International Journal of Research in Industrial Engineering

www.riejournal.com

Int. J. Res. Ind. Eng. Vol. x, No. x (xx) x–x.

Paper Type: Original Article

An Interval Type-2 Fuzzy AHP Approach for Success Factors of Green Supply Chain Management

Davod Andalib Ardakani[1], Mehrdad Kiani[2], Ali saffari darberazi[3], Fatemeh Zamzam*[4], Elham Mofatehzadeh[5]

[1] Associate Professor, Department of Management, Yazd University, Yazd, Iran; andalib@yazd.ac.ir.
[2] Ph. D, Department of Management, Yazd University, Yazd, Iran; Mehrdad.kiani@stu.yazd.ac.ir.
[3]Assistant Professor of Bam Higher Education Complex, Bam, Iran; a.saffari@bam.ac.ir.
[4] Ph. D, Department of Management, Yazd University, Yazd, Iran; Fateme.zmzm@stu.yazd.ac.ir.
[5] Ph. D Candidate, Department of Management, Yazd University, Yazd, Iran; Elhammz@stu.yazd.ac.ir.

Abstract

The purpose of this study was to design a model for identifying and ranking the factors influencing green supply chain management in the tile and ceramic industry, which is a significant industry in Iran. The study consisted of three main stages.In the first stage, a systematic review of the literature and the Meta-synthesis method were employed to identify and categorize the factors that contribute to the success of green supply chain management. In the second stage, The factors were thoroughly examined and refined through the content validity method. As a result of these steps, a comprehensive model was developed, comprising 30 factors categorized into six dimensions: green suppliers, green technology and expertise, green human resources, green products, Green Organization and Communications, and Green regulations and Support. In the third stage, the Interval Type-2 Fuzzy Analytic Hierarchy Process (IT2FS-AHP) method was utilized to rank the dimensions and factors. Experts' opinions were gathered through a questionnaire to determine the importance of each dimension and factor. The results indicated that the dimensions of green technology and expertise, as well as Green regulations and Support, were deemed the most critical. Furthermore, factors such as "Attention to social responsibility in the organization," "Design and development of evaluation and selection systems of suppliers based on environmental criteria," and "support of operational, middle, and senior managers in implementing the green supply chain" were identified as highly influential in the success of green supply chain management. Overall, the identification and ranking of key factors in green supply chain management contribute to mitigating the adverse environmental impact of industrial activities and enhancing customer satisfaction.

Keywords: Green Supply Chain Management, Environmental effects, Tile and ceramic Industry, Meta-synthesis, Interval Type-2 Fuzzy AHP

1 | Introduction

Today, the supply chain has become an important and vital factor in global markets so that supply chains are in serious competition more than organizations themselves[1-4]. Consequently, the importance of the concept of supply chain and its performance is one of the paradigms of the new century to improve competitiveness

Corresponding Author:

as a result of which, organizations have paid more attention to it than before[5]. According to the definition of [6], the supply chain includes all the steps that directly and indirectly meet customers` demands. With this view, not only does the supply chain include the manufacturer and supplier, but it includes carriers, wholesalers, retailers and customers. Companies that are in the supply chain, convert raw materials into end products and create added value. [7] identified the supply chain as a network of organizations that are engaged in various processes and activities through the up and down links and create value for the end customer in the form of products and services. On the other hand, concepts like lean, green, agile and most recently resilience supply chain management are unique supply chain management strategies that have been introduced to improve supply chain performance [3, 8] Green supply chain is an integral part of companies' activities to adapt to the environment. According to the World Health Organization, the cause of 24% (about a quarter) of diseases in the world is the environmental pollution and each year, the environmental factors cause more than 13 million deaths all around the world [9, 10]. On the other hand, some researchers raised the green supply chain management as an important organizational issue that plays a key role in improving the efficiency and coordination of partners and adapting executive performance in accordance with the environment, minimizes non-recyclable waste, reduces environmental risks and negative effects on the environment , and at the same time, is responsible for upgrading and improving the quality and ecological efficiency of their organizations and companies [11]. Green supply chain management is similar to the product life cycle. Product life cycle management begins with planning and continues to design, building, supporting, and repelling processes. Green supply chain management is a combination of environmental concerns that have been featured in the form of various green measures such as lifecycle analysis, green design, green shopping, 3R (recycling, reuse, reconstruction), environmental technologies, green logistics, cooperation with suppliers, distributors and customers [4, 12, 13]. At present, all aspects of traditional supply chain management are under great pressure from the customer and regulations related to the environmental organization.

Green Supply Chain Management is a well-established concept in injecting ethical and environmental considerations into the traditional supply chain with the goal of meeting the needs of environmental policies and ultimately customers [14]. Green Supply Chain Management seeks to improve the environmental performance of supply chain companies and protect the environment at the community level. Extensive studies have been conducted on green supply chain management, including implementation factors and obstacles, as well as case studies which have shown that currently, most researchers are concerned about the global environment [15]. The tile and ceramic industry has always been in the focus of attention of Iranian artisans and has played an effective role in the currency accumulation and promotion of Iran's economy in the world market; but in addition to such benefits, it also has disadvantages, the most important of which are environmental pollutants, including heavy metals, phosphate, chloride, effluent, and so on. Thus, identifying the factors affecting the success of the supply chain in the tile and ceramic industry can be effective in controlling and reducing the negative consequences of this industry on the environment. According to the review of previous research records on the subject of factors affecting the success of green supply chain management it was determined that relatively high research has been conducted in this regard. However, none of them has addressed this issue with a comprehensive and systematic approach and using a Meta synthesis method. Therefore, it seems that paying attention to this important part is one of the necessities of research activities. It is important to note that organizations do not usually have a written plan for implementing a green supply chain and in most cases, green areas in organizations are based on legal requirements in the field of environment. on the other hand, previous research conducted in the field of Green supply chain management has approached the subject from various perspectives [4, 5, 16-18] However, considering the diverse approaches and the lack of a comprehensive examination of the factors influencing the implementation of green supply chain management, the current study adopted a Meta-Synthesis approach to utilize and analyze the findings of previous studies in order to generate a new summary. Additionally, the Interval Type-2 Fuzzy Analytic Hierarchy Process (IT2FS-AHP) method was employed to weight and prioritize the factors. IT2FSs were chosen due to their advantages over traditional fuzzy sets. They can more accurately represent linguistic variables, especially in uncertain environments, and they incorporate decision makers' confidence levels in their evaluations. Compared to other extensions of Type-1 Fuzzy Sets (T1FSs), IT2FSs provide a more intuitive and simpler tool [19]. Hence, the IT2FS-AHP method, which has demonstrated success in various studies, was selected for this research [20, 21]. Consequently, the objective of the present study is to design a model that identifies the factors influencing the success of green supply chain management in the tile and ceramic industry of Yazd province.

The primary contribution of this research is the development of a new framework and classification for the success factors of green supply chain management in the tile and ceramic industry of Yazd, which is recognized as a strategic and polluting industry in Iran. This was achieved through the systematic approach of metasynthesis and the prioritization of these factors using the IT2FS-AHP method.

The research aims to address the following questions:

1. What are the success factors of green supply chain management?
2. How can the success factors of green supply chain management in the tile and ceramic industry be prioritized?

The remaining sections of this article are organized as follows: Section 2 presents a review of the relevant literature. Section 3 outlines the methodology proposed in this study. The findings of the research are presented in Section 4. Finally, Section 5 concludes the paper with a discussion of the research, its implications, and suggestions for future studies.

2| Theoretical Framework

2.1| Green supply chain

Due to the economic, social and environmental challenges that have threatened organizations in recent decades, the customer-oriented approach and focus on its demands as well as the design of the organization's strategy based on this (customer satisfaction) has lost its ability to create competitive advantage in organizations. If in the last two decades, customer orientation has been a factor in the organization's competitive advantage, today, because of the challenges posed by customer orientation, organizations have moved away from this focus. Customers always desire the best, the cheapest and the fastest access to the product. As a result, this attitude leads to polluted environment and produces products and processes that are not in harmony with the environment. In this regard, organizations have found their survival in accountability in three areas including economic, social and environmental [10, 22]. It is important to consider environmental issues in supply chain management, including product design, material selection and sourcing, manufacturing process, delivery of the final product to the customer, and product management after consumption and its useful life. However, in the supply chain literature, the concepts of sustainable supply chain management and green supply chain management are usually used interchangeably; these two concepts are slightly different. Sustainable supply chain management includes economic dimensions and social and environmental sustainability. Sustainable supply chain management includes economic, social and environmental dimensions. Thus, the concept of sustainable supply chain management is broader than green supply chain management, and green supply chain management is a part of sustainable supply chain management [23, 24]. [25] has compiled and classified previous literature on green supply chain management. He described the management of the green supply chain as follows: Consider environmental issues in supply chain management, including product design, material selection and sourcing, manufacturing process, delivery of the end product to the customer, and goods management after consumption and its useful life. According to this definition, green supply chain management covers a wide range of productions from product design to recycling. Green supply chain management is similar to the product life cycle. Product life cycle management begins with planning and continues until designing, manufacturing, supporting, and repercussion processes.Green Supply Chain measures are a set of activities that seek to create a healthy and efficient environment, protect resources (energy, land, water and materials) from damages, protect the environment and minimize environmental pollution. The result of these activities is the adaptation of products to the environment throughout their life cycle [26]. A green supply chain is a supply chain system that focuses on the environmental impact and proper use of energy. If the system is able to track all the information about the environmental impact, a green supply chain will emerge. In other words, the green supply chain is a supply chain that focuses on environmental pressures and the impact of used energy. Green supply chain management is a set of green purchases, green production, green packaging, green distribution and green marketing. The purpose of the green supply chain is to prevent hazardous industrial systems from entering the environment in order to protect the environment [13]. The difference between supply chain management and green supply chain management is the importance that each attaches to the environment. Green supply chain management begins with factory production design and deals with the useful life of the product and ultimately it's recycling, given the concerns about the environment [27].

2.2| Research background

According to extensive researches on green supply chain management, and prevention of increasing the volume of paper, some researches have been related to this research topic and the factors mentioned in these studies have been presented in Table 1.

Table 1. A Summary of research background and extracted factors

Publication year and authors(s)	Title/purpose	Method	Case study	Key Factors
(Beloor et al., 2023) [4]	Modelling Framework for Critical Success Factors of Green Supply Chain Management -An Integrated Approach of Pareto, ISM and SEM	Pareto, ISM and SEM	Indian manufacturing sectors	Green Policies; Institutional Pressure; Green Manufacturing and Packaging; Green Purchasing and Reverse logistics
(Agrawal et al., 2023) [16]	analyse the critical success factors (CSFs) for effective adoption of Sustainable Green supply chain management (SGSCM) practices In the Indian brass manufacturing industry	AHP, TOPSIS and DEMATEL methods	In the Indian brass manufacturing industry	Top Management Commitment; Adoption of New Technology and Processes; Customer Requirements; Employee Involvement; Brand Image Building; Government Regulations and Standards
(Banik et al., 2022) [5]	examines critical success factors (CSFs) for the implementation of green supply chain management (GSCM) for the electronics industry of an emerging economy	DEMATEL method	electronics industry	top management commitment; government regulations and standards; pollution prevention and hazardous waste management and environment management certification (ISO 14000)
(Thakkar, 2021) [28]	identify various critical success factors to implement GSCM in Indian tube manufacturing SMEs by consultation with the industry experts and academicians	Interpretive Structural Modeling (ISM)	Indian Tube Manufacturing Industries	Lack of natural resources; Societal pressures/issues; Government regulations and legislation; High energy consumption rates and High cost for disposal of hazardous materials/products
(Chatterjee et al., 2018) [29]	Evaluating the performance of suppliers for green supply chain implementation in electronics industry	R'AMATEL-MAIRCA method	electronics industry	Increasing innovation capabilities; Abstaining from toxic substances; Green Image; Saving Energy; Green competencies;Green management abilities
(Vanalle et al., 2017) [30]	investigation of pressures, practices, and performance within the Brazilian automotive supply chain	PLS-SEM	suppliers of a Brazilian automotive supply chain	Institutional Pressures; Internal Environmental management; Green Purchasing; Cooperation with customers including environmental requirements; Eco-design; Investment Recovery

Corresponding Author:

Publication year and authors(s)	Title/purpose	Method	Case study	Key Factors
(Agi & Nishant, 2017) [31]	establish a set of 19 influential factors on the implementation of Green Supply Chain Management (GSCM) practices and analyse the interaction between these factors and their effect on the implementation of GSCM practices using the Interpretive Structural Modelling (ISM) method and MICMAC	ISM and MICMAC	---	size of the company; Dependence relationships with SC partners;Top management commitment; Applying quality management principles; Use of Information technology
(Scur & Barbosa, 2017) [32]	identify and analyze the practices of green supply chain management adopted by home appliance manufacturers. To analyze green practices in this industry,	interview and Qualitative approach	Brazilian home appliance industry	Reversing Logistics; Waste Management; Green Manufacturing and Remanufacturing; Eco-Design; Life Cycle Assessment; Internal Environmental Management; green purchasing; Cooperation with Customers
(Luthra et al., 2016) [33]	Examines the impacts of CSFs to implement GSCM towards sustainability on current green practices implemented by Indian automobile industry	multiple regression	automobile industry of India	Regulations; Internal management; Competitiveness,
(Kusi-Sarpong et al., 2015)[34]	Green Supply Chain Practices Evaluation in the Mining Industry	rough set theory elements and fuzzy TOPSIS	Mining Industry	Green Information Technology and Systems; Strategic Suppliers Partnership; Operations and Logistics Integration; Internal Environmental Management; Eco-Innovation practices; End-of-Life practices
(Lee, 2015) [35]	examine the effects of green supply chain management (GSCM) on environmental and operational performances with a perspective of social capital accumulation in the supply chain.	exploratory factor analysis (EFA) and a confirmatory factor analysis (CFA)	supplying firms in South Korea	Assessment of environmental performance through a formal and green procurement process; establishing an environmental management systems; environmental audits on a regular basis; developing environmental friendlier products; providing relevant and helpful information on how to comply with its environmental requirements; providing technical, managerial; and financial assistance to address environmental issues; developing environmental conscious products

3| Methodology

Generally, the approach of this research was hybrid. In a hybrid research, the researcher uses both quantitative and qualitative approaches for implementing the research plan. At the first stages of this study, the qualitative method of meta-synthesis was used to identify and classify the factors effecting the success of the green supply chain. In the next step, quantitative methods of content validity and Interval Type-2 Fuzzy AHP respectively, were used to finalize and rank the effective factors of green supply chain success. The statistical population in the first stage of the research included all articles published in reputable scientific databases related to the green supply chain until the completion of this research. In the second and third stages of the research, the statistical population included university professors, managers and experts in the field of supply chain in the tile and ceramic industry, and statistical samples were selected purposefully by 15 and 8 people, respectively. The research steps have been summarized in Table 2.

Table 2. Phases of the research

phases	Title	Tools	Analysis method	statistical population
1	Identifying the factors and dimensions of green supply chain management	Review of studies	Meta-synthesis	Published research
2	Institutionalizing of the factors and dimensions of green supply chain management	questionnaire	Content validity	Experts in the field of supply chain in tile and ceramic Industry
3	Ranking the factors and dimensions of green supply chain management	questionnaire	Interval Type-2 Fuzzy AHP	Experts in the field of supply chain in tile and ceramic Industry

3.1| Type-2 Fuzzy Sets

Type 2 fuzzy sets were first introduced by Zadeh in 1975 as a development of fuzzy sets [36]. Then, to distinguish between fuzzy sets and type-2 fuzzy sets, previous fuzzy sets were commonly called as Type-1 fuzzy sets [37]. Type-2 fuzzy sets are the fuzzy sets having fuzzy membership functions. Thus, they are also called fuzzy-fuzzy sets, which are able to reduce the effect of uncertainties and can model them when they face uncertainties. Also, type-2 fuzzy sets perform better in reducing uncertainty in fuzzy rules. In addition to reducing the uncertainty in fuzzy rules, due to the fuzzy nature of membership functions in fuzzy-type 2 sets, the possibility of modeling linguistic uncertainties and data has been effectively improved [38]. Generally, the history of the development of fuzzy type-2 theory has been presented in two sections as general and interval. For the first time, Interval type-2 fuzzy sets was introduced by [38].

3.2| Interval type 2 fuzzy AHP

analysis hierarchical process (AHP) is a structured decision making approach that was introduced by Saaty in 1980. It is a weighted factor-scoring model that has the appropriate capability to identify and combine inconsistencies in the decision-making process. In this methodology, participanted experts must compare the factors two by two and determine the importance of each factor by other factors and compare them by assigning a score from 1 to 9 [39]. Scholars suggest that the utilization of Interval Type-2 Fuzzy Sets and Analytic Hierarchy Process (AHP) can effectively enhance the organization, control, and reduction of uncertainty and ambiguity in the decision-making process. These two methods can be seamlessly integrated to provide more robust and accurate decision-making outcomes [40, 41]. According to the guidelines of experts in this field, the steps of the interval type-2 fuzzy AHP method are as follows [20, 21]:

Step 1. The pairwise comparisons of factors and dimensions are extracted by consulting experts using language variables.

Corresponding Author:

Step 2. The consistency of the fuzzy pair wise comparison is analyzed. At this stage, if the result of the pairwise comparison matrix (A) be consistent, then the result of type -2fuzzy pairwise comparison matrix type 2 ($\tilde{A}$) would be also consistent. If Consistency rate (CR) be 0.1 or less, it would be considered as acceptable. Also, in this study, the method of [42] was sed to calculate the CR.

Step 3. The pairwise comparison matrix is constructed using Equation 1 according to Type 2 fuzzy linguistic term. The linguistic terms are shown in Table 3.

Table 3. Definition and type 2 fuzzy scales of the linguistic variables (Celik & Akyuz, 2018)

Linguistic variables	IT2FSs	Reciprocal IT2FSs
Extremely more important (9)	((8;9;9;10;1;1), (8.5;9;9;9.5;0.9;0.9))	((0.1;0.11;0.11;0.13;1;1), (0.11;0.11;0.11;0.12;0.9;0.9))
Intermediate value (8)	((7;8;8;9;1;1),(7.5;8;8;8.5;0.9;0.9))	((0.11;0.13;0.13;0.14;1;1), (0.12;0.13;0.13;0.13;0.9;0.9))
Very strong more important (7)	((6;7;7;8;1;1),(6.5;7;7;7.5;0.9;0.9))	((0.13;0.14;0.13;0.14;1;1), (0.13;0.14;0.13;0.13;0.9;0.9))
Intermediate value (6)	((5;6;6;7;1;1),(5.5;6;6;6.5;0.9;0.9))	((0.14;0.17;0.17;0.2;1;1), (0.15;0.17;0.17;0.18;0.9;0.9))
Strongly more important (5)	((4;5;5;6;1;1),(4.5;5;5;5.5;0.9;0.9))	((0.17;0.2;0.2;0.25;1;1), (0.18;0.2;0.2;0.22;0.9;0.9))
Intermediate value (4)	((3;4;4;5;1;1),(3.5;4;4;4.5;0.9;0.9))	((0.2;0.25;0.25;0.33;1;1), (0.22;0.25;0.25;0.29;0.9;0.9))
Moderately more important (3)	((2;3;3;4;1;1),(2.5;3;3;3.5;0.9;0.9))	((0.25;0.33;0.33;0.5;1;1), (0.29;0.33;0.33;0.4;0.9;0.9))
Intermediate value (2)	((1;2;2;3;1;1),(1.5;2;2;2.5;0.9;0.9))	((0.33;0.5;0.5;1;1;1), (0.4;0.5;0.67;0.9;0.9;0.9))
Exactly Equal (1)	((1;1;1;1;1;1),(1;1;1;1;0.9;0.9))	((1;1;1;1;1;1),(1;1;1;1;0.9;0.9))

$$\tilde{A} = \begin{bmatrix} 1 & \tilde{a}_{12} & \dots & \tilde{a}_{1m} \\ \tilde{a}_{21} & 1 & \dots & \tilde{a}_{2m} \\ \vdots & \vdots & \ddots & \vdots \\ \tilde{a}_{m1} & \tilde{a}_{m2} & \dots & 1 \end{bmatrix} = \begin{bmatrix} 1 & \tilde{a}_{12} & \dots & \tilde{a}_{1m} \\ \tilde{1}/\tilde{a}_{12} & 1 & \dots & \tilde{a}_{2m} \\ \vdots & \vdots & \ddots & \vdots \\ \tilde{1}/\tilde{a}_{1m} & \tilde{1}/\tilde{a}_{2m} & \dots & 1 \end{bmatrix} \quad \textbf{(1)}$$

$$where\ \tilde{1}\Big/\tilde{a}_{ij} = \left(\left(\frac{1}{a_{ij4}^U}, \frac{1}{a_{ij3}^U}, \frac{1}{a_{ij2}^U}, \frac{1}{a_{ij1}^U}; H_1(a_{ij}^U), H_2(a_{ij}^U)\right), \left(\frac{1}{a_{ij4}^L}, \frac{1}{a_{ij3}^L}, \frac{1}{a_{ij2}^L}, \frac{1}{a_{ij1}^L}; H_1(a_{ij}^L), H_2(a_{ij}^L)\right)\right)$$

Step 4. The geometric mean method was used to obtain the fuzzy geometric mean (Equation 2).

$$\tilde{r}_j = (\tilde{a}_{j1} \times \tilde{a}_{j2} \times \dots \times \tilde{a}_{jn})^{1/n} \quad \textbf{(2)}$$

$$where\ \sqrt[n]{\tilde{a}_{i1}} = \left(\left(\sqrt[n]{a_{ij1}^U}, \sqrt[n]{a_{ij2}^U}, \sqrt[n]{a_{ij3}^U}, \sqrt[n]{a_{ij4}^U};\ H_1(a_{ij}^U), H_2(a_{ij}^U)\right), \left(\sqrt[n]{a_{ij1}^L}, \sqrt[n]{a_{ij2}^L}, \sqrt[n]{a_{ij3}^L}, \sqrt[n]{a_{ij4}^L};\ H_1(a_{ij}^L), H_2(a_{ij}^L)\right)\right)$$

Step 5. In this stage, the fuzzy weight of each factor was calculated as follows.

$$\widetilde{w}_j = \tilde{r}_j \times (\tilde{r}_1 + \tilde{r}_2 + \dots + \tilde{r}_n)^{-1} \quad \textbf{(3)}$$

Step 6. To obtain the weight of each factor, the center of area defuzzification method, which is presented by [42], was used (Equation 4).

$$Defuzzified(\widetilde{w}_j) = \frac{\frac{(a_{j4}^U - a_{j1}^U) + (H_1(\tilde{A}_j^U) * a_{j2}^U - a_{j1}^U) + (H_2(\tilde{A}_j^U) * a_{j3}^U - a_{j1}^U)}{4} + a_{j1}^U + \frac{(a_{j4}^L - a_{j1}^L) + (H_1(\tilde{A}_j^L) * a_{j2}^L - a_{j1}^L) + (H_2(\tilde{A}_j^L) * a_{j3}^L - a_{j1}^L)}{4} + a_{j1}^L}{2} \quad \textbf{(4)}$$

Step 7. Finally, the weight of the factors were normalized using Equation 5 and the crisp weights were obtained.

$$w_j = Defuzzified\,(\widetilde{w_j}) / \sum_{j=1}^{n} Defuzzified\,(\widetilde{w_j}) \quad (5)$$

4| Finding

4.1| Extract and categorize the success factors of the green supply chain using Meta-synthesis method

In this study, the seven-step method of [43] has been used to perform the Meta-synthesis method as follows.

4.1. Asking research questions:

in the Meta-synthesis method, the research questions must have the characteristics presented in Table ٤. In this regard, only documents should be included in this study in which the success factors in green supply chain management are discussed more. The selected time period is between 2000 and 2024; Because the concept of green supply chain management entered the field of application in industries from the beginning of the 21st century. In addition, document search was limited to "article" and "English" language.

Table 4. Research Questions

Research Component	Research Questions
What	What are the success factors of green supply chain management?
Who	Published articles in the Scopus database
When	2000 to 2024
How	Reviewing articles, identifying and coding indicators, analyzing the studied concepts, and categorizing concepts

4.1.2. Systematic review of research literature:

In this stage, relevant texts are searched in reputable scientific databases using keywords related to the research question. In the present study, this search was conducted in the Scopus scientific database within the time range of 2000 to 2024. The reason for choosing Scopus is its larger coverage compared to other scientific databases such as WoS. Additionally, Scopus provides a set of quality rankings for journals.

"supply chain***" OR "SCM"
AND
"Green" OR "Environmental" OR "Sustainabl***" OR "Ecological"
AND
"Success factors" OR "Drivers" OR "enablers"

4.1.3. Searching for and selecting appropriate papers:
In this stage, the researcher excludes a number of articles that do not meet the criteria for inclusion in the meta-synthesis process. In this step, the studies that meet the criteria for inclusion are selected, and the inclusion and exclusion criteria are determined based on the study (Table 5). The inclusion criteria refer to the criteria based on which a particular study is included in the analysis, while the exclusion criteria act as a second filter in selecting appropriate studies.

Table 5. Criteria for Inclusion and Exclusion of Sources in the Present Study

Inclusion Criteria	Exclusion Criteria
Scientific articles published in the relevant field in the Scopus database	Studies that did not provide sufficient information about the objectives of this research
Research that reports sufficient data and information related to the research objectives	Studies that lacked appropriate methodological frameworks
Research that has undergone expert peer review process and is published as a full article either online or in print	Studies that lacked the necessary quality, as they were published in low-quality journals
Articles and research published in the relevant field between the years 2000 and 2024	Review studies and library-based research
Articles and research that have examined the subject of interest and influential factors using scientific methods	Studies conducted prior to the year 2000

In the present study, the review process is summarized in Figure 1. As can be seen, a total of 129 sources were identified as relevant and acceptable during the search and selection process.

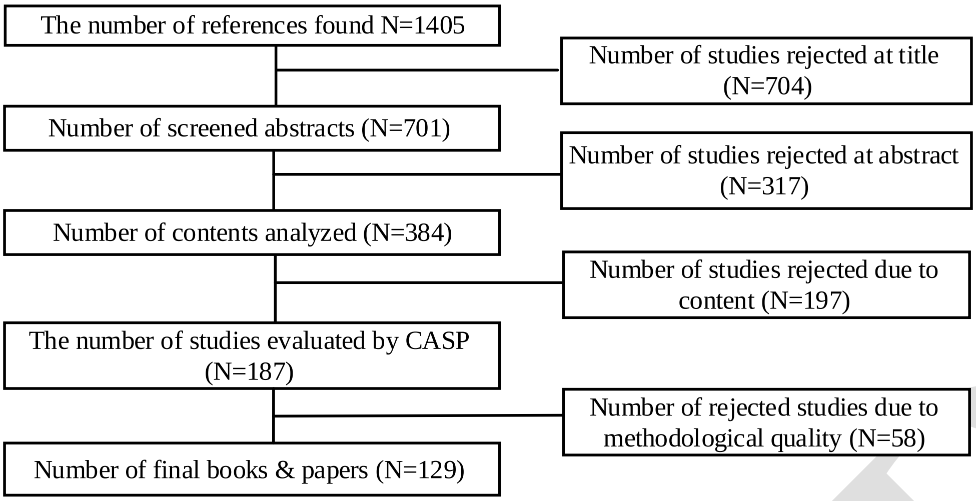

Figure 1 A schematic summary of the search results and selected resources

According to Figure 1, a total of 129 relevant references were identified and selected during the search process. These selections were based on specific inclusion criteria, which included clear statements of aims, methodology, research design, sampling, data collection, reflection of ethical issues, sufficient data analysis, clear statement of findings, and research value. To assess the methodological quality of these studies using the Critical Appraisal Skills Programme (CASP), each selected work was assigned a score based on the ten mentioned criteria. The scores of the 129 papers ranged from 21 as the lowest score to 49 as the highest score out of 50. Among the 187 papers evaluated, 58 received scores below 20 (indicating average or low quality) or did not meet the inclusion criteria and were subsequently excluded. Consequently, through the evaluation process, out of the initial 1405 publications, 1276 were eliminated, and finally, 129 publications were chosen for the subsequent data analysis procedure.

4.1.4. Extract the results:
In the entire process of meta-synthesis, the resources selected for the final analysis were scrutinized several times to accurately find factors influencing in green supply chain management. The information representing the references were categorized as follows: the data related to each reference was recorded (e.g. author name, year of publication), and the factors influencing green supply chain management were derived as explored in each resource.

4.1.5. Analyze and synthesize qualitative data:
The meta-synthesis method was used to create a unified and new understanding of the findings. The method was used to clarify the concepts, patterns and results. Through the analysis process, some themes (topics)

were identified. [43] called such a procedure a "thematic analysis", through which, researchers would try to find themes or topics. When the themes were clearly identified in this study, some categorizes were shaped and similar categories were put under the ones with thematic similarity. The themes were the foundations for providing explanations (models) and theories (working hypotheses). After the data were derived from the selected corpus, 384 codes were identified. Although after the overlapping (synonymous) of the notions, only 57 codes or concepts were extracted. Given the contents of these codes, they were categorized into a similar concept shaping a "factor." Ultimately 30 factors were derived. Following that the factors were broken into 6 groups, which were considered to be the "dimensions" in this study.

4.1.6. Quality control:

To ensure research quality and reliability, the Kappa Statistic was employed as a measure of agreement. An expert, who was unaware of the code combinations and concepts, was asked to re-group the concepts. The groups proposed by the expert were then compared to the original groups suggested by the authors. In Table 6, it can be observed that the authors suggested 6 groups, while the expert proposed 7 groups. Out of these sets of groups, 5 were common. The Kappa Statistic was calculated to be 0.617, as shown in Table 7. This value falls within an acceptable range, providing evidence for the reliability of the model.

Table 6. The comparison between groups suggested by the present authors and the expert

		Authors' grouping		
		Yes	No	Aggregate of codification 1
Expert's grouping	Yes	A=5	B=1	6
	No	C=2	D=0	2
	Aggregate of codification 2	7	1	N=8

Observed agreement: $\frac{A+D}{N} = \frac{5}{8} = 0.625$

Accidental agreement: $\frac{A+B}{N} \times \frac{A+C}{N} \times \frac{C+D}{N} \times \frac{B+D}{N} = \frac{6}{8} \times \frac{7}{8} \times \frac{2}{8} \times \frac{1}{8} = 0.0205$

Kappa Statistic value: $\frac{\text{Observed agreement}-\text{accidental agreement}}{1-\text{ accidental agreemnet}} = \frac{0.625-0.0205}{1-0.0205} = 0.617$

Table 7. Kappa Statistic results

Agreement status	**Numerical value of Kappa Statistic**	**Agreement status**	**Numerical value of Kappa Statistic**
Weak	Less than 0	Substantial	0.41 – 0.60
Slight	0 - 0.2	Moderate	0.61 - 0.80
Fair	0.21 - 0.40	Perfect	0.81 – 1

4.1.7. Presentation of the findings:

At this stage of the Meta-synthesis method, the findings of the previous steps have been presented, which can be seen in Table 8. After extracting and classifying the factors affecting the success of green supply chain management, to confirm the extracted factors, the opinions of experts and content validity method of [44] were used. The method proposed by Lawshe for content Validity was that the opinion of experts on the proposed indicators at the three-set Likert scale, including "Essential", "useful but not Essential" and "not Essential" were collected. These three modes were encoded in the letters E, U, and N; and for calculating the average number of judgments, the numbers 2, 1, and 0 were considered for them. According to [44] formula, the values of content validity ratio (CVR) and content validity index (CVI) were obtained using Equations 6 and 7. According to [44], 0.49 was the minimum acceptable value of CVR for fifteen experts.

$$CVR = (ne - \frac{N}{2})/(\frac{N}{2}) \quad \textbf{(6)}$$

In this formula, N is the total number of panels and "ne" is the number of panels that answered "Essential".

$$CVI = \sum \frac{CVR}{Retained\ numbers} \quad \textbf{(7)}$$

N represents the total number of experts and retained numbers represents the number of approved options. The CVR, Mean numerical Judgment (MnJ), and CVI were calculated for each of the success factors of the green supply chain (Table 8). The acceptance criteria were as follows:

- Unconditional acceptance of factors whose CVR value was greater than 0.49.
- Accepting options whose CVR value was between 0 and 1 and the MnJ was equal to or greater than 1.5. This situation showed that more than half of the experts agreed with the Essential of that factor. According to the opinion of [45], at least 60 percent of the reported reliability has also been achieved.

The results of content validity have been also shown in Table 8. Based on this table, all extracted factors were approved by experts and the content validity of the model was accepted.

Table 8. The results of the meta-synthesis and content validity

Dimension		Factors	CVR	MnJ	CVI
Green suppliers (GS)	(GS1)	Suppliers' participation in environmental protection	0.73	1.86	0.7
	(GS2)	Suppliers' desire to exchange industry-related environmental information	0.6	1.8	
	(GS3)	Design and development of evaluation and selection systems of suppliers based on environmental criteria	0.86	1.93	
	(GS4)	Tracking and monitor the observance of environmental principles by suppliers	0.6	1.73	
Green technology and expertise (GTE)	(GTE1)	Existence of technical expertise and alternative design for products in accordance with environmental requirements	0.73	1.86	0.706
	(GTE2)	Use innovative methods in the supply chain to protect the environment	0.73	1.86	
	(GTE3)	Existence of environmentally friendly equipment for transporting materials, end product and waste	0.86	1.93	
	(GTE4)	Use of machinery, physical equipment and green technologies in the organization	0.6	1.73	
	(GTE5)	Sale of additional capital equipment and waste	0.6	1.73	
Green regulations and Support (GRS)	(GRS1)	government regulations for adopting environmentally friendly policies	0.6	1.8	0.633
	(GRS2)	Supervision and guidance of supervisory authorities to protect the environment	0.6	1.73	
	(GRS3)	support of operational, middle and senior managers in implementing the green supply chain	0.73	1.86	
	(GRS4)	Allocate the necessary cost for the implementation of environmental programs	0.6	1.8	
	(GRS5)	Access to special facilities to encourage green production, the green process and ultimately green supply chain	0.73	1.86	
Green products (GP)	(GP1)	Use of environmentally friendly packaging (green packaging)	0.6	1.8	0.71
	(GP2)	procurement environmentally friendly raw materials (green procurement)	0.86	1.93	
	(GP3)	Product design for reuse and recycling (green design)	0.73	1.86	
	(GP4)	Product life cycle management	0.6	1.8	
	(GP5)	Increase customer demand for green products	0.73	1.8	
	(GP6)	Easy and low cost access to green raw materials	0.86	1.93	
	(GP7)	Use lean production	0.6	1.73	

Dimension		Factors	CVR	MnJ	CVI
Green Organization and Communications (GOC)	(GOC1)	Collaborate with the customer in designing green products	0.6	1.8	0.633
	(GOC2)	Attention to social responsibility in the organization	0.73	1.73	
	(GOC3)	Risk-taking organization and development environmental risk management	0.6	1.8	
	(GOC4)	Cooperation with environmental recycling and protection organizations	0.6	1.8	
Green human resources (GHR)	(GHR1)	Implement an Employee Suggestion System on environmental issues	0.6	1.8	0.653
	(GHR2)	Existence of Human Resources specialized in environmental management	0.73	1.8	
	(GHR3)	Holding environmental training conferences and classes for employees	0.6	1.73	
	(GHR4)	Promoting green culture and environmental considerations in the work environment of the organization	0.6	1.8	
	(GHR5)	Involving human resources in processes support the environment	0.73	1.8	

4.2| Prioritize Factors Affecting Successful Green Supply Chain Management Using Type-2 Fuzzy AHP

In this study, Type-2 Fuzzy AHP technique was used to weigh and prioritize the factors. For this purpose, 8 experts in the field of supply chain in the tile and ceramic industry were surveyed through a pairwise comparison questionnaire and were asked to compare the dimensions and indicators using verbal expressions. In the next step, the numbers related to the Linguistic terms became the fuzzy numbers of type 2 (according to Table 3), which have been described in Table 9 for the first expert.

Table 9. Transformation of Linguistic terms to fuzzy numbers of type 2 for the first expert

	GS	GTE	GRS	GP	GOC	GHR
GS	((1,1,1,1;1,1), (1,1,1,1;0.9,0.9))	((0.25,0.33,0.33,0.5;1,1), (0.28,0.33,0.33,0.4;0.9,0.9))	((0.33,0.5,0.5,1;1,1), (0.4,0.5,0.5,0.66;0.9,0.9))	((1,2,2,3;1,1), (1.5,2,2,2.5;0.9,0.9))	((1,2,2,3;1,1), (1.5,2,2,2.5;0.9,0.9))	((2,3,3,4;1,1), (2.5,3,3,3.5;0.9,0.9))
GTE	((2,3,3,4;1;1), (2.5,3,3,3.5;0.9,0.9))	((1,1,1,1;1,1), (1,1,1,1;0.9,0.9))	((1,2,2,3,1;1,1), (1.5,2,2,2.5;0.9,0.9))	((4,5,5,6;1,1), (4.5,5,5,5.5;0.9,0.9))	((3,4,4,5;1,1), (3.5,4,4,4.5;0.9,0.9))	((5,6,6,7;1,1), (5.5,6,6,6.5;0.9,0.9))
GRS	((1,2,2,3;1,1), (1.5,2,2,2.5;0.9,0.9))	((0.33,0.5,0.5,1;1,1), (0.4,0.5,0.5,0.66;0.9,0.9))	((1,1,1,1;1,1), (1,1,1,1;0.9,0.9))	((2,3,3,4;1,1), (2.5,3,3,3.5;0.9,0.9))	((1,2,2,3;1,1), (1.5,2,2,2.5;0.9,0.9))	((3,4,4,5;1,1), (3.5,4,4,4.5;0.9,0.9))
GP	((0.33,0.5,0.5,1;1,1), (0.4,0.5,0.5,0.66;0.9,0.9))	((0.16,0.2,0.2,0.25;1,1), (0.15,0.2,0.2,0.22;0.9,0.9))	((0.25,0.33,0.33,0.5;1,1), (0.28,0.33,0.33,0.4;0.9,0.9))	((1,1,1,1;1,1), (1,1,1,1;0.9,0.9))	((1,2,2,3;1,1), (1.5,2,2,2.5;0.9,0.9))	((2,3,3,4;1,1), (2.5,3,3,3.5;0.9,0.9))
GOC	((0.33,0.5,0.5,1;1,1), (0.4,0.5,0.5,0.66;0.9,0.9))	((0.2,0.25,0.25,0.33;1,1), (0.22,0.25,0.25,0.28;0.9,0.9))	((0.33,0.5,0.5,1;1,1), (0.4,0.5,0.5,0.66;0.9,0.9))	((0.33,0.5,0.5,1;1,1), (0.4,0.5,0.5,0.66;0.9,0.9))	((1,1,1,1;1,1), (1,1,1,1;0.9,0.9))	((2,3,3,4;1,1), (2.5,3,3,3.5;0.9,0.9))
GHR	((0.25,0.33,0.33,0.5;1,1), (0.28,0.33,0.33,0.4;0.9,0.9))	((0.14,0.16,0.16,0.2;1,1), (0.15,0.16,0.16,0.18;0.9,0.9))	((0.2,0.25,0.25,0.33;1,1), (0.22,0.25,0.25,0.28;0.9,0.9))	((0.25,0.5,0.5,1;1,1), (0.28,0.33,0.33,0.4;0.9,0.9))	((0.25,0.33,0.33,0.5;1,1), (0.28,0.33,0.33,0.4;0.9,0.9))	((1,1,1,1;1,1), (1,1,1,1;0.9,0.9))

After converting Linguistic terms to fuzzy numbers of type 2 for each expert, the experts' opinions were aggregated through geometric mean (Table 10). It should be noted that the inconsistency ratio for all tables of pairwise comparisons among experts was found to be less than 0.1, indicating the consistency of the tables

Table 10. The aggregated IT2F comparison matrix

	GS	GTE	GRS	GP	GOC	GHR
GS	((1,1,1,1;1,1), (1,1,1,1;0.9,0.9))	((0.5,0.73,0.73,1.07;1,1), (0.61,0.73,0.73,0.88;0.9,0.9))	((0.64,0.73,0.73,0.92;1,1), (0.68,0.73,0.73,0.81;0.9,0.9))	((0.87,1.33,1.33,1.73;1,1), (1.11,1.33,1.33,1.53;0.9,0.9))	((0.66,1.09,1.09,1.73;1,1), (0.87,1.09,1.09,1.36;0.9,0.9))	((0.9,1.23,1.23,1.54;1,1), (1.07,1.23,1.23,1.38;0.9,0.9))
GTE	((0.66,0.96,0.96,1.41;1;1), (0.81,0.96,0.96,1.16;0.9,0.9))	((1,1,1,1;1,1), (1,1,1,1;0.9,0.9))	((0.68,1.13,1.13,1.73;1,1), (0.9,1.13,1.13,1.39;0.9,0.9))	((0.98,1.32,1.32,1.94;1,1), (1.13,1.32,1.32,1.57;0.9,0.9))	((1.07,1.42,1.42,1.86;1,1), (1.24,1.42,1.42,1.62;0.9,0.9))	((1.14,1.36,1.36,1.6;1,1), (1.25,1.36,1.36,1.47;0.9,0.9))
GRS	((0.84,1.04,1.04,1.21;1,1), (0.95,1.04,1.04,1.12;0.9,0.9))	((0.58,0.88,0.88,1.46;1,1), (0.72,0.88,0.88,1.11;0.9,0.9))	((1,1,1,1;1,1), (1,1,1,1;0.9,0.9))	((1.09,1.57,1.57,2.03;1,1), (1.33,1.57,1.57,1.79;0.9,0.9))	((0.76,1.19,1.19,1.73;1,1), (0.97,1.19,1.19,1.43;0.9,0.9))	((1.14,1.44,1.44,1.74;1,1), (1.29,1.44,1.44,1.59;0.9,0.9))
GP	((0.58,0.75,0.75,1.15,1;1,1), (0.65,0.75,0.75,0.9;0.9,0.9))	((0.52,0.76,0.76,1.02;1,1), (0.64,0.76,0.76,0.88;0.9,0.9))	((0.49,0.64,0.64,0.92;1,1), (0.56,0.64,0.64,0.75;0.9,0.9))	((1,1,1,1;1,1), (1,1,1,1;0.9,0.9))	((0.76,1.09,1.09,1.61;1,1), (0.92,1.09,1.09,1.3;0.9,0.9))	((0.98,1.41,1.41,1.9;1,1), (1.19,1.41,1.41,1.63;0.9,0.9))
GOC	((0.58,0.92,0.92,1.51,1;1,1), (0.74,0.92,0.92,1.15;0.9,0.9))	((0.54,0.7,0.7,0.93;1,1), (0.62,0.7,0.7,0.81;0.9,0.9))	((0.58,0.84,0.84,1.32;1,1), (0.7,0.84,0.84,1.03;0.9,0.9))	((0.62,0.92,0.92,1.32;1,1), (0.77,0.92,0.92,1.09;0.9,0.9))	((1,1,1,1;1,1), (1,1,1,1;0.9,0.9))	((0.87,1.21,1.21,1.53;1,1), (1.04,1.21,1.21,1.37;0.9,0.9))
GHR	((0.65,0.81,0.81,1.11;1,1), (0.72,0.81,0.81,0.94;0.9,0.9))	((0.79,0.93,0.93,1.11;1,1), (0.86,0.93,0.93,1.01;0.9,0.9))	((0.58,0.7,0.7,0.88;1,1), (0.63,0.7,0.7,0.77;0.9,0.9))	((0.53,0.71,0.71,1.02;1,1), (0.61,0.71,0.71,0.84;0.9,0.9))	((0.65,0.83,0.83,1.15;1,1), (0.73,0.83,0.83,0.96;0.9,0.9))	((1,1,1,1;1,1), (1,1,1,1;0.9,0.9))

In the next step, for each dimension, the fuzzy numbers of type 2 have had geometric mean in a raw[1]. Then the weighted matrix was obtained and finally the defuzzified was performed and the final weight of the dimensions and factors was obtained. Table 11 shows the final results of dimensional prioritization. According to the results, the Green technology and expertise dimension had the highest weight and the most important dimension, and the dimensions of Green regulations and Support and green suppliers were ranked second and third.

Table 11. The final weight of green supply chain management dimensions

Dimension	IT2F geometric mean	IT2F weights	Crisp weights	Normalized weights
Green suppliers	((0.74,0.99,0.99,1.29;1,1), (0.87,0.99,0.99,1.13;0.9,0.9))	((0.09,0.17,0.17,0.28;1,1), (0.13,0.17,0.17,0.21;0.9,0.9))	0.172	0.165
Green technology and expertise	((0.9,1.19,1.19,1.55;1;1), (1.04,1.19,1.19,1.35;0.9,0.9))	((0.12,0.2,0.2,0.34;1,1), (0.15,0.2,0.2,0.26;0.9,0.9))	0.206	0.198
Green regulations and Support	((0.88,1.16,1.16,1.49;1,1), (1.02,1.16,1.16,1.31;0.9,0.9))	((0.11,0.19,0.19,0.32;1,1), (0.15,0.19,0.19,0.25;0.9,0.9))	0.200	0.193
Green products	((0.69,0.91,0.91,1.22;1,1), (0.8,0.91,0.91,1.04;0.9,0.9))	((0.09,0.15,0.15,0.27;1,1), (0.12,0.15,0.15,0.2;0.9,0.9))	0.159	0.152
Green Organization and Communications	((0.68,0.92,0.92,1.25;1,1), (0.8,0.92,0.92,1.06;0.9,0.9))	((0.09,0.15,0.15,0.27;1,1), (0.12,0.15,0.15,0.2;0.9,0.9))	0.160	0.154
Green human resources	((0.68,0.82,0.82,1.04;1,1), (0.75,0.82,0.82,0.92;0.9,0.9))	((0.09,0.14,0.14,0.23;1,1), (0.11,0.14,0.14,0.17;0.9,0.9))	0.143	0.137

According to Table 12, in the dimension of green suppliers, the factor of "Designing and development of evaluation and selection systems of suppliers based on environmental criteria", in the dimension of Green technology and expertise, the factor of "Using innovative methods in the supply chain to protect the environment", in the dimension of Green human resources, the factor of "Existence of Human Resources specialized in environmental management", in the dimension of Green products, the factor of "Use of environmentally friendly packaging (green packaging)", in the dimension of Green Organization and Communications, the factor of "Attention to social responsibility in the organization"; Finally, in the dimension of Green regulations and Support, the factor of "support of operational, middle and senior managers in implementing the green supply chain" were the most important factors affecting the success of green supply chain management. In another analysis, among 30 factors, factors of Attention to social responsibility in the organization, Designing and development of evaluation and selection systems of suppliers based on environmental criteria, support of operational, middle and senior managers in implementing the green supply chain, Use of innovative methods in the supply chain to protect the environment and government regulations for adopting environmentally friendly policies were identified as the most important factors.

Table 12. The final weight of the factors affecting the success of green supply chain management

Dimension	Weight		Factors	Score	Weight	Final Weight	Rank
Green suppliers	0.165	(GS1)	Suppliers' participation in environmental protection	0.224	0.219	0.036	14
		(GS2)	Suppliers' desire to exchange industry-related environmental information	0.242	0.236	0.039	11
		(GS3)	Design and development of evaluation and selection systems of suppliers based on environmental criteria	0.333	0.326	0.054	2
		(GS4)	Tracking and monitor the observance of environmental principles by suppliers	0.223	0.218	0.036	15
Green technology and expertise	0.198	(GTE1)	Existence of technical expertise and alternative design for products in accordance with environmental requirements	0.228	0.223	0.044	6
		(GTE2)	Use innovative methods in the supply chain to protect the environment	0.250	0.244	0.048	4
		(GTE3)	Existence of environmentally friendly equipment for transporting materials, end product and waste	0.198	0.193	0.038	12
		(GTE4)	Use of machinery, physical equipment and green technologies in the organization	0.202	0.197	0.039	10
		(GTE5)	Sale of additional capital equipment and waste	0.147	0.144	0.029	22
Green human resources	0.137	(GHR1)	Implement an Employee Suggestion System on environmental issues	0.169	0.164	0.028	23
		(GHR2)	Existence of Human Resources specialized in environmental management	0.249	0.242	0.042	7
		(GHR3)	Holding environmental training conferences and classes for employees	0.151	0.147	0.025	26
		(GHR4)	Promoting green culture and environmental considerations in the work environment of the organization	0.215	0.209	0.036	13
		(GHR5)	Involving human resources in processes support the environment	0.244	0.238	0.041	8
Green products	0.152	(GP1)	Product design for reuse and recycling (green design)	0.100	0.098	0.015	29

		(GP2)	procurement environmentally friendly raw materials (green procurement)	0.143	0.141	0.022	27
		(GP3)	Use lean production	0.179	0.175	0.027	25
		(GP4)	Use of environmentally friendly packaging (green packaging)	0.207	0.204	0.031	19
		(GP5)	Increase customer demand for green products	0.112	0.110	0.017	28
		(GP6)	Easy and low cost access to green raw materials	0.092	0.090	0.014	30
		(GP7)	Product life cycle management	0.186	0.182	0.028	24
Green Organization and Communications	0.154	(GOC1)	Collaborate with the customer in designing green products	0.187	0.185	0.029	21
		(GOC2)	Attention to social responsibility in the organization	0.356	0.352	0.054	1
		(GOC3)	Risk-taking organization and development environmental risk management	0.259	0.256	0.040	9
		(GOC4)	Cooperation with environmental recycling and protection organizations	0.209	0.207	0.032	18
Green regulations and Support	0.193	(GRS1)	government regulations for adopting environmentally friendly policies	0.240	0.234	0.045	5
		(GRS2)	Supervision and guidance of supervisory authorities to protect the environment	0.158	0.154	0.030	20
		(GRS3)	support of operational, middle and senior managers in implementing the green supply chain	0.282	0.275	0.053	3
		(GRS4)	Allocate the necessary cost for the implementation of environmental programs	0.173	0.169	0.033	16
		(GRS5)	Access to special facilities to encourage green production, the green process and ultimately green supply chain	0.173	0.168	0.032	17

5| Discussion and Conclusion

The model presented in this study had 30 factors in 6 dimensions of green suppliers, green technology and expertise, green human resources, green products, Green Organization and Communications and Green regulations and Support. These factors and dimensions were prioritized using the Interval Type-2 Fuzzy AHP method. According to the results, green technology and expertise was the most important dimension and the Use of innovative methods in the supply chain to protect the environment was the most important factor in this dimension. Wang et al [23], Chatterjee et al [29], Kusi-Sarpong et al [34], Gandhi et al [46], Chan and Chan [49] also mentioned this dimension and factor. The use of machinery, physical equipment and green technologies in the organization was one of the factors that played a major role in the success of the green supply chain in the ceramic tile industry. Paying attention to the appropriate technology is a strategic factor, since it covers the main production operations. The second important dimension in the success of the green supply chain in the ceramic tile industry were Green regulations and Support, and the most important factors in this dimension were the support of operational, middle and senior managers in implementing the green supply chain and government regulations for adopting environmentally friendly policies. Many researchers, including Agi et al [31], Luthra et al [33], Gandhi et al [46], Govindan et al [50], and Dubey et al [51], also pointed to these factors and dimensions. It is clear that in most industrial activities, due to the cost of changing the system as a whole, it is not possible to greening without pressure and law enforcement. Strict regulations on accelerating the green supply chain process and equal pressure on all companies are equally important; In addition to regulations, financial support such as loan payments and decreasing the tax to green organizations, as well as spiritual supports such as the appreciation of these organizations will lead them to be ahead in being green. Also, the presence of the senior management and her representative in the green supply chain establishment committee and her awareness of the consequences of the green supply chain can be effective. By changing the traditional form of supply chain to a new one, managers must engage themselves directly and avoid delegating responsibility to others. Many believe that if the supply chain does not have the support of managers and managers are reluctant to design, produce and recycle green supply chain, the results would not be significant. In other words, the support of managers for the green supply chain will lead to the encouragement and commitment of all human resources. The dimension of green suppliers is another important issue in the success of the green supply chain, in which the factor of Designing and development of evaluation and selection systems of suppliers based on environmental criteria was identified as the most important factor. Researchers who have mentioned this dimension and factor in their studies were [22, 33, 34, 46, 47]. Therefore, before selecting and concluding a contract with suppliers and developing a supply network, it is necessary to evaluate them by considering all technical and product, organizational and green dimensions and select high-level suppliers. The issue of supplier selection, which is one of the key issues in supply chain management, plays a key role in the success of companies, as it will have a significant impact on product production costs. Increasing concerns about environmental warnings have attracted the attention of governments, customers and organizations, and have led to the importance of meeting environmental requirements in the production of products. Since most of the materials and components of the products are supplied by external suppliers, it is very important to pay attention to environmental criteria in the process of evaluating and selecting suppliers. In other words, the evaluation and selection of suppliers of the organization based on environmental criteria should be considered due to the great impact of goods and services received from suppliers on the environmental performance of the organization. Another important dimension in the success of the supply chain is the dimension of the Green Organization and Communications, in which, it is very important to pay attention to social responsibility in the organization, so that in the present study this factor has gained first priority among all factors. Luthra et al [33], Govindan et al [50], Kuo et al [52] and Tseng et al [54 also mentioned this factor in their studies. Attention to social responsibility can affect other factors, ecause committed and environmentally responsible organizations consider it necessary to take steps to make the supply chain green, regardless of the situations that lead to financial losses. Individuals and organizations are responsible for the community and the environment to which they belong, and the results of their responsibility are shared by the whole community. Companies have found that they must act responsibly in order to be productive, competitive, and able to respond to rapid global change. Although the factors mentioned above were identified as the most important factors influencing the success of the green supply chain in the ceramic tile industry, this industry must pay enough attention to all identified factors to compete in the world class by focusing on the most important factors. Using clear guidelines and checklists of effective factors in decision making can make decision making easier, and increase decision-making power. Therefore, it is suggested that based on the factors and the importance of them that were identified in this research, instructions and checklists be prepared and provided to the executive managers.

One of the important limitations of this study is the population, which was limited to the tile and ceramic factories in Yazd. This can restrict the generalizability of the results. Considering that the current research aimed to investigate the success factors of green supply chain management and, on the other hand, employed the Type-2 Fuzzy AHP approach to establish a hierarchical structure among the factors, the lack of a network perspective and the use of methods to examine causal relationships are among other limitations of this study. Additionally, the categorization of factors was done qualitatively. To address these limitations, future researchers are recommended to conduct similar studies in other industries to obtain better and more suitable results. Ultimately, a more comprehensive model can be designed as different industries possess distinct and specific characteristics and success factors.

It is also recommended that the naming and analysis categorization of dimensions be conducted using quantitative survey methods such as cluster analysis and factor analysis. Additionally, considering one of the limitations of the current study was the lack of identification of relationships between the factors, it is suggested that future researchers employ quantitative techniques (such as DEMATEL, ANP, etc.) as well as qualitative methods (SODA, Cognitive Map, ISM, etc.) to identify these relationships. This will enable the development of a roadmap for success in the supply chain. Furthermore, future researchers can utilize other weighting methods (BWM, FUCOM, DIBR, LBWA, etc.) and compare their results with those obtained in the present study.

Funding

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors

Conflicts of Interest

No potential conflict of interest was reported by the author(s).

References

1. Jaklic, J., et al., *Enhancing lean supply chain maturity with business process management.* Journal of information and organizational sciences, 2006. **30**(2): p. 205-223.
2. Ketchen Jr, D.J. and G.T.M. Hult, *Bridging organization theory and supply chain management: The case of best value supply chains.* Journal of operations management, 2007. **25**(2): p. 573-580.
3. Cabral, I., et al. *Modelling lean, agile, resilient, and green supply chain management*. in *Proceedings of the ITI 2011, 33rd International Conference on Information Technology Interfaces*. 2011. IEEE.
4. Beloor, V., T. Nanjundeswaraswamy, and D. Swamy, *MODELLING FRAMEWORK FOR CRITICAL SUCCESS FACTORS OF GREEN SUPPLY CHAIN MANAGEMENT-AN INTEGRATED APPROACH OF PARETO, ISM AND SEM.* Proceedings on Engineering, 2023. **5**(3): p. 503-524.
5. Banik, A., et al., *Critical success factors for implementing green supply chain management in the electronics industry: an emerging economy case.* International Journal of Logistics Research and Applications, 2022. **25**(4-5): p. 493-520.
6. Chandra, C. and J. Grabis, *Supply chain configuration*. 2007: Springer.
7. Stadtler, H., et al., *Supply chain management and advanced planning: concepts, models, software, and case studies*. 2015: Springer.
8. Maleki, M. and V.C. Machado, *Generic integration of lean, agile, resilient, and green practices in automotive supply chain.* Revista de Management Comparat International, 2013. **14**(2): p. 237.
9. Shojaei, P., M. Jajarmizadeh, and M. Esfandyari Mahni, *Evaluating and Prioritizing Barriers of Implementation Green Supply Chain by Using Interpretive Ranking Process (IRP) Case: South Electric Power Generation Company).* Journal of Executive Management, 2018. **9**(18): p. 63-88.
10. Nekmahmud, M., et al., *A systematic literature review on development of green supply chain management.* Polish Journal of Management Studies, 2020. **22**(1): p. 351-370.
11. Govindan, K., et al., *Barriers analysis for green supply chain management implementation in Indian industries using analytic hierarchy process.* International journal of production economics, 2014. **147**: p. 555-568.

12. Jabbour, C.J.C. and A.B.L. de Sousa Jabbour, *Green human resource management and green supply chain management: Linking two emerging agendas.* Journal of cleaner production, 2016. **112**: p. 1824-1833.
13. Jayant, A. and M. Azhar, *Analysis of the barriers for implementing green supply chain management (GSCM) practices: an interpretive structural modeling (ISM) approach.* Procedia Engineering, 2014. **97**: p. 2157-2166.
14. Gold, S., R. Hahn, and S. Seuring, *Sustainable supply chain management in "Base of the Pyramid" food projects—A path to triple bottom line approaches for multinationals?* International Business Review, 2013. **22**(5): p. 784-799.
15. Khiewnavawongsa, S. and E.K. Schmidt. *Barriers to green supply chain implementation in the electronics industry*. in *2013 IEEE international conference on industrial engineering and engineering management*. 2013. IEEE.
16. Agrawal, V., et al., *Analyzing critical success factors for sustainable green supply chain management.* Environment, development and sustainability, 2023. **25**(8): p. 8233-8258.
17. Thakur, A.S., et al. *An Analysis of Critical Success Factors of Implementation of Green Supply Chain Management in Indian Tube Manufacturing Industries*. in *Human Systems Engineering and Design II: Proceedings of the 2nd International Conference on Human Systems Engineering and Design (IHSED2019): Future Trends and Applications, September 16-18, 2019, Universität der Bundeswehr München, Munich, Germany*. 2020. Springer.
18. Elhidaoui, S., et al., *Critical success factors of blockchain adoption in green supply chain management: contribution through an interpretive structural model.* Production & Manufacturing Research, 2022. **10**(1): p. 1-23.
19. Tavana, M., et al., *A novel Interval Type-2 Fuzzy best-worst method and combined compromise solution for evaluating eco-friendly packaging alternatives.* Expert Systems with Applications, 2022. **200**: p. 117188.
20. Çolak, M. and İ. Kaya, *Prioritization of renewable energy alternatives by using an integrated fuzzy MCDM model: A real case application for Turkey.* Renewable and Sustainable Energy Reviews, 2017. **80**: p. 840-853.
21. Kahraman, C. and S.Ç. Onar, *INTUITIONISTIC FUZZY ORIGINATED TYPE-2 FUZZY AHP.* International Journal of the Analytic Hierarchy Process, 2018. **10**(2).
22. Tachizawa, E.M., C. Gimenez, and V. Sierra, *Green supply chain management approaches: drivers and performance implications.* International Journal of Operations & Production Management, 2015. **35**(11): p. 1546-1566.
23. Wang, X., et al., *A two-stage fuzzy-AHP model for risk assessment of implementing green initiatives in the fashion supply chain.* International journal of production economics, 2012. **135**(2): p. 595-606.
24. Tariq, M.I., et al., *Assessing the role of green supply chain management in enhancing Pakistan manufacturers' performances.* Environmental Science and Pollution Research, 2023. **30**(32): p. 78495-78506.
25. Srivastava, S.K., *Green supply-chain management: a state-of-the-art literature review.* International journal of management reviews, 2007. **9**(1): p. 53-80.
26. Liu, S., D. Kasturiratne, and J. Moizer, *A hub-and-spoke model for multi-dimensional integration of green marketing and sustainable supply chain management.* Industrial Marketing Management, 2012. **41**(4): p. 581-588.
27. Dhull, S. and M. Narwal, *Drivers and barriers in green supply chain management adaptation: A state-of-art review.* Uncertain Supply Chain Management, 2016. **4**(1): p. 61-76.
28. Thakkar, J.J., *Multi-criteria decision making.* Vol. 336. 2021: Springer.
29. Chatterjee, K., D. Pamucar, and E.K. Zavadskas, *Evaluating the performance of suppliers based on using the R'AMATEL-MAIRCA method for green supply chain implementation in electronics industry.* Journal of cleaner production, 2018. **184**: p. 101-129.
30. Vanalle, R.M., et al., *Green supply chain management: An investigation of pressures, practices, and performance within the Brazilian automotive supply chain.* Journal of cleaner production, 2017. **151**: p. 250-259.
31. Agi, M.A. and R. Nishant, *Understanding influential factors on implementing green supply chain management practices: An interpretive structural modelling analysis.* Journal of environmental management, 2017. **188**: p. 351-363.
32. Scur, G. and M.E. Barbosa, *Green supply chain management practices: Multiple case studies in the Brazilian home appliance industry.* Journal of cleaner production, 2017. **141**: p. 1293-1302.
33. Luthra, S., D. Garg, and A. Haleem, *The impacts of critical success factors for implementing green supply chain management towards sustainability: an empirical investigation of Indian automobile industry.* Journal of cleaner production, 2016. **121**: p. 142-158.
34. Kusi-Sarpong, S., et al., *Green supply chain practices evaluation in the mining industry using a joint rough sets and fuzzy TOPSIS methodology.* Resources Policy, 2015. **46**: p. 86-100.
35. Lee, S.-Y., *The effects of green supply chain management on the supplier's performance through social capital accumulation.* Supply Chain Management: An International Journal, 2015. **20**(1): p. 42-55.
36. Calache, L.D.D.R., N.R. Galo, and L.C.R. Carpinetti, *A comparison between intuitionistic and hesitant fuzzy applied to supplier selection group decision-making problems.* International Journal of Applied Decision Sciences, 2021. **14**(3): p. 231-273.
37. Zadeh, L.A., *The concept of a linguistic variable and its application to approximate reasoning—I.* Information sciences, 1975. **8**(3): p. 199-249.
38. Karnik, N.N., J.M. Mendel, and Q. Liang, *Type-2 fuzzy logic systems.* IEEE transactions on Fuzzy Systems, 1999. **7**(6): p. 643-658.

39. Kilic, M. and İ. Kaya, *Investment project evaluation by a decision making methodology based on type-2 fuzzy sets.* Applied Soft Computing, 2015. **27**: p. 399-410.
40. Kahraman, C., İ.U. SARI, and E. TURANOĞLU, *Fuzzy analytic hierarchy process with Type-2 fuzzy sets*, in *Uncertainty Modeling in Knowledge Engineering and Decision Making*. 2012, World Scientific. p. 201-206.
41. Uçal Sarý, I., B. Öztayşi, and C. Kahraman, *Fuzzy analytic hierarchy process using type-2 fuzzy sets: An application to warehouse location selection.* Multicriteria decision aid and artificial intelligence: Links, theory and applications, 2013: p. 285-308.
42. Kahraman, C., et al., *Fuzzy analytic hierarchy process with interval type-2 fuzzy sets.* Knowledge-Based Systems, 2014. **59**: p. 48-57.
43. Sandelowski, M. and J. Barroso, *Handbook for synthesizing qualitative research*. 2006: springer publishing company.
44. Lawshe, C.H., *A quantitative approach to content validity.* Personnel psychology, 1975. **28**(4): p. 563-575.
45. Rajabzadeh, M. and H. Fatorachian, *Modelling Factors Influencing IoT Adoption: With a Focus on Agricultural Logistics Operations.* Smart Cities, 2023. **6**(6): p. 3266-3296.
46. Kuo, R.J., Y.C. Wang, and F.C. Tien, *Integration of artificial neural network and MADA methods for green supplier selection.* Journal of cleaner production, 2010. **18**(12): p. 1161-1170.
47. Hu, A.H. and C.W. Hsu, *Critical factors for implementing green supply chain management practice: an empirical study of electrical and electronics industries in Taiwan.* Management research review, 2010. **33**(6): p. 586-608.