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Review of Studies Addressing Technology Companies, Environmental Sustainability and Multi-Criteria Decision Making

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Abstract: *In this study, environmental sustainability, one of the important dimensions of sustainability, is discussed. Environmental sustainability will be examined in the context of technology companies. The diversity of product networks of technology companies also causes environmental sustainability activities to differ. Therefore, examining the activities of these companies will make a difference. Considering that the activities of technology companies affect environmental sustainability and that companies need to develop appropriate strategies with an effective decision-making process, the concept of multi-criteria decision-making is an important issue. Therefore, multi-criteria decision making is one of the concepts examined in studies.* ***Keywords:*** *Technology Companies, Environmental Sustainability, Multi-Criteria Decision Making*

1. INTRODUCTION:

The Concept of sustainability is a concept that is becoming increasingly popular today and is a serious competitive element among companies Considering that natural resources are decreasing day by day and starting to pose a threat to subsequent generations, environmental sustainability is becoming an important issue. At the same time, in terms of sustainability, companies have a responsibility in this regard, in that not only their approaches from an economic perspective, but also their environmental and social dimensions should be taken into account. For this purpose, strategies should be developed by taking this issue into consideration when technology companies produce their products. Multi-criteria decisionmaking techniques can be used for an effective decision-making process in this regard.

2. SUSTAINABILITY:

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2.1 Sustainability Concept:

The Concept of sustainability, which is becoming increasingly popular today and comes from Latin, means to continue, to maintain, to exist. The idea underlying the concept of sustainability is to transfer a cleaner ecological structure to future generations. Sustainability means the use of existing natural resources by future generations and their continuation and existence by using harmless methods for nature without disturbing the balance of nature.

In order for living creatures living in nature to meet their needs and to continue their lives, their environment must be suitable for providing these. With the emergence of the idea of protecting nature for living things, the idea that resources should be sustainable has gained importance. In fact, in ancient times, people gave the first examples of sustainability when they began to protect areas and animals that they believed were important. Therefore, the concept of sustainability dates back to ancient times [1]. The concept of sustainability has environmental, economic, social, etc. Since it has many dimensions such as, it can be seen that there are many studies on this subject and different definitions made by different people. When talking about sustainability, it is wrong to say that this concept is limited only to the environment, as it is generally used in an ecological sense. This concept is widely used economically, socially and institutionally [2]. Since sustainability is a subject of universal value, there are many studies, conferences and reports on this subject. For example Google, Amazon, etc. There are sustainability reports prepared by technology companies on this subject.

2.2 Dimensions of Sustainability:

Basically, the dimensions of the concept of sustainability are divided into environmental, social and economic.

Environmental Sustainability is the preservation of the environment and its natural balance. Care should be taken to ensure that resources are protected and renewable. The activities of companies and people affect the environment. Environmental sustainability is the dimension of sustainability defined as reducing the negative aspects of these impacts, protecting the natural environment and transferring it to meet the needs of next generations [3].

Social Sustainability is the provision of social services such as education and equality as required. To have more conscious and healthy societies. Social sustainability aims to protect social institutions, social relations and values between people [3].

Economic Sustainability is the efficient use of resources and their management in an economically balanced manner. Economic sustainability aims to increase the general level of development by using resources effectively and efficiently and at the same time minimize the harmful effects on the environment [3].

2.3 Sustainability Development:

Since the environment we live in is also a place where future generations will live, and the unbalanced use of resources due to high population growth, the environment we live in poses a threat to future generations. In order to prevent this, people need to be aware of the seriousness

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of the situation and be educated. Sustainable Development is the combination of the concept of development and sustainability. Sustainable Development goals can be achieved when not only one of these dimensions, but also the total dimension that includes environmental, social and economic dimensions are taken into account [3].

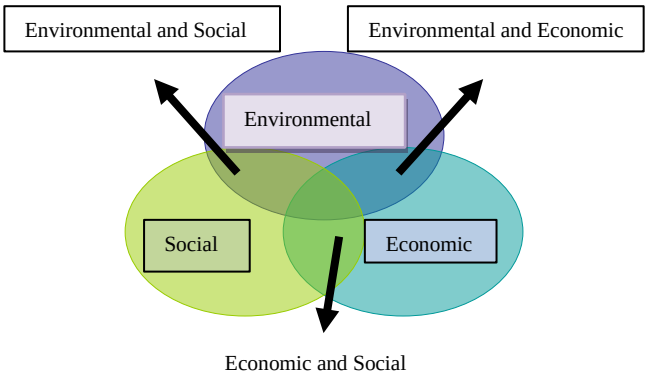

Fig.1. Dimensions of Sustainability

2.4 Sustainability from The Technology Companies:

Technology has progressed from ancient times to the present day. In ancient times, technology began when people found tools they used to hunt along with their struggle for survival. With the beginning of mechanization with the industrial revolution, technology has made greater progress. Nowadays, technology has reached its peak with the use of digitalization, robots, and technological product diversity and network.

Technological developments also directly affect economic growth. The fact that countries produce technology and use it efficiently also increases the development level of countries. The technology sector is full of companies that produce a large number of products (Müslümov and Aras, 2002). The increasing and developing structure of technology and its use in almost every field changes our habits in production and consumption. This production and consumption change also affects ecological sustainability (Koyuncu and Akpolat, 2023). Therefore, they need to be produced and consumed in a controlled manner.

When companies create new products or services, they should not only be limited to this but should also be encouraged to produce environmentally friendly products or services. They need to see economic, social and environmental risks and evaluate them correctly. Therefore, strategies that take these issues into account should be added to business activities. Environmental and social challenges with sustainable technology are essential to tackle this issue. Sustainable technologies help to use resources efficiently and turn to energy sources that do not harm the environment, thereby achieving economic development goals. For example; Using renewable energy sources reduces environmentally damaging uses such as fossil fuels.

The use of energy storage systems regulates power usage. Transportation vehicles using artificial intelligence reduce greenhouse gas emissions.
Nowadays, as societies become more conscious and customer expectations increase, sustainability has become an issue that companies need to address more carefully. At this point, the concept of corporate sustainability, which combines economic, social and environmental dimensions, emerges. Companies' management practices and processes should be integrated into their strategic plans by minimizing the negative effects on the ecosystem, which is based on sustainability, and by taking into account the elements that make up the environment. Most companies now define and implement their duties and responsibilities based on protecting the environment. It also creates annual financial and environmental reports as a result of its activities. Creating strategies that take the environment into consideration both increases the efficiency of companies and enables them to gain an advantage in competition.

3. MULTI-CRITERIA DECISION MAKING:

Multi-criteria decision making, briefly MCDM, is the general name for methods that enable selection of the most appropriate alternative among multiple criteria applied simultaneously. These are methods that can produce and evaluate results by making common inferences by expressing the criteria numerically.

Multi-criteria decision making (MCDM) is an advanced subject in the field of decisionmaking with its theoretical and practical development. It has a strong application area with its logical structure.

Multi-criteria decision making (MCDM) is a process in which the decision maker makes a choice among many alternatives and conflicting criteria. When making multi-criteria decision making, first the criteria and alternatives related to the subject are determined.

Then, the weights of the criteria relative to each other, that is, their degree of importance, are determined. Alternatives are evaluated by comparing the criteria and as a result of this evaluation, the alternatives are ranked relative to each other. The purpose of applying multicriteria decision-making methods is to make decisions as quickly as possible among many criteria and alternatives. The most frequently mentioned concepts in multi-criteria decisionmaking processes are criteria, alternatives, objectives and decision matrix (Arslankaya and Göraltay, 19).
Criteria are parameters that specify the characteristics of alternatives.
Alternatives are concepts that are the purpose of the application. The aim is to choose a suitable one from many alternatives.
Goals are the goals that the criteria are specified for what the decision maker wants to achieve.

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Since there are many criteria and alternatives in the decision matrix, multi-criteria decisionmaking process, these alternatives and the results of the transactions are presented in the form of a matrix. This is called the decision matrix.
Multi-criteria decision making (MCDM) methods generally work on the selection problem, ranking problem and classification problem. The goals of the decision maker are different in these problem types. For example; In the selection problem, the aim of the decision maker is to choose the best alternative, in the ranking problem, it is to arrange the alternatives relatively to each other, and in the classification problems, it is to classify the alternatives in line with certain purposes.

4. LITERATURE REVIEW:

Within the scope of this study, a detailed literature review was conducted using the concepts of environmental sustainability, multi-criteria decision making and technology and the Scopus database. The concepts that were used together for the literature review are given in the table. In addition, the author of the studies examined, the method used in the study, the sustainability concepts emphasized in the study, the technology concepts emphasized in the study and information about the year in which the study was conducted are also given in the table.
As a result of the literature review of the concepts of "environmental sustainability", "multi criteria decision making" and "technology", information about the authors of the studies examined, the methods used in the study and the year in which the study was conducted are given in Table 4.1.

Table 4.1 Method Table Used for "Environmental Sustainability", "Multi-Criteria Decision Making", "Technology" Concepts.

Authors	Application Method	Year
Renfrew et al. [4]	Fuzzy AHP, Fuzzy TOPSİS	2024
Jiang et al. [5]	Fuzzy AHP, TOPSİS-Grey	2023
Pamucar et al. [6]	Fuzzy Schweizer-Sklar Weight Valuation Method Based on Ordered Priority Approach	2023
Falsafi et al. [7]	AHP, Multiple Expert Modeling Approach	2023
Li et al. [8]	Grey Correlation Valuation, TOPSİS	2023
Rahayani and Nair [9]	Data Envelopment Approach (DEA), AHP	2023
Toshniwal et al. [10]	Pivot Two-Way Relative Criteria Importance Assessment (PIPRECIA), Fuzzy Measurement of Alternatives and Compromise Solution Approach (F-MARCOS)	2024

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Table 4.1 Method Table Used for "Environmental Sustainability", "Multi-Criteria Decision Making", "Technology" Concepts (Continued).

Authors	Application Method	Year
Kırda and Aytekin, [11]	KA decision software (Python)	2023
Chaudhari et al. [12]	TOPSİS	2022
Deveci et al. [13]	Distance from Mean Solution based on Dombi Norms (EDAS) and Logarithm Addition Weights Methodology (LMAW)	2022
Fetanat and Tayebi [14]	Complex Gloval Fuzzy Cluster Based Joint Distance Based Evaluation (CODAS)	2022
Palit et al. [15]	Principal Component Analysis (PCA), Interpretive Structural Modeling (ISM), Cross Effect Matrix Multiplication Applied to Classification (MICMAC)	2022
Mastrocinque et al. [16]	Fuzzy Inference System	2022
Agarwal and Singh [17]	Fuzzy Delphi, Fuzzy AHP	2022
Liaqat et al. [18]	AHP	2022
Rani et al. [19]	Pythagorean Fuzzy Set (PFS), Weighted Discrimination Based Approach (WDBA)	2021
Shah et al. [20]	Fuzzy Set Theory	2021
Yadegaridehkordi et al. [21]	Fuzzy Decision Making Trial and Evaluation Laboratory (DEMATEL)	2020
Wei et al. [22]	AHP	2020
Liu et al. [23]	Fuzzy Set Theory (FST), AHP, TOPSİS	2020
Arroyo and MolinosSenante [24]	AHP, Selection Approach by Advantages (CBA)	2018
An et al. [25]	AHP, ELECTRE	2017
Aydiner et al. [26]	AHP	2016
Kucukvar et al. [27]	Hybrid Triple Bottom Line (TPL-LCA)	2014
Jiang et al. [28]	AHP	2011
Mujtaba et al. [29]	Fuzzy Logic, AHP, TOPSİS, PROMETHEE II	2024
Tran [30]	MAIRCA, SPOTİS, COMET, CRITIC weighting	2024
Zhou [31]	Shannon Entropy, Fuzzy Membership Function	2022

As a result of the literature review of the concepts of "environmental sustainability", "multi criteria decision making" and "technology", information about the sustainability concepts emphasized in the study, the year in which the study was conducted are given in Table 4.2.

Table 4.2 Sustainability Concepts Considered for "Environmental Sustainability", "Multi-Criteria Decision Making", "Technology" Concepts.

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Authors	Sustainability Concepts	Year
Renfrew et al. [4]	Environmental	2024
Jiang et al. [5]	Environmental, Social, Governance	2023
Pamucar et al. [6]	Environmental	2023
Falsafi et al. [7]	Economic, Technological, Environmental	2023
Li et al. [8]	Environmental	2023
Rahayani and Nair [9]	Environmental	2023
Toshniwal et al. [10]	Environmental	2024
Kırda and Aytekin [11]	Environmental	2023
Chaudhari et al. [12]	Environmental	2022
Deveci et al. [13]	Environmental, Economic, Governance	2022

Table 4.2 Sustainability Concepts Considered for "Environmental Sustainability", "Multi-Criteria Decision Making", "Technology" Concepts (Continued).

Authors	Sustainability Concepts	Year
Fetanat and Tayebi [14]	Environmental, Social, Economic, Technical	2022
Palit et al. [15]	Environmental	2022
Mastrocinque et al. [16]	Environmental, Social, Economic	2022
Agarwal and Singh [17]	Environmental, Social, Economic	2022
Liaqat et al. [18]	Environmental, Economic	2022
Rani et al. [19]	Environmental	2021
Shah et al. [20]	Environmental	2021
Yadegaridehkordi et al. [21]	Environmental	2020
Wei et al. [22]	Environmental, Economic, Technical	2020
Liu et al. [23]	Environmental, Social, Economic	2020
Arroyo and Molinos-Senante [24]	Environmental, Social, Economic	2018
An et al. [25]	Environmental, Social, Economic	2017
Aydiner et al. [26]	Environmental, Economic, Technical, Administrative	2016
Kucukvar et al. [27]	Environmental, Social, Economic	2014
Jiang et al. [28]	Environmental, Economic	2011
Mujtaba et al. [29]	Environmental	2024
Tran [30]	Environmental	2024
Zhou [31]	Environmental	2022

As a result of the literature review of the concepts of "environmental sustainability", "multi criteria decision making" and "technology", information about the authors of the studies examined, the technological concepts emphasized in the study and the year in which the study was conducted are given in Table 4.3.

Table 4.3 Technology Concepts Considered for "Environmental Sustainability", "Multi-Criteria Decision Making", "Technology" Concepts.

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Authors	Technology Concept	Year
Renfrew et al. [4]	Technology Selection and Operation, Decision Support Systems	2024
Jiang et al. [5]	Low Carbon Technologies	2023
Pamucar et al. [6]	metaverse	2023
Falsafi et al. [7]	Electric Arc Furnace Steel Production	2023
Li et al. [8]	Carbon capture and storage technologies	2023
Rahayani and Nair [9]	Geographic information system technology	2023
Toshniwal et al. [10]	Industry 4.0 Technologies	2024
Kırda and Aytekin [11]	negative greenhouse gas emission technologies	2023
Chaudhari et al. [12]	Blockchain-Io Technology	2022
Deveci et al. [13]	Freight Transportation System with Metaverse	2022
Fetanat and Tayebi [14]	Soil Pollution Control Technology, Biorestoration Technology, Excavation Technology, Soil Aeration Technologies, Soil Washing and Hydraulic Barrier Technologies	2022
Palit et al. [15]	Electric vehicles, Internal combustion engine vehicles	2022

Table 4.3 Technology Concepts Considered for "Environmental Sustainability", "Multi-Criteria Decision Making", "Technology" Concepts (Continued).

Authors	Technology Concept	Year
Mastrocinque et al. [16]	Industry 4.0 technologies, Photovolatic supply chain	2022
Agarwal and Singh [17]	Textile wastewater treatment technology	2022
Liaqat et al. [18]	Storage technologies	2022
Rani et al. [19]	Bioenergy technologies	2021
Shah et al. [20]	Waste to energy conversion technology, Gasification technology	2021
Yadegaridehkordi et al. [21]	Green production buildings and technologies	2020
Wei et al. [22]	Biological treatment technologies	2020
Liu et al. [23]	Sewage treatment technologies	2020
Arroyo and Molinos-Senante [24]	Wastewater treatment technologies	2018
An et al. [25]	Groundwater purification technologies, Monitored natural slimming technology, pump purification technologies	2017

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Aydiner et al. [26]	Wastewater production technology, Osmosis and membrane distillation technologies	2016
Kucukvar et al. [27]	Warm mix asphalt technology	2014
Jiang et al. [28]	Remanufacturing Technology	2011
Mujtaba et al. [29]	Storage technologies	2024
Tran [30]	Sustainable electrical technology	2024
Zhou [31]	electrification	2022

As a result of the literature review carried out together with the concepts of "environmental sustainability" and "multi criteria decision making", information about the authors of the studies examined, the methods used in the study and the year in which the study was conducted are given in Table 4.4.

Table 4.4 Method Table Used for "Environmental Sustainability", "Multi-Criteria Decision Making" Concepts.

Authors	Application Method	Year
Sujanto et al. [32]	Fuzzy Delphi, Best-Worst Method	2024
Cao et al. [33]	Weighted power geometric operator, TODIM	2024
Wakijra et al. [34]	Machine Learning Models	2024
Sorooshian et al. [35]	Hybrid bibliometric analysis, Multi-criteria decision analysis	2024
Ramirez Olivares and Castillo-Vergara [36]	AHP	2023
Gonca and Çağdaş [37]	TOPSİS	2023
Huang and Peng [38]	Fuzzy Delphi	2023

Table 4.4 Method Table Used for "Environmental Sustainability", "Multi-Criteria Decision Making" Concepts (Continued).

Authors	Application Method	Year
Pratap et al. [39]	Fuzzy VIKOR	2023
Wang Et al. [40]	Function analysis system technique, Fuzzy Set Theory	2023

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Diaz-Sarachaga et al. [41]	SIRSDEC (Infrastructure Rating system), AHP, MIVES (Integrated Value Model)	2017
Yilmaz and Harmancioglu [42]	SAW (Simple Additive Weighting), CP (Consensus Programming), TOPSIS	2010

As a result of the literature review of the concepts of "environmental sustainability", "multi criteria decision making" and "technology", information about the sustainability concepts emphasized in the study and the year in which the study was conducted are given in Table 4.5.

Table 4.5 Sustainability Concepts Considered for "Environmental Sustainability", "Multi-Criteria Decision Making" Concepts.

Authors	Sustainability Concept	Year
Sujanto et al. [32]	Environmental	2024
Cao et al. [33]	Environmental	2024
Wakijra et al. [34]	Economic, Environmental	2024
Sorooshian et al. [35]	Environmental	2024
Ramirez Olivares and Castillo-Vergara [36]	Social, Environmental	2023
Gonca and Çağdaş [37]	Environmental	2023
Huang and Peng [38]	Environmental, Social, Economic	2023
Pratap et al. [39]	Environmental, Economic	2023
Wang et al. [40]	Environmental	2023
Diaz-Sarachaga et al. [41]	Environmental, Social, Economic	2017
Yilmaz and Harmancioglu [42]	Environmental, Social, Economic	2010

As a result of the literature review of the concepts of "environmental sustainability", "multi criteria decision making" and "technology", information about the authors of the studies examined, the technological concepts emphasized in the study and the year in which the study was conducted are given in Table 4.6.

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Table 4.6 Sustainability Concepts Considered for "Environmental Sustainability", "Technology Companies" Concepts.

Authors	Sustanability Concept	Year
Vlăduțescu et al. [43]	Environmental, Social, Economic	2023
Kaipainen and Aarikka-Stenroos [44]	Environmental	2022
Saunila et al. [45]	Environmental, Social, Economic	2019

As a result of the literature review carried out together with the concepts of "environmental sustainability" and "technology companies", information about the authors of the studies examined, the technological concepts emphasized in the study and the year in which the study was conducted are given in Table 4.7.

Table 4.7 Technology Concepts Considered for "Environmental Sustainability", "Technology Companies" Concepts.

Authors	Technology Concept	Year
Vlăduțescu et al. [43]	Metaverse	2023
Kaipainen and Aarikka-Stenroos [44]	Sustainable Technology	2022
Saunila et al. [45]	Green Technology	2019

When the results of the literature review are examined, it has been seen that among the multicriteria decision-making methods, methods such as AHP, fuzzy AHP, TOPSIS, Fuzzy, Topsis, Fuzzy Set Theory are the most used in the studies. It has been observed that DEMATEL and Fuzzy Delphi methods, which are also new methods, are more common after methods such as AHP and TOPSIS.

As a result of the literature review, when the social and environmental dimensions of sustainability are taken into consideration, the number of studies that examine the relevant dimensions mentioned together in addition to environmental sustainability is quite high. In fact, after the environmental dimension of environmental sustainability, the most emphasized issue is economic sustainability.

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In addition, the environmental sustainability criteria obtained as a result of the literature review and the sustainability reports prepared by my technology companies are given in the table. To compile sustainability metrics, sustainability reports of companies such as Google, Amazon, IBM, Apple and Amazon were examined.

Table 4.8 Subcriteria for GreenHouse Gase Emissions

Criteria	Sub-Criteria	References
GHG (Green Houses Gases) Emissions	Emissions inventory	Google 2022 Environmental Report; Apple Environmental Progress Report 2021
	Operational emissions; Product lifecycle emissions	Google 2022 Environmental Report; IBM 2021 ESG Report
	Emisssions reductions and compensations for our operations	Google 2022 Environmental Report
	Carbon intensity	Google 2022 Environmental Report; IBM 2021 ESG Report
	Decarbonizing the supply chain	Amazon sustainability Report 2021

Table 4.9 Subcriteria for Energy

Criteria	Sub-Criteria	References
Energy	Energy use; Energy consumption within the organization; Energy conservation	Google 2022 Environmental Report; Microsoft 2021; IBM 2021 ESG Report; Apple Environmental Progress Report 2021
	Energy Efficiency	Google 2022 Environmental Report; IBM 2021 ESG Report; Apple Environmental Progress Report 2021
	Energy intensity	Microsoft 2021 (Disclosure 302-3: Energy intensity from the GRI standart: 302 Energy 2016)
	Renewable energy; powering operations with %100 renewable energy	Google 2022 Environmental Report; IBM 2021 ESG Report; Amazon Sustainability Report 2021
	%100 Renewable electricity disclosure	Microost 2021; Amazon sustainability Report 2021; Apple Environmental Progress Report 2021

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Table 4.10 Subcriteria for Waste

Criteria	Sub-Criteria	References
Waste	Waste generated	Google 2022 Environmental Report; IBM 2021 ESG Report
	Waste diversion; Waste-diverted from disposal	Google 2022 Environmental Report; Microsoft 2021(Disclosure 306-4: Waste diverted from disposal from the GRI Standard: 306 Waste 2020) ; IBM 2021 ESG Report; Apple Environmental Progress Report 2021
	Data center hardware	Google 2022 Environmental Report

Table 4.10 Subcriteria for Water

Criteria	Sub-Criteria	References
Water	Operational water	Google 2022 Sustainability Report; Apple Environmental Progress Report 2021
	Water withdrawal	Microsoft 2021 (Disclosure 303-3: Water withdrawal from the GRI Standard: 303 Water and Effluents 2018); IBM ESG Report 2021
	Water discharge	Microsoft 2021 (Disclosure 303-3: Water withdrawal from the GRI Standard: 303 Water and Effluents 2018)
	Water consumption	Microsoft 2021 (Disclosure 303-3: Water withdrawal from the GRI Standard: 303 Water and Effluents 2018)

Table 4.11 Subcriteria for Workplaces&Ecosystems

Criteria	Sub-Criteria	References
Workplaces & Ecosystems	Green Building Certifications; constructing more-sustainable buildings	Google 2022 Sustainability Report; IBM ESG Report 2021
	Sustainable commuting; Developing moresustainable transportation infstracture	Google 2022 Sustainability Report; Amazon sustainability Report 2021

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	Urban ecelogy; Ecology	Google 2022 Sustainability Report; IBM ESG Report 2021; Microsoft 2021 , Amazon 2021
	Energy efficient data-centers	IBM ESG Report 2021

Table 4.12 Subcriteria for Management

Criteria	Sub-Criteria	References
Management	Conforming and Maintaning ISO 14001 (Environmental Management System)	IBM ESG Report 2021
	Conforming and Mainataning ISO 50001 (Energy Management System)	IBM ESG Report 2021

5. CONCLUSION AND RECOMMADATIONS:

A detailed literature review was conducted using the Scopus database to examine studies on technologies companies, environmental sustainability and multi-criteria decision making.

The results of the literature review, the author who conducted the study, the method used in the study, the sustainability dimension discussed in the study and the technology concepts discussed in the study are given in separate tables. As a result of the study examined, it was seen that the more commonly used multi-criteria decision making methods such as Fuzzy AHP, Fuzzy Topsis and Fuzzy Set Theory were used in the applied methods. In the studies examined, the number of studies in which the environmental, social and economic dimensions of sustainability are discussed together is very high. If we evaluate these dimensions separately, in the studies examined, the environmental dimension was discussed mostly, followed by the economic dimension, and the social dimension was discussed at least. In addition, environmental sustainability criteria and sub-criteria were compiled by examining the sustainability reports of large companies such as Google, IBM and Amazon. These criteria can be weighted using multi-criteria decision-making approaches for technology companies to develop an appropriate environmental sustainability strategy. Another dimension can be added to the problem by using fuzzy sets for criterion weighting.

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6. References:

[1] Arcagök, U., & Çilan, Ç. A. (2022). SÜRDÜRÜLEBİLİRLİK ANALİZİ İLE KURUMLARIN SÜRDÜRÜLEBİLİRLİĞİNİN MODELLENMESİ VE YENİ BİR SÜRDÜRÜLEBİLİRLİK İNDEKSİNİN GELİŞTİRİLMESİ. EĞİTİM YAYINEVİ.

[2] Özerdinç, F., KIZILAY, E., & Hamalosmanoğlu, M. (2022). EĞİTİMDE SÜRDÜRÜLEBİLİR KALKINMA İLE İLGİLİ YAPILAN ÇALIŞMALARIN ANALİZİ: BİR META-SENTEZ ÇALIŞMASI. *Aksaray Üniversitesi Sosyal Bilimler Enstitüsü Dergisi*, *6*(1), 33-51.

[3] Gedik, Y. (2020). Sosyal, ekonomik ve çevresel boyutlarla sürdürülebilirlik ve sürdürülebilir kalkinma. *Uluslararası Ekonomi Siyaset İnsan ve Toplum Bilimleri Dergisi*, *3*(3), 196-215.

[4] Renfrew, D., Vasilaki, V., & Katsou, E. (2024). Indicator based multi-criteria decision support systems for wastewater treatment plants. *Science of The Total Environment*, 169903.

[5] Jiang, Y., Ni, H., Ni, Y., & Guo, X. (2023). Assessing environmental, social, and governance performance and natural resource management policies in China's dual carbon era for a green economy. *Resources Policy*, *85*, 104050.

[6] Pamucar, D., Deveci, M., Gokasar, I., Delen, D., Köppen, M., & Pedrycz, W. (2023). Evaluation of metaverse integration alternatives of sharing economy in transportation using fuzzy Schweizer-Sklar based ordinal priority approach. *Decision Support Systems*, 113944.

[7] Falsafi, M., Terkaj, W., Guzzon, M., Malfa, E., Fornasiero, R., & Tolio, T. (2023). Assessment of valorisation opportunities for secondary metallurgy slag through multi-criteria decision making. *Journal of Cleaner Production*, *402*, 136838.

[8] Li, W., Xu, D., Ding, S., & Dong, L. (2023). Sustainability assessment of CCS technologies by combining multi-criteria decision making with life cycle assessment. *The International Journal of Life Cycle Assessment*, *28*(5), 479-494.

[9] Rahayani, R. D., & Nair, N. K. C. (2023, October). A Double MCDM-GIS Analysis for Solar Power Plant Site Selections in Disaster-Prone Area: A case study of Hawkes Bay. In *2023 International Conference on Power and Renewable Energy Engineering (PREE)* (pp. 64-69). IEEE.

[10] Toshniwal, V. P., Jain, R., Soni, G., Mangla, S. K., & Narula, S. (2024). Technology adoption theories towards environmentally sustainable pharma 4.0: a rational selection approach. *Management of Environmental Quality: An International Journal*, *35*(3), 684-711.

[11] Kırda, K., & Aytekin, A. (2023). Assessing industrialized countries' environmental sustainability performances using an integrated multi-criteria model and software. *Environment, Development and Sustainability*, 1-46.

[12] Chaudhari, R. S., Mahajan, S. K., Rane, S. B., & Agrawal, R. (2022). Modeling Barriers in Circular Economy Using TOPSIS: Perspective of Environmental Sustainability & Blockchain-IoT Technology. *International Journal of Mathematical, Engineering and Management Sciences*, *7*(6), 820.

[13] Deveci, M., Gokasar, I., Castillo, O., & Daim, T. (2022). Evaluation of Metaverse integration of freight fluidity measurement alternatives using fuzzy Dombi EDAS model. *Computers & Industrial Engineering*, *174*, 108773.

[14] Fetanat, A., & Tayebi, M. (2022). Sustainability prioritization of technologies for cleaning up soils polluted with oil and petroleum products: a decision support system under complex spherical fuzzy environment. *Chemosphere*, *308*, 136328.

[15] Palit, T., Bari, A. M., & Karmaker, C. L. (2022). An integrated Principal Component Analysis and Interpretive Structural Modeling approach for electric vehicle adoption decisions in sustainable transportation systems. *Decision Analytics Journal*, *4*, 100119.

[16] Mastrocinque, E., Ramírez, F. J., Honrubia-Escribano, A., & Pham, D. T. (2022). Industry 4.0 enabling sustainable supply chain development in the renewable energy sector: A multi-criteria intelligent approach. *Technological Forecasting and Social Change*, *182*, 121813.

[17] Agarwal, S., & Singh, A. P. (2022). Performance evaluation of textile wastewater treatment techniques using sustainability index: An integrated fuzzy approach of assessment. *Journal of Cleaner Production*, *337*, 130384.

[18] Liaqat, M., Ghadi, Y. Y., Adnan, M., & Fazal, M. R. (2022). Multicriteria evaluation of portable energy storage technologies for electric vehicles. *IEEE Access*, *10*, 64890-64903.

[19] Rani, P., Mishra, A. R., Saha, A., & Pamucar, D. (2021). Pythagorean fuzzy weighted discrimination-based approximation approach to the assessment of sustainable bioenergy technologies for agricultural residues. *International Journal of Intelligent Systems*, *36*(6), 2964-2990.

[20] Shah, S. A. A., Longsheng, C., Solangi, Y. A., Ahmad, M., & Ali, S. (2021). Energy trilemma based prioritization of waste-to-energy technologies: implications for post-COVID-19 green economic recovery in Pakistan. *Journal of cleaner production*, *284*, 124729.

[21] Yadegaridehkordi, E., Hourmand, M., Nilashi, M., Alsolami, E., Samad, S., Mahmoud, M., ... & Shuib, L. (2020). Assessment of sustainability indicators for green building manufacturing using fuzzy multi-criteria decision making approach. *Journal of cleaner production*, *277*, 122905.

[22] Wei, C., Wei, J., Kong, Q., Fan, D., Qiu, G., Feng, C., ... & Wei, C. (2020). Selection of optimum biological treatment for coking wastewater using analytic hierarchy process. *Science of the total environment*, *742*, 140400.

[23] Liu, B., Tang, J., Li, Z., Yan, Y., & Chen, J. (2020). Optimal selection of sewage treatment technologies in town areas: a coupled multi-criteria decision-making model. *Environmental Management*, *66*, 709-721.

[24] Arroyo, P., & Molinos-Senante, M. (2018). Selecting appropriate wastewater treatment technologies using a choosing-by-advantages approach. *Science of the Total Environment*, *625*, 819-827.

[25] An, D., Xi, B., Ren, J., Wang, Y., Jia, X., He, C., & Li, Z. (2017). Sustainability assessment of groundwater remediation technologies based on multi-criteria decision making method. *Resources, Conservation and Recycling*, *119*, 36-46.

[26] Aydiner, C., Sen, U., Koseoglu-Imer, D. Y., & Dogan, E. C. (2016). Hierarchical prioritization of innovative treatment systems for sustainable dairy wastewater management. *Journal of Cleaner Production*, *112*, 46054617.

[27] Kucukvar, M., Noori, M., Egilmez, G., & Tatari, O. (2014). Stochastic decision modeling for sustainable pavement designs. *The international journal of life cycle assessment*, *19*, 1185-1199.

[28] Jiang, Z., Zhang, H., & Sutherland, J. W. (2011). Development of multi-criteria decision making model for remanufacturing technology portfolio selection. *Journal of Cleaner Production*, *19*(17-18), 1939-1945.

[29] Mujtaba, M. A., Munir, A., Imran, S., Nasir, M. K., Muhayyuddin, M. G., Javed, A., ... & Qazi, A. (2024). Evaluating sustainable municipal solid waste management scenarios: A multicriteria decision making approach. *Heliyon*.

[30] Tran, N. T. (2024). Application of the multi-criteria analysis method mairca, spotis, comet for the optimisation of sustainable electricity technology development. *EUREKA: Physics and Engineering*, (1), 180-188.

[31] Zhou, Y. (2022). Low-carbon transition in smart city with sustainable airport energy ecosystems and hydrogen-based renewable-grid-storage-flexibility. *Energy Reviews*, *1*(1), 100001.

[32] Sujanto, R. Y., Kao, S. L., & Yang, M. F. (2024). Multicriteria Assessment of Green Logistics in Taiwan's Maritime Freight Transport: Green Packaging and Green Transportation as Driving Aspects. *TransNav, International Journal on Marine Navigation and Safety od Sea Transportation*, *18*(1), 35-44.

[33] Cao, Y., Han, X., Wu, X., Deveci, M., Kadry, S., & Delen, D. (2024). Evaluation of food waste treatment techniques using the complex q-rung orthopair fuzzy generalized TODIM method with weighted power geometric operator. *Journal of Environmental Management*, *353*, 120105.

[34] Wakjira, T. G., Kutty, A. A., & Alam, M. S. (2024). A novel framework for developing environmentally sustainable and cost-effective ultra-high-performance concrete (UHPC) using advanced machine learning and multi-objective optimization techniques. *Construction and Building Materials*, *416*, 135114.

[35] Sorooshian, S., Ahadi, N., & Abideen, A. Z. (2024). Leading countries and research networks advancing clean production and environmental sustainability in Southeast Asia. *International Journal of Development Issues*, (ahead-of-print).

[36] Ramírez Olivares, E., & Castillo-Vergara, M. (2023). Analytical Hierarchical Process to Establish the Criteria for Choosing Explosives Suppliers in Small and Medium Mining Companies. *Eng*, *4*(3), 2407-2420.

[37] Gonca, Ş. G., & Çağdaş, G. (2023). Performance evaluation of sustainability in a textile firm via multi-criteria decision-making method. *Industria Textila*, *74*(4), 426-432.

[38] Huang, M. F., & Peng, L. P. (2023). Extracting Evaluation Factors of Social Resilience in Water Resource Protection Areas Using the Fuzzy Delphi Method. *Sustainability*, *15*(18), 13764.

[39] Pratap, S., Jauhar, S. K., Daultani, Y., & Paul, S. K. (2023). Benchmarking sustainable E-commerce enterprises based on evolving customer expectations amidst COVID-19 pandemic. *Business strategy and the environment*, *32*(1), 736-752.

[40] Wang, X., Xu, S. Y., Leung, M. Y., & Liang, Q. (2023). A value-based multi-criteria decision-making approach towards floating house development: a case study in Hong Kong. *Journal of Civil Engineering and Management*, *29*(3), 223-237.

[41] Diaz-Sarachaga, J. M., Jato-Espino, D., & Castro-Fresno, D. (2017). Methodology for the development of a new Sustainable Infrastructure Rating System for Developing Countries (SIRSDEC). *Environmental Science & Policy*, *69*, 65-72.

[42] Yilmaz, B., & Harmancioglu, N. (2010). Multi-criteria decision making for water resource management: a case study of the Gediz River Basin, Turkey. *Water SA*, *36*(5).
[43] Vlăduțescu, Ș., & Stănescu, G. C. (2023). Environmental Sustainability of Metaverse: Perspectives from Romanian Developers. *Sustainability*, *15*(15), 11704.
[44] Kaipainen, J., & Aarikka-Stenroos, L. (2022). How to renew business strategy to achieve sustainability and circularity? A process model of strategic development in incumbent technology companies. *Business Strategy and the Environment*, *31*(5), 1947-1963.
[45] Saunila, M., Rantala, T., Ukko, J., & Havukainen, J. (2019). Why invest in green technologies? Sustainability engagement among small businesses. *Technology Analysis & Strategic Management*, *31*(6), 653-666.