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EVALUATION OF KEY TECHNOLOGICAL TOOLS IN TERMS OF SUPPLY CHAIN SUSTAINABILITY IN THE DIGITALIZATION ERA WITH DIFFERENT ANALYTIC HIERARCHY PROCESS METHODS

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Abstract

The complex business processes bring various problems with them in supply chain management. Basic sustainability problems, lack of transparency in supply chain processes, asymmetrical information flow, lack of security, and insufficient traceability are decrease service quality and increase costs. Besides, it brings social inequality along with its environmental effects. The concept of industry 4.0, which came into our lives with the age of digitalization, has brought disruptive technological developments with it. These technological developments are expected to contribute to the sustainability concept with the advantages they bring. This study examines the impact of new concepts and technologies such as IoT, blockchain, big data, cloud computing, and robotics on supply chain sustainability. In this study, Analytic Hierarchy Process (AHP) and its variations (Fuzzy AHP, Intuitionistic Fuzzy AHP, Pythagorean Fuzzy AHP, and Spherical Fuzzy AHP) are discussed, the evaluation of innovative technologies in terms of each method is made through the concept of sustainability. The results obtained are important in showing both the consistency of AHP methods among themselves and which technologies are at the forefront of sustainability.

1. Introduction

- There has been a serious paradigm shift in digitalization and business processes in the world in recent years. It is quite clear that emerging technologies and their integration into existing structures have a devastating effect on traditional business processes .

- The new technologies, which are digitalization tools, may have different effects on the dimensions of the concept of sustainability. For this reason, it is necessary to provide a framework in terms of priority digitalization policies by considering the characteristics of each process. Thus, the road maps in the technological transformation process can be revealed more clearly.

Motivation of the Study

- As far as the authors know, although there are studies in the literature that evaluate new technologies on different cases using multi-criteria decision-making methods, there is no study evaluating more than one technology that affects sustainability with multi-criteria decision-making methods. It is also a study that fills the MCDM literature gap in terms of handling and evaluating 5 different AHP methods together in the same case study.

2. Literature Review

- Studies in the literature show that IoT will be one of the main drivers of sustainable supply chain processes in the future (Končar et al., 2020; Mastos et al., 2020; Garrido-Hidalgo et al., 2020). Studies address the integration of blockchain technology into supply chain processes that are rapidly increasing, such as IoT (Saberi et al., 2019; Yadav and Singh, 2020).

2. Literature Review

- Blockchain technology offers reliable data storage and monitoring with its distributed structure. Asymmetric information flow can be eliminated by increasing the transparency of supply chain processes with data input. Thus, it can be seen as an innovation that can contribute to the criteria of sustainability. This technology, which emerged with financial solutions in the foreground, currently attracts many industry players.

2. Literature Review

- Other technologies and concepts such as Cloud computing, Robotics, and Big Data Analytics, continue to replace traditional information technologies. Chang et al. (2016) conducted a risk analysis and revenue analysis on two cases of cloud computing technology within the framework of organizational sustainability. In another study addressing environmental sustainability, beef supplier selection was handled within the framework of cloud computing, and a solution was sought with Fuzzy AHP, DEMATEL, and TOPSIS methods (Singh et al., 2018).

2. Literature Review

- Hazen et al. (2016) conducted a study on the sustainability of the supply chain processes of the concept of big data theoretically. They discussed the effects of big data based on social, administrative, and corporate data. Another study uses dynamic capability theory as a basis to evaluate the role of big data analytical capacity as an operational excellence approach to improving sustainable supply chain performance (Bag et al., 2020).

Hypotheses/Objectives

- The study offers implementation on the same problem for each of the AHP and its extensions. These methods are evaluated based on the evaluations made by the same decision-makers and experts. Then the effect of increasing the complexity of the models on the result is investigated. Of course, within the framework of technological development, it has pioneering ideas to show the sustainability concept's dimensions.

Hypotheses/Objectives

In line with the defined purposes, the research questions of this study are as follows:

- Is there a significant difference between AHP, F-AHP, Pythagorean F-AHP, Intuitionistic FAHP, and Spherical FAHP methods in terms of the results obtained? If different results are obtained, which methods differ from others in what direction?
- What indicators do technologies in the Industry 4.0 ecosystem concentrate on supporting sustainability (security, transparency, calculation, etc.)? When the sustainability dimensions (economic, social, environmental, technological, administrative) affected by these indicators are considered, do the impact weights of technologies differ?

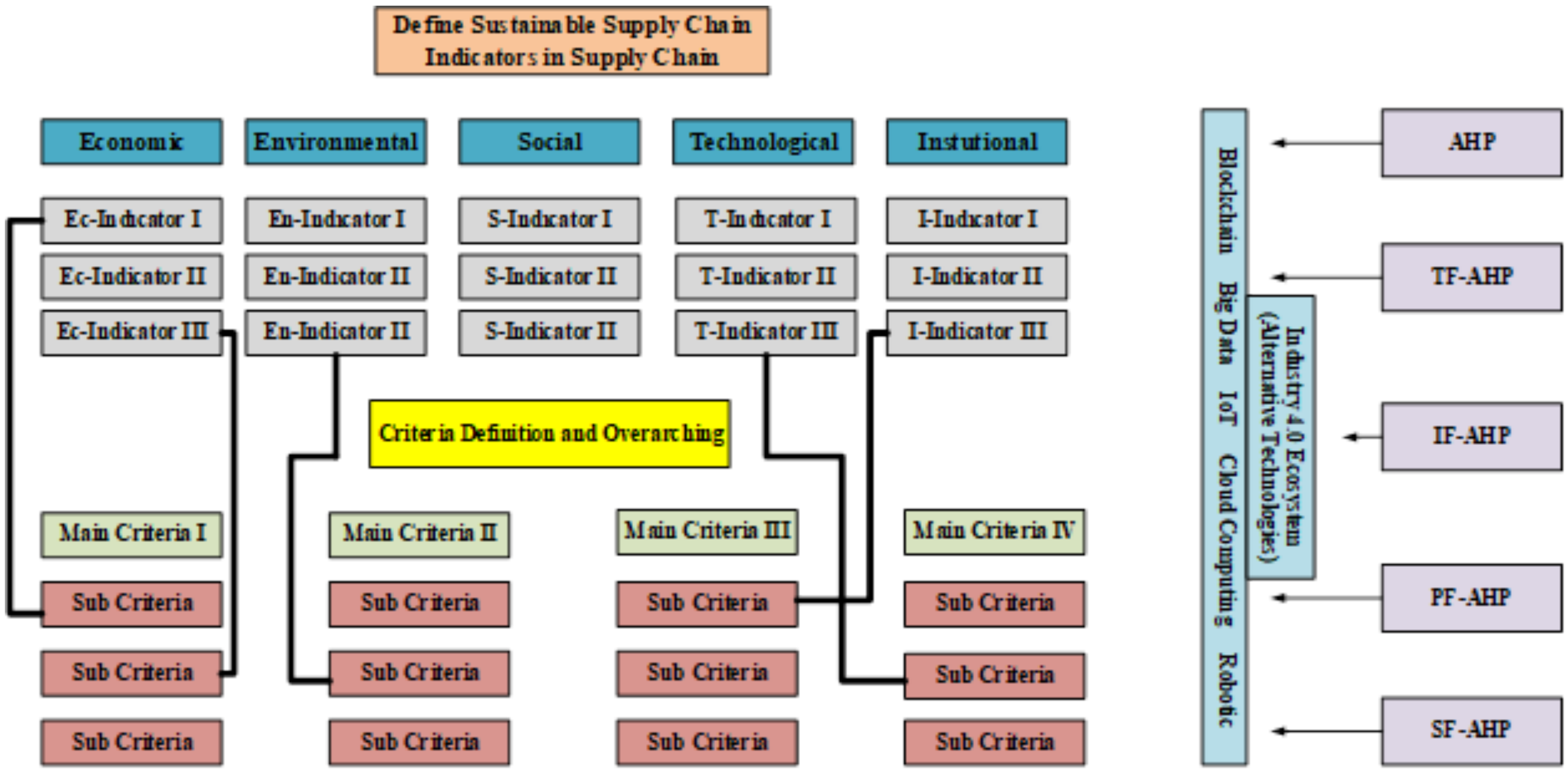
Data and Model Analysis

- Experts made evaluations on the presented AHP method and its variations. The experts are in the IT ecosystem and have work experience in different industries. Two of the experts have approximately seven years of experience in e-commerce, and they received computer engineering training. One of the other three experts has ten years of experience in logistics management and industrial engineering background. Besides, he is in a manager position in the R&D department of the company. The remaining two experts have 7 and 9 years’ experience in the automotive industry and work in the logistics department. The criteria and alternatives determined were obtained from the experts' opinions and the information obtained from the literature.

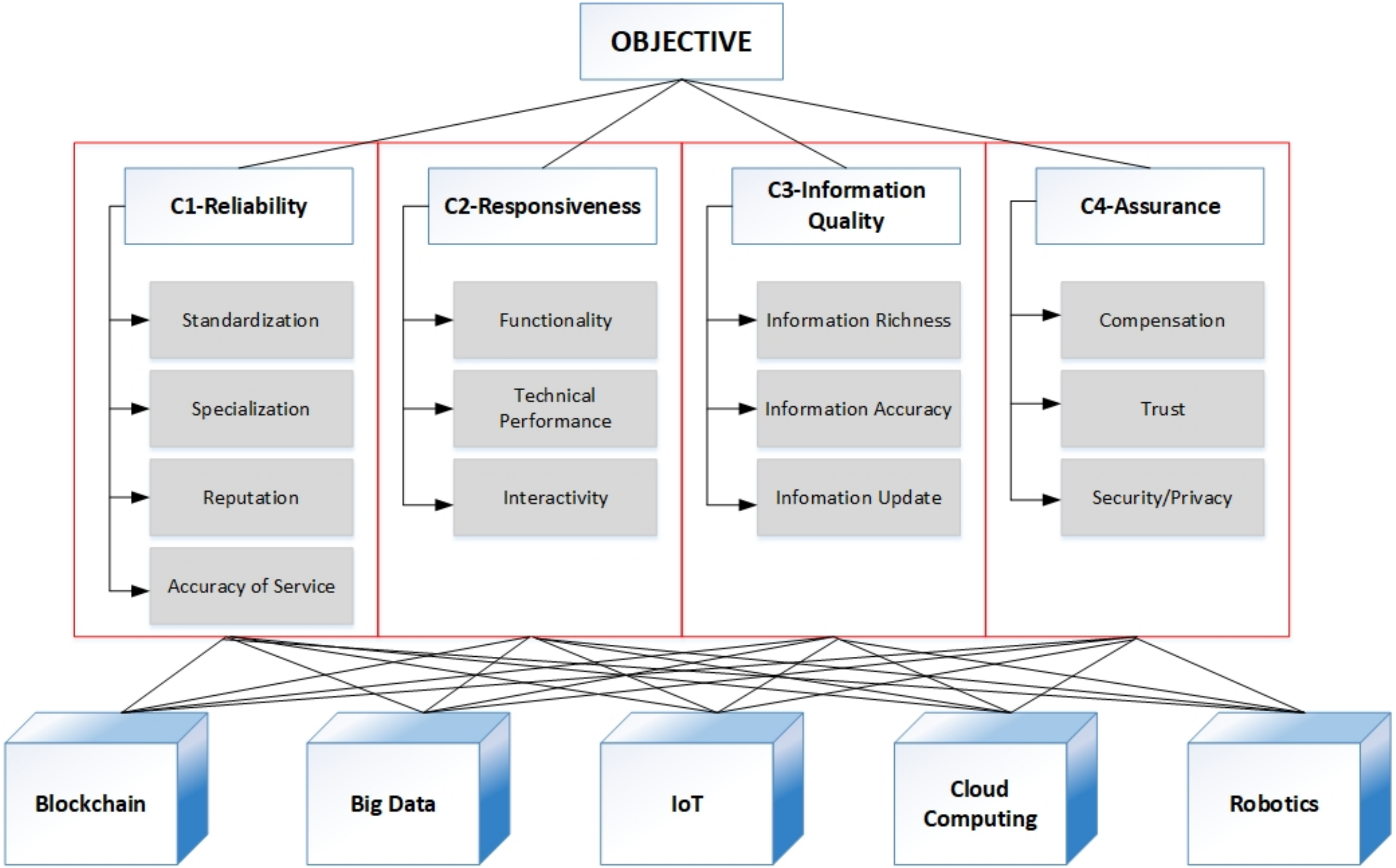
Data and Model Analysis

- Within this study's scope, the AHP method and different variations of the AHP method (F-AHP, Pythagorean F-AHP, Intuitionistic FAHP, and Spherical FAHP methods) have been used. Technologies included in the Industry 4.0 ecosystem are evaluated according to the concept of the sustainable supply chain. The graphical summary of the study is presented in Figure 1.

Data and Model Analysis



Case Study


OBJECTIVE
C1-Reliability
Standardization
Specialization
Reputation
Accuracy of Service
C2-Responsiveness
Functionality
Technical Performance
Interactivity
C3-Information Quality
Information Richness
Information Accuracy
Infomation Update
C4-Assurance
Compensation
Trust
Security/Privacy
Blockchain
Big Data
IoT
Cloud Computing
Robotics

Spherical Fuzzy AHP Application

Table Linguistic variables of importance used for pairwise comparison

	(μ, ν, π)	Score Index (SI)
Absolutely more importance (AMI)	(0.9, 0.1, 0.0)	9
Very high importance (VHI)	(0.8, 0.2, 0.1)	7
High importance (HI)	(0.7, 0.3, 0.2)	5
Slightly more importance (SMI)	(0.6, 0.4, 0.3)	3
Equally importance (EI)	(0.5, 0.4, 0.4)	1
Slightly low importance (SLI)	(0.4, 0.6, 0.3)	1/3
Low importance (LI)	(0.3, 0.7, 0.2)	1/5
Very low importance (VLI)	(0.2, 0.8, 0.1)	1/7
Absolutely low importance (ALI)	(0.1, 0.9, 0.0)	1/9

Spherical Fuzzy AHP Application

The consistency ratios of the pairwise comparison matrices are calculated based on the corresponding numerical values in classical AHP method for the linguistic scale given in previous slide. Pairwise comparisons and the obtained spherical weights ($\tilde{\boldsymbol{w}}^s$) and crisp weights ($\bar{\boldsymbol{w}}^s$) are given in the following Tables together with their consistency ratios (CR).

Because of the space constraints, we do not give the rest of the pairwise comparison matrices of alternatives with respect to the other criteria and sub-criteria.

Spherical Fuzzy AHP Application

Table Pairwise comparison of main criteria

Criteria	**C1**	**C2**	**C3**	**C4**	$\tilde{w}^s$	$\bar{w}^s$
C1	EI	VHI	HI	SMI	(0.372, 0.605, 0.289)	(0.167)
C2	VLI	EI	LI	VLI	(0.727, 0.263, 0.206)	(0.357)
C3	LI	HI	EI	SLI	(0.559, 0.428, 0.289)	(0.264)
C4	SLI	VHI	SMI	EI	(0.460, 0.526, 0.309)	(0.210)

CR = 0.091 (C1: Reliability; C2: Responsiveness; C3: Information Quality; C4: Assurance)

Spherical Fuzzy AHP Application

Table Pairwise comparison of technologies caused by reliability conditions

C1	**C11**	**C12**	**C13**	**C14**	$\tilde{w}^s$	$\bar{w}^s$
C11	EI	HI	AMII	SMI	(0.702, 0.261, 0.224)	(0.360)
C12	LI	EI	SMI	LI	(0.355, 0.632, 0.271)	(0.158)
C13	ALI	SLI	EI	VLI	(0.373, 0.615, 0.292)	(0.169)
C14	SLI	HI	VHI	EI	(0.657, 0.358, 0.253)	(0.313)

CR = 0.066

Spherical Fuzzy AHP Application

Table Pairwise comparison of alternatives caused by standardization sub-criteria

C11	**A1**	**A2**	**A3**	**A4**	**A5**	$\tilde{w}^s$	$\bar{w}^s$
A1	EI	SMI	VHI	SMI	SLI	(0.696, 0.302, 0.241)	(0.260)
A2	SLI	EI	SMI	SLI	SMI	(0.542, 0.443, 0.308)	(0.198)
A3	VLI	SLI	EI	VLI	SMI	(0.428, 0.570, 0.293)	(0.151)
A4	SLI	SMI	VHI	EI	AMI	(0.723, 0.294, 0.221)	(0.273)
A5	VLI	SLI	SLI	ALI	EI	(0.347, 0.668, 0.265)	(0.118)

CR = 0.069

Spherical Fuzzy AHP Application

Table Score values, normalized values and ranking obtained from completely fuzzy approach

Alternatives	Total	Score value	Normalized Value	Ranking
A1	(0.593, 0.570, 0.293)	(12.215)	(0.245)	**2**
A2	(0.562, 0.302, 0.241)	(10.706)	(0.215)	**3**
A3	(0.456, 0.443, 0.308)	(8.157)	(0.164)	**4**
A4	(0.617, 0.294, 0.221)	(13,312)	(0.267)	**1**
A5	(0.413, 0.327, 0.198)	(5.325)	(0.107)	**5**

As seen in the normalized table, Alternative 4 is the best alternative according to the result. In the spherical fuzzy AHP approach the ranking obtains as A4>A1>A2>A3>A5.

Result of AHP Application

Table Normalized values and ranking obtained from AHP

Alternatives	Normalized Value	Ranking
A1	(0.354)	**2**
A2	(0.315)	**4**
A3	(0.320)	**3**
A4	(0.371)	**1**
A5	(0.303)	**5**

Result of Fuzzy AHP Application

Table Normalized values and ranking obtained from fuzzy AHP

Alternatives	Normalized Value	Ranking
A1	(0.262)	**2**
A2	(0.154)	**3**
A3	(0.149)	**4**
A4	(0.323)	**1**
A5	(0.109)	**5**

Result of Intuitionistic Fuzzy AHP Application

Table Normalized values and ranking obtained from Intuitionistic Fuzzy AHP approach

Alternatives	Normalized Value	Ranking
A1	(0.245)	**2**
A2	(0.196)	**3**
A3	(0.152)	**4**
A4	(0.304)	**1**
A5	(0.103)	**5**

Result of Pythagorean Fuzzy AHP Application

Table Normalized values and ranking obtained from Pythagorean Fuzzy AHP approach

Alternatives	Normalized Value	Ranking
A1	(0.236)	**2**
A2	(0.188)	**3**
A3	(0.169)	**4**
A4	(0.265)	**1**
A5	(0.142)	**5**

Comparison of Different Variations of AHP Methods

Alternatives	AHP	F-AHP	IFAHP	PFAHP	SFAHP
A1	(0.354)	(0.262)	(0.245)	(0.236)	(0.245)
A2	(0.315)	(0.154)	(0.196)	(0.188)	(0.215)
A3	(0.320)	(0.149)	(0.152)	(0.169)	(0.164)
A4	(0.371)	(0.323)	(0.304)	(0.265)	(0.267)
A5	(0.303)	(0.109)	(0.103)	(0.142)	(0.107)

When the methods were compared, it was observed that all methods except AHP gave similar results.

Conclusion

This article has introduced different Industry 4.0 technologies and their impact on sustainable supply chain performance. For this purpose, first of all, different technologies in the Industry 4.0 ecosystem have been defined. Sustainable supply chain indicators (economic, social, environmental, technological, and institutional) and related sub-criteria are determined. The main conclusion and contribution of this paper include;

Conclusion

i) In this study, the effects of Industry 4.0 technologies on sustainable supply chains were compared using five different AHP methods simultaneously. Then, the solutions and consistencies of these AHP methods were also compared regarding the same problem.

ii) We applied the proposed method in a case study based on expert views and data from the production industry.

iii) We proposed a framework for evaluating Industry 4.0 technologies and sustainable supply chain goals and expert opinion.

Conclusion

iv) According to the result Industry 4.0 Technologies rankigns obtained as follow; Cloud Computing, Blockchain, Big-data, IoT and Robotics.

v) When the methods were compared, it was observed that all methods except AHP gave similar results.

Limitations

This study focuses on AHP methods only. However, there are many MCDM methods in the literature. The use of these methods in evaluations is important in terms of confirming the results. Many new technologies will also contribute to supply chain sustainability other than the evaluated new technologies. This study can be further expanded and supported by both different criteria and new alternatives.

THANK YOU FOR LISTENING