as a result of strengthening ESG criteria. [27]

Hluszko, Barros, Souza, Huarachi, Ulloa, Moretti, Puglieri, Francisco (2024) examined the relationships between the actions implemented to develop ESG themes in Latin American industry. This development was done by using content analysis method. When the reports are analyzed from a social perspective, many issues such as inequality and working conditions in Latin America are important. Finally, in terms of governance, the importance of trust in management is emphasized. As a result of this study, it is seen that companies need studies that cover ESG as a whole for sustainability. [6]

2.3. Studies on Sustainability Index

Aytekin and Erol (2018) researched in order to determine whether financial performance is a sufficient indicator for the companies included in the sustainability index to be included in the index. In this study, the ARAS method was used to evaluate the findings. As a result of the study, it was concluded that the sustainability index might contain financial performance as a sufficient indicator. [1]

In their study, Karadağ and Yıldız (2019) carried out the department and university satisfaction indices of statistics students in Türkiye with the method of creating a weighted index with AHP. As a result, the satisfaction index ranking of universities was made according to the results of the evaluation indices. [15]

Subramanian, Alexiou, Nellis, Steele, Tolani (2020) develop a sustainability index applicable to public healthcare supply chains. DEA, ANP and AHP methods were used in this study. As a result, the developed index aims to improve health outcomes and service coverage by serving as a tool to assess and improve the sustainability of public healthcare supply chains. [22]

In their study, Guo, Yu, See (2024) aim to develop an SDG index to assess the SDG performance of Organisation for Economic Co-operation and Development (OECD) countries. The study utilises the Hierarchical Data Envelopment Analysis (H-DEA) model. As a result, the study develops an index to assess the performance of sustainable development goals for OECD countries. [12]

2.4. Studies on FCM

Glykas (2012) discussed the FCM approach to strategy maps (SMs). In addition, example maps including causal relationships are also included. Two case studies were conducted with the methodology and tool. In the project, a network of performance indicators based on critical success factors is created. For this, SM principles were developed using FCM, a modeling technique. This method has been tested in other applications. As a result, it is predicted that the integration of the proposed method will be useful. [11]

Uygun, Demir and Erkan (2017) evaluate the enterprises in terms of green supply chain management by using the FCM method in their study. Firstly, factors affecting the green supply chain method was determined and expert opinions were received. Afterwards, the relationship weights between the factors were determined by the FCM method. The determined weights were used as input in the FCM algorithm. Three scenarios were evaluated in terms of green supply chain management. As a result, green supply chain management performance was measured using the FCM method. [24]

In their study, Erkan, Uygun and Kiraz (2017) developed a model to analyse the level of institutionalisation of organisations and to predict the future situation. The study aims to develop a model that can make quantitative predictions about the future of institutionalisation. Three different are examined using FCM. As a result, it has been determined that institutionalisation can be increased in organisations in a short time by managing the concepts that are effective in institutionalisation well. [10]

Kiraz, Canpolat, Erkan, and Uygun (2019) created a model that predicts the level of Industry 4.0 with the FCM method by considering the IMPULS model criteria in their study. The model was used on three different scenarios and the criteria which has the effect on Industry 4.0 were

analysed. Consequently, the criteria that have the biggest impact on Industry 4.0 level were identified. [17]

3. ORIGINALITY

As seen in the literature review, it cannot be found any study which addresses the issue in a multidimensional manner with SDG and ESG frameworks. In this case, it is thought that this study will bring a different perspective to literature. In addition to the methods used in the studies in the literature, using the FCM method when developing a sustainability index compatible with SDGs and ESGs helps to better understand and model the internal relationships of these two systems. Although these two systems have overlapping objectives, they have different priorities, and the FCM can analyze their interactions and provide a roadmap on how to achieve balance. Thus, organizations can develop more effective sustainability strategies.
Another reason is that it is flexible and can work with incomplete information, as stated in the study by Uygun, Demir, and Erkan (2017). While the concepts that are considered unnecessary among the concepts that define the system can be easily removed from the system, the concepts that are thought to affect the system can be easily included in the system [10]. This enables a more dynamic approach to the system. Erkan, Uygun, Canpolat, Kiraz (2017) also mentioned the dynamic structure of variables in their study. In addition, given the static data structure of existing sustainability indices, this approach provides the opportunity to monitor and evaluate sustainability performance more effectively.

4. SCOPE OF THE PROJECT AND METHODS:

The FCM method is a decision support system technique introduced to literature by Bart Kosko in 1986. Cognitive Maps are graphics that are expressed with the help of nodes and reveal the causal relationship that exists between these nodes. The FCM method was developed and created by integrating fuzzy logic application into the interaction-based approach of cognitive maps. This method offers an effective approach to analyzing complex systems by emphasizing visualization. In this way, it allows a better understanding of complex systems and dynamics and provides more comprehensive and effective support in decision-making processes.
Thanks to the FCM method, a qualitative model is created in which we show the relationships between concepts using fuzzy sets. Thanks to this qualitative model, experts can easily transfer their expertise to the system with simple linguistic expressions instead of precise numerical expressions. This approach makes the information more understandable and accessible. Foreign experts can comprehend the method more easily and accurately thanks to these features. Thus, the method can be easily applied in different disciplines. In addition to these advantages, the biggest advantage of FCM is that it can work with incomplete and flexible information. Thanks to this advantage, any change that may occur can be easily integrated into the system.

WP 1: Determination of Criteria

The first step in starting the FCM method is to determine the criteria. These criteria should be relevant to the project topic. In this project, in order to develop a sustainability index, the criteria that will affect sustainability are determined within the framework of SDG's and ESG perspectives. These criteria are decided by the project team members.

Additionally, as a last criterion the sustainability performance of organizations was written. This criterion shows the sustainability performance of organizations. This criterion was determined as zero in the initial status vector. After applying the FCM method, the reached value reveals the sustainability performance of the company.

WP 2: Obtaining opinions of the expert committee

After determining the criteria which occurs via framework of SDG and ESG, experts are contacted to get their opinions. In order to learn the relationship between the criteria, the opinions of experts in the field are taken and the effects of the criteria determined by these opinions on each other are learned. Experts communicate the relationship between the criteria with verbal expressions such as very strong, negative very strong, etc. called linguistic variables. Additionally, a different matrix are created for each expert.

Linguistic variables may differ among the studies. They do not have a fixed number or structure [19]. Decision makers determine the number of these variables. However, there is a point to be considered when determining this number. If the number of linguistic variables is too high, it will be difficult to clearly define the effect between the criteria. Therefore, it is useful not to have too many linguistic variables. These linguistic variables are then take numerical values in the range [-1,1] and the weight matrix are created accordingly. [10]

When it is looked at the other studies conducted with this method in the literature, it is seen that eight linguistic variables were used in the study conducted by Uygun, Erkan, Demir (2017). The linguistic variables used are fuzzified with triangular membership functions.

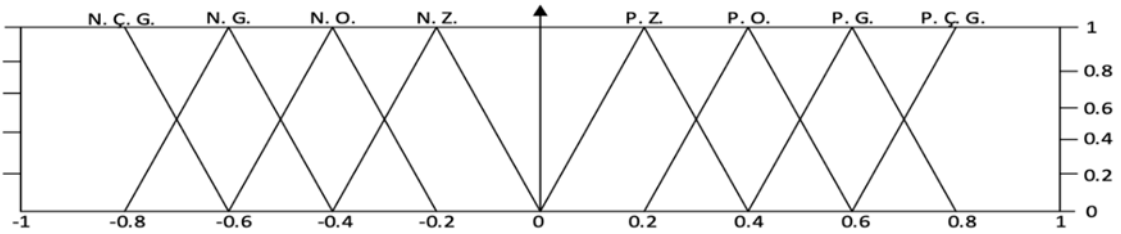

Figure 2. Structure of Linguistic Variables in Uygun, Demir and Erkan (2017)

N.V.S → Negative Very Strong P.V.S → Positive Very Strong

N.S → Negative Strong P.S → Positive Strong

N.M → Negative Medium P.M →. Positive Medium

N.W → Negative Weak P.W → Positive Weak

N → Neutral

FCM method is a method that can solve models with the structure of linguistic variables in cases where it is not healthy to obtain numerical data [10]. In this method, fuzzy membership functions are used to convert the opinions received from experts with linguistic variables into weights [17]. When it is looked at the literature, it is seen that triangular membership functions are frequently used due to the ease of intuitive construction.

WP 3: Calculation of the impact weights of the criteria on each other

The matrices to be formed with linguistic variables are converted into weight matrices using Figure 1. The weight matrices to be formed are different from each other and their number is equal to the number of experts. In the next step, the relationship weight matrix is formed by applying the center of gravity method. This relationship weight center covers the opinions of all experts.

Let's assume that the opinions of M experts are received. Therefore, the number of matrices formed is M. If W_{ij} is called as each connection weight, $W_{ij}^{(k)}$ will be the weight given by expert k.

$$W_{ij}^{compound} = \frac{1}{M}\sum_{k=1}^{M} W_{ij}^{(k)} \quad (1)$$

By using this equation, a common weight matrix is obtained. In this weight matrix, the opinions of all experts is treated equally. If weighting is to be done by considering the reliability level or experience of the experts, the equation is as follows:

$$W_{ij}^{compound} = \sum_{k=1}^{M} \alpha_k \times W_{ij}^{(k)} \quad (2)$$

In Equation 2, α_k represents the weight of expert k. The sum of α_k's should be 1.

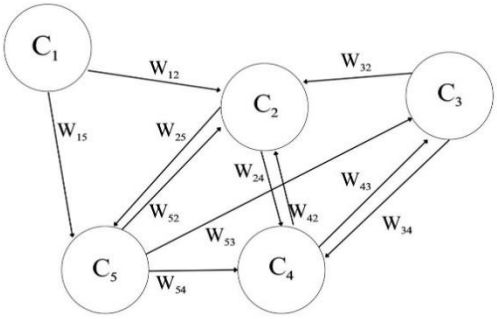

Figure 3. An Example of Fuzzy Cognitive Map Structure

Figure 2 shows a simple FCM structure. The arrows represent the causality between the factors. At the tip of the arrow is the affected factor. The weight of influence of the factors on each other is indicated by W_{ij} shown next to the arrows. The W_{ij} value can also be explained as the value showing the effect of the variable C_i on the variable C_j. W_{ij} value can be evaluated in three cases according to whether it is greater than, less than or equal to zero. [17]

- $W_{ij}>0$ indicates a positive relationship between the variables C_i and C_j. This means that if C_i increases, C_j also increase. If C_i decreases, C_j also decrease. [17]

- $W_{ij}<0$ indicates that there is a negative relationship between the variables C_i and C_j. This means that if there is an increase in C_i, a decrease is observed in C_j. If there is a decrease in C_i, an increase in C_j is observed. [17]

- $W_{ij}=0$ indicates that there is no relationship between the variables C_i and C_j. [17]

WP 4: Creating an index with using FCM

The threshold function simplifies concept values into a normalized range, enabling comparisons between different concepts [14]. In Fuzzy Cognitive Maps, there are four types of threshold functions: bivalent, trivalent, sigmoid, and tangent. The choice of function depends on the specific question being addressed within the problem domain [24].

The bivalent function (3) identifies whether concepts, represented by the values zero and one, are active or inactive [14].

$$f(x) = \begin{cases} 0, & x \leq 0 \\ 1, & x > 0 \end{cases} \qquad (3)$$

The trivalent function (4) determines whether concepts are in a positive growth state (+1), a negative decline state (-1), or a state of equilibrium (0) [14].

$$f(x) = \begin{cases} -1, & x > 0 \\ 0, & x = 0 \\ 1, & x < 0 \end{cases} \quad (4)$$

Sigmoid and hyperbolic tangent functions, which are capable of representing the degree of increase or decrease in concepts, are more frequently utilized in the literature. The sigmoid function, as described in Equation 5, is a unipolar function operating within the range [0,1]. The parameter λ (λ>0) allows adjustment of the sharpness with which the input value is mapped to the output [17].

$$f(x) = \frac{1}{1+e^{-\lambda \times x}} \quad \lambda > 0 \quad (5)$$

The hyperbolic tangent (tanh(x)) function in Equation 6 is used when it is desired that the values of the concepts are in the range [-1,1], that is, the concept values can take both positive and negative values [17].

$$f(x) = \frac{e^{2x}-1}{e^{2x}+1} \quad (6)$$

The value $A_i^{(k+1)}$ for each conceptual variable C_i is given by Equation (7), which is derived from the activation function used by Kosko in 1986 for the FCM method [9].

$$A_i^{(k+1)} = f((2 \times A_i^{(k)} - 1) + \sum_{\substack{j=1 \\ j \neq i}}^{N} W_{ij} \times (2 \times A_j^{(k)} - 1)) \quad (7)$$

A_ik denotes the value of the conceptual variable C_i at time k; $A_i^{(k+1)}$ denotes the value of the conceptual variables C_j that influence the conceptual variable C_i at time (k+1); W_{ij} denotes the influence value from the conceptual variable C_j to the conceptual variable C_i; N denotes the number of criteria and f denotes the threshold function [9].

Once the system structure has been created, the FCM algorithm is run as follows;

Step 1: Define the vector $A^{(k)}$ representing the current state of the system [8].

Step 2: $A^{(k+1)}$ is obtained by determining which formulas to use and applying them [8].

Step 3: The obtained $A^{(k+1)}$ is the new $A^{(k)}$ vector of the next iteration [8].

Step 4: Steps 2 and 3 are repeated until $A^{(k+1)} - A^{(k)} < 0.001$ [8].

After achieving the final version of status vector, the sustainability performance of the organizations is also achieved. While determining the criteria, the sustainability performance status of the organization is determined as the last criterion. Therefore, in the final version, the last value which is reached represents the sustainability performance status of the organization directly.

WP 5: Writing the code using Python language

An index value is calculated as a result of the proposed framework using the balanced criteria values as specified in the previous work package. Using a programming language in the implementation of the FCM technique will provide great advantages in automating the calculations of the model, facilitating fuzzy logic operations, performing dynamic simulations and visualizing the results to make them understandable. Accordingly, Python is used as the programming language for the implementation of the FCM technique.

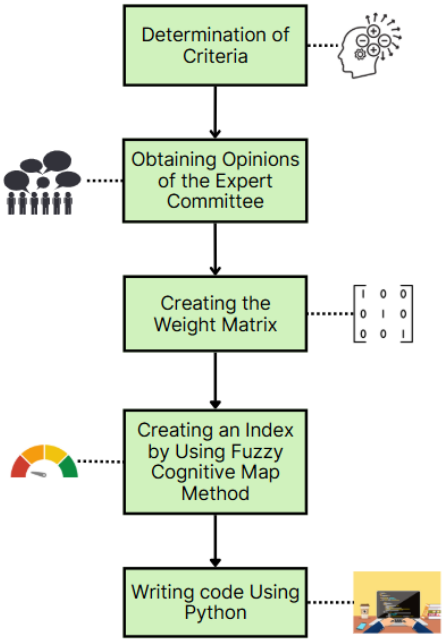

Figure 4. Flowchart of the Project Implementation

5. PROJECT TARGETS AND SUCCESS CRITERIA

In the FCM method, the first step is determination the criteria about the topic. For this project, it is considered that 9 criteria which are in the light of ESG and SDG frameworks will be sufficient. Therefore, when 9 criteria are identified, it can be said that this work package has been successfully completed.

In the second work package, the experts evaluate the relationship between the criteria using linguistic variables. It was decided that at least 3 expert opinions should be consulted for this project. Therefore, when the opinions of 3 experts are obtained, this package can be considered successfully completed.

The third work package is the calculation of the impact weights of the criteria on each other. In this work package, the linguistic variables are converted into numerical data and a separate relationship matrix are created for each expert. Then, a common relationship matrix are calculated from these matrices. If the relationship matrix to be used in the FCM method is created, we can say that this work package has been successfully completed.

The fourth work package is the index creation step of the project. The success criterion of this package is the correct handling of mathematical operations and obtaining a numerical index. In other words, when a numerical index is obtained, it can be said that this package has been completed successfully.

The last work package is writing the code using the Python language. Ensuring that the code runs without errors can be shown as the success criterion of this work package.

Table 1. Work Package Targets Their Assessment, and The Contribution of Each Work Package to Overall Project Success.

Work package	Target	Measurable outcome	Contribution to overall success(%)
1	Determination of the criteria to be used in the FCM method.	Determination of 9 criteria	20
2	Selecting experts in the field and getting their opinions about the impact levels of the determined criteria on each other.	Obtaining opinions from at least 3 experts	25
3	Calculating the impact weights of criteria on each other using FCM.	Creation of the weight matrix to be used in the method	20
4	Obtaining an index value that companies can use to evaluate their own sustainability performance.	Obtaining a numerical index value	20
5	Performing mathematical operations while creating the index	Error-free code execution	15
			Total:100

At the end of the project, all targets were achieved.

6. PROJECT MANAGEMENT RISKS AND B PLANS

Table 2. Risks and Their B Plans of the Project.

Work Package#	Risk	B-Plan
WP #2	The insufficiency of experts	The pool of experts can be expanded, and more experts can be consulted.
WP #5	Code errors and possible errors when using Python language for FCM technique application.	Code errors and technical problems that may arise in the implementation of the FCM technique. Regular version control and error tracking can be done during the coding process.
WP #5	Difficulties in using the Python language in the implementation of the FCM technique.	Possible difficulties in using Python language in the implementation of the FCM technique. MATLAB can be used as an alternative platform.

None of the above risks were encountered during the project.

7. WORK TIME PLAN OF THE PROJECT

Table 3. Detailed Definition of Work and Activity Project-1.

WP No	Detailed Definition of Work and Activity
1	Researching about the project topic and key words.
2	Literature review about sustainability, sustainability index, SDG, ESG, FCM.
3	TÜBİTAK 2209-A application file preparation
4	Completing and reporting project graduation report
5	Researching the application of FCM method, learning how to use the method and examining the different examples

Table 4. Detailed Definition of Work and Activity Project-1.

WP No	Detailed Definition of Work and Activity
1	Determining the criteria within the framework of SDG and ESG perspectives
2	Obtaining expert opinions for the determined criteria
3	Calculation of the impact weights of the criteria on each other
4	Writing the code for the FCM method using Python language
5	Obtaining sustainability performance by using code

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Table 5. The Work-Activity Plan for Project 1.

Work and Activity Project 1	**Responsible Group Member**	**Timeline**													
		1. week	2. week	3. week	4. week	5. week	6. week	7. week	8. week	9. week	10. week	11. week	12. week	13. week	14. week
1. Understanding the project topic and researching	BK & EHÖ & BS & ŞY														
2. Literature review	BK & EHÖ & BS & ŞY														
3. TÜBİTAK project study	BK & EHÖ & BS & ŞY														
4. Preparation of graduation project report	BK & EHÖ & BS & ŞY														
5. Researching on FCM method	BK & EHÖ & BS & ŞY														

Table 6. The Work-Activity Plan for Project 2.

Work and Activity Project 2	**Responsible Group Member**	**Timeline**													
		1. week	2. week	3. week	4. week	5. week	6. week	7. week	8. week	9. week	10. week	11. week	12. week	13. week	14. week
1. Determination of criteria	BK & EHÖ & BS & ŞY														
2. Obtaining opinions of the expert committee	BK & EHÖ & BS & ŞY														
3. Calculating the impact weights of the criteria on each other	BK & EHÖ & BS & ŞY														
4. Creating an index with using FCM	BK & EHÖ & BS & ŞY														
5. Writing the code using Python language	BK & EHÖ & BS & ŞY														

BK: Berna KOTAN, EHÖ: Emre Hakan ÖZCAN, BS: Büşra SAPAN, ŞY: Şüheda YARDIM

8. CASE STUDY APPLICATIONS

In order to obtain the study, the first step is determining the criteria. These criteria are defined in the SDG and ESG frameworks. Moreover, while determining these criteria, studies in literature are taken as reference. The criteria have been determined as carbon emission and energy management, waste management and recycling, employee health and safety, financial transparency and performance, workforce diversity and inclusion, data security and technological compatibility. As a last criterion, sustainability performance was added.

Table 7. Determined Criteria for The Study.

Number of the Criteria	Name of the Criteria
C_1	Carbon Emissions and Energy Management
C_2	Waste Management and Recycling
C_3	Employee Well-being and Workers' Rights
C_4	Corporate Governance and Transparency
C_5	Insufficient Diversity, Equality and Inclusion in the Workforce
C_6	Lack of Innovation and Sustainable Product Development
C_7	Community Engagement and Social Impact
C_8	Inadequate Regulatory Compliance and Ethical Risk Management
C_9	Sustainability Performance

Additionally, these determined criteria's objectives, which parts of SDG and ESG are related to, and the referenced article are shown in Table-4.

Table 8. Information about Criteria.

Criteria	Goal	SDG's	ESG	Reference Article
C_1	Measures the carbon footprint and energy consumption efficiency of companies or regions.	SDG7-Affordable and clean energy SDG13-Climate action	Environmental	Rad, Fard, Khazanedari, Toopshekan, Ourang, Khanali, Gorjian, Fereidooni, Kasaeian (2024)
C_2	Includes strategies for reducing waste production, recycling, and reusing resources to increase efficiency.	SDG12-Responsible consumption and production SDG15-Life on land	Environmental	Baffo, Leonardi, D'Alberti, Petrillo (2024)
C_3	Measures aspects like occupational health and safety, fair wages, and opportunities for employee training and development.	SDG3-Good health and well-being SDG8-Decent work and economic growth	Social	Olabi, Abdelkareem, Mahmoud, Mahmoud, Elsaid, Obaideen, Rezk, Eisa, Chae, Sayed (2024)
C_4	Measures the effectiveness of governance structures, transparency in decision-making, accountability, and ethical management practices.	SDG16- Peace, justice and strong institutions	Governance	Chu, Moktadir, Ren (2024)
C_5	Gender, age, ethnic and cultural diversity is ignored, equal opportunities are not ensured and inclusive policies are not implemented.	SDG5-Gender Equality SDG10-Reduced inequalities	Social	Doğan, Kevser (2020)
C_6	There is insufficient focus on sustainable infrastructure, the number of sustainable products, R&D expenditure ratio, and the availability of eco-certified products.	SDG9-Industry, innovation and infrastructure	Environmental	Baffo, Leonardi, D'Alberti, Petrillo (2024)

		SDG12-Responsible consumption and production		
C_7	Evaluates the development of local communities, participation in social projects, and investments in social responsibility.	SDG11-Sustainable cities and communities	Social	Chu, Moktadir, Ren (2024)
C_8	Risk plans are inadequate, compliance with ethical standards is not monitored and business practices do not fully comply with legislation.	SDG16- Peace, justice and strong institutions	Governance	Chu, Moktadir, Ren (2024)

After deciding the criteria, the questionnaire was created via Google Forms for getting the expert's opinions with linguistic variables. For this project, four different experts were consulted. These experts are on different sectors in the business area. The professional backgrounds and perspectives of the experts:

Expert 1 is an industrial engineer who is currently consulting. After getting about eleven years of experience in the consulting company, she founded her own consulting company. Currently she works on sustainability in the FMCG (Fast-Moving Consumer Goods) sector. After taking the opinions, the Table 9 was created according to the answers of the expert.

Table 9. The Weight Matrix with Linguistic Variables which is Created According to First Expert's Opinion.

	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9
C_1	-	PS	PW	PM	N	NS	PM	NVS	PVS
C_2	PS	-	N	N	N	NM	PW	NVS	PVS
C_3	PW	PM	-	PW	NS	N	PW	NVS	PVS
C_4	PVS	PVS	PVS	-	NVS	NS	PVS	NVS	PVS
C_5	N	N	NVS	NVS	-	NW	NM	NS	NS
C_6	NS	NS	NM	N	N	-	N	NM	NVS
C_7	PS	PS	PW	PW	NW	N	-	N	PS
C_8	NVS	NVS	NVS	NS	NM	NM	N	-	NVS
C_9	-	-	-	-	-	-	-	-	-

Expert 2 is an economist with a degree in Economics and has been working in the FMCG sector. He spent eight years in the finance department of his current company before transitioning to the sustainability department. For the past five years, he has held the position of global sustainability coordinator in the is one of the leading and largest consumer goods companies in FMCG sector.

Table 10. The Weight Matrix with Linguistic Variables which is Created According to Second Expert's Opinion.

	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9
C_1	-	PS	PW	PS	NW	NS	PW	NM	PVS
C_2	PM	-	N	PW	NW	NM	PW	NM	PS
C_3	N	N	-	PM	NM	NW	PVS	NW	PM
C_4	PS	PS	PM	-	NM	NM	PM	NM	PM
C_5	N	N	NS	NS	-	NW	NS	NS	NS
C_6	NS	NS	NW	NW	NW	-	NW	NW	NS
C_7	PM	PM	PS	PM	PVS	PM	-	PM	PS
C_8	NS	NS	NS	NS	NW	NM	NM	-	NS
C_9	-	-	-	-	-	-	-	-	-

Expert 3 is currently working as a sustainability expert and has a background in chemistry. She has 8 years of experience in the textile industry and, as of 2025, holds the position of sustainability manager at Türkiye-based textile company that provides production support to many world-famous fast fashion brands. She has been working in this position for a year.

Table 11. The Weight Matrix with Linguistic Variables which is Created According to Third Expert's Opinion.

	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9
C_1	-	PS	N	PM	N	NVS	N	NS	PVS
C_2	PS	-	N	PM	N	NS	N	NS	PVS
C_3	N	N	-	PM	NVS	N	PVS	NS	PVS
C_4	PS	PW	PVS	-	NVS	NW	PM	NS	PVS
C_5	N	N	NS	NS	-	N	NVS	N	NM
C_6	NS	NS	N	N	N	-	N	N	NM
C_7	N	N	PW	N	PM	N	-	PW	PS
C_8	NS	NS	NM	NW	NW	N	PW	-	NW
C_9	-	-	-	-	-	-	-	-	-

Expert 4 holds a degree in textile engineering and has been working at her current company for four years. For the past year, she has been serving as a sustainability specialist at a textile manufacturer serving many world-famous fast fashion brands.

Table 12. The Weight Matrix with Linguistic Variables which is Created According to Fourth Expert's Opinion.

	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9
C_1	-	PVS	PM	PS	NM	NVS	PS	NVS	PVS
C_2	PVS	-	PS	PS	NS	NVS	PS	NVS	PVS
C_3	PM	PM	-	PS	NS	NS	PS	NVS	PS
C_4	PS	PS	PVS	-	NVS	NVS	PVS	NVS	PVS
C_5	NW	NW	NW	NW	-	NW	NW	NW	NW
C_6	NS	NVS	NS	NVS	NVS	-	NVS	NVS	NVS
C_7	PM	PS	PS	PS	PS	PS	-	PS	PS
C_8	NS	NS	NS	NS	NS	NM	NS	-	NS
C_9	-	-	-	-	-	-	-	-	-

The matrices created with these linguistic variables were transformed into matrices which is created with numerical values by using triangular membership functions. Table-8 shows which linguistic variable corresponds to which values.

Table 13. Numerical Values of Linguistic Variables.

	a	b	c
PVS	0,6	0,8	1
PS	0,4	0,6	0,8
PM	0,2	0,4	0,6
PW	0	0,2	0,4
N	-0,2	0	0,2
NW	-0,4	-0,2	0
NM	-0,6	-0,4	-0,2
NS	-0,8	-0,6	-0,4
NVS	-1	-0,8	-0,6

After the expert opinions which were received with linguistic variables were converted into numerical matrices with numerical values of linguistic variables, they were available to create a common weight matrix with central weight method. Due to the fact that two different sectors were evaluated in this project, the common weight matrices which is used in the evaluation of the sectors were also created differently. While common weight matrix 1, which was obtained by taking the opinions of Expert 1 and Expert 2, will be used in the evaluation of institutions in the FMCG sector, common weight matrix 2, which was determined by the opinions of Expert 3 and Expert 4, will be used in the evaluation of institutions in the textile sector. Moreover, these matrices show the effects of the criteria on each other.

Table 14. The Common Impact Weight Matrix for FMCG Sector.

	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9
C_1	0	0,6	0,2	0,5	-0,1	-0,6	0,3	-0,6	0,8
C_2	0,5	0	0	0,1	-0,1	-0,4	0,2	-0,6	0,7
C_3	0,1	0,2	0	0,3	-0,5	-0,1	0,5	-0,5	0,6
C_4	0,7	0,7	0,6	0	-0,6	-0,5	0,6	-0,6	0,6
C_5	0	0	-0,7	-0,7	0	-0,2	-0,5	-0,6	-0,6
C_6	-0,6	-0,6	-0,3	-0,1	-0,1	0	-0,1	-0,3	-0,7
C_7	0,5	0,5	0,4	0,3	0,3	0,2	0	0,2	0,6
C_8	-0,7	-0,7	-0,7	-0,6	-0,3	-0,4	-0,2	0	-0,7
C_9	0	0	0	0	0	0	0	0	0

Table 15. The Common Impact Weight Matrix for Textile Sector.

	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9
C_1	0	0,7	0,2	0,5	-0,2	-0,8	0,3	-0,7	0,8
C_2	0,7	0	0,3	0,5	-0,3	-0,7	0,3	-0,7	0,8
C_3	0,2	0,2	0	0,5	-0,7	-0,3	0,7	-0,7	0,7
C_4	0,6	0,4	0,8	0	-0,8	-0,5	0,6	-0,7	0,8
C_5	-0,1	-0,1	-0,4	-0,4	0	-0,1	-0,5	-0,1	-0,3
C_6	-0,6	-0,7	-0,3	-0,4	-0,4	0	-0,4	-0,4	-0,6
C_7	0,2	0,3	0,4	0,3	0,5	0,3	0	0,4	0,6
C_8	-0,6	-0,6	-0,5	-0,4	-0,4	-0,2	-0,2	0	-0,4
C_9	0	0	0	0	0	0	0	0	0

8.1. Scenario 1 – Environmental Perspective

In this scenario, it was assumed that environmental criteria were well managed, while social and governance criteria were poorly managed. The criteria under the environmental heading, Carbon Emissions and Energy Management (C_1), Waste Management and Recycling (C_2), and Lack of Innovation and Sustainable Product Development (C_6), were evaluated positively due to the environmental focus of this scenario. The reason for the low evaluation of criterion C_6 is that it is a negative criterion.

Additionally, the reasons for the negative evaluation of the Employee Well-being and Workers' Rights (C_3), Corporate Governance and Transparency (C_4), Insufficient Diversity, Equality, and Inclusion in the Workforce (C_5), Community Engagement and Social Impact (C_7), and Inadequate Regulatory Compliance and Ethical Risk Management (C_8) criteria are that these criteria fall under the social and governance headings. Furthermore, the reason for the high evaluation of criteria C_5 and C_8 is that these criteria are considered negative in this scenario.

The initial status values of Scenario-1 are as follows:

$$A^{initial} = [0.9, 0.9, 0.3, 0.2, 0.9, 0.1, 0.2, 0.8, 0]$$

8.2. Scenario 2 – Social Perspective

In this scenario, the social criteria were well managed, while the environmental and governance criteria were poorly managed. The criteria under the social heading, Employee Well-being and Workers' Rights (C_3), Equality and Inclusion in the Workforce (C_5), and Community

Engagement and Social Impact (C_7), were evaluated positively due to the social focus of this scenario. The reason for the low evaluation of the C_5 criterion is that it is a negative criterion.

In addition, the Carbon Emissions and Energy Management (C_1), Waste Management and Recycling (C_2), Corporate Governance and Transparency (C_4), Lack of Innovation and Sustainable Product Development (C_6), and Inadequate Regulatory Compliance and Ethical Risk Management (C_8) criteria were evaluated negatively because they fall under the social and governance headings. Furthermore, the reason for the high evaluation of the C_6 and C_8 criteria is that these criteria are considered negative in this scenario.

The initial status values of Scenario-2 are as follows:

$$A^{initial} = [0.3, 0.2, 0.9, 0.2, 0.1, 0.9, 0.9, 0.8, 0]$$

8.3. Scenario 3 – Governance Perspective

In this scenario, it is assumed that corporate criteria are well managed, while social and environmental criteria are poorly managed. The criteria under the corporate heading, Corporate Governance and Transparency (C_4), Inadequate Regulatory Compliance and Ethical Risk Management (C_8), were evaluated positively due to the corporate focus of this scenario. The reason for the low evaluation of the C_8 criterion is that it is a negative criterion.

Additionally, the criteria Carbon Emissions and Energy Management (C_1), Waste Management and Recycling (C_2), Employee Well-being and Workers' Rights (C_3), Insufficient Diversity, Equality, and Inclusion in the Workforce (C_5), and Community Engagement and Social Impact (C_7) were evaluated negatively because they fall under the social and environmental headings. Furthermore, the reason for the high evaluation of the C_5 and C_6 criteria is that these criteria are considered negative in this scenario.

The initial status values of Scenario-3 are as follows:

$$A^{initial} = [0.3, 0.2, 0.3, 0.9, 0.7, 0.7, 0.2, 0.1, 0]$$

9. FINANCIAL EVALUATION:

Table 16. Proposed Budget in TL.

	ITEMS				
	PEOPLE	MACHINE-INSTRUMENT	MATERIALS	SERVICE	TRAVEL
IMU FUND	-	-	-	-	-
SPONSOR COMPANY FUND	-	-	1000	-	8000
TOTAL			1000		8000

10. RESULTS

In this project, three different scenarios were analyzed by entering the initial vector and each sector's own weight matrix into the FCM algorithm for the FMCG and textile sectors. In addition, after the iterations were obtained, future sustainability performances were obtained and analyzed. The scenario results and explanations are given below.

10.1. Scenario 1 – FMCG Sector

According to scenario 1, the organizations where environmental factors are well managed, but social and governance factors are poorly managed were discussed. The initial vector which represents these organizations is given below.

$$A^{initial} = [0.9, 0.9, 0.3, 0.2, 0.9, 0.1, 0.2, 0.8, 0]$$

The final state vector was found with the Python code. The values in the final vector represent the expected future trends of the criteria. Moreover, sustainability status has been determined as the last criterion. And the last value in this vector shows the sustainability status which the organization reached in the future.

The final matrix below was obtained as a result of the 12^{th} iteration.

$$A^{final} = [0.028\ 0.024\ 0.043\ 0.052\ 0.753\ 0.821\ 0.055\ 0.907\ 0.005]$$

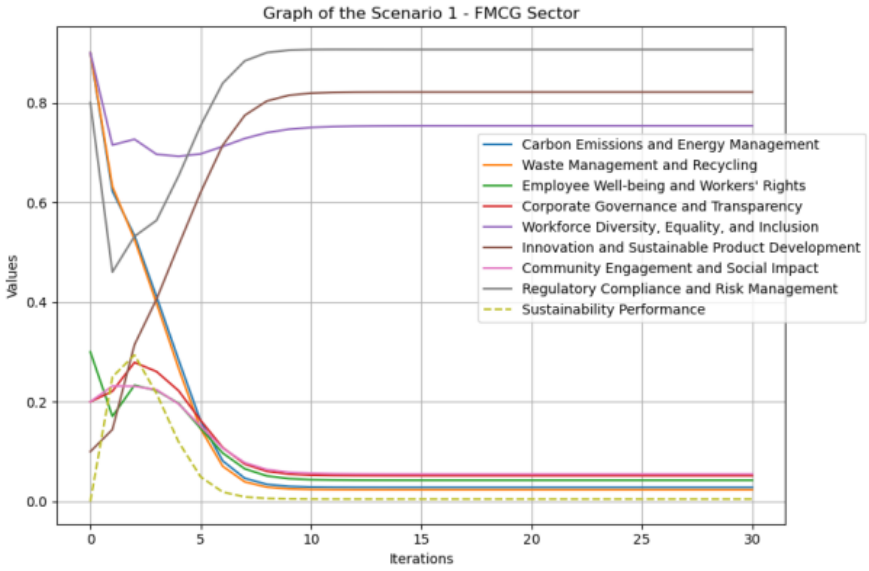

Figure 5. Final Graph of Scenario 1 - FMCG Sector

By applying equations (5) and (7) mentioned in the study, the future trends of the criteria and where they will be in terms of sustainability performance are obtained in the final vector, and these were visualized via graph 1. According to the results of the analyses, only good management of environmental criteria in the organization which are in FMCG sector has not been able to improve sustainability performance sufficiently. In particular, poor management of social and governance frameworks has negatively affected the overall sustainability level. In this scenario, while the criteria C_5, C_6 and C_8, which are negative impact on sustainability, show an increasing trend in the future, the other criteria which are positive impact on sustainability are close to 0, which is a bad level. This reveals that sustainability of the organization which has this initial vector will have a bad position in the future and cannot achieve in a holistic manner.

As a result, in this scenario, the organisation which has this initial matrix has bad sustainability performance in the future. Moreover, it is seen that only good management of environmental criteria is not sufficient in terms of sustainability performance in the FCGM sector.

10.2. Scenario 1 – Textile Sector

According to scenario 1, the organizations where environmental factors are well managed, but social and governance factors are poorly managed were discussed. The initial vector which represents these organizations is given below.

$$A^{initial} = [0.9, 0.9, 0.3, 0.2, 0.9, 0.1, 0.2, 0.8, 0]$$

The final state vector was found with the Python code. The values in the final vector represent the expected future trends of the criteria. Moreover, sustainability status has been determined as the last criterion. And the last value in this vector shows the sustainability status which the organization reached in the future.

The final matrix below was obtained as a result of the 13th iteration.

$$A^{final} = [\,0.975\ 0.974\ 0.9696\ 0.972\ 0.216\ 0.0750\ 0.972\ 0.0599\ 0.996]$$

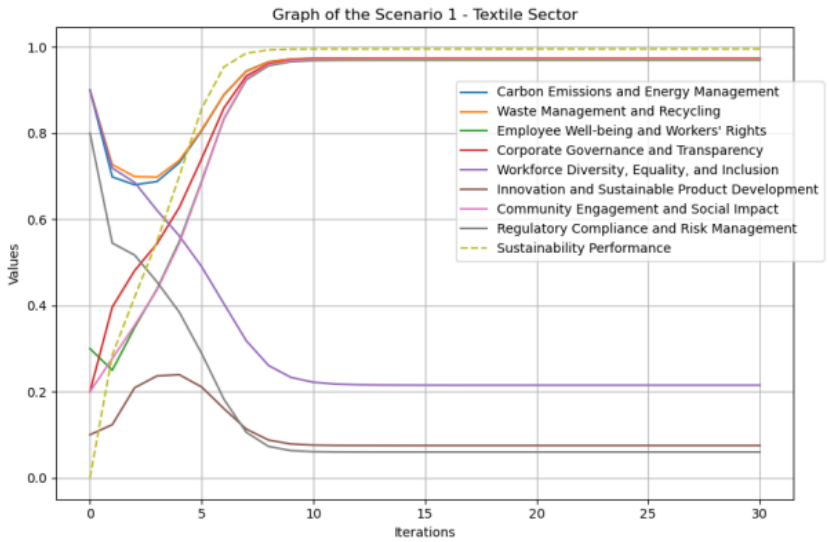

Figure 6. Final Graph of Scenario 1 – Textile Sector

By applying equations (5) and (7) mentioned in the study, the future trends of the criteria and where they will be in terms of sustainability performance are obtained in the final vector and these were visualized via graph 2. According to the results of the analysis, only good management of environmental criteria in the organization which are in textile sector has a positive impact on sustainability performance. In the graph, it is seen that C_1, C_2, C_3, C_4 and C_7 criteria converge to 1, which is the good level. This shows that good management of environmental criteria has a strong impact on these criteria. In addition, the convergence of C_5, C_6 and C_8 criteria to 0, which is a bad level, has a positive effect on sustainability performance. This is due to the fact that these criteria are negative impact criteria. This shows that a textile company with this starting point will be in a good position in terms of sustainability in the future and will also reduce the risks that may arise due to social and governance criteria.

As a result, in this scenario, the future sustainability performance of the organization with this starting matrix will be good. In addition, it is seen that only good management of environmental criteria is sufficient in terms of sustainability performance in the textile sector

10.3. Scenario 2 – FMCG Sector

According to scenario 2, the organizations where social factors are well managed, but environmental and governance factors are poorly managed were discussed. The initial vector which represents these organizations is given below.

$$A^{initial} = [0.3, 0.2, 0.9, 0.2, 0.1, 0.9, 0.9, 0.8, 0]$$

The final state vector was found with the Python code. The values in the final vector represent the expected future trends of the criteria. Moreover, sustainability status has been determined as the last criterion. And the last value in this vector shows the sustainability status which the organization will reach in the future.

The final matrix below was obtained as a result of the 12th iteration.

$$A^{final} = [0.028\ 0.023\ 0.043\ 0.052\ 0.752\ 0.821\ 0.056\ 0.907\ 0.005]$$

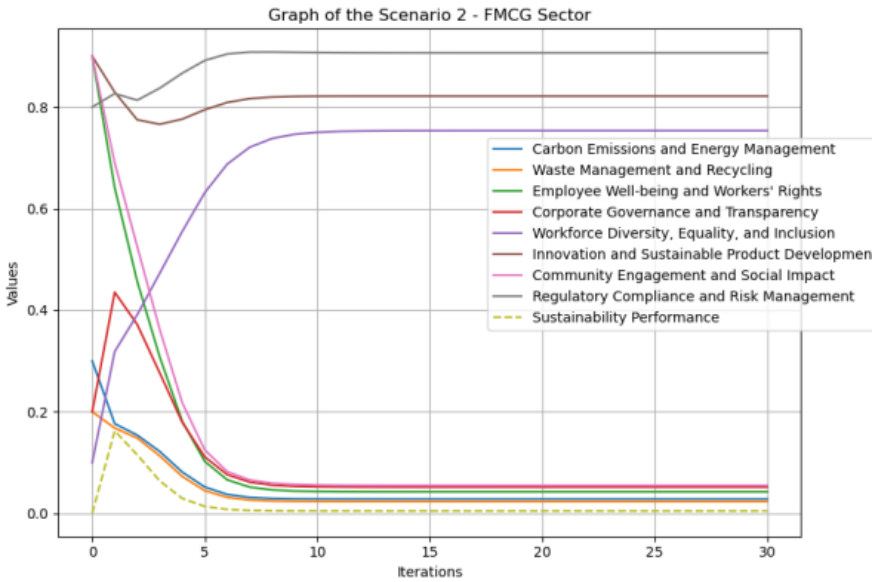

Figure 7. Final Graph of Scenario 2 – FMCG Sector

By applying equations (5) and (7) mentioned in the study, the future trends of the criteria and where they will be in terms of sustainability performance are obtained in the final vector, and these were visualized via graph 3. According to the results of the analyses, only good management of social criteria in the organization which are in FMCG sector has not been able to improve sustainability performance sufficiently. In particular, poor management of

environmental and governance frameworks has negatively affected the overall sustainability level. In this scenario, while the criteria C_5, C_6 and C_8, which are negative impact on sustainability, show an increasing trend in the future, the other criteria which have positive impact on sustainability are close to 0, which is a bad level. This reveals that the sustainability of the organization which has this initial vector will have a bad position in the future and cannot achieve in a holistic manner.

As a result, in this scenario, the organization which has this initial matrix has bad sustainability performance in the future. Moreover, it is seen that only good management of environmental criteria is not sufficient in terms of sustainability performance in the FCGM sector.

10.4. Scenario 2 – Textile Sector

According to scenario 2, the organizations where social factors are well managed, but environmental and governance factors are poorly managed were discussed. The initial vector which represents these organizations is given below.

$$A^{initial} = [0.3, 0.2, 0.9, 0.2, 0.1, 0.9, 0.9, 0.8, 0]$$

The final state vector was found with the Python code. The values in the final vector represent the expected future trends of the criteria. Moreover, sustainability status has been determined as the last criterion. And the last value in this vector shows the sustainability status which the organization reached in the future.

The final matrix below was obtained as a result of the 10^{th} iteration.

$$A^{final} = [0.025\ 0.026\ 0.030\ 0.028\ 0.784\ 0.925\ 0.028\ 0.940\ 0.004]$$

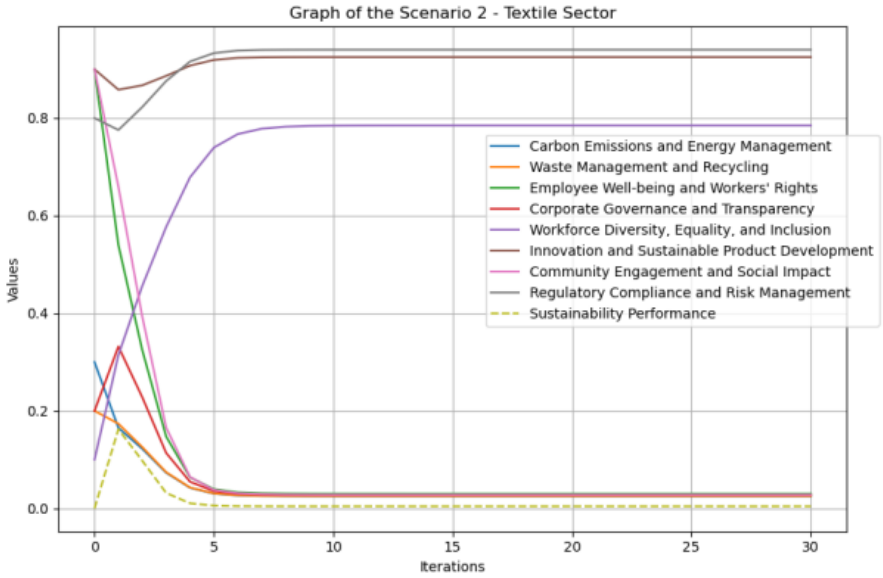

Figure 8. Final Graph of Scenario 2 – Textile Sector

By applying equations (5) and (7) mentioned in the study, the future trends of the criteria and where they will be in terms of sustainability performance are obtained in the final vector and these were visualized via graph 4. According to the results of the analyses, only good management of social criteria in the organization which are in textile sector has not been able to improve sustainability performance sufficiently. In particular, poor management of environmental and governance frameworks has negatively affected the overall sustainability level. In this scenario, while the criteria C_5, C_6 and C_8 which are negative impact on sustainability show an increasing trend in the future, the other criteria which are positive impact on sustainability are close to 0, which is a bad level. This reveals that sustainability of the organization which has initial vector will have bad position in the future and cannot achieved in a holistic manner.

As a result, in this scenario, the organizations which has this initial matrix has bad sustainability performance in the future. Moreover, it is seen that only good management of social criteria is not sufficient in terms of sustainability performance in the textile sector.

10.5. Scenario 3 – FMCG Sector

According to scenario 3, the organizations where governance factors are well managed, but environmental and governance factors are poorly managed were discussed. The initial vector which represents these organizations is given below.

$$A^{initial} = [0.3, 0.2, 0.3, 0.9, 0.7, 0.7, 0.2, 0.1, 0]$$

The final state vector was found with the Python code. The values in the final vector represent the expected future trends of the criteria. Moreover, sustainability status has been determined as the last criterion. And the last value in this vector shows the sustainability status which the organization reached in the future.

The final matrix below was obtained as a result of the 17th iteration.

$$A^{final} = [0.972, 0.977, 0.957, 0.948, 0.247, 0.179, 0.945, 0.093, 0.995]$$

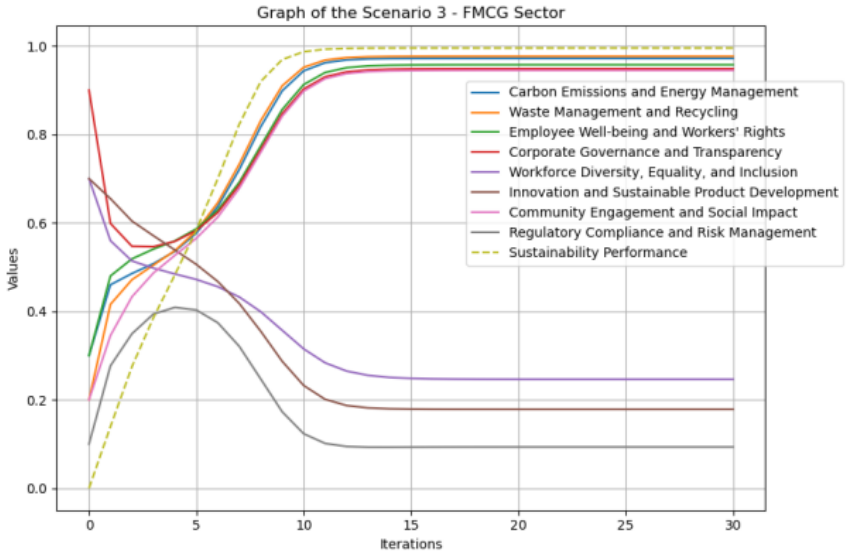

Figure 9. Final Graph of Scenario 3 - FMCG Sector

By applying equations (5) and (7) mentioned in the study, the future trends of the criteria and where they will be in terms of sustainability performance are obtained in the final vector and these were visualized via graph 5. According to the results of the analyses, only good management of governance criteria in the FMCG sector has been able to improve sustainability performance sufficiently. In particular, poor management of social and environmental frameworks has negatively affected the overall sustainability level. In this scenario, C_1, C_2 and C_3 are the criteria that may show an increasing trend in the future. However, it is seen that social and environmental criteria such as C_5, C_6, C_8 are close to 0, which is a bad level.

As a result, in this scenario, the future sustainability performance of the organization with this starting matrix will be good. In addition, it is seen that only good management of governance criteria is sufficient in terms of sustainability performance in the FMCG sector.

10.6. Scenario 3 – Textile Sector

According to scenario 3, the organizations where governance factors are well managed, but social and environmental factors are poorly managed were discussed. The initial vector which represents these organizations is given below.

$$A^{initial} = [0.3, 0.2, 0.3, 0.9, 0.7, 0.7, 0.2, 0.1, 0]$$

The final state vector was found with the Python code. The values in the final vector represent the expected future trends of the criteria. Moreover, sustainability status has been determined as the last criterion. And the last value in this vector shows the sustainability status which the organization reached in the future.

The final matrix below was obtained as a result of the 11th iteration.

$$A^{final} = [0.0253\ 0.0256\ 0.0303\ 0.0276\ 0.783\ 0.924\ 0.028\ \ 0.940\ \ 0.004]$$

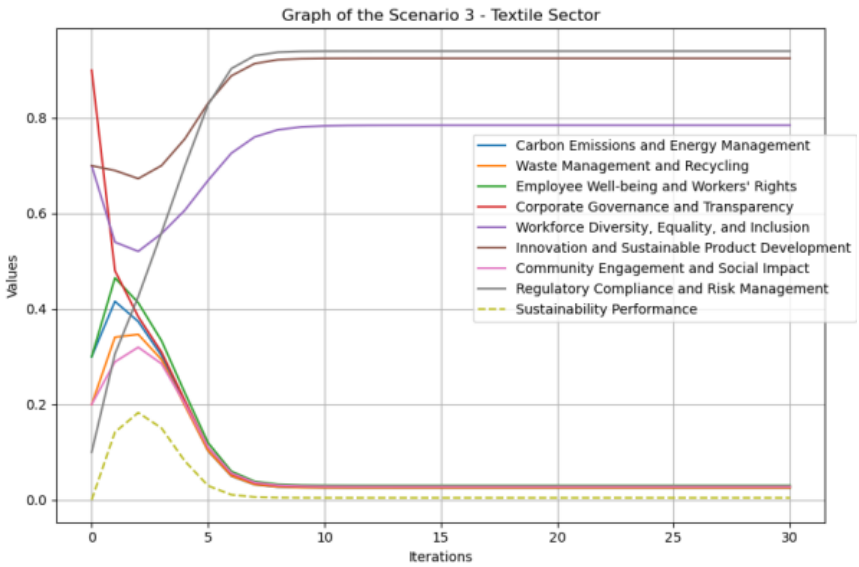

Figure 10. Final Graph of Scenario 3 – Textile Sector

By applying equations (5) and (7) mentioned in the study, the future trends of the criteria and where they will be in terms of sustainability performance are obtained in the final vector and these were visualized via graph 5. According to the results of the analyses, only good management of governance criteria in the organization which are in FMCG sector has been able to improve sustainability performance sufficiently. In the graph, it is seen that C_1, C_2, C_3, C_4 and C_7 criteria converge to 1, which is the good level. This shows that good management of governance criteria has a strong impact on these criteria. In addition, the convergence of C_5, C_6

and C8 criteria to 0, which is a bad level, has a positive effect on sustainability performance. This is due to the fact that these criteria are negative impact criteria. This shows that a FMCG company with this starting point will be in a good position in terms of sustainability in the future and will also reduce the risks that may arise due to environmental and social criteria.

As a result, in this scenario, the future sustainability performance of the organization with this starting matrix will be good. In addition, it is seen that only good management of governance criteria is sufficient in terms of sustainability performance in the FMCG sector.

11. DISCUSSION

In this project, three different scenarios were examined, and these scenarios were also evaluated on sectoral basis. Scenario 1 considers organizations where environmental factors are well managed and other factors are poorly managed. Moreover, this scenario was analyzed for two different sectors. When this scenario was applied to the first one, the FMCG sector, it was observed that sustainability performance would deteriorate if the current criteria values continued in this way. Based on this observation, it is concluded that only good management of criteria with environmental impact is not enough to have good sustainability performance in the future. On the other hand, when this scenario is examined in an organization in the textile sector, which is another sector examined, it is seen that if the current criteria values continue in this way, the organization has a good sustainable performance in the future, unlike the FMCG sector. The implication of this result is that if only the criteria with environmental impact are managed well in the textile sector, sustainability still improves. Thus, it is understood that the impact of criteria with environmental impact on sustainability performance is high. The reason for this sector-based differentiation is that the weight matrices created by taking the opinion of experts used in the application of the FCM algorithm are different. Thus, it is observed that the impacts of the criteria on each other differ on a sectoral basis. Therefore, it is concluded that while good management of only environmental impacts is sufficient to have good sustainable performance in the textile sector, it is not sufficient in the FMCG sector.

In Scenario 2, the organizations in both sectors where the criteria with social impact are well managed and the criteria with environmental and governance impact are missing are examined by this scenario. The results show that for both sectors, only good management of social impact criteria is not sufficient to have good sustainability performance for organizations. Thus, it is concluded that in both sectors, social impact criteria should be supported by criteria that have an impact on other frameworks.

In Scenario 3, organizations in both sectors where the criteria with governance impact are well managed and the criteria with environmental and social impact are missing are examined by

scenarioizing. When this scenario is considered in an organization in the FMCG sector, it is seen that it has good sustainability performance. The implication of this is that only good management of governance criteria has a positive impact on sustainability performance and is sufficient to be good version in the future. On the other hand, when this scenario is examined for an organization in the textile sector, it is seen that, unlike the FMCG, it is not sufficient to manage only the governance effective criteria well. It is concluded that in order to have good sustainability performance, in addition to governance effective criteria, other criteria should be well managed.

In addition to the scenarios, they were also analyzed within the sectors themselves. Firstly, when the applications of the three scenarios in the FMCG sector are examined, it is observed that sustainability performance is getting good in the future when only governance effective criteria are well managed, whereas sustainability performance deteriorates when only environmental criteria are well managed or only social criteria are well managed. Thus, it is concluded that managing only social criteria or only environmental criteria well in the FMCG sector does not have a positive impact on sustainability and should be supported by another framework.

Additionally, when it is looked at the applications of the three scenarios in the textile sector, it can be said that good management of only environmental criteria is sufficient to have good sustainability performance. On the other hand, in scenarios where only social or governance criteria are well managed, it is seen that managing only these criteria well do not have a positive impact on sustainability performance. For this reason, it is argued that they should be supported by another framework.

Addition to these, the results of the scenarios are consistent with real-life examples. For example, one of the world's largest FMCG companies headquartered in Switzerland is taking action on environmental sustainability by reducing packaging waste and minimizing the use of plastic. However, the fact that the company has been criticized in the past on social issues (such as child labor, violation of the rights of local people through water use) leads to deficiencies in the social and governance aspects of sustainability. Moreover, the overall perception of the brand is that it is not a brand that customers associate with sustainability. As a result, it is not enough for FMCG companies to take action only from the environmental perspective of sustainability, as this real example of a company shows. As another example, when one of the world's largest fast-fashion fashion distribution groups is examined, it is seen that the brand supports social issues such as employee rights and women's employment. However, due to the company’s high environmental impact and carbon footprint, social success alone is not enough in terms of sustainability.

12. ASSESMENT OF ENGINEERING STANDARTS

In this project, there are some standards which are related to the topic which can be referenced through the project. These are ISO 26000 for criteria assessment and PEP 8 for the Python coding.

The project is based on the internationally recognized ISO 26000 Social Responsibility Guidelines for the identification and assessment of sustainability criteria. This guide provides a guiding framework for setting environmental, social and governance (ESG) criteria, ensuring that the criteria are objective, measurable and in line with universal standards. In particular, the comprehensive approach of ISO 26000 addresses how sustainability indicators can be integrated with companies' social responsibility practices. This enabled a standardized assessment of sustainability performance both within companies' own processes and in cross-sector comparisons.

Python programming language was used in software development processes and PEP 8 (Python Enhancement Proposal 8) standards were adopted to ensure the accuracy and consistency of coding processes. In addition to improving the readability of the code, PEP 8 facilitated collaboration between team members by adopting a common coding standard. Throughout the project, attention was paid to coding practices such as variable naming, line length, whitespace usage and function configuration to make the code easy to understand and maintain. This ensured that the code could be shared among the team members and that the code could be updated at later stages.

13. UNIVERSAL AND SOCIAL EVALUATION OF THE PROJECT/ LIMITATIONS

The sustainability index developed in this project offers decision-makers in companies the opportunity to evaluate the organization's sustainability performance from a holistic perspective, considering environmental, social, and governance dimensions. However, this developed model also works effectively within a certain framework, as in every engineering solution. In other words, the project can produce successful results provided that this framework is correctly defined and managed sustainably.
During the data collection process of the project, companies may have reservations about transparency. At this point, some organisations may be negative about sharing governance or social performance data. In order to minimise such limitations, anonymised data collection methods are used.
Furthermore, the project planned as a dynamic system designed to update the data regularly. The validity of the index will be maintained by periodically updating it with new data. Thanks

to periodic data input, the model will be valid not only for a specific moment but also for long-term use. In order to avoid this limitation, expert opinions should be taken again at regular intervals and the outputs of the model and the direction in which sustainability performance evolves should be reviewed.

14. CONCLUSION

This project aims to develop a sustainability index that enables companies to assess themselves within the framework of the SDGs and ESG criteria. In this study, the FCM method was used to examine the impact of the criteria established within the SDGs and ESG frameworks on each other and to reveal how sustainability performance varies depending on the sector. In the developed index model, the dynamic structure of sustainability was successfully modelled using weight matrices created based on expert opinions.

As can be seen from the literature, a flexible and applicable sustainability model that addresses the issue in a multidimensional manner with SDG and ESG frameworks is very limited in number. Thanks to the FCM model used in the project, the cause-effect relationships between the criteria can be modelled effectively; in addition, the method's ability to work with incomplete and uncertain data has made a significant contribution to real-world decision-making processes. Within the scope of the study, three different scenarios were created, which simulated situations where each of the environmental, social and governance criteria were managed strongly on their own. Moreover, these scenarios were evaluated and analysed separately for both FMCG and textile sectors. The findings can be summarised as follows:

- In the FMCG sector, only good management of governance criteria was sufficient to improve sustainability performance, while focusing only on environmental or social criteria was insufficient.

- In the textile sector, only good management of environmental criteria was sufficient to improve sustainability performance, while the impact of other criteria was limited.

- In both sectors, only good management of social criteria was insufficient and these criteria alone did not have a significant impact on sustainability.

As a result of the scenarios examined and the analysis, it is thought that sustainability cannot be achieved by focusing on a single dimension. It is also concluded that sustainability strategy should be developed sector-specific. In addition, the interaction networks between the criteria obtained for use in the FCM method have been an effective tool to examine the structure and sectoral differentiation of sustainability management.

Within the scope of this project, a Python-based model was developed. In this way, calculations were automated, scenarios could be analysed quickly and results were easily visualized with graphs. At the same time, with this easy-to-use aspect, this project provides organizations with a practical tool to evaluate their own sustainability performance.

As a result, this project contributes to the measurement of sustainability in conceptual and methodological terms. The sustainability index developed using the FCM method supports institutions in many areas. For example, it helps institutions identify areas that need to be prioritized, shape strategic decisions before they are made, and create sector-specific roadmaps. Future studies aim to incorporate the opinions of experts from various sectors into the index and to use it more effectively.

15. PLAN FOR FUTURE STUDIES

In the long term, this work aims to be transformed into a comprehensive sustainability performance decision support tool with sectoral adaptability. Only four expert's opinions can be obtained on the application of this project. In the future, by expanding the pool of experts, this project can be actualized for different sectors. Additionally, the Python interface was created. It can be visually improved to appear more professional. It is also planned to prepare training packages on how companies can enter data to facilitate the usability of the developed index. Addition to these, it is believed that the findings obtained could form the basis for a master's thesis or academic publication in the future.

16. ASSESMENT OF ENGINEERING COURSES

While creating the sustainability index in the project, Python application was used to write the code to apply the FCM method. For this process, the gains from the "Introduction to Programming and "Advanced Programming" courses were used. Coding was done correctly thanks to the course contents such as elementary programming learned in the introduction to programming course and then basic algorithms, Python Data Structures, advanced features of Python learned in the advanced programming course. In the criterion determination part of the project, the gains from the "Quality Engineering" course were used. Criteria were determined in accordance with ISO 26000, one of the ISO quality standards mentioned in this course. Also, "Linear Algebra" course, which is one of the courses taken in the matrix creation part of the project, was helpful. Thanks to the matrix structures and matrix operations learnt in the course, the matrix structure to be used in the FCM method was created. Moreover, Excel studies in courses such as Production Planning, Facility Design and Supply Chain contributed to some Excel calculations performed within the scope of the project.

17. APPENDICES

Appendix-1: Criteria Relationship Survey Form

In this appendix, experts are asked to assess the degree of influence each criterion has on the others, which served as the basis for constructing the FCM.

Access the questionnaire via the following link:

https://docs.google.com/forms/d/e/1FAIpQLSfopLZHCEaf5tKo1eWrADFUFbATGdl1qjvgeM_fSoid38ZEPw/viewform?usp=dialog

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