Evaluation of Key Technological Tools in terms of Supply Chain Sustainability in the Digitalization Era with Different Analytic Hierarchy Process Methods

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.

Keywords: *AHP, Industry 4.0, Technology, Sustainability, Supply Chain*

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 (Koh et al., 2019). This destructive effect led to the emergence of the concept of Industry 4.0. However, in the Industry 4.0 ecosystem, the advantages of these technologies are not systematically adequately addressed. The restructured business processes must be sustainable for economic, social, environmental, technological, and institutional aspects. These 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.

Many tools have a pioneering role in technological developments in the age of Industry 4.0. These tools can contribute to different sectors. Blockchain, IoT, Big Data Analytics, Advanced Robotics, and Cloud Computing are some of these tools, and each stands out with its different features. In terms of the solutions they offer, they have features that can minimize the problems in existing business processes. Blockchain stands out with its capabilities such as data security, visibility, and traceability, while Big Data Analytics has the features that enable the processing of the data made visible in the best way (Zheng et al., 2020; Hazen et al., 2018). With cloud computing, system and hardware requirements are eliminated, and large data can be processed in a short time (Hazen et al., 2018). Autonomous vehicles (drones, industrial robots, etc.) that work integrated with all these technologies enable the fast, reliable, traceable, and controllable data provided by information technologies to be transferred from the virtual to the physical side. These technologies can play an active role in the control of existing supply chain processes. The increasing interest in the concept of sustainability in recent years has enabled the developments related to these technologies to be of interest to researchers. In the literature, research on technological transformations is intensely concentrated in producing solutions to basic problems such as economic crises, climate change, and social inequalities from the perspective of supply chain sustainability.

In this study, the integration of new technologies into supply chain processes is discussed in the context of sustainability. The main goal is to scale the impact of the AHP method and its variations on sustainability in the supply chain. Chan et al. (2019) investigated whether there is a significant difference between AHP and FAHP methods regarding the results obtained. This study aims to reveal the differences between AHP-based multi-criteria decision-making methods by observing the consistency results.

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. The examination of sustainability dimensions for each technology can be shown as another contribution to be presented to the current literature.

Literature Review

Supply chain processes have a very complex structure in terms of information and product flow. Various studies in the literature examine supply chain sustainability with a focus on technological development. Manavalan and Jayakrishna (2019) presented a review study on supply chain sustainability based on the Internet of Things (IoT). Also, a framework for IoT integration has been proposed in the industry 4.0 ecosystem. For this purpose, they created five different aspects of the sustainability evaluation template and made evaluations based on sub-criteria affecting sustainability. Again, a similar study was conducted by Ben-Daya et al. (2019). IoT effects on different stages of supply chain processes (warehousing, transportation etc.) have been evaluated.

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). 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.

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). 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.

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.

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.

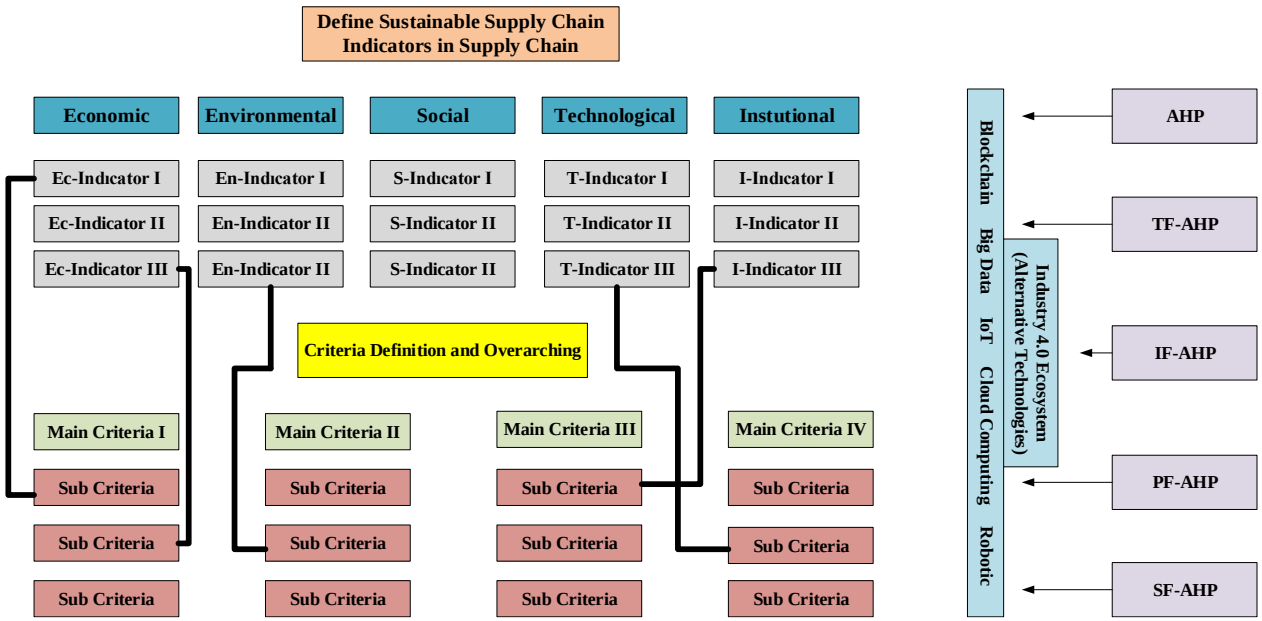

Figure 1. Sustainable Supply Chain Indicators in Supply Chain

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.

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;

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.

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