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Research Article

Evaluating factors affecting the performance of flower cold chain logistics in Kenya: Application of improved fuzzy SWARA method

Kenya'da çiçek soğuk zincir lojistiğinin performansını etkileyen faktörlerin değerlendirilmesi: Geliştirilmiş bulanık SWARA yönteminin uygulanması

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Abstract

The floriculture industry in Kenya is experiencing rapid growth, especially in the cut flower sector. The efficiency of cold chain logistics for flowers is crucial to maintaining their freshness, quality, and vase life from harvest to end consumer. The study aims to identify and evaluate the various factors that affect the performance of cold chain logistics for Kenyan cut flowers. The study examined a total of fourteen factors that were identified through an extensive literature review and expert meeting. Five flower logistics experts participated in the decision meeting. For this purpose, a multi-criteria decision-making method (MCDM) based on improved fuzzy stepwise weight assessment ratio analysis (IMF-SWARA) is applied to evaluate the factors affecting the performance of cut flower logistics. The findings indicated that the shortage of skilled labour is the most critical factor affecting the performance of Kenyan flower cold chain logistics. In contrast, the least important factor is the Responsiveness of the demand.

Keywords: IMF SWARA Method, Flower Cold Chain Performance, Floriculture Industry

Jel Codes: Q13, Q17

Öz

Kenya'daki çiçekçilik endüstrisi, özellikle kesme çiçek sektöründe hızlı bir büyüme yaşamaktadır. Çiçekler için soğuk zincir lojistiğinin verimliliği, hasattan son tüketiciye kadar tazeliğini, kalitesini ve raf ömrünü korumak için kritik öneme sahiptir. Çalışmanın amacı, Kenya kesme çiçekleri için soğuk zincir lojistiğinin performansını etkileyen çeşitli faktörleri belirlemek ve değerlendirmektir. Çalışmada, kapsamlı literatür incelemesi ve uzman görüşmesi yolu ile belirlenen toplam on dört faktör incelenmiştir. Karar toplantısına beş çiçek lojistiği uzmanı katılmıştır. Bu amaçla, kesme çiçek lojistiğinin performansını etkileyen faktörleri değerlendirmek için geliştirilmiş Bulanık Adım Adım Ağırlık Değerlendirme Oranı Analizi 'ne (IMF-SWARA) dayalı çok kriterli bir karar verme yöntemi uygulanmıştır. Sonuçlar, Kenya kesme çiçek soğuk zincir lojistiğinin performansını etkileyen en kritik faktörün nitelikli işgücü eksikliği olduğunu, en az önemli faktörün ise talep duyarlılığı olduğunu göstermektedir.

Anahtar Kelimeler: IMF SWARA Yöntemi, Çiçek Soğuk Zincir Performansı, Çiçekçilik Endüstrisi

JEL Kodları: Q13, Q17

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Introduction

Kenya has heavily relied on agriculture as the backbone of its economy. Throughout history, the agricultural sector has played a pivotal role in contributing to the country's gross domestic product (GDP). Exporting perishable horticultural products, especially flowers, is essential to the Kenyan economy. The floriculture sector traces its origins back to the early 20th century when small farmers started cultivating cut flowers (Button, 2020). Due to its favourable climate and fertile lands, Kenya has emerged as a prominent exporter of cut flowers globally. Cut flowers are highly perishable and require careful handling throughout the entire process, from harvest to the final consumer. Manufacturing flowers for export is particularly challenging due to their fragility and perishable nature (Ksoll, Macchiavello, & Morjaria, 2021). Additionally, it has a significant environmental impact and relies heavily on timely delivery.

Cold chain logistics establishes a system to ensure product quality and reduce product losses by storing refrigerated and frozen products at a constant low temperature (Zhang et al., 2022). The quality and freshness of flowers from farm to market greatly need a cold chain logistics system. This system ensures that flowers reach consumers in the best possible condition. The cut flower industry's success depends on efficient cold-chain logistics management to ensure product quality and freshness. In recent times, there has been a significant rise in the demand for temperature-sensitive items globally, resulting in the rapid growth of cold chain logistics. However, this expanding industry costs more energy and equipment than traditional transportation. The cold chain logistics industry faces several challenges when transporting flowers, including problems with packaging, handling, customs clearance, contamination issues, the perishability of the product, rising transportation costs, and other challenges associated with the cold chain.

The efficiency of cold chain logistics has a significant impact on the overall performance of the flower supply chain. Successful cold chain logistics ensures that products are delivered to the customer in optimal condition, at the right time, and without damage through effective logistical planning. It affects many stakeholders, including growers, distributors, retailers, and consumers. Therefore, a comprehensive understanding of the factors affecting flower cold chain logistics performance is essential. This knowledge will help managers optimise operations and maintain the quality of flowers at every stage of their supply chain.

This study comprehensively examines and analyses the factors affecting Kenyan floral logistics performance. It aims to offer valuable insights to stakeholders involved in managing and optimising floral supply chains by systematically identifying and prioritising the critical factors that affect Kenyan floral logistics. In the study, the Improved Fuzzy-SWARA (IMF-SWARA) Multi Criteria Decision-Making approach was used to establish a framework supporting decision-making processes.

The remainder of the study is structured as follows. First, the floriculture industry and cold chain, Kenyan floriculture sector, factors affecting flower cold chain logistics are examined. The following section introduces the (IMF SWARA) method and how it was applied to prioritise the key criteria affecting the performance of the cut flower cold chain. The following section provides the results and presents the discussions. The final section gives conclusions, contributions, and implications of the study.

Floriculture industry and cold chain

Floriculture is a branch of horticulture that produces ornamental and flowering plants for gardens and floristry (Wani et al., 2018). Floriculture or flower farming is divided into several product categories: cut flowers, bedding/garden plants, cut foliage, and potted plants (Xia et al., 2006). The production of flowers has been an essential part of human civilisation throughout human history. Floriculture products are traded internationally and are of great importance to the rural economies of some countries (Rout & Das, 2022). Due to its contribution to export earnings, the floriculture industry has become a significant economic factor for most developing countries (Macheka & Kockelkoren, 2012). Floriculture has evolved into a rapidly growing industry as urbanisation and rising living standards have increased the demand for flowers and flower products, making floriculture one of the most critical sectors of trade in agriculture (Wani et al., 2018).

There are two types of cut flowers: "fresh cut flowers" and "non-fresh cut flowers" such as preserved flowers. Fresh-cut flowers have only a limited number of life-sustaining functions by absorbing water through their stems, which makes them highly perishable (Mishra & Dwivedi, 2015). Cut flowers lose beauty and attractiveness after just a few days (Sudaria et al., 2017). The quality of the flowers is at its best when harvested and quickly deteriorates afterwards if they are not appropriately handled. The main objectives of post-harvest handling and processing of flowers are (Senapati et al., 2016): i) to preserve the quality of the flowers (texture and appearance) and ii) to minimise post-harvest losses between flower harvest and consumption. The flowers must always be fresh, so they should be sold immediately after harvesting. Inadequate post-harvest management leads to quantitative losses throughout the entire product value chain.

The only way to reduce these losses is through effective cold-chain logistics. Macheka and Kockelkoren (2012) analysed possible strategies to realise the added value of investments in cold supply chains for cut flowers. They recommended that internal quality factors such as vase life should be considered in addition to the external quality metrics currently used in the valuation system at flower auctions. It is believed that the value of an investment in cut flower cold chain management is realised when internal quality factors such as vase life are considered. Logistics are an essential part of post-harvest procedures in floriculture, where products must be marketed quickly after cutting due to their fragility (Menesatti et al., 2012). Post-harvest losses can occur during several processes in the supply chain, including harvesting, pre-cooling, cold storage, packaging, transporting, and marketing (Li & Thomas, 2014; Lan et al., 2022). Managing each process in the supply chain can significantly improve the shelf life and quality of the flowers in the vase life. These processes are briefly described as follows:

Harvesting

The harvest predetermines about 70 % of the long-term quality of cut flowers (Vijayakumar et al., 2021). The flowers continue to live and fulfil their metabolic functions even after the harvest, resulting in rapid degradation by microbes, water stress, increased ethylene production, depletion of carbohydrates, and increased temperature and respiration rate (Maya et al., 2023). Harvesting, grading, and packaging should be carried out dry without water or chemical solutions (Reid, 2012).

Pre-cooling

Pre-cooling removes the field heat from the goods to lower the flower temperature quickly and maintain high quality and customer satisfaction (Brosnan & Sun, 2001). Flowers can be pre-cooled using various techniques, e.g., room cooling, air cooling, hydro-cooling, vacuum, slurry, or liquid ice (Elansari et al., 2019). The temperature is lowered from 20°-30°C to 10°C in a comparatively short time by forced air cooling or hydro cooling (Senapati et al., 2016).

Cold storage

The storage of cut flowers in cold stores enables the accumulation of large quantities of flowers and the adaptation of the supply of flowers and other plant materials to market demand (Senapati et al., 2016). Low temperatures have several benefits for extending the vase life, including reducing respiration and internal enzyme degradation, reducing water loss and wilting, slowing the growth of disease organisms, reducing ethylene production, and "time" for proper handling, packaging, and marketing (Gast et al., 1994).

Packaging

In flower logistics, there are often problems with temperature control, broken or poorly packaged goods, contamination, damaged products, lengthy document exchanges, and many other obstacles in the cold chain (Tang et al., 2023). Shinde et al. (2023) developed a paper-based method for the antimicrobial packaging of cut roses to extend the shelf life of the flowers. The results show that extending the shelf life of cut roses reduces post-harvest losses and increases the value of the flower industry both domestically and in export markets.

Transportation

Transportation plays a vital role in the supply chain for cut flowers, as it influences product quality and delivery time (Aleksis, 2024). Fresh goods are transported by land, air, and sea. Most goods that require cold chain logistics are usually transported by air freight due to their fragility, short shelf life, and time sensitivity (Babalola, 2011).

Marketing

Kenya is the continent's largest flower producer and one of the world's largest cut flower exporters but faces increasing competition from Europe, Latin America, and the emerging African markets (Adeola et al., 2018). Most of the flowers exported from Kenya are sold at Dutch auctions, while others are sold directly to consumers, such as florists and supermarkets in other international markets (Thursd, 2024).

Kenyan floriculture sector

The flower export sector in Kenya has grown significantly in recent years. Horticultural exports reached a record high of 580,648 tons in 2023, with cut flowers accounting for 110,811 tons (Fresh Plaza, 2023). The flower industry is of great economic value to Kenya as it is a primary foreign exchange earner alongside tourism and the tea sector (Capitalfm, 2024). Cut flowers, potted plants, cut foliage, seeds, tubers, bulbs, rooted cuttings, and dried flowers or foliage make up most items produced in the flower industry (Anumala & Kumar, 2021). Many African countries export flowers worldwide, with Kenya being one of the largest countries, ranking fourth globally after the Netherlands, Colombia, and Ecuador (World Bank, 2023). Table 1 lists the world's largest exporters of cut flowers.

Table 1: List of Top Exporters of Cut Flowers Globally (1.000 USD)

	2018	2019	2020	2021	2022	2023
Netherlands	4,031,954.63	4,040,439.19	3,961,505.73	5,352,504.09	4,462,344.79	4,649,658.91
Colombia	820,167.83	858,292.87	1,321,639.53	1,704,726.15	1,422,230.91	1,415,983.62
Ecuador	754,159.55	801,956.08	808,190.46	897,638.23	992,301.05	965,764.48
Kenya	572,945.58	582,777.54	569,967.83	722,675.85	625,669.38	660,847.75

Source: World Bank (2023) modified by author

Kenya's top export flower markets include The Netherlands, The United Arab Emirates (UAE), The United Kingdom (UK), Kazakhstan, Saudi Arabia, Germany, and Norway (Mordor Intelligence, 2024). Kenya's exports of cut flowers account for 38% of imports into the European Union flower market (Mwangi, 2019). The Netherlands imports and distributes a considerable quantity of Kenyan cut flowers, which form the supply chain between Kenyan flower growers and European customers (Trend Economy, 2024). Figure 1 indicates the trend of Kenyan flower export to the Netherlands from 2009 to 2023.

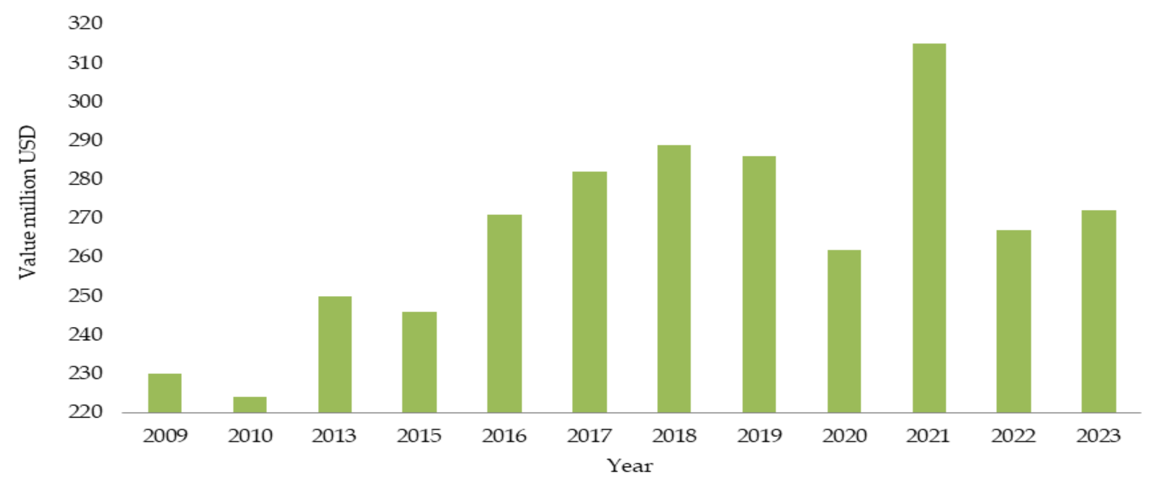

Figure 1: Kenya Exports to the Netherlands in Million USD (2009-2023)

Source: Trend Economy (2024) modified by author

The growing production and consumption of fresh agricultural products have increased the demand for cold chain logistics of fresh farm products. Cold chain logistics is a supply chain in which a fresh produce manufacturer sends the goods via a specialised logistics provider to a distant market, where a trader buys them and sells them to the final consumers (Cai et al., 2013). Developing and implementing supply chain applications enables companies to gain a competitive advantage and make better profits (Quang et al., 2016). The cold chain system in Kenya has gradually evolved to respond to the specific needs and requirements that underlie it. The primary supply chain for the cut flower industry, which is a dynamic, globally expanding sector, consists of growers, wholesalers, and retailers. The actors that make up the logistics of the flower cold chain are retailers, wholesalers, industrial manufacturers, and primary producers. Each actor has more than one supplier and customer. This study focused on determining the factors that affect the logistics of the flower cold chain between these actors.

Factors affecting flower cold chain logistics

This study aims to select the most effective and essential factors (criteria) of the cut flower cold chain logistics sector in Kenya and evaluate the sector's performance according to these factors. The most common criteria were obtained from a comprehensive literature review. After the results of face-to-face interviews with experts involved in the study, 14 criteria were selected. These criteria are listed below and summarised in Table 2.

Information Technologies Level (C_1): Flower growers have often benefited from advances in information technology in recent years. This criterion measures the level of usage of this technology in the Kenyan floral industry. Blockchain is a new technology that has the potential to change the planning and operation of supply networks completely (De Carvalho et al., 2022). Introducing digital technologies such as the Internet of Things and artificial intelligence is reshaping traditional companies.

Cold Chain Infrastructure (C_2): The criterion discusses the state of development of Kenya's cold chain infrastructure, including refrigeration facilities, refrigerated containers, trucks, and the mechanisms for transporting flowers to their export destination. According to Nordås et al. (2006), the global trade in cut flowers requires cold storage, refrigerated transport facilities, and a well-organised land and air freight infrastructure to maintain freshness.

Security and domestic political instability (C_3): Although Kenya has the best economy in the East African Community, political conflicts during election periods affect the cold chain system and cause disruptions. Ksoll et al. (2023) analysed the disruption and performance of the flower cold chain in the 2008 post-election conflict.

Service quality level and reliability (C_4): Cut flower supply chains require precise management and reliable transport for timely delivery worldwide (Nowakowska & Tubis, 2015). Transporting flower parcels over tens of thousands of kilometres requires a highly reliable supply chain that combines efficient logistics. This criterion, therefore, emphasises the reliability of the cold chain and product quality.

Lack of innovation (C_5): Cold chain innovation strategies must be developed to reduce the excessive number of emergency orders in floriculture and enable more responsive and efficient logistical processes (Van Der Vorst et al., 2012). This criterion involves measuring the availability of innovative startups in the Kenyan flower sector, such as creative strategies for the flower auction system to produce and export flowers to new markets.

Perishability and loss (C_6): The perishability of agricultural produce begins after the harvest (Yahia, 2019; Sazvar et al., 2016). This criterion states that a mechanism must be in place to control the quality of the flower after harvest until it reaches its destination. The quality of fresh flowers depends on implementing post-harvest handling techniques (Hassan, 2010).

Government policies and regulations (C_7): In the floristry industry, deficiencies in legislation and standards can affect many areas, such as flower safety, sustainable production, environmental impact, and workers' rights (Rikken, 2011). The criteria define the availability of regulation standards to compete in international markets. The Kenya flower exporters face challenges with labelling standards in European markets (Maurer, 2023).

Natural disasters (C_8): Disasters are one of the factors that disrupt the flower supply chain. Bloomberg (2024) reported that the heavy rains in East Africa, which have claimed hundreds of lives, affect cut flower production in Kenya, a major producing country. The cold supply chain is a significant issue in underdeveloped countries, where infrastructure is inadequate, and logistical challenges can affect the vase life of flowers. Natural disasters exacerbate these problems, disrupting the entire cold chain logistics (D'Alessandro et al., 2015; Coulibaly et al., 2020).

Shortage of skilled labour (C9): This criterion implies that lacking skilled labour in cold chain logistics can result in handling errors and significant losses. Logistics and distribution staff must receive specialised training to ensure product quality. The flower sector in Kenya experiences a shortage of skilled labour; in their study, Dolan et al. (2012) indicated that the floral sector demands predominantly skilled workers instead of short-term unskilled workers.

Knowledge and information sharing level (C_{10}): This criterion measures the level of knowledge sharing in farmers and exporters and promotes floricultural knowledge and expertise that will impact the social relations of its members and knowledge-sharing practices (Guzman, 2023; Riasi, 2015).

Supply chain network design (C_{11}): The system of service and distribution decisions related to the supply of goods and their delivery to end customers is called the supply chain network (Awuor, 2012). This criterion shows how the floriculture companies manage their supply chain. It intends to determine the number, size, and location of facilities in a supply chain, which is one of the many decisions the Supply chain network designers must make (Farahani, 2014; de Keizer et al., 2015).

Responsiveness of the demand (C_{12}): The cut flower industry is concerned about freshness and time, as flowers have a short product life cycle. Cold chain management and shortening lead time are important aspects to consider (Sirisaranlak, 2017). The criterion determines maximising responsiveness to demand and minimising energy consumption (Bogataj et al., 2005).

Lack of investment (C_{13}): Lack of investment in cold chains such as distribution centres, long-distance transport, and cold storage results in poor quality. Flowers from a cold chain that is properly maintained will stay in the vase longer and earn a higher price. Despite these advantages, the introduction of the cold chain requires a considerable investment (Wang et al., 2021; Riasi, 2015). The criterion defines the level of investment in cold chain logistics by both local and multinational companies.

Logistics collaboration level (C_{14}): Supply chain collaboration in floriculture refers to the cooperation between different stakeholders to make the process from grower to consumer more efficient, sustainable, and profitable. This collaboration includes coordination between Kenyan flower growers, suppliers, logistics providers, retailers, and end consumers. Collaboration in the supply chain repeatedly shows how important it is for improving supply chain performance (Nha Trang, 2022).

Table 2: Literature Review Factors Affecting Flower Cold Chain Logistics Performance

Code	Criteria	Description	References
C_1	Information technologies level	It covers all technologies used to collect, process, and present user information.	Zhang et al. (2022), Raut et al (2018), De Carvalho et al. (2022)
C_2	Cold chain infrastructure	Cold chain infrastructure typically includes grading, sorting, packing, storage, processing, and transportation facilities.	Han et al. (2021), Balaji & Arshinder (2016), Rathore (2010), Nordås et al. (2006)
C_3	Security and domestic political instability	It measures the degree of election violence and political stability.	Ksoll et al. (2023), Justus (2015)
C_4	Service quality level and reliability	The quality level of the service and operational reliability of the Flower Cold Chain.	Zhang et al. (2020), Babalola (2011), Nowakowska & Tubis, (2015)
C_5	Lack of innovation	The level of innovation in cold chain logistics	Dai et al. (2020), Vorst et al. (2012), Kuzichev & Kuzicheva (2016)
C_6	Perishability and loss	The degree of perishability of cut-flower in the cold chain	Han et al. (2021), Sazvar et al. (2016), Yahia (2019), Hassan (2010)
C_7	Government policies and regulations	Government regulations and policies	Rikken (2011), Maurer(2023)
C_8	Natural disasters	The occurrence of rains, droughts, and other natural disasters	Justus (2015), D'Alessandro et al. (2015), Coulibaly et al. (2020)
C_9	Shortage of skilled labour	The availability of skilled workforce in the cold chain logistics	Gebreeyesus & Iizuka (2012)
C_{10}	Knowledge and information sharing level	The level of information sharing and knowledge management in the sector	Hotrawaisaya et al. (2014), Riasi (2015)
C_{11}	Supply chain network design	The supply chain network is a system composed of service and distribution decisions that involve providing materials and their delivery to end consumers.	De Keizer et al. (2015), Van Der Vorst et al. (2016)
C_{12}	Responsiveness of the demand	Order fulfillment responsiveness	de Keizer (2015), Van Der Vorst (2016), Bogataj et al. 2005
C_{13}	Lack of investment	The level of investment in cold chain logistics by both local and multinational companies.	Riasi (2015), Wang et al. (2021)
C_{14}	Logistics collaboration level	Level of cooperation between stakeholders, especially flower export companies.	Janssen et al. (2016). Hotrawaisaya et al. (2014), Nha Trang (2022)

Source: Author

Methodology

This section describes the research method used to determine the importance of the factors affecting the Kenyan cut flower cold chain logistics.

Research framework

This study examines the utility of the IMF-SWARA method in assessing the factors affecting the logistic performance of the cold chain for flowers in Kenya. Expert opinion and a literature review led to the conclusion that there is limited research on cold supply chains in Kenya, and no previous studies have investigated this topic.

Figure 2 shows the methodology and research flow used to evaluate the factors affecting cold logistics in cut flowers. Firstly, we developed a list of suitable criteria based on the opinions of related experts and a comprehensive literature review. In the second phase, we conducted a questionnaire on a prioritised list of criteria and collected them with decision-makers (DMs) to perform the evaluation. In the third phase, we applied the IMF-SWARA method to obtain the final weighting of the criteria and rank them accordingly. The reason for choosing the IMF SWARA method is that it is a powerful MCDM method for calculating the weighting of the criteria. It can handle uncertainty and simulate the uncertainty of human judgment. Finally, discussions and conclusions were presented based on the results. Figure 2 shows the research framework formulated for this study.

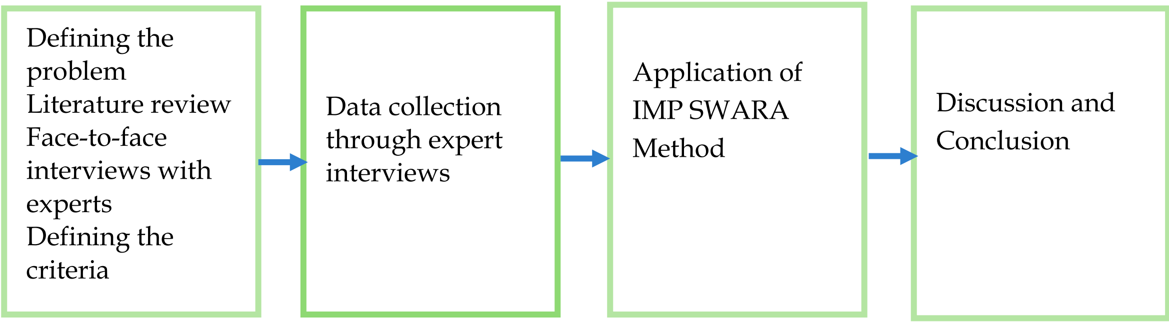

Figure 2: Research Framework of this Study

IMF SWARA technique

SWARA (Stepwise Weight Assessment Ratio Analysis) was proposed by Kersuliene, Zavadskas, and Turskis in 2010 and is one of the MCDM methods that allows the inclusion of the opinions of decision-makers regarding the weights of the criteria (Keršuliene et al., 2010). Mardani et al. (2017) stated that the SWARA procedure attempts to determine decision-maker preferences and uses these estimates to evaluate the procedure. The SWARA method eliminates uncertainties in the linguistic evaluation of criteria and decision options. This method can easily integrate expert opinions and thoughts into the process. At this point, expert opinions are critical. The ability and experience of the people giving opinions are the most essential points in determining the importance of each criterion in the SWARA method. To list the significance of the requirements that affect the subsequent cold chain supply, we used the Improved Fuzzy SWARA (IMF SWARA) approach and followed the implementation steps described by Vrtagić et al. (2021). The IMF-SWARA method is a modified version of the Fuzzy-SWARA method (Vrtagić et al., 2021; Stević et al., 2022; Stojanović et al., 2023). It follows the same process but uses a different scale of values (Table 3). Table 3 summarises the literature on the IMF- SWARA method and their respective fields of study.

Table 3: IMF SWARA Literature

Author & Year	Approach	Application area	Study purpose
Pajić et al. (2024)	IMFSWARA and MARCOS	Logistics	Strategic warehouse location selection
Stojanović et al. (2023)	IMF SWARA	Project management	Supplier selection for project organisations
Stević et al. (2022)	IMF SWARA and Fuzzy SWARA	Logistics	Comparative analysis
Vojinović et al. (2022)	IMF SWARA-FDWGA-PESTEL	Health care	Analysis for assessment of the healthcare system
Zolfani et al. (2021)	Hybrid IMF SWARA and fuzzy MABAC techniques	Logistics	Evaluating logistics villages in Turkey using
Vrtagić et al. (2021)	IMF SWARA	Construction	ranking road sections
Atlı and Senir (2024)	IMF SWARA and Fuzzy WASPAS	Agriculture	green supplier selection for agricultural pesticides

The following steps adequately demonstrate the process of obtaining the relative weights of criteria using the IMF SWARA method:

Step 1: The decision criteria are given, and each decision maker scores them from best to worst based on their knowledge and experience. The total scores assigned by the decision makers for each criterion yield the aggregate ranks. C_j (j = 1, 2, ... ,n) denotes a criterion. C and C_n are the best and the worst criterion, respectively, when the aggregate ranks are considered. Depending on the problem, the attributes (criteria) are determined in the phase by literature review and/or expert opinions.

Step 2: For each criterion, the criterion j's relevance relates to the previous (j-1) criterion. This ratio is called the comparative importance of average, s_j (Keršuliene et al., 2010). At this stage, experts/decision-makers rank the determined list of criteria/attributes. Vrtagić et al. (2021) found that the difference between SWARA and IMF-SWARA lies in the TFN (Triangular Fuzzy Number) scale and that the original F-SWARA method was poorly designed. Table 4. shows Fuzzy Linguistic scales IMF SAWARA techniques and TFNs.

Table 4: Fuzzy Linguistic Scales IMF SAWARA Techniques and TFNs

Linguistic Variable	Abbreviation	TFN Scale		
Absolutely less significant	ALS	1	1	1
Dominantly less significant	DLS	1/2	2/3	1
Much less significant	MLS	2/5	1/2	2/3
Really less significant	RLS	1/3	2/5	1/2
Less significant	LS	2/7	1/3	2/5
Moderately less significant	MDLS	1/4	2/7	1/3
Weakly less significant	WLS	2/9	1/4	2/7
Equally significant	ES	0	0	0

Source: Vrtagić et al. (2021)

Step 3: By binary comparison, the coefficients of each criterion are determined and denoted as k_j. This coefficient shows the importance of criterion j+1 relative to criterion j. Determine the coefficient k_j as follows:

$$K_j = \begin{cases} 1 & j = 1 \\ s_j + 1 & j > 1 \end{cases} \tag{1}$$

Step 4: Determine the recalculated weight q_j as follows:

$$q_j = \begin{cases} 1 & j = 1 \\ \frac{q_{j-1}}{k_j} & j > 1 \end{cases} \tag{2}$$

Step 5: The fuzzy weight coefficients are calculated as the following equation:

$$w_j = \frac{q_j}{\sum_{k=1}^{n} q_k} \tag{3}$$

with w_j symbolising the fuzzy relative weight of criterion j, and m denoting the total number of criteria

Step 6: Defuzzification of the relative fuzzy weights of criterion j is performed using the center-of-area method, which is the most practical and straightforward approach (Agarwal et al. 2020).

$$w_j = \frac{1}{3}\widehat{w}_j = \frac{1}{3}\left(\widehat{w}_{ja} + \widehat{w}_{jB} + \widehat{w}_{jy}\right) \tag{4}$$

Data collection

Five experts with experience in the sector participated in this study to determine the weighting of criteria for cold chain logistics of cut flowers in Kenya. The experts were selected based on their relevant experience in the sectors concerned in Kenya and their general knowledge of cold chain logistics. Table 5 shows the information about the experts.

Table 5: Information on the Experts

Decision maker (DM)	Experience years	Education	Specialty	Position
DM1	12	Master	MBA	Logistics expert
DM2	14	Master	Horticulture	Floriculture expert
DM3	7	PhD	Engineering	R &D Expert
DM4	15	Bachelor	Flower export	Manager
DM5	20	Bachelor	Management	Logistics expert

In this context, the factors affecting cut flower cold chain performance are Information technologies level (C_1), Cold chain infrastructure (C_2), Security and domestic political instability (C_3), Service quality level and reliability (C4), Lack of innovation (C_5), perishability and loss (C_6), Government policies and regulations (C_7), Natural disasters (C_8), Shortage of skilled labour (C_9), Knowledge and information sharing level (C_{10}), Supply chain network design (C_{11}), Responsiveness of the demand (C_{12}), lack of investment (C_{13}), Logistics collaboration level (C_{14}), respectively, in Table 2. is also given. After determining the criteria, experts calculate the weights through a specific sequence of steps.

Results

The factors affecting the performance of floral cold chains were weighed using methods, and the opinions of five experts in the floriculture sector were consulted to determine the weights. The criteria's relative importance was determined using the IMF SWARA approach, with five decision-makers ranking them from most important to the least important. Each decision-maker evaluated the requirements using the linguistic terms listed in Table 3, which were transformed into TFNs according to the scale. Tables 6–10 show the evaluation results for the five DMs. The final weights of each decision maker are computed using the equations (1). (2), (3) respectively.

Table 6: The Evaluation Results of DM1

	sj			$\mathbf{k_j}$			$\mathbf{q_j}$			$\mathbf{w_j}$		
	l	m	u	l	m	u	l	m	u	l	m	u
C5				1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	0.2253	0.2496	0.2821
C13	0.2857	0.3333	0.4000	1.2857	1.3333	1.4000	0.7143	0.7500	0.7778	0.1609	0.1872	0.2194
C2	0.2222	0.2500	0.2857	1.2222	1.2500	1.2857	0.5556	0.6000	0.6364	0.1252	0.1498	0.1795
C10	0.3333	0.4000	0.5000	1.3333	1.4000	1.5000	0.3704	0.4286	0.4773	0.0834	0.1070	0.1347
C8	0.2222	0.2500	0.2857	1.2222	1.2500	1.2857	0.2881	0.3429	0.3905	0.0649	0.0856	0.1102
C9	0.2500	0.2857	0.3333	1.2500	1.2857	1.3333	0.2160	0.2667	0.3124	0.0487	0.0666	0.0881
C1	0.2857	0.3333	0.4000	1.2857	1.3333	1.4000	0.1543	0.2000	0.2430	0.0348	0.0499	0.0686
C4	0.5000	0.6667	1.0000	1.5000	1.6667	2.0000	0.0772	0.1200	0.1620	0.0174	0.0300	0.0457
C3	0.4000	0.5000	0.6667	1.4000	1.5000	1.6667	0.0463	0.0800	0.1157	0.0104	0.0200	0.0326
C7	0.0000	0.0000	0.0000	1.0000	1.0000	1.0000	0.0463	0.0800	0.1157	0.0104	0.0200	0.0326
C14	0.2500	0.2857	0.3333	1.2500	1.2857	1.3333	0.0347	0.0622	0.0926	0.0078	0.0155	0.0261
C6	1.0000	1.0000	1.0000	2.0000	2.0000	2.0000	0.0174	0.0311	0.0463	0.0039	0.0078	0.0131
C12	0.2222	0.2500	0.2857	1.2222	1.2500	1.2857	0.0135	0.0249	0.0379	0.0030	0.0062	0.0107
C11	0.2222	0.2500	0.2857	1.2222	1.2500	1.2857	0.0105	0.0199	0.0310	0.0024	0.0050	0.0087
							3.5445	4.0062	4.4384			

Table 7: The Evaluation Results of DM2

	sj			$\mathbf{k_j}$			$\mathbf{q_j}$			$\mathbf{w_j}$		
	l	m	**u**	l	m	u	l	m	u	l	m	u
C9				1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	0.1786	0.1945	0.2152
C2	0.2222	0.2500	0.2857	1.2222	1.2500	1.2857	0.7778	0.8000	0.8182	0.1389	0.1556	0.1761
C10	0.2222	0.2500	0.2857	1.2222	1.2500	1.2857	0.6049	0.6400	0.6694	0.1080	0.1245	0.1441
C7	0.2500	0.2857	0.3333	1.2500	1.2857	1.3333	0.4537	0.4978	0.5355	0.0810	0.0968	0.1153
C1	0.2500	0.2857	0.3333	1.2500	1.2857	1.3333	0.3403	0.3872	0.4284	0.0608	0.0753	0.0922
C5	0.0000	0.0000	0.0000	1.0000	1.0000	1.0000	0.3403	0.3872	0.4284	0.0608	0.0753	0.0922
C8	0.2857	0.3333	0.4000	1.2857	1.3333	1.4000	0.2431	0.2904	0.3332	0.0434	0.0565	0.0717
C14	0.0000	0.0000	0.0000	1.0000	1.0000	1.0000	0.2431	0.2904	0.3332	0.0434	0.0565	0.0717
C6	0.2500	0.2857	0.3333	1.2500	1.2857	1.3333	0.1823	0.2258	0.2666	0.0326	0.0439	0.0574
C4	0.2857	0.3333	0.4000	1.2857	1.3333	1.4000	0.1302	0.1694	0.2073	0.0233	0.0329	0.0446
C11	0.2222	0.2500	0.2857	1.2222	1.2500	1.2857	0.1013	0.1355	0.1696	0.0181	0.0264	0.0365
C12	0.0000	0.0000	0.0000	1.0000	1.0000	1.0000	0.1013	0.1355	0.1696	0.0181	0.0264	0.0365
C13	0.2857	0.3333	0.4000	1.2857	1.3333	1.4000	0.0723	0.1016	0.1319	0.0129	0.0198	0.0284
C3	0.2222	0.2500	0.2857	1.2222	1.2500	1.2857	0.0563	0.0813	0.1080	0.0100	0.0158	0.0232
SUM							4.6467	5.1420	5.5995			

Table 8: The Evaluation Results of DM3

	s_j			k_j			q_j			w_j		
	l	m	**u**	l	m	u	l	m	u	l	m	u
C_2				1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	0.2624	0.2714	0.2825
C_9	1.0000	1.0000	1.0000	2.0000	2.0000	2.0000	0.5000	0.5000	0.5000	0.1312	0.1357	0.1412
C_5	0.2222	0.2500	0.2857	1.2222	1.2500	1.2857	0.3889	0.4000	0.4091	0.1020	0.1085	0.1156
C_1	0.0000	0.0000	0.0000	1.0000	1.0000	1.0000	0.3889	0.4000	0.4091	0.1020	0.1085	0.1156
C_{13}	0.0000	0.0000	0.0000	1.0000	1.0000	1.0000	0.3889	0.4000	0.4091	0.1020	0.1085	0.1156
C_{10}	0.2500	0.2857	0.3333	1.2500	1.2857	1.3333	0.2917	0.3111	0.3273	0.0765	0.0844	0.0924
C_{11}	1.0000	1.0000	1.0000	2.0000	2.0000	2.0000	0.1458	0.1556	0.1636	0.0383	0.0422	0.0462
C_6	0.2500	0.2857	0.3333	1.2500	1.2857	1.3333	0.1094	0.1210	0.1309	0.0287	0.0328	0.0370
C_8	0.2500	0.2857	0.3333	1.2500	1.2857	1.3333	0.0820	0.0941	0.1047	0.0215	0.0255	0.0296
C_{12}	0.2222	0.2500	0.2857	1.2222	1.2500	1.2857	0.0638	0.0753	0.0857	0.0167	0.0204	0.0242
C_3	0.0000	0.0000	0.0000	1.0000	1.0000	1.0000	0.0638	0.0753	0.0857	0.0167	0.0204	0.0242
C_4	0.0000	0.0000	0.0000	1.0000	1.0000	1.0000	0.0638	0.0753	0.0857	0.0167	0.0204	0.0242
C_{14}	0.5000	0.6667	1.0000	1.5000	1.6667	2.0000	0.0319	0.0452	0.0571	0.0084	0.0123	0.0161
C_7	0.3333	0.4000	0.5000	1.3333	1.4000	1.5000	0.0213	0.0323	0.0428	0.0056	0.0088	0.0121
							3.5401	3.6850	3.8108			

Table 9: The Evaluation Results of DM4

	s_j			k_j			q_j			w_j		
	l	**m**	**u**	l	m	u	l	m	u	l	m	u
C_{10}				1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	0.1684	0.1747	0.1825
C_5	0.0000	0.0000	0.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	0.1684	0.1747	0.1825
C_9	0.0000	0.0000	0.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	0.1684	0.1747	0.1825
C_{13}	0.2500	0.2857	0.3333	1.2500	1.2857	1.3333	0.7500	0.7778	0.8000	0.1263	0.1359	0.1460
C_2	0.2222	0.2500	0.2857	1.2222	1.2500	1.2857	0.5833	0.6222	0.6545	0.0982	0.1087	0.1194
C_1	1.0000	1.0000	1.0000	2.0000	2.0000	2.0000	0.2917	0.3111	0.3273	0.0491	0.0543	0.0597
C_3	0.2857	0.3333	0.4000	1.2857	1.3333	1.4000	0.2083	0.2333	0.2545	0.0351	0.0408	0.0464
C_8	0.2222	0.2500	0.2857	1.2222	1.2500	1.2857	0.1620	0.1867	0.2083	0.0273	0.0326	0.0380
C_6	0.0000	0.0000	0.0000	1.0000	1.0000	1.0000	0.1620	0.1867	0.2083	0.0273	0.0326	0.0380
C_7	0.2500	0.2857	0.3333	1.2500	1.2857	1.3333	0.1215	0.1452	0.1666	0.0205	0.0254	0.0304
C_{12}	0.2857	0.3333	0.4000	1.2857	1.3333	1.4000	0.0868	0.1089	0.1296	0.0146	0.0190	0.0236
C_{14}	0.2857	0.3333	0.4000	1.2857	1.3333	1.4000	0.0620	0.0817	0.1008	0.0104	0.0143	0.0184
C_{11}	1.0000	1.0000	1.0000	2.0000	2.0000	2.0000	0.0310	0.0408	0.0504	0.0052	0.0071	0.0092
C_4	0.2857	0.3333	0.4000	1.2857	1.3333	1.4000	0.0221	0.0306	0.0392	0.0037	0.0053	0.0072
SUM							5.4809	5.7250	5.9395			

Table 10: The Evaluation Results of DM5

	s_j			k_J			q_J			w_J		
	l	m	u	l	m	u	l	m	u	l	m	u
C_2				1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	0.1688	0.1774	0.1884
C_9	0.0000	0.0000	0.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	0.1688	0.1774	0.1884
C_{13}	0.0000	0.0000	0.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	0.1688	0.1774	0.1884
C_5	0.2500	0.2857	0.3333	1.2500	1.2857	1.3333	0.7500	0.7778	0.8000	0.1266	0.1380	0.1507
C_1	0.2857	0.3333	0.4000	1.2857	1.3333	1.4000	0.5357	0.5833	0.6222	0.0904	0.1035	0.1172
C_{10}	0.2222	0.2500	0.2857	1.2222	1.2500	1.2857	0.4167	0.4667	0.5091	0.0703	0.0828	0.0959
C_{11}	1.0000	1.0000	1.0000	2.0000	2.0000	2.0000	0.2083	0.2333	0.2545	0.0352	0.0414	0.0479
C_6	0.5000	0.6667	1.0000	1.5000	1.6667	2.0000	0.1042	0.1400	0.1697	0.0176	0.0248	0.0320
C_7	0.2857	0.3333	0.4000	1.2857	1.3333	1.4000	0.0744	0.1050	0.1320	0.0126	0.0186	0.0249
C_{14}	0.0000	0.0000	0.0000	1.0000	1.0000	1.0000	0.0744	0.1050	0.1320	0.0126	0.0186	0.0249
C_{12}	0.2500	0.2857	0.3333	1.2500	1.2857	1.3333	0.0558	0.0817	0.1056	0.0094	0.0145	0.0199
C_8	0.2222	0.2500	0.2857	1.2222	1.2500	1.2857	0.0434	0.0653	0.0864	0.0073	0.0116	0.0163
C_4	0.4000	0.5000	0.6667	1.4000	1.5000	1.6667	0.0260	0.0436	0.0617	0.0044	0.0077	0.0116
C_3	0.2222	0.2500	0.2857	1.2222	1.2500	1.2857	0.0203	0.0348	0.0505	0.0034	0.0062	0.0095
							5.3092	5.6365	5.9237			

Table 11: Average Fuzzy Evaluation Results

Code	Criteria	l	m	u	Defuzzified Weights	Ranking
C_1	Information technologies level	0.0674	0.0783	0.0906	0.0788	6
C_2	Cold chain infrastructure	0.1325	0.1454	0.1609	0.1463	2
C_3	Security and domestic political instability	0.0131	0.0186	0.0252	0.0190	13
C_4	Service quality level and reliability	0.0129	0.0190	0.0262	0.0194	12
C_5	Lack of innovation	0.1315	0.1444	0.1600	0.1453	3
C_6	Perishability and loss	0.0206	0.0269	0.0340	0.0272	10
C_7	Government policies and regulations	0.0453	0.0539	0.0637	0.0543	7
C_8	Natural disasters	0.0362	0.0457	0.0565	0.0461	8
C_9	Shortage of skilled labour	0.1654	0.1769	0.1913	0.1779	1
C_{10}	Knowledge and information sharing level	0.1064	0.1195	0.1345	0.1202	4
C_{11}	Supply chain network design	0.0155	0.0201	0.0253	0.0203	11
C_{12}	Responsiveness of the demand	0.0124	0.0173	0.0230	0.0176	14
C_{13}	Lack of investment	0.0955	0.1065	0.1197	0.1072	5
C_{14}	Logistics collaboration level	0.0206	0.0275	0.0356	0.0279	9

The arithmetic means of the evaluation results of the five decision makers (DM) are calculated to determine the average fuzzy weighting values for all criteria. These average fuzzy weights are then presented in Table 11. The defuzzified weights are then calculated using Equation 4. The result indicates that the most influential factors in Kenyan floral cold chain logistics performance are the shortage of skilled labour (C_9), Cold chain infrastructure (C2), and Lack of innovation (C5); the least important factor is the responsiveness of demand (C_{12}). Table 10 shows the results obtained with the help of the IMF SWARA method. Accordingly, the criteria formed as C_9> C_2> C_5> C_{10}> C_{13}> C_1> C_7> C8> C_{14}> C_6> C_{11}> C_4> C_3> C_{12} show the importance levels of the criteria obtained through the SWARA method. Figure 3 shows the results of IMF SWARA criteria prioritisation.

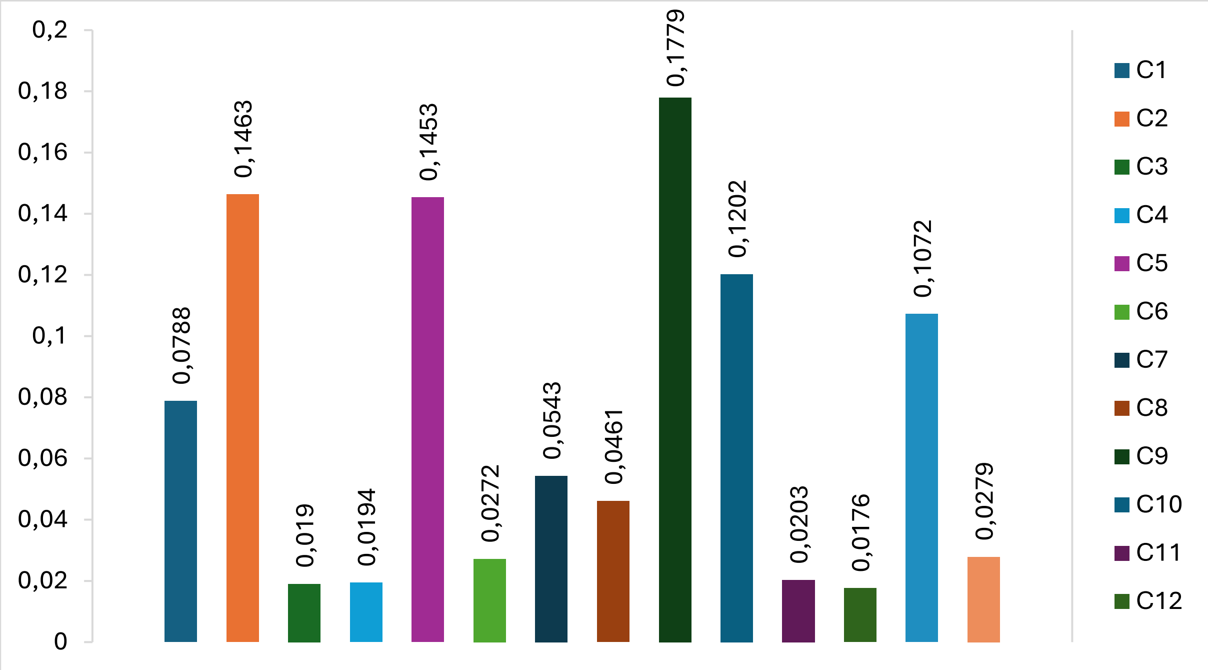

Figure 3: Results of IMF SWARA Criteria Prioritization

Discussion

The flower cold chain logistics ensures cut flowers' longevity and freshness from harvest to distribution to the end consumer. This process depends on several factors that affect the quality and vase life. The study identified the criteria influencing the logistics of cut flower supply with the help of five experienced decision-makers in the field and a literature review. It also analysed the pairwise comparison and considered how cold chain logistics could be improved to provide a more efficient and sustainable service. The main framework of the research considered all relevant factors affecting the functioning of the flower cold chain system.

According to the results of the implemented model, the most crucial criterion in flower chain logistics is the "shortage of skilled labour," with a weighting value of (0.1779). It indicates that a shortage of skilled labour affects the quality and competitiveness of exported flowers. Floriculture in Kenya is a key sector of the economy, with a high demand for skilled labour to manage the cold chain. Cassey et al. (2018) examine the impact of post-harvest labour markets and commodity prices in the horticultural sector. They also found that labour shortages lead growers to benefit from higher prices despite lower production, with spoilage along the transport network due to post-harvest labour shortages eroding these gains. They highlighted the economic inefficiencies caused by labour shortages, particularly for industries with high spoilage rates and price-sensitive demand. According to their study (Christiaensen et al., 2020), agricultural productivity in Africa is still low, so investments in education, mechanisation, and integrative value chains are needed to raise employment standards.

The second most significant attribute is the "cold chain infrastructure," with a weighting value of (0.1463), as inadequate cold chain infrastructure is a considerable challenge, leading to high post-harvest losses, lower product quality, and weaker competitiveness in international markets. The third most significant attribute is "Lack of innovation," with a weighting value of (0.1453), whose importance level is almost equal to that of "cold chain infrastructure." The lack of innovation in the cold chain also contributes to post-harvest losses in the logistics process for the supply of cut flowers. This factor is also one of the main obstacles to the country's competitiveness.

Conclusion

This study addresses the criterion prioritisation issue for flower cold chain logistics performance, modelling it as a multi-criteria decision-making (MCDM) problem. The flower industry today is quite a dynamic international economic sector. Kenya is one of Africa's most important, oldest, and most successful cut flower industries. The country's location in the equatorial region offers good climatic conditions for high-quality flower production throughout the year. The production and export of floriculture goods are key components of Kenya's economy, which is known as the flowery country of East Africa. The purpose of this study is to determine the importance of criteria that influence the performance of cold chain logistics for cut flowers in the flower industry in Kenya.

The IMF-SWARA method demonstrates the superiority of the criteria over the other criteria and calculates the weighting of the criteria. According to the values obtained, this paper determines that the essential criterion for flower chain performance is the shortage of skilled labour, and the least important is the responsiveness of the demand. This study provides the criteria sequence from highest to lowest: shortage of skilled labour (C_9), cold chain infrastructure (C_2), lack of innovation (C_5), Knowledge and information sharing level (C_{10}), lack of investment (C_{13}), information technologies level (C_1), government policies and regulations (C_7), natural disasters (C_8), logistics collaboration level (C_{14}), Perishability and loss (C_6), supply chain network design (C_{11}), service quality level and reliability (C_4), security and domestic political instability (C_3), responsiveness of the demand (C_{12}).

Kenya has a potential export market in the horticultural sector, especially for cut flowers. Effective cold chain management is essential to maintain the quality of flowers and extend their vase life, thereby minimising losses and maximising the sector's profitability. However, the performance of this supply chain slows down due to challenges such as limited experience, labour, infrastructure, power outages, and lack of technological integration. This study is helpful to top management, cold chain logistics firms, all employees, new researchers, existing flower companies, and new flower businesses in Kenya. This study reveals that there might be a way to boost Kenya's flower export performance, which would be helpful for the country's economy.

Theoretical implications

The study contributes to the literature in the following ways. Firstly, it improves understanding of cold chain logistics, especially in the floriculture industry. The cold chain in logistics is still under-researched, especially in developing countries such as Kenya. They face a lack of skilled labour, cold chain infrastructure, and a lack of innovation. The study suggests policymakers should consider improving cold chain logistics for floriculture goods to improve safety and competitiveness. The results provide valuable information that companies and actors at different levels of the cold chain need to achieve the objectives of strengthening cold storage and logistics in Kenya. The study is the first of its kind to be conducted. It contributes to the literature on cold chain improvement in Kenya and other developing East African countries.

Managerial implications

The study suggests policymakers should consider improving cold chain logistics for perishable goods to increase cut flowers' vase life and the Kenyan market's competitiveness. Attracting talented people to the cold chain is key to addressing the shortage of skilled labour in cold chain logistics. The country should improve working conditions and offer performance bonuses and social benefits. Employee satisfaction would increase with infrastructure modernisation and improved working conditions, such as safety and adapted equipment. Strategic investments through public-private partnerships, government support, and industry development are needed to enhance Kenya's cold chain. Creating appropriate infrastructure such as refrigerated transport, cold storage, renewable energy sources, staff training, and educating local actors on effective logistics management and preservation techniques is essential. Better coordination and traceability would be possible using innovative technologies such as Artificial intelligence, the Internet of Things, blockchain, and mobile software.

Finally, a more effective cold chain would promote a reduction in post-harvest losses and an improvement in market accessibility by strengthening the regulatory framework, which includes quality standards and institutional support. The SWARA approach is highly adaptable and valuable in various decision-making contexts. Future research could integrate other multi-criteria decision analysis approaches, such as COPRAS, into the fuzzy calibration process.

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