E-ISNN: 2676-7007

FUZZY OPTIMIZATION AND MODELLING JOURNAL 5(2) (2024) 53-71

Contents lists available at FOMJ

Fuzzy Optimization and Modelling Journal

Journal homepage: https://sanad.iau.ir/journal/fomj/

Paper Type: Research Paper

Collaboration in Supply Chain 4.0 based on Trust with Fuzzy Hierarchical Analysis (Case Study: FMCG Industries)

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ARTICLE INFO

Article history:
Received 30 December 2023
Revised 25 March 2024
Accepted 7 July 2024
Available online 7 July 2024

Keywords:
Industry 4.0
Meta-synthesis
Fuzzy Hierarchical Analysis
Fast-moving Consumer Goods Industry

ABSTRACT

This study aims to analyze collaboration in supply chain 4.0. To attain these objective initiators, barriers, and outcomes of the collaboration concept are categorized by a meta-synthesis method. In this classification, Industry 4.0 technologies were among the most important initiators, and sustainable performance and trust were considered the most important results. In the next part of the research, the impact of trust as one of the most important collaboration results in the FMCG industry was quantitatively analyzed. A fuzzy hierarchical analysis method has been used to prioritize trust indicators in the pharmaceutical industry. Questionnaires were distributed among 25 experts familiar with information technology concepts and active in pharmaceutical companies such as Barij Essence Kashan. Trust factor's normal weight in the supply chain collaboration system shows that Social Support and Gap in education skills and human resources were respectively the most and the least influenced by trust. Collaboration factors based on trust were classified into initiators and barriers with decision tree. In the initiator's section, Social Support with a weight of 0.23241, and in the barriers section uncertainty and risk with a weight of 0.21521 ranked first. Trust factor's normal weight in the supply chain collaboration system shows that Social Support and Gap in education skills and human resources were respectively the most and the least influenced by trust.

1. Introduction

Supply chain management (SCM) has become one of the most interesting and important operational titles due to its influence on the cycle of organizational processes in various industries (Alshurideh et al., [1]). Meanwhile, the dynamics of supply chains are increasing in response to the business environment changes. There is intense competition between companies because of the arrival of emerging technologies (Yu et al., [63]). Each of

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DOI: 10.71808/FOMJ.2024.1002654

the competitors must discover new market opportunities to maintain and excel in this competition (Wu et al., [61]). In today's turbulent and competitive environment, restrictions are imposed on organizations and businesses according to the changes of the day, which is a severe obstacle to commercial and non-commercial companies achieving optimal performance in their specialized field of activity. In this situation, supply chain collaboration (SCC) is considered a practical collective approach against market competitors (Camarinha-Matos et al., [13]). In today's world of management, the expansion of new technologies changes traditional work methods. Industry 4.0 technologies lead to fundamental changes in the way of supply chain exchanges. Also, megatrends and customer expectations transform the playing field as important factors. Industry 4.0 has pushed companies to rethink their supply chain design. In addition to the need to adapt, chains can take advantage of emerging digital supply chain business models and transform the organization into a digital supply chain. The FMCG (fast-moving consumer goods industry) is impactful in many regions. The advent of digital technology has changed practices in FMCG. The success of businesses across industries, including those in the procurement industry, increasingly depends on how well they embrace digital transformation (Shakil, [52]).

There is a great expectation that Industry 4.0 technologies enable to achieve better results for the sustainable performance of companies in some fields such as economic and financial policies (Di Maria et al., [19]). Integration between players along the chain, smart production technologies, and supporting technologies for sustainable performance increase the possibility of achieving the goals of this industrial generation. The quality of industries has improved significantly due to the existence of Industry 4.0 and this guarantees a better future for industrial sectors (Ammar et al., [7]). Industry 4.0 creates conditions for the supply chain that are referred to as the supply chain 4.0 (Satori et al., [50]). Supply chain technologies are the main drivers of supply chain strategic outcomes. According to this fact, companies should adopt and integrate Industry 4.0 technologies to improve their supply chain (Alhalalmeh, [3]). Through changing trends and possible problems caused by companies with current conditions, supply chain collaboration can be considered an essential element in maintaining the chain's strength. For this purpose, updating the chain by focusing on Industry 4.0 developments is necessary. The broad concept of technology is a component that must be used to update the chain. Artificial intelligence, the Internet of Things (IoT), big data, blockchain, and machine learning are some of the technologies of Industry 4.0 that are creating tremendous effects on people, organizations, and supply chains.

According to the types of collaboration between SC partners, advanced technologies are used to support them. The most important advanced technologies involving operational issues, with big data analytics (Azevedo, [9]). Companies need proper supply chain collaboration for growth and survival in the competitive situations of the new generation. For this reason, the main objective of research is to know the initiators, barriers, and outcomes of collaboration and their influence on them to make a platform for collaboration in the supply chain. Therefore, the main question of the research is how the reinforcement of a collaborative supply chain in Industry 4.0 by controlling barriers leads to sustainable performance.

There are significant points related to the managerial applications of this study. Attending to the types of collaboration that exist between SC partners, the advanced technologies most used to support them are those involving more operational issues (Azevedo, [9]). SC partners do not collaborate beyond their frontier operations in the co-development of projects. Also, the coordinated collaboration presents a low level of implementation. It means that there is no closer relationship among SC partners. For example, outsourcing certain activities that do not make part of the company’s core businesses. Proposing a model that includes a collaboration driver leads to solving this problem. Industry 4.0 technologies that are used in this research are among these drivers. For example, cloud computing is identified as the technology with the highest influence on SC 4.0 collaboration. Big data analytics makes it possible to connect suppliers and retailers and to reach quality, inventory management, communication, and delivery improvements (Azevedo, [9]). The Internet of Things can contribute to horizontal integration and vertical integration. Moreover, IoT enables process integration and information communication among SC partners. There are some applications of a collaborative model at the supply chain level such as Efficient execution of transactions between SC partners, information sharing on demand planning, order confirmations, inventory levels and delivery status, and demand and inventory replenishment planning programs.

In the following, there is the literature review on collaboration in the supply chain and the most relevant research. In the methodology section, there are the steps of meta-synthesis and refining the articles. In the finding section, there are three meta-synthesis tables for initiators, barriers, and outcomes. Finally, there is a collaboration model in Supply Chain 4.0. Then, a fuzzy hierarchical analysis method was investigated on Collaboration factors by creating a decision tree based on trust.

2. Literature Review

Generally, the latest technological advancements have forced logistics and supply chain digitization. Organizations that embrace and prepare for change can survive and maintain a competitive position in the new global business environment. In contrast, if industrial businesses do not implement the new rules, they will not survive for long and eventually will be obsolete. Therefore, the concept of digitization and Industrial Revolution 4.0 in supply chain management was intended to be reviewed to determine its trending dimensions (Ali, [4]). The intensity of the competitive environment, the change in customer expectations, and the new technologies of the fourth generation lead to fundamental changes in organizations and the supply chain. For this reason, to develop the chain's performance in the new space, creating appropriate factors to operationalize the concept of collaboration in the context of new technologies requires a comprehensive approach.

Collaboration in supply chain 4.0, with the activation of Information and communication management, Collaborative decisions for business goals, Technology, and business development, Performance evaluation in integrated processes, marketing, and Customer Orientation can lead to sustainable performance. Collaboration is considered an essential and fundamental factor in businesses' adaptation due to trend changes, penetration of technologies, and problems caused by companies' non-compliance with current conditions. A thorough inspection is needed to uncover collaboration performance under the industry 4.0 technologies to use of businesses for now about a collaborative approach among companies. For this reason, it is important to know the initiators, barriers, and outcomes of collaboration to make a platform for supply chain 4.0.

Also, the case of this research is related to the FMCG industry. Data was collected from experts in supply chains who were familiar with information technology concepts and were active in pharmaceutical companies such as Barij Essence Kashan. Barij Essence Company is considered a knowledge-based company and has scientific collaboration with research and academic centers of the country, the use of native plant raw materials of Iran, and the development, promotion, and cultivation of plants in its program. Focusing on the effectiveness quality and Maximum productivity of medicines of the country, dynamism and being a leader in various fields, self-sufficiency, and trust in the best domestic products are the plans of Barij Company. This company is among the examples of the FMCG industry in Iran. The supply chain of Barij has been able to find a reliable place in the industry with collaboration between partners. 25 supply chain experts familiar with information technology concepts were examined to analyze the trust-based collaboration model. In this regard, FMCG companies are selected as the case study due to the availability of specialists. Moreover, FMCG is products that are sold quickly and at a relatively low cost (Nozari et al., [43]). The FMCG industry supply chain is a changing organizational and company system encompassing individuals, data, and resources in the manufacturing, processing, and distribution of products from raw material suppliers to consumers. Because of the nature of products in the FMCG industry, industry 4.0 and supply chain management have a specific place in this industry. Products in these industries can be perishable; therefore, delivery systems with specific times and distribution are important. Duo FMCG products meet many people’s daily needs, so their demands are high, and meeting the demands at the right time is another important component of the supply chain in these industries. Therefore, Industry 4.0 technologies such as IoT, as one of the most important solutions for the maintenance and tracking of data, can have a huge impact on the supply chain of these companies (Nozari et al., [42]).

New technological advancements triggering Industry 4.0 have been shaping supply chains through digital transformation. With the application potential of these technologies, the supply chain will benefit the most from

Industry 4.0 due to increased supply chain visibility into how services and products are manufactured, stored, distributed, and sold (Büyüközkan, [12]). For this reason, in this research, the term supply chain 4.0 was used to form a deeper synchronization with the practical conditions of the current world.

Due to the rapid growth of technological developments and ever-increasing changes, it will be difficult to develop businesses and consequently the supply chain without establishing collaborative relationships. For this reason, familiarity with the concept of collaboration and how to create collaborative exchanges was important in this research. It is not possible to understand the effectiveness of collaboration without identifying its drivers and enablers. Therefore, the cases that can lead to collaboration between supply chain partners were investigated. Only identifying positive influencing factors was not enough, because the hindering factors disrupt the speed of forming collaborative relationships. Creating a conceptual framework focusing on positive and negative influencing components can make businesses and industries understand the dimensions of collaboration. The publication and development of such frameworks can eventually lead to the creation of a coordinated voice by the scientific community to business owners and supply chain managers. With the growth of collaborative relationships, in addition to increasing the efficiency of supply chains and the profitability of stakeholders, civil society will also feel significant changes. Pointing to the concept of sustainable performance with economic, social, and environmental dimensions as the results of collaborative communication, expresses the same issue.

Another noteworthy point is trust, which is considered one of the multifaceted factors of collaboration. In this research, trust was mentioned as an effective result of collaboration. In this way, following the creation and development of collaborative relationships throughout the supply chain and observing the expected results by business partners, mutual trust is built between business owners, managers, and employees of the supply chain. Also, by continuing such a process and by increasing mutual trust, supply chain collaboration will be strengthened and trust will play a facilitating role. For this reason, trust is a multi-faceted factor in the supply chain. The application of mutual trust in the context of collaborative relationships in the first layer is aimed at businesses and the commercial community, but over time, the supply chain employees and the environmental community will benefit from positive effects such as saving time, facilitating communication, and expanding the variety of choices.

The classified analysis of this research can be used as a comprehensive view to create a basis for decision-making in different case studies. Also, presenting a fuzzy analysis based on the decision tree inspired by trust shows that the implementation of a collaborative model in supply chain 4.0 is significantly dependent on human parameters and the output of the results of the quantitative part of the research has led to a qualitative result. For this reason, the implementation of collaboration in the supply chain, on the one hand, leads to the creation of trust in the supply chain, and on the other hand, the trust resulting from collaboration leads to a change in the initiators and barriers of collaboration. There is a mutual and two-way relationship between the dimensions of collaboration and trust at the level of supply chain 4.0, which was investigated for the first time in this research.

Creating collaborative relationships among supply chain partners, along with industry 4.0 developments such as the Internet of Things, is a factor that requires the concept of trust. Trust provides credibility and a suitable social position for partners to predict the future better than before to achieve more competitive advantage and faster response. Therefore, trust is an emphatic variable resulting from collaboration in the 4.0 generation supply chain. The necessity of supply chain collaboration 4.0 creates long-term commitments related to the sharing of up-to-date technology, integrated control, developing business partners' goals, and redesigning joint structural processes. Collaboration is considered one of the key success factors in Supply Chain 4.0. Also, supply chain 4.0 provides a framework for collaboration to increase organizations' effectiveness, efficiency, and success in the digital platform which depends on identifying drivers, enablers, and outcomes of collaboration. There are relevant Articles for the study in Table 1.

Table 1. Relevant articles were extracted from the databases

Authors	Source Title	Method	Analysis	Meta-synthesis	4.0 tech	Quantitative method	Case
Shafique et al. (2024)	Roles of top management support in big data predictive analytics for SSC	Partial least squares–structural equation modeling technique	big data predictive analytics	×	✓	✓	Supply chain
Silva et al. (2024)	Motivating factors for blockchain from the perspective of SCC	An Integrative Systematic Literature Review	Framework presentation	×	✓	×	Inter-organizational
Xia et al. (2023)	The Effect of Blockchain Technology on SCC	Systematic review	Conceptual model	×	✓	✓	Case study of Lenovo
Kunkel et al. (2022)	Industry 4.0 in sustainable supply chain collaboration	Qualitative content analysis/ MaxQDA	Big data analytics	×	✓	✓	Electronics industry
Azevedo et al. (2022)	The role of supply chain 4.0 on supply chain collaboration	Qualitative methodology	Big data analytics	×	✓	×	Automotive industry
Cisneros-Cabrera et al. (2021)	The decision to form Industry 4.0 SCC	Design Science Research (DSR)	Synthetic data reflecting	×	✓	✓	Manufacturing
Gebhardt et al. (2021)	Industry 4.0 technologies as enablers of SCC	Systematic literature review	Content analysis	×	✓	×	Supply chain
Kozma & Varga (2020)	Collaboration in supporting Digital Supply Chains by IoT	literature review	Arrowhead approach	×	✓	×	Digital supply chain
Lazarova-Molnar et al. (2019)	Enabling collaboration for added benefits for Industry 4.0	Collaborative data analytics (CDAs)	Big data analysis	×	✓	✓	Customer data facilitate relevant processes
Pal & Gustafsso (2019)	SCC key themes and future directions	literature review	Hierarchical cluster analysis	×	×	✓	Supply chain
Lynch (2019)	Effective SCC	literature review	SEM	×	×	✓	Supply chain
Jung et al. (2018)	Drivers and resistors for SCC	Review	Framework presentation	×	×	×	Supply chain
Simatupang & Sridharan (2018)	Complementarities in SCC	Review	Framework presentation	×	×	✓	Supply chain
Liu (2018)	The antecedents and consequences of reduction within a SCC	Review	SEM	×	×	✓	SCC-led CO 2 emission reductions
Ralston et al. (2017)	The past and future of SCC	A systematic review of the literature	Framework presentation	×	×	×	Supply chain
Soosay & Hyland (2015)	SCC and directions for future research	A systematic review of the literature	Content analysis	×	×	✓	Supply chain
Ramanathan (2014)	Performance of supply chain collaboration	Review & simulation study	Framework presentation	×	×	✓	Packaging industry
This study	Initiators, Barriers, and Outcomes of collaboration in supply chain 4.0	Meta-synthesis & Decision	Qualitative & Quantitative	✓	✓	✓	Supply chain

According to the previous studies, in this research, a qualitative and quantitative approach is formed by creating a conceptual framework based on trust. Considering the comprehensive approach to collaboration in supply chain 4.0 and providing a comprehensive model with the help of which each of the players can understand and use, regardless of their position, leads to solving the problem of lack of collaborative relationships in the supply chain. In this study, trust is considered as a part of a comprehensive model that can change the collaboration among partners in an Industry 4.0 environment. Interpretation of the analytical system of the collaboration model as an output can enable partners at the chain level to analyze big data with the help of artificial intelligence. Also, AI will be able to collect big data extracted from the IoT and achieve results in addition to the primary data. The research questions are as follows:

- What are the drivers, enablers, and barriers of collaboration in supply chain 4.0?
- What are the outcomes of implementing collaboration for the partners in the supply chain?
- What is the impact of trust as one of the most important collaboration results on initiators and supply chain barriers?

3. Methodology

The research's methodology concentrated on a mixed method which is based on two qualitative and quantitative phases.

3.1. Meta-synthesis

The first phase reviewed the collaboration literature focusing on Initiators, Barriers, and Outcomes, and data analysis was done in three sections using a meta-synthesis qualitative method. Meta-synthesis is a systematic study that examines past research. New interpretations obtained from meta-synthesis cannot be found in early articles (Sandelowski & Barroso, [49]). Meta-synthesis uses summarized information and findings extracted from other studies with a similar topic (Zimmer, [66]). This research uses this seven-step method (Figure 1).

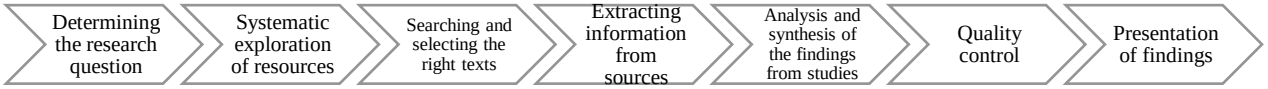

Figure 1. General steps and methods of meta-synthesis

After several reviews and the refinement of scientific papers, many sources were rejected and excluded from the meta-synthesis. The refinement and review process are briefly outlined in Figure 2 based on the inclusion and exclusion criteria.

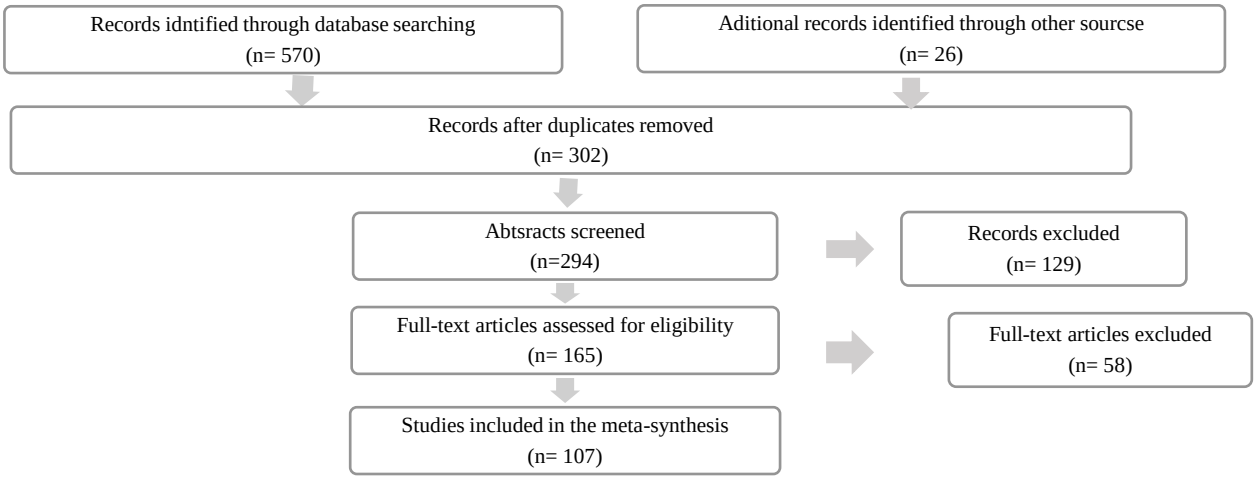

Figure 2. Preferred Reporting Items for meta-synthesis flow chart

3.2. Fuzzy hierarchical analysis

In the second part, a fuzzy hierarchical analysis method has been used to prioritize trust indicators in the pharmaceutical supply chain. The statistical population of this section consisted of experts proficient in digital technologies in the pharmaceutical industry at Barij Essence Kashan Company. Significant criteria were used for selecting individuals. The required academic level was a master's degree or higher. The work experience of individuals was over 5 years. Ultimately, 20 specialists in the production of pharmaceuticals at the mentioned company completed the questionnaires as a statistical sample. The results are detailed and examined in the findings section.

4. Finding

The meta-synthesis results in the first part refer to the Initiators including drivers and enablers. Drivers cause collaboration. Drivers are reasons that compel companies along the chain to lean toward collaboration in the supply chain. Enablers emphasize improving collaboration. Meta-synthesis analysis of Initiators is shown in Table 2.

Table 2. Meta-synthesis analysis of initiators

Authors	First-order themes	Second-order themes	Aggregate dimensions
Sivadevuni et al. (2023)	Moving towards automation and reducing the amount of human participation in the supply chain	Internet of Things	Industry 4.0 technologies
El Jaouhari et al. (2022)	Solving consumers' concerns about buying products that are incompatible with the environment		
Kale et al. (2022)	Building new relationships with suppliers with IoT		
Kale et al. (2022)/ Kale et al. (2022)	Shifting focus from mechanical production to intelligent production		
Singh et al. (2022)	Growth of product innovation	Artificial Intelligence	
Singh et al. (2022)	Improve efficiency at minimum cost		
Teerasoponpong & Sugunnasil. (2022)	Expanding intelligent production from the retail floor space to the ocean scale of the supply chain		
Najafi et al. (2022)	Business transformation of manufacturing jobs in the FMCG industry		
Chen et al. (2023)	Increasing trust and flexibility of the supply chain	Blockchain	
Zaman et al. (2023)	Product tracking, payments, database management, security		
Chen et al. (2023)	Growing transparency, traceability, transaction-related items		
Barzizza et al. (2023)	Processing information assets with special characteristics such as volume, speed, diversity, accuracy, and value	Big Data	
Patil et al. (2023)	Knowledge creation and centralized education process for digitalization of supply chains		
Narwane et al. (2021)	Artificial neural network model as a product for information delivery		
Barzizza et al. (2023)	Interpretation of digital streams	Machine learning	
Yadav et al. (2022)	Managing the huge amount of data generated by industrial activities		
Heydarbakian & Spehri (2022)	Reducing the risks of disruptions related to traditional data		
Whipple et al. (2010)/ Adams et al. (2014)/ Lehoux et al. (2014)	Orientation to long-term relationships (relationship management and relationship-specific investment)	Communication infrastructure	Information and communication technology (ICT) infrastructure
Ramanathan et al. (2011)/ Chong et al. (2013)/ Kumar et al. (2016)	Correct communication		
Hartmann & De Grahl (2011)	Effective communication insight of supply chain partners		
Al-Doori (2019)	Electronic information exchange		
Gumboh & Gichira (2015)	Communication technologies		
Salam (2017)	IT tools	Technology infrastructure	
Gumboh & Gichira (2015)/ Ma et al. (2020)	Information technology		
Chen et al. (2017)	Integration of supply chain infrastructure		
Richey et al. (2012)	Complementarity of technology		
Fawcett et al. (2012)	Rapid change in technology		
Nyaga et al. (2010)/ Ramesh et al. (2010)/ Whipple et al. (2010)/ Holimchayachotikul et al. (2014)/ Afshan et al. (2018)/ Ho et al. (2020)/ Uddin & Akhter (2022)	commitment	commitment	Cultural capital
Buyukozkan and Vardaloglu (2012)/ Holimchayachotikul et al. (2014)	Talent in recognition		
de Almeida et al. (2015)	Investment for commitment		
Bout (2011)/ Solaimani & van der Veen (2022)	Cultural resources	Cultural topics	
Gumboh & Gichira (2015)	Organizational Culture		

Table 3. Continued

Authors	First-order themes	Second-order themes	Aggregate dimensions
Nyaga et al. (2010)/ Ramesh et al. (2010)/ Whipple et al. (2010)/ Holimchayachotikul et al. (2014)/ Afshan et al. (2018)/ Ho et al. (2020)/ Uddin & Akhter (2022)	commitment	commitment	Cultural capital
Buyukozkan and Vardaloglu (2012)/ Holimchayachotikul et al. (2014)	Talent in recognition		
de Almeida et al. (2015)	Investment for commitment		
Bout (2011)/ Solaimani & van der Veen (2022)	Cultural resources	Cultural topics	
Gumboh & Gichira (2015)	Organizational Culture		
Wu & Chiu (2018)	Cognitive capital	Cognitive abilities	Cognitive capital
Kumar et al. (2016)/ Ghazal & Alzoubi (2022)	Tendency to learn		
Preuss & Fearne (2022)	Cognitive processes in SCM	Cognitive management	
Al-Omoush et al. (2023)	Cognitive function		
Al-Refaie (2014)	Mutuality	Mutual interaction	Social support
Lehoux et al. (2014)	Cooperation in supply chain activities		
Wu & Chiu (2018)	Interactive justice		
Holimchayachotikul et al. (2014)/ Kumar et al. (2016)	Active participation in scheduled meetings		
Gumboh & Gichira (2015)/ Panahifar et al. (2017)	Security	Social norms	
Wu & Chiu (2018)	Procedural justice		
Wu & Chiu (2018)	Distributive justice		
Derrouiche et al. (2010) /Ramjaun et al. (2022)	Formal agreements	Structural stability	Structural properties
Derrouiche et al. (2010)/ Holimchayachotikul et al. (2014)/ Agrawal et al. (2022)	The role of power		
Fawcett et al. (2012)/ Fu et al. (2022)	Organizational structure for supporting SCC		
Fawcett et al. (2012)/ de Almeida et al. (2015)	Flexibility		
Dung (2015)/ Davis-Sramek et al. (2019)	Reducing the distance between partners in the supply chain		
Fawcett et al. (2012)/ Mofokeng & Chinomona (2019)	Merger and change of ownership of supply chain companies		
Chen et al. (2010) /Ho et al. (2020)	Creative management for creative teams	Employee capabilities and performance	
Chen et al. (2010)/ Zhang & Yousaf (2020)	Specialized abilities in customer service		
Heaver (2015)/ Sarkar et al. (2020)	Concern about increasing uncertainty	Customer-related concerns	External environmental conditions
Fawcett et al. (2011)/ Chi et al. (2020)	Concern about demand		
Fawcett et al. (2012)	Concern about customer attitude		
Heaver (2015)/ Alzoubi et al. (2020)	Competitive pressures affected by increased competition	External pressures for change	
Zacharia et al. (2011)/ Yuliana et al. (2021)	Pressures from the external environment for globalization		
Fawcett et al. (2012)	The information revolution focused on the supply chain		
Eyaa et al. (2010)	Control of financial pressures	Financial control	Firms financial conditions
Soni et al. (2022) Maheshwari & Kamble (2023)	Proportional Payments		
Maheshwari & Kamble (2023)	Alternative financing strategies	Financial optimization	
Belhadi et al. (2021)/ Maheshwari & Kamble (2023)	Optimal financial decision-making		
Soni et al. (2022) Maheshwari & Kamble (2023)	optimization of financial resources		

The Initiators of collaboration were identified with the meta-synthesis and were constructed at eight main variables. In the next section, Table 3 shows the analysis of collaboration barriers. Barriers are resistant to changing collaboration among supply chain partners.

The main barriers were grouped into eight sections. The barriers prevent the creation of collaboration during the supply chain process. In the Table 4, the outcomes of creating collaboration were analyzed in four main sections. Outcomes refer to the positive results that are obtained for partner beneficiaries and non-beneficiaries after collaborative activities.

Table 4. Meta-synthesis analysis of barriers

Authors	First-order themes	Second-order themes	Aggregate dimensions
Ramesh et al. (2010)/ Annosi et al. (2021)	Inconsistencies in technical capabilities among supply chain partners	Operational barriers	Operational and structural barriers
Panahifar et al. (2017)/ Mahmud et al. (2021)	The complex nature of collaboration organizations, especially during implementation		
Panahifar et al. (2017)/ Hollmann et al. (2015)	Lack of integrity and internal alignment	Structural barriers	
Fawcett et al. (2012)/ Ali & Aboelmaged (2022)	Inappropriate organizational policies and structures		
Touboulic & Walker (2015)/ Anderson et al. (2023)	The challenging nature of creating collaboration		
Fawcett et al. (2012)/ Panahifar et al. (2017)/ de Almeida et al. (2015)	Communication problems	Resistance to change in organizations	Relationship barriers
Camilo et al. (2012)/ Ali & Aboelmaged (2022)	Confidentiality in the supply chain		
de Almeida et al. (2015)/ Hollmann et al. (2015)/ Kouhizadeh et al. (2021)	High dependence on technology	technological barriers to communication	
de Almeida et al. (2015)/ Touboulic & Walker (2015)	Conflict in the use of technological capabilities		
Jung et al. (2018)/ Sarkar et al. (2020)	Uncertainty due to high dependency	Uncertainty	Uncertainty and risk
Jung et al. (2018)	Uncertainty due to reduced competitiveness		
Jung et al. (2018)	Uncertainty due to additional supply chain costs		
Pradabwong et al. (2017)	Risk of investment failure and loss of money	Operational risks	
Jeng (2015)/ Shekarian & Mellat Parast (2021)	The high failure rate in implementing supply chain collaboration		
Pradabwong et al. (2017)	Risk of increasing operational complexity		
Ramesh et al. (2010)/ Hollmann et al. (2015)/ Baah et al. (2022)	Lack of shared understanding	Lack of appropriate visibility	Gap in education skills and human resources
Ramesh et al. (2010)/ Hollmann et al. (2015)	Short-term visibility throughout the supply chain		
Panahifar et al. (2017)/ Lehoux et al. (2014)	Lack of understanding of collaboration benefits		
Panahifar et al. (2017)/ Lehoux et al. (2014)	Inability to calculate economics from collaboration performance		
Hollmann et al. (2015)	Inadequate understanding of collaboration and supply chain philosophy		
Ramesh et al. (2010)/ Fawcett et al. (2012)	Inappropriate education	Gap in education	
Ramesh et al. (2010)/ Mahadevan et al. (2021)	Lack of education to accept new mindsets and skills		
Gumboh & Gichira (2015)/ JS et al. (2019)	Lack of knowledge and awareness		
Fawcett et al. (2012)	Not sharing risks and rewards among partners and individuals	personal interest attitudes and values	Personal benefits
Hollmann et al. (2015)/ Normal et al. (2023)	Focus on optimizing personal and organizational processes instead of the supply chain		
Fawcett et al. (2012)/ Panahifar et al. (2017)	Inconsistent objectives in the supply chain	Personal vision purpose	
Fawcett et al. (2012)/ Camilo et al. (2012)/ Lv & Qi (2019)	Conflicting perspectives		
Ramesh et al. (2010)/ Fawcett et al. (2012)/ Baah et al. (2022)	lack of trust	Cultural system	Cultural issues
Fawcett et al. (2012)/ Panahifar et al. (2017)/ Shin et al. (2019)	Lack of management commitment		
Panahifar et al. (2017)/ Hollmann et al. (2015)	Different work culture and values		
Duong & Chong (2020)	Unfamiliarity with a collaborative culture	Lack of collaborative culture	
Kouhizadeh et al. (2021)	Cultural diversity		
Fawcett et al. (2012)	Misalignment of incentives	Misalignment	Alignment barriers
Gumboh & Gichira (2015)/ Zimon et al. (2020)	Alignment barriers		
Zaridis et al. (2021)	inequality constraints	Inequality	
Cloutier et al. (2020)	inequality of opportunity		
Gumboh & Gichira (2015)	Effectiveness measure	Performance measures	Effectiveness Metrics
Ramesh et al. (2010)/ Sudusinghe & Seuring (2022)	Inappropriate performance measures		
Qiao & Yan (2019)	Incorrect evaluation methods	Evaluation method	
Mahmud et al. (2021)	Interventional evaluation		

The main barriers were grouped into eight sections. The barriers prevent the creation of collaboration during the supply chain process. In Table 5, the outcomes of creating collaboration were analyzed in four main sections. Outcomes refer to the positive results that are obtained for partner beneficiaries and non-beneficiaries after collaborative activities.

Table 5. Meta-synthesis analysis of outcomes

Authors	First-order themes	Second-order themes	Aggregate dimensions
Cao et al. (2010) / Ramanathan et al. (2011)/ Narayanan et al. (2015)/ Chen et al. (2017)/ Pradabwong et al. (2017)/ Al-Doori (2019)/ Ghazal & Alzoubi (2022)	Reducing inventory costs, inventory levels, uncertainty, lead time and dealing with its risks, time about joint product development, supply chain cycle time, and related costs	Economic performance (production and operation)	Sustainable performance
Jeenanunta & Visanvetchakij (2013)/ Panahifar et al. (2017)	Faster Inventory turnover and Inventory Transparency		
Ramanathan (2014)	Economies of scale in production		
Salam (2017)	Improved forecasting		
Heaver (2015)	Matching supply and demand		
Touboulic & Walker (2015)	Coping with the uncertain external environment		
Aggarwal & Srivastava (2016)	Time-related items such as lower delays		
Pradabwong et al. (2017)	Flexibility in supply chain operations		
Lynch (2019)	Agility in supply chain operations		
Ho et al. (2020)	Achieving goals faster		
Afshan et al. (2018)	Continuous replenishment in the supply chain		
Aggarwal & Srivastava (2016)	Better selection of suppliers		
Chen et al. (2017)/ Al-Doori (2019)	Create faster cycles for R&D and ordering		
Narayanan et al. (2015)/ Lynch (2019)	Sustainable development		
Ramanathan et al. (2011)/ Panahifar et al. (2017)	Timely response	Economic performance (customers)	
Cao et al. (2010)/ Al-Doori (2019)	Fast response		
Cao & Zhang (2010)/ Salam (2017)	Improve quality		
Aggarwal & Srivastava (2016)/ Ho et al. (2020)	Increase customer service		
Narayanan et al. (2015)/ Lynch (2019)	Improve customer service		
Touboulic & Walker (2015)/ Al-Doori (2019)	Improve value for customers		
Heaver (2015)/ Lynch (2019)	Responding to customer demand with minimal cost		
Jeenanunta & Visanvetchakij (2013)/ Salam (2017)	Improve product accessibility		
Narayanan et al. (2015)/ Al-Doori (2019)	Profit sharing	Economic performance (financial)	
Aggarwal & Srivastava (2016)	Increase revenue through resource synergy		
Touboulic & Walker (2015)	Improving financial performance through profitability		
Cao & Zhang (2010)/ Panahifar et al. (2017)	Increase Rate of return		
Cao et al. (2010)/ Salam (2017)	Improve risk management		
Ramanathan et al. (2011)/ Al-Doori (2019)	Better pricing		
Heaver (2015)/ Lynch (2019)	Price stability		
Aggarwal & Srivastava (2016)/ Ho et al. (2020)	Reduce costs	Economic performance (cost)	
Narayanan et al. (2015)/ Al-Doori (2019)	Reducing the cost of transactions		
Cao & Zhang (2010)/ Lynch (2019)	Cost saving		
Jeenanunta & Visanvetchakij (2013)/ Panahifar et al. (2017)	Cost competitiveness		
Touboulic & Walker (2015)/ Ho et al. (2020)	Cost reduction		
Cao et al. (2010)/ Salam (2017)	Globalization	Economic performance (market)	
Aggarwal & Srivastava (2016)	More intense competition		
Chen et al. (2017)	Creating a competitive advantage		
Heaver (2015)/ Al-Doori (2019)	Promotion of competitive advantage		
Pradabwong et al. (2017)	Creating a strategic advantage against market competitors		
Al-Doori (2019)/ Ho et al. (2020)	Improving competitiveness		
Narayanan et al. (2015)/ Afshan et al. (2018)	Improving performance and market position through access to markets		
Pradabwong et al. (2017)	Better sales		

Table 5. Continued

Authors	First-order themes	Second-order themes	Aggregate dimensions
Ramanathan et al. (2011)/ Lynch (2019)	Increasing the knowledge level of Partners in the supply chain	Economic performance (knowledge and innovation)	Sustainable performance
Cao et al. (2010)/ Panahifar et al. (2017)	Increasing innovative methods resulting from the sharing of knowledge and experience among partners		
Cao et al. (2010)/ Lynch (2019)	Development of tacit knowledge		
Ramanathan et al. (2011)/ Afshan et al. (2018)	Knowledge transfer beyond company boundaries		
Heaver (2015)	Promotion of innovative capabilities		
Aggarwal & Srivastava (2016)	Improve capabilities	Economic performance (capabilities and competencies)	
Narayanan et al. (2015)	Competence development and continuous improvement		
Cao et al. (2010)/ Lynch (2019)	Focus on key activities, capabilities, and competencies of the organization		
Cao & Zhang (2010)/ Salam (2017)	Better access to resources		
Chen et al. (2017)	Better use of resources		
Touboulic & Walker (2015)	Access to additional features		
Pradabwong et al. (2017)	Use the expertise of partner		
Aggarwal & Srivastava (2016)	Achieving a win-win solution		
Heaver (2015)/ Afshan et al. (2018)	Improving the performance of the company and the supply chain		
Ramanathan (2014)/ Lynch (2019)	Social stability	Social Performance	
Aggarwal & Srivastava (2016)	Benefits for people		
Chen et al. (2017)/ Afshan et al. (2018)	Improving sustainability and social performance through the optimal use of raw materials		
Ramanathan (2014)/ Aggarwal & Srivastava (2016)	Environmental sustainability	Environmental Performance	
Chen et al. (2017)	Increasing green purchases		
Lynch (2019)	Improving biodiversity		
Govindan et al. (2017)	Reducing harmful environmental effects and promoting sustainability		
Ahmed et al. (2020)	Waste reduction		
Aggarwal & Srivastava (2016)	Reducing carbon emissions		
de Almeida et al. (2015)/ Panahifar et al. (2017)/ Salam (2017)/ Shayganmehr et al. (2021)/ Baah et al. (2022)/ (Alshurideh et al., 2022)/ Chishti & Ahmed (2023)	The concept of trust	Trust	
Shayganmehr et al. (2021)	Rapid trust through coordination among partners		
Chishti & Ahmed (2023)	Increasing human interactions based on trust		

The sixth step of meta-synthesis is dedicated to quality control and validation. The CASP (Critical Skills Appraisal Program) criterion was used to evaluate validity. Every article with a score higher than good (30) was removed. Thus, the number of final articles reached 107. To evaluate the reliability, the Kappa coefficient was used. In addition, its value was calculated as 0.708, which is higher than the acceptable value. In the seventh step, the collaboration model is presented. Validation of the model was done with the help of academic experts in fields connected to the research topic. The supply chain 4.0 collaboration model is shown in Figure 3.

According to the Collaboration model in Supply Chain 4.0, there are 8 groups of initiators and barriers and 4 groups of outcomes. In the next part of the research, a trust-based decision tree was designed because of its importance in the supply chain. Trust in this tree was examined from two aspects: Improver for Initiators (W1) and Reducer for Barriers (W2) with 16 sections. This approach was used to clarify the effect of trust on Collaboration in the supply chain. The collaboration model in Supply Chain 4.0 based on trust in Decision Tree is shown in Figure 4.

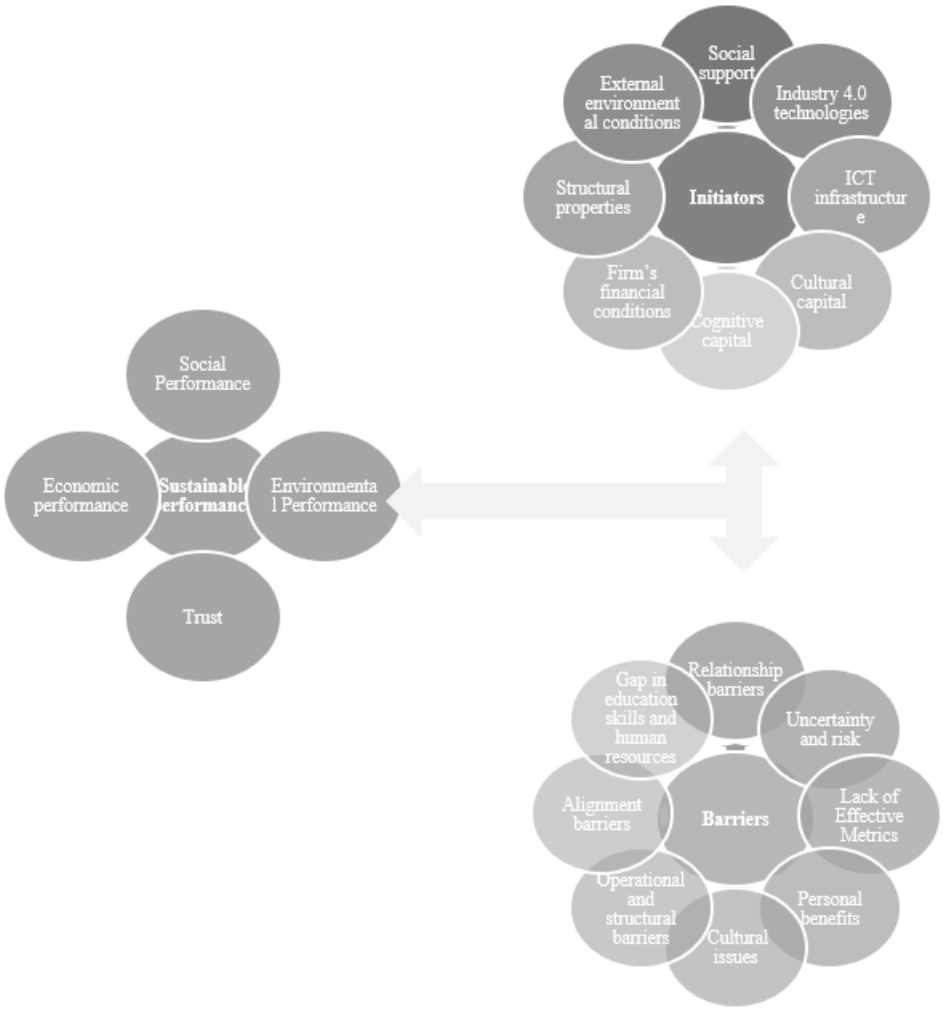

Figure 3. Collaboration model in Supply Chain 4.0

In this research, a fuzzy hierarchical analysis method has been used to prioritize trust indicators in the supply chain collaboration. This method will achieve the weights of the factors by creating a non-linear programming model and then solving it. One of the unique features of this technique is that by solving the model, in addition to the weights of the factors, the inconsistency rate of pairwise comparisons is also obtained. The steps to use this method are as follows:

- Hierarchical structure drawing: which is shown in Figure 4.
- Forming the matrix of fuzzy pairwise comparisons: consensus matrices of fuzzy judgment are formed based on experts' opinions in FMCG industries. For this reason, fuzzy numbers have been used to express experts' preferences in this research. Linguistic variables and their fuzzy scale are presented in Table 6.

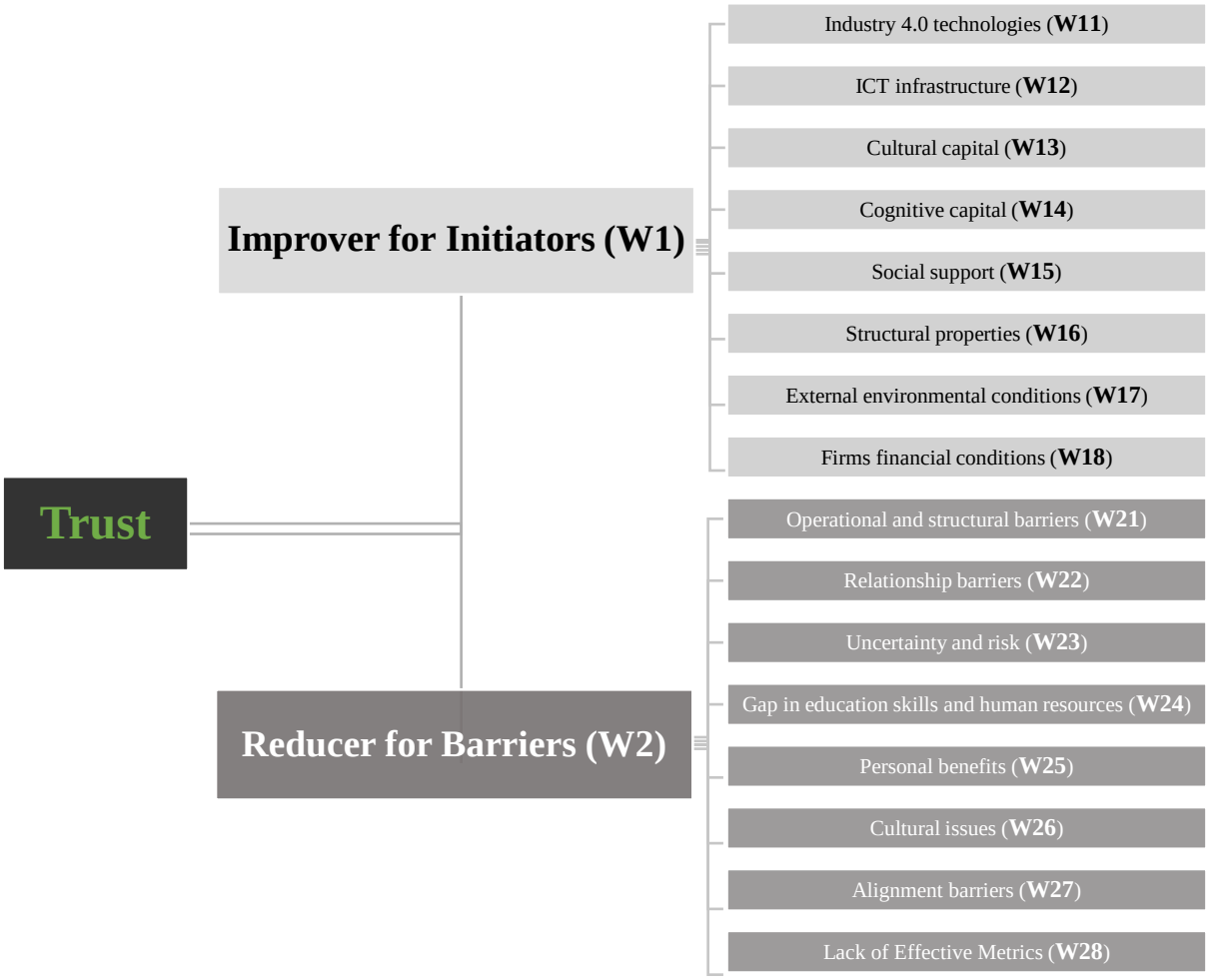

Figure 4. Collaboration model in Supply Chain 4.0 based on trust in Decision Tree

Table 6. Linguistic variables for pairwise comparisons

Linguistic variable	Triangular fuzzy Scale
(1,2,3)	Very low
(2,3,4)	Low
(3,4,5)	Medium
(4,5,6)	High
(5,6,7)	Very High

As seen in the table above, fuzzy triangular numbers are used for language scales, which is one of the types of fuzzy numbers. In this method, the following non-linear programming model is formed and solved to calculate the weights. The value of λ is the inconsistency rate of the model, and the values of W_i are the weights of the criteria, which are obtained from solving the model. A positive value lambda in the model answer indicates the compatibility of pairwise comparisons and a negative value lambda indicates incompatibility.

The deterministic vector of weight (priority) $w = (w_1, w_2, \ldots, w_n)$ is extracted in such a way that the priority rate is almost within the range of the basic fuzzy judgments. In other words, the weights are determined in such a way that the following relationship is established.

$$l_{ij} \leq \frac{w_i}{w_j} \leq u_{ij} \qquad (1)$$

Any deterministic weight vector (w) with a degree applies to the above fuzzy inequalities, which can be measured through the linear membership function of the following relationship (in terms of the unknown rate):

$$\mu_{ij}(\frac{w_i}{w_j}) = \begin{cases} \dfrac{(w_i / w_j) - l_{ij}}{m_{ij} - l_{ij}} & \dfrac{w_i}{w_j} \le m_{ij} \\ \dfrac{u_{ij} - (w_i / w_j)}{u_{ij} - m_{ij}} & \dfrac{w_i}{w_j} \ge m_{ij} \end{cases} \quad (2)$$

Considering the specific form of the membership functions, the fuzzy prioritization problem becomes a non-linear optimization problem as follows.

$$\begin{aligned} &\max\ \lambda \\ &subject\ to: \\ &(m_{ij} - l_{ij})\lambda w_j - w_i + l_{ij} w_j \le 0; \\ &(u_{ij} - m_{ij})\lambda w_j + w_i - u_{ij} w_j \le 0; \\ &i = 1,2,..., n-1,\ \ j = 2,3,..., n,\ \ j > i, \\ &\sum_{k=1}^{n} w_k = 1,\ \ w_k > 0,\ \ k = 1,2,..., n, \end{aligned} \quad (3)$$

Considering the non-linearity of the relationship (3), surely it is not possible to solve it without using software. Therefore, *GAMS* software was used to solve the models created in this research.

The process of ranking factors related to trust in the supply chain collaboration based on digital technologies in this study is divided into two main parts:

1) Determining the matrix of pairwise comparisons based on the integration of experts' opinions
2) Using mathematical modeling to rank and obtain the weight of indicators in the research model.

To prioritize the 16 final factors extracted in this research, fuzzy questionnaires using language variables were sent to 25 experts and university professors. 20 questionnaires were completed and received. These paired comparison tables are shown in Tables 7 to 9. These tables were used for calculations using the nonlinear fuzzy ranking method.

Table 7. Matrix of pairwise comparisons for Trust factor in SCC

	W1			W2		
W1	2.1	2.75	3.1	1.75	2.8	4.25
W2	1.2	2.1	4.1	1.5	2.5	3.25

By putting the data obtained from Tables 7 to 9 in the non-linear relationship (**3**), as a model providing weights and ranks based on hierarchical analysis and solving the model using *GAMS* software, the weight and rank of each of the evaluation indicators can be obtained in general dimensions as well as in exclusive categories. The calculation results related to solving the non-linear model for general categories and individual indicators are shown in Tables 10 to 12.

Table 8. Matrix of pairwise comparisons for Trust improver for Initiators

	W11			W12			W13			W14			W15			W16			W17			W18		
W11	1.2	2.1	2.75	1.5	2.5	3.25	2	2.1	3	2.12	2.74	3.01	1.2	2.8	3.6	1.01	2.1	2.75	1.5	1.8	1.9	1.2	1.7	1.9
W12	2.1	2.75	3.1	1.75	2.1	3.2	2.1	2.5	3.25	1.75	1.95	2.5	2.2	2.8	3.1	1.25	2.01	3.1	2.1	2.4	2.5	1.1	1.5	2.1
W13	2.25	3	4.1	2.1	2.5	3.4	1.2	1.75	2	1.8	2.5	3.5	2	2.3	4	1.35	2.01	3	1.7	2.5	4.2	2.1	2.4	2.5
W14	2.1	3.01	3.89	1.75	2.25	3.5	0.75	1.5	3	2	2.1	2.8	1.2	3.1	3.78	1.4	1.75	4.1	1.5	2.7	4.9	1.7	2.5	4.2
W15	2.75	3.5	4	1.5	2.5	3.5	1.2	1.5	1.75	2.1	2.5	2.8	1.1	3.4	4.3	1.51	2.1	3	2.1	3.1	4.2	1.5	2.7	4.9
W16	1.75	2	2.75	2	2.25	3	1.5	2	2.75	1.25	1.75	2.65	1.5	3.25	4.2	1.32	1.75	2.5	2.2	3.01	4.1	2.1	3.1	4.2
W17	1.25	2.01	3.25	1.2	1.75	3	1.02	1.5	1.9	2	3.5	4.32	2.1	3.75	4.21	1.5	2	2.75	2.3	3.1	4.2	2.2	3.01	4.1
W18	1.7	2.5	4.2	2.2	2.8	3.1	1.25	2.01	3.1	2.1	2.4	2.5	1.75	2.25	3.5	1.5	2.7	4.9	2.2	3.01	4.1	4	1.35	2.01

Table 9. Matrix of pairwise comparisons for Reducer for Barriers

	W21			W22			W23			W24			W25			W26			W27			W28		
W21	1.2	1.7	1.9	2.75	3.5	4	1.5	2.5	3.5	1.2	1.5	1.75	1.5	2.5	3.25	1.1	1.5	2.1	1.7	2.5	4.2	2.75	2	2.25
W22	1.1	1.5	2.1	1.75	2	2.75	2	2.25	3	1.5	2	2.75	1.75	2.1	3.2	2.1	2.4	2.5	1.5	2.7	4.9	3.25	1.2	1.75
W23	2.1	2.4	2.5	1.25	2.01	3.25	1.2	1.75	3	1.02	1.5	1.9	2.1	2.5	3.4	1.7	2.5	4.2	2.1	3.1	4.2	3.1	1.25	2.01
W24	1.7	2.5	4.2	2.2	2.8	3.1	1.25	2.01	3.1	2.1	2.4	2.5	1.75	2.25	3.5	1.5	2.7	4.9	2.2	3.01	4.1	4	1.35	2.01
W25	1.5	2.7	4.9	2	2.3	4	1.35	2.01	3	1.7	2.5	4.2	1.5	2.5	3.5	2.1	3.1	4.2	2.3	3.1	4.2	3.78	1.4	1.75
W26	2.1	3.1	4.2	1.2	3.1	3.78	1.4	1.75	4.1	1.5	2.7	4.9	2	2.25	3	1.5	2.5	3.25	2	2.1	3	2.12	2.74	3.01
W27	2.2	3.01	4.1	1.1	1.5	2.1	1.75	2	2.75	2	2.25	3	1.2	1.75	3	1.75	2.1	3.2	2.1	2.5	3.25	1.75	1.95	2.5
W28	2.3	3.1	4.2	1.75	2.25	3.5	1.5	2.7	4.9	2.2	3.01	4.1	4	1.35	2.01	2.1	2.5	3.4	1.2	1.75	2	1.8	2.5	3.5

Table 10. Weight and ranking of the main categories

Category	Code	Weight	Rank	The objective function
Improver for Initiators	W1	0.57	1	0.38
Reducer for Barriers	W2	0.43	2	

Table 11. Weight and ranking of the Improver for Initiators

Category	Code	Weight	Rank	The objective function
Industry 4.0 Technologies	W11	0.14045	3	0.54
ICT Infrastructure	W12	0.15421	2	
Cultural capital	W13	0.11201	6	
Cognitive capital	W14	0.09822	7	
Social support	W15	0.23241	1	
Structural properties	W16	0.11452	5	
External environmental conditions	W17	0.07021	8	
Firms' financial conditions	W18	0.12121	4	

Table 12. Weight and ranking of the Reducer for Barriers

Category	Code	Weight	Rank	**The objective function**
Operational and structural barriers	W21	0.10211	5	0.42
Relationship barriers	W22	0.19915	2	
Uncertainty and risk	W23	0.21521	1	
Gaps in education skills and human resources	W24	0.07421	8	
Personal benefits	W25	0.12325	3	
Cultural issues	W26	0.08541	7	
Alignment barriers	W27	0.08741	6	
Lack of Effective Metrics	W28	0.11241	4	

The normal weight of factors is shown in Figure **5**.

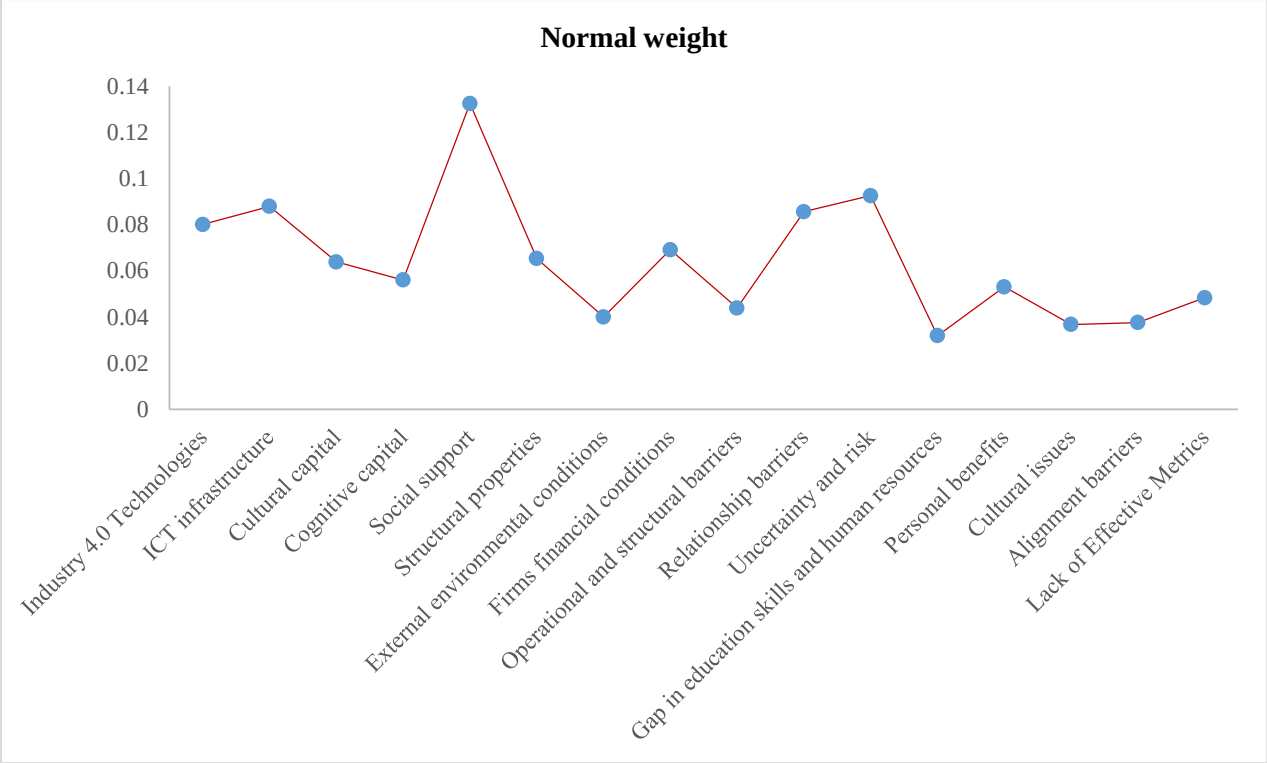

Figure 5. The normal weight of trust factors in the supply chain collaboration system

5. Conclusion

This paper represents an important contribution for academics and companies in the FMCG industry to clarify the SC 4.0 concept duo to highlight a set of technologies considered strategic in the actual fourth industrial revolution. This paper is affecting not only individual companies but also the SCs (Azevedo, [9]). Conclusions are divided into three subsections: main conclusion, research implications, limitations, and future research directions.

5.1. Main conclusions

Collaboration factors based on trust were classified into initiators and barriers with decision tree. In the initiators section, Social Support with a weight of 0.23241, and in the barriers section uncertainty and risk with a weight of 0.21521 were first. Also, the normal weight of trust factors in the supply chain collaboration system shows that Social Support with a weight of 0.23241, and Gap in education skills and human resources with a weight of 0.07421 are respectively the most and the least factors influenced by trust. Sharing trust between supply chain partners improves collaboration through its indicators. Except for social support, trust affects seven other initiators of collaboration. Industry 4.0 technologies and ICT infrastructure are the other high-rank initiators.

5.2. Research implications

According to the results analysis and the type of collaboration, the most used in the case study are the ones that involve more operational issues. The FMCG industry's supply chain was considered a special case in this research. These industries play a significant role due to the nature of the production and distribution of products. In addition, a literature review of previous research and opinions of experts in FMCG industries are used for this research (Nozari et al., [42]).

Compared to similar studies investigating collaboration in the supply chain 4, there are distinct and prominent points in this research. The classified analysis presented in the meta-synthesis method creates a comprehensive view of the research indicators. Also, these indicators can be used as a basis for decision-making in various case studies. The presentation of a fuzzy analysis based on the decision tree, which was inspired by the concept of trust, shows

that implementing a collaborative model in supply chain 4.0 significantly depends on human parameters such as trust. Of course, it is necessary to test parameters such as trust in the framework of Industry 4.0 tools. Also, it is possible to implement these concepts in line with new technologies.

5.3. Future research directions

On one hand, the implementation of collaboration in the supply chain leads to the creation of trust in the supply chain, and on the other hand, the trust resulting from collaboration leads to changes in the initiators and barriers of collaboration. There is a reciprocal and two-way relationship between the dimensions of collaboration and trust. In terms of future research, it will be interesting to replicate this study in a company from the FMCG industry. Also, examining other aspects of the collaboration variable can help to develop the current model and lead to the creation of a more comprehensive model of the concept of collaboration at the supply chain 4.0 level. For example, identifying and introducing dimensions and indicators for measuring partner collaborative relationships can be a suitable option.

Conflict of interest: The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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