Assessing the sustainable food system in Thailand under uncertainties: governance, distribution and storage drive technological innovation

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Abstract

This study contributes to the assessment of the sustainable food system in Thailand, showing that governance, distribution and storage lead to technological innovation under uncertainties. Prior studies to evaluate attributes of the sustainable food system under uncertainties are lacking. By nature, the sustainable food system has various attributes and applies the fuzzy Delphi method to construct a valid set of measurements of qualitative information. This study uses a fuzzy decision-making trial and evaluation laboratory method to visualize the causal-effect interrelationships among the proposed attributes. The food system needs to include governance and behavioral changes to assess quality, food waste and production. Practical solutions must focus on enhancing environmental friendliness, product labeling for authenticity arguments, and the reuse and recycling of products. The results show that production assessment and distribution and storage lead to technological innovation.

Keywords: sustainable food system; multi-criteria decision making; causal-effect analysis; fuzzy Delphi method; fuzzy DEMATEL

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1. Introduction

Food services and delivery platforms are booming, with a growth rate of up to 14%, because Thailand's government contained the dangerous situation caused by the outbreak of coronavirus disease 2019 (COVID-19) (Bank of Thailand, 2020). The COVID-19 pandemic has boosted the usage and emergence of online delivery platforms that integrate online-to-offline (O2O) delivery, increasing food consumption, and the immense volume of food waste generated has raised interest in sustainability activities through waste recycling (Liu et al., 2020[a]; Liu et al., 2020[b]). Mitigating food waste is a significant challenge for sustainability; however, for developing countries such as Thailand, sustainable activities are considered less important when people's awareness of environmental preservation is low (Liu et al., 2020[b]). Existing studies have shown that food waste is predominantly produced by hospitality services and negatively impacts society, the economy and the environment (Filimonau and De Coteau, 2019; Dhir et al., 2020). Efforts to reduce food waste in the food system are complex, and it is difficult to justify the benefits with tangible rewards (Witzel et al., 2021; Widaningrum et al., 2020). To ensure the feasibility and success of food waste reduction efforts, the perceived interlinkages between firms and consumers in the food system need to be investigated. In line with previous studies, a sustainable food system (SFS), which redesigns the existing food system and its elements, such as food firm productivity, should also encompass a value-added element, such as boosting social effectiveness and economic performance, together with environmental developments. Therefore, this study proposes to understand and validate the attributes of an SFS.

An SFS specifies an interconnection of multiple criteria networks over occasional relationships by improving systematic thinking regarding several aspects. It seeks to advance food system effectiveness and productivity by considering feedback, trade-offs and activities to support sustainability (Camarena, 2020). Galli et al. (2020) highlighted that the implementation of an SFS to address sustainability problems based on the government and ecological situation translated into economic benefits, social effectiveness and environmental impact through regulation and governance. For example, environmental sustainability in the food system context is inadequate without focusing on waste reduction, the packaging consumed, and product reuse and recognizing health concerns. Moreover, the notion of an SFS is important and intensifies resource allocation, distribution management, firm performance, and consumption behavior (Steenis et al., 2018; Sigurdsson et al., 2020; Herrero et al., 2021; Hoek et al., 2021). For instance, (Tseng et al., 2020) highlighted that SFS resource allocation is calibrated by recycling and/or reusing food waste in the process of transforming raw material into food products. In addition, Paciarotti and Torregiani (2021) pointed out that a sustainable food distribution system would be developed through redesigned food delivery time integrated into the uncoordinated distribution system.

Previous studies have shown that the goal of an SFS will be achieved by considering collaboration for favorable social, economic, and environmental impacts (triple bottom line; TBL) (Choi and Johnson, 2019; Rohmer et al., 2019, Ali and Suleiman, 2016). Niederle and Schubert (2020) highlighted that the social effects of the food system are a fundamental driver of the TBL to boost and enhance sustainability. Specifically, food consumption is commonly attached to health concerns and hence translated into changes in consumer behavior to green food consumption that are in line with sustainability. Trends in food consumption and purchasing behavior are affected by social judgments based on information offered by firms. Economically, consumers assess food products based on food functions, value consumption, supply chain distribution and good production governance (Hoek et al., 2017; Sigurdsson et al., 2020). In addition, an SFS can have environmental impacts through the implementation of green practices by firms and consumers. Green practices carried out by both firms and consumers can reduce and eliminate food waste by utilizing recycled food waste and food loss and by using eco-friendly materials for food components that are not associated with end food products, i.e., green packaging, to achieve sustainability in the food system (Thogersen et al., 2017; Amiri et al., 2020; Boer et al., 2021). Myriad studies have been conducted on the sustainable attributes of the food system and found positive improvements in sustainability. However, the literature still lacks effective guidance on how firms can make sustainability efforts and ultimately create an SFS and meet consumers' needs.

Heterogeneous consumer demands have led to a complex food system, flooding the industry with meta-systems and certifications that complicate the discussion on the SFS (Ali and Suleiman, 2018). Galvez, Mejuto and Simal-Gandara (2018) argued that the meta-systems in the food industry are overlapping, conflicting and demanding, leading to more challenges in contextualizing and conceptualizing SFS research. A common perspective is an important antecedent in constructing a set of valid fundamental measurements for classification to achieve an SFS. Therefore, providing the essential sustainable attributes of the food system requires careful interpretation of implicit meanings and interrelationships in the real situation. Moreover, previous research has used food parameters as a study concept and research output and thus lacks methodological guidance to group and classify measurements. In other words, discussion of food parameters is vague, and information is commonly conceptual and qualitative in nature, which is similar to an SFS. Following this argument, this study applies the fuzzy Delphi method (FDM) (1) to transform qualitative SFS parameters into quantifiable measures and (2) to examine and confirm the validity of the transformed SFS qualitative information by excluding unreliable attributes (Wu et al., 2019; Bui et al., 2020; Tseng et al., 2020). The interrelationships of the valid SFS attributes are further investigated using the fuzzy decision-making trial and evaluation laboratory (FDEMATEL) method to handle the qualitatively described attributes and their interrelationships under uncertainties (Lago et al., 2020; Tseng et al., 2020; Pourjavad and Shahin, 2020). In short, this study uses the FDM to confirm the valid set attributes and the FDEMATEL method to analyze the interrelationships among the valid attributes, and it visualizes the interrelationships among the attributes (Bocken et al., 2015). The objectives of this study are as follows:

- To build valid SFS attributes based on qualitative information;
- To understand SFSs and their interrelationships under uncertainties; and
- To provide industrial guidelines for SFSs.

The contributions of this study are as follows: (1) it validates the attributes of SFSs by considering food industry requirements regarding crises in the food system; (2) it builds an SFS hierarchical structure in hospitality based on social effectiveness, economic benefits and environmental impacts; and (3) it provides food industries with practical improvement guidelines for achieving greater sustainability.

This study is organized as follows. The literature review, proposed methods and proposed attributes are presented in Section 2. The FDM and FDEMATEL method are explained in Section 3, and the results are discussed in Section 4. Theoretical and managerial implications are provided in Section 5. Finally, the conclusions and limitations of this study and future research suggestions are offered in Section 6.

2. Literature review

This section discusses the food system literature and TBL perspective to provide an in-depth understanding of SFSs. This study proposes measures and analytical methods.

2.1. Sustainable food system

Regarding environmental issues, the interrelationships between food and humans are complicated. An appropriate design for the food system and its sustainability that considers multiple perspectives is necessary to promote accurate decision-making and best practices (Filimonau and De Coteau, 2019; Amiri et al., 2020; Camarena, 2020). Gil et al. (2019) addressed the consistency of the social, economic and environmental contexts by describing and examining sustainable development goals, which are the most substantial contribution of prior studies of food sustainability. Dhir et al. (2020) noted that food industry activities that are important in influencing and enhancing improvements in the food system are increasing, especially those that focus on sustainable socioeconomic outcomes by removing barriers to sustainability. For instance, the food distribution phase in the supply chain is optimized by redesigning the route and reorganizing approaches (Thogersen et al. 2017; Widaningrum et al., 2020). Not only is such optimization carried out for socioeconomic development, but it also affects outcomes related to environmental sustainability. Similarly, Ali and Suleiman (2016) indicated that food production practices have a significant relationship with sustainable practices. Thus, incorporating socioeconomic and environmental factors in addition to being aware of the need to incorporate contemporary attributes under the TBL approach can serve as a bridge to sustainability in the food system.

An SFS requires a clear boundary and understanding of the characteristics that can facilitate the transformation of existing sustainable resource management systems (Niederle and Schubert, 2020; Paciarotti and Torregiani, 2021). Bisht et al. (2017) noted that food systems are complex and involve different communities with their own standards and controls, but the lack of appropriate monitoring and governance will damage society and result in worse health and malnutrition. Rohmer et al. (2019) claimed that achieving food security and better nutrition is included in sustainable development priorities, with aspects of social health and nutrition playing the most prominent role in an SFS. Social impact is considered a crucial viewpoint for boosting the capacity of consumption behavior to analyze SFSs (Choi and Johnson, 2019). Hafez and Elakkad (2020) showed that various studies have defined different attributes of social sustainability that are able to control natural resources. Farooque et al. (2020) asserted that green food consumption plays a role in social resources to improve healthy lifestyles and raise health concerns in customer behavior with the end goal of achieving sustainability. Tseng et al. (2020) explained that green consumption is considered a social perspective through communication with experts in terms of healthy lifestyles and health concerns while achieving sustainability that encompasses the TBL. In addition, Lago et al. (2020) argued that customer judgments depend on the social and moral sense of individual buyers when purchasing and consuming food, while information on the social effects of goods is offered by organizations to customers to achieve greater SFS performance.

SFS implementation also aims to provide economic benefits while meeting consumer demand through governance and production assessment (Boesen et al., 2019; Gil et al., 2019). Witzel et al. (2021) demonstrated that the food system is part of the economic benefits of sustainability, which can benefit from a high level of cooperation and trust between consumers and firms with regard to good production performance in an SFS. Sigurdsson et al. (2020) explained that from an economic perspective, the delivery time in distribution and storage activities plays an important role as an aspect of consumers' food hygiene anxiety, while sustainable products are already considered a means of achieving an SFS. In addition, Galli et al. (2020) argued that the economic conditions of individual countries and food system growth should provide an indication of individual countries' SFS performance. Hoek et al. (2017) argued that the worldwide food system integrates production assessment and governance management at different levels of strategic practices that can lead to economic benefits for a universal SFS. Steenis et al. (2018) claimed that to achieve an SFS, sustainability resources are characterized by the dimensions of the TBL, which contain governance for economic resilience in the global value chain of the food system and consumption. In addition, the economic perspective is considered to create a balance between the use of capital and economic growth that obliges the food system use responsive business practices that enhance sustainability (Sigurdsson et al., 2017; Herrero et al., 2021; Boer et al., 2021).

Myriad food production regulations and standards have been expanded to incorporate a more sustainable approach, drawing interest in research that endeavors to contribute to more precise environmental concern criteria, particularly with regard to decreasing natural resources and mitigating and preventing the loss of natural value in the food system (Camerana, 2020; Tseng et al., 2020; Herrero et al., 2021). Elhously (2020) showed that food supplies and sustainable restaurants need a standard environmental perspective to minimize environmental impacts by applying green practices for instant elimination of food waste and recycling campaigns associated with powerful energy and water use as a tool to offer consumers choices that are beneficial for sustainability. Batat (2020) argued that environmental attributes should be studied differently, as the literature fails to establish well-constructed SFS attributes due to the convergence among consumers, companies, and employees regarding green and eco-friendly technology. Improving environmental strategies throughout the supply chain is necessary to investigate environmental effects considering the crucial interactive characteristics involved in achieving an SFS (Amiri, 2020; Paciarotti and Torregiani. 2021). Thus, the environmental concerns in SFSs must be characterized to effectively allocate diminishing natural resources.

2.2. Proposed method

Existing SFS research has involved thorough analyses based on quantitative and qualitative approaches tailored to analytical purposes (Rohmer et al., 2019; Lago et al., 2020; Niederle and Schubert, 2020). Ebrahimi and Bridgelall (2020) developed an SFS assessment benchmark, and data analysis that transforms qualitative data into quantitative data is exceedingly useful for evaluating the unification of expert knowledge and judgment. When gathering data and using a quantitative method for analysis, in addition to an increased number of barriers, there is a great opportunity to use practical experiences based on expert opinions with controlled feedback under an uncertain environment (Zhang, 2017; Choi and Johnson, 2019). Recently, SFSs have been widely recognized and addressed by researchers, but in-depth investigations into the reliability and applicability of their attributes are still lacking. Only a few studies have applied quantitative testing to construct a complete classification of effective attributes, especially regarding SFSs (Bui et al., 2020; Padilla-Rivera et al., 2021). In addition, to take into account the advantages and disadvantages of analyzing and exploring outcomes from a practical perspective based on expert judgment to obtain efficacious SFS attributes, it is necessary to conduct analysis through a quantitative method by using the FDM and FDEMATEL method (Ebrahimi and Bridgelall, 2020; Pourjavad and Shahin, 2020).

The FDM technique was introduced to obtain reliably constructed attributes evaluated based on experts' judgment, where decision-making reflects experience and expertise, enhancing the approach to outcome validation by removing barriers and invalid attributes (Deveci et al., 2020; Niederle and Schubert, 2020; Padilla-Rivera et al., 2021). Dawood et al. (2021) indicated that the FDM technique starts by (1) assembling expert panels, (2) computing Likert-scale ratings into equivalent triangular fuzzy numbers (TFNs), (3) computing the threshold value, (4) reaching a consensus among the experts, and (5) performing a defuzzification analysis to address the formally redefined attributes. Du and Li (2020) noted several previous studies that applied the FDEMATEL method to different fields to solve complicated problems, such as the real situation based on triple dominance along with the combination of portraying the whole image effect, identifying interrelationships and computing dependent attributes. Farooque et al. (2020) indicated that in sustainable management, many multicriteria decision-making methods have been used to eliminate obstacles, but the most commonly highlighted is the FDEMATAL, whereas the most effective method of investigating causal interrelationships is to construct hierarchical structural attributes.

Tseng et al. (2020) proposed applying the FDM to the transition to sustainable food consumption to evaluate valid attributes and identify lesser necessary attributes based on a hierarchical relationship consisting of complete attributes and higher outcomes. Padilla-Rivera et al. (2021) selected the appropriate social indicators in SFSs by applying fuzzy decision-making to fulfill the purpose of their study. However, few studies have explained sustainable food attributes and hierarchical structures through a solid measurement to indicate causal interrelationships. Moreover, to obtain systematic attributes for a visual map of an SFS, qualitative approaches are not utilized or reliable. Altuntas and Gok (2021) adapted the DEMATEL method to consider the causal interrelationships among attributes and aimed to develop a chart to reflect the interrelationships between variables based on the SFS concept. Song et al. (2020) integrated the FDM and FDEMATEL method to obtain better and more powerful results. In their study, the FDM was used to screen out unnecessary attributes based on expert opinions, and the FDEMATEL method was then used to qualify and mitigate anxiety over the interdependencies among legitimate attributes or barriers. In summary, that study aggressively applied a hybrid method to obtain results.

2.3. Proposed attributes

This study presents a set of attributes that include 3 perspectives, 9 aspects and 26 criteria. In this study, the perspectives consist of society, the economy and the environment, as shown in Table 1. The social perspective consists of behavioral change (A1) and green food consumption

(A2), which is defined as a complex natural adaptive system that is linked to humans through dynamic processes and feedback mechanisms along with exchanges in substantial energy and material over social boundaries that have already been established (Tseng, 2020).

Behavioral change (A1) is a transformation in decision-making regarding human behavior in the food system that is affected by social sense. In accordance with this concept, consumer confidence (C1) relates to the determination of sustainable products that affect consumption patterns based on consumer attitudes (Vermeir and Verbeke, 2008; Tseng, 2020). An environmentally friendly attitude (C2) relates to consumer behavior concerning the general concepts of being environmentally friendly (Tseng, 2020). Regarding dependence on the traditional market (C3), consumers' consumption is controlled by the traditional market based on conventional transportation and food consumption patterns (Tseng, 2020). Dietary health (C4) indicates that a balanced and healthy diet can help sustain or boost individuals' health (Rohmer et al., 2019). Food promotion (C5) indicates a major motivation for individual consumers' intended consumption and preferences by persuading consumers based on cutting or reducing prices and raising brand awareness simultaneously with the dissemination of persuasive messages via communication (Galli et al., 2020).

Green food consumption (A2) is defined by customer choice regarding food consumption between green and nongreen attributes derived from customer knowledge and perceptions of health. A healthy lifestyle (C6) works as a conscious realization of health and is also achieved by buying green products (Thogersen, 2017; Lago et al., 2020). Health concerns (C7) have a crucial effect on green food consumption (Hoek et al., 2017; Lago et al., 2020). Knowledge about sustainability (C8) relates to ensuring that people have a higher degree of sustainability awareness, as well as the trend of increasing the consumption of green food products (Choi and Johnson, 2019; Lago et al., 2020). Food and nutritional security (C9) provides an interlinkage between the dedicated dimensions of the food industry and the sociocultural environment (Niederle and Schubert, 2020).

The economic perspective concerns the effectiveness of an SFS based on a country's individual economic stages to strengthen sustainable growth through opportunities for process transformation (Sigurdosson et al., 2020; Galli et al., 2020). Distribution and storage (A3) are indicated by the delivery time (C10), which is measured by the duration between order placement on any online shopping platform and the receipt of consumer goods (Sigurdsson et al., 2017; Boesen et al., 20). Production assessment (A4) is the production status in organizations. Product design (C11) is the design that contains a firm's waste production (Tseng et al., 2020). Packaging material (C12) refers to a firm's choice of material for product packaging based on a concern for sustainability (Boesen et al., 2019; Steenis et al., 2019; Tseng et al., 2020). Product labeling (C13) refers to a firm's choice of a sustainable logo to provide descriptive information and messages on product packaging (Tseng et al., 2020). Food hygiene (C14) is a step and condition that must be controlled by firms to ensure the safety of food consumption after production (Galli et al., 2020). Additionally, effectively established governance (A5) based on economic capital is expressed by the factors that affect the achievement of an SFS and is explained by the cost impact in the purchase stage (C15), which refers to an external index of the food system that is measured by economic regulation, such as value-added tax (Herrero et al., 2021).

From an environmental perspective, food systems must select relevant processing, distribution and consumption activities to examine environmental outcomes while contributing to relevant drivers of change in the environment (Gil et al., 2019; Camarena, 2020; Sigurdsson et al., 2020). Quality assessment (A6) concerns the reporting of quality based on certification standards, and many customers use the reported values in their food consumption decision-making. Prices (C16) represent the cost of purchasing goods (Sigurdsson et al., 2020). Product ratings (C17) refer to information on product rating constraints and are an indicator of consumer preferences (Sigurdsson et al., 2017; Sigurdsson et al., 2020).

Food waste (A7) is the residual food system and is the cause of environmental issues. Food waste is appropriately handled by considering waste reduction (C18) regarding the appreciable impact of consumption on green food purchasing (Sigurdsson et al., 2017; Sigurdsson et al., 2020). Package recyclability (C19) has potential as an important feature of green purchases (Sigurdsson et al., 2017; Sigurdsson et al., 2020). Product recycling (C20) is defined as a sustainable activity performed by recycling product waste (Tseng et al., 2020). Regarding product reuse (C21), consumers are persuaded to use existing products as a sustainability activity (Tseng et al., 2020). Food waste at the retail and consumer level (C22) refers to building and optimizing a prototype of energy-friendly behaviors tested by experts to gain consumer participation (Sigurdsson et al., 2017; Sigurdsson et al., 2020).

Production regulation (A8) in the food system refers to the responsibility of the government through its policies and provides solutions to problems in the environment that stem from waste in the industry. This type of regulation is necessary to enforce standards in the food system to protect consumers' health and reduce harmful environmental impacts on society. It ensures the wholesomeness of food. Political engagement (C23) concerns sustainability in regard to food movements through formal programs based on the political environment (Niederle and Schubert, 2020). General food law (C24) refers to regulations that control the production activities that take place until consumers handle food, including food control, food safety and food quality policies (Galli et al., 2020; Widaningrum et al., 2020).

Technological capability (A9) involves modern machines or procedures and the ability and performance of technology to manage the food system to achieve sustainability by generating advantageous outcomes in organizations and minimizing the negative use of resources. Technological capability (C25) in the food system, is mostly focused on service design and innovation, is an advanced creative system involving the application of new methodologies and conceptualizes workflows to enhance performance in the food system, which implies examining the nature of the human-service relationship through technology and innovation (Camerana, 2020). Changes in technology (C26) are also highlighted; such changes are positive changes in processes and the food-supply chain of the food system based on the application of technology and innovation in industry practices (Camerana, 2020).

(INSERT TABLE 1)

3. Method

This section provides the industrial background of the food system and the SFS in Thailand, as well as the FDM, FDEMATEL method and data analysis procedures.

3.1 Industrial background

In Thailand, small and medium-sized enterprises are the backbone of the country's financial competitiveness, and technology and digital transformation have increased, accounting for the largest portion of all existing businesses and 45% of the country's total gross domestic product (GDP), i.e., $215 billion (Asian development bank, 2020). This is because the regulations imposed by Thailand's government during the global COVID-19 pandemic have significantly contributed to firms' and businesses' empowerment of online channels. According to the Statista Research Department, in 2020, food delivery services had the largest O2O growth rate, reaching 15.1% (Statista, 2020). In the global food industry, both online food delivery and hospitality/restaurant services contribute to increasing food waste. With online food delivery, customers always ensure that their orders meet the minimum price to receive free delivery as a launched promotion even though the size of the order exceeds what they actually desire. Meanwhile, with offline food services, enterprises always provide food in advance to meet customer demand even though this management design sometimes causes too much food to be prepared. These pressing issues are the root cause of the food waste generated in the environment. For this reason, an SFS is urgently needed as a key to balance and maintain unlimited customer demand under existing limited natural resources.

In the food industry, as solid waste, plastic packaging is perceived as an environmental problem due to a lack of product recycling and product reuse. Solid waste is generated more naturally and is a main contributor to climate change. Moreover, in line with the required higher efficiency of food production and food distribution to meet consumer expectations, the food service industry has become a more urgent problem, hindering social and economic sustainability. Satisfying the needs of the current food industry to ensure the ecosystem's health for coming generations promotes the quality of food production and distribution through local infrastructure within approachable and budget-friendly means for organizational sustainability. However, in this situation, great efforts are made to achieve an SFS. Evaluations of the available local resources of the food system in the context of social, economic and environmental assessment still fail to incorporate sustainability concerns about solid waste and product recycling due to excessive reduction. To overcome existing issues, this study emphasizes highlighting decision-makers as a benchmark in the food industry to achieve an SFS while eliminating social burdens and ensuring that economic benefits are aligned with reducing environmental concerns. This study includes 10 experts from academia with doctoral degrees, 3 experts from government offices, and 17 experts from the hospitality industry serving as top managers and practitioners, as shown in appendix 3.

3.2. FDM

The FDM combines fuzzy set theory with the Delphi method to obtain valid and effective constructs evaluated based on expert perceptions and judgments through questionnaires (Farooque, 2020). Dawood (2021) indicated that the benefit of the FDM is that it shortens the length of time set aside for interviews to maintain consistency and preferences in experts' perceptions and judgments. Tseng et al. (2020) presented a method that significantly emphasizes the attributes and provides better results by eliminating invalid attributes based on expert perceptions. Wu et al. (2019) indicated that without appropriate indicators in decision-making, the objective cannot be optimally achieved. Hence, this study uses the FDM to generate robust outcomes.

The significance value of b is assessed by expert α as $j = (x_{ab}; y_{ab}; z_{ab}), \alpha = 1, 2, 3, \dots, n; b = 1, 2, 3, \dots, m$; then, weight j_b of element b is $j_b = (x_b; y_b; z_b)$, where $x_{ab} = \min(x_{ab}), y_b = (\prod_1^n y_{ab})^{1/n}$, and $z_b = \max\ (z_{ab})$. The linguistic terms and TFNs are then transformed into linguistic values, as shown in Table 2. Later, an α cut is adopted to generate the result.

$$u_b = z_b - \alpha\ (z_b - y_b), l_b = x_b - \alpha(y_b - yx_b), b = 1, 2, 3, \dots, m \quad (1)$$

In general, 0.5 is used to denote α under the common situation within the range of 0 to 1 depending on the positive or negative nature of the experts' perceptions. The exact value of $D_b$is generated as follows:

$$u_b = \int(u_b, l_b) = \delta[u_b + (1 - \delta)l_b] \quad (2)$$

where δ is used to explain the decision-maker's positivity level and to establish equilibrium across the fundamental judgments among the experts. Then, $\gamma = \sum_{\alpha=1}^{n}(D_b/n)$ is the threshold for screening the major criteria. If $D_b >\ \gamma$, the criteria are accepted; otherwise, they are rejected.

(INSERT TABLE 2)

3.3. FDEMATEL method

The decision-making trial and evaluation laboratory (DEMATEL) method is an effective tool for solving problems related to complex interrelationships where the interrelationships among cause-and-effect attributes are transformed (Tseng et al., 2018; Wang and Chuu, 2004). The FDEMATEL method uses defuzzification to transform qualitative information into fuzzy linguistic information. The process obtains crisp values from TFNs. The left and right values are determined by the minimum and maximum numbers, respectively, and are transformed into crisp values (Oprocovic and Tzeng, 2004). The fuzzy membership functions $\hat{j} = (\hat{x}_{ab}^k; \hat{y}_{ab}^k; \hat{z}_{ab}^k)$, are used to compute the total weighted values. The crisp values are displayed in a matrix of total direct relationships to map a diagram that simplifies the analytical results. The cause-and-effect groups that contain certain attributes represent the structured interrelationships and effects. Therefore, a set of attributes, $F = \{f1, f2, f3, \cdots, fn\}$, is proposed, and certain pairwise interrelationships are used to create the mathematical relationship. The analytical steps are as follows:

Step 1: Obtaining and accumulating crisp values

This study uses a linguistic scale consisting of very low performance/importance (VLI), low performance/importance (L), moderate performance/importance (M), high performance/importance (HI), and very high performance/importance (VHI); see Table 2. If there are k members in the decision group, the assessment of $\hat{j}$ denotes the fuzzy weight of the a^{th} attribute, which affects the b^{th} attribute and is assessed by the k^{th} evaluator.

The fuzzy numbers are normalized as follows:

$$F = (f\hat{x}_{ab}^k, f\hat{y}_{ab}^k, f\hat{z}_{ab}^k) = \left[\frac{(\hat{x}_{ab}^k - min\hat{x}_{ab}^k)}{\Delta}, \frac{(\hat{y}_{ab}^k - min\hat{y}_{ab}^k)}{\Delta}, \frac{(\hat{z}_{ab}^k - min\hat{z}_{ab}^k)}{\Delta}\right] \quad (3)$$

where$\Delta = max\hat{z}_{ab}^k - mine$

The left (ln) and right (rm) normalized values are computed as follows:

$$(ln_{ab}^{n}, rm_{ab}^{n}) = \left[\frac{(f\hat{y}_{ab}^{k}}{(1+\ f\hat{y}_{ab}^{k}-f\hat{x}_{ab}^{k})}, \frac{\hat{z}_{ab}^{k}}{(1+f\hat{z}_{ab}^{k}-\ f\hat{y}_{ab}^{k})}\right] \quad (4)$$

The total normalized crisp values (cv) are generated as follows:

$$cv_{ab}^{k} = [ln_{ab}^{n}(1-ln_{ab}^{n}) + (rm_{ab}^{n})^{2}]/(1-ln_{ab}^{n}+rm_{ab}^{n}) \quad (5)$$

Synthetic value notation is adopted to accumulate the individual perceptions of k respondents:

$$\hat{\jmath} = (cv_{ij}^{1} + cv_{ij}^{2} + cv_{ij}^{3} + \cdots + cv_{ij}^{\mathrm{k}})/k \quad (6)$$

Step 2: Setting the crisp values in an interrelationship matrix and aspect-and-criteria grouping

The initial matrix of direct relationships (ρ) is an $n \times n$ matrix that is acquired by pairwise comparison. In this matrix, $\hat{\jmath}$ is assigned as the level at which attribute i affects attribute j, amended as $IM = [\hat{\jmath}]_{n\times n}$.

The normalized direct relationship matrix (φ) is created as follows:

$$U = \tau \otimes \rho$$
$$\tau = 1/\max_{1\le i\le k}\sum_{j=1}^{k}\hat{\jmath} \quad (7)$$

From the normalized direct relationship matrix, the interrelationship matrix (R) is obtained as follows:

$$R = \varphi(I-\varphi)^{-1} \quad (8)$$

where R refers to$[r_{ab}]_{n\times n}$ $\quad i,j = 1,2,\cdots n$

Step 3: Mapping the diagram of causal interrelationships

The values of the driving power (α) and dependence power (β) are obtained from the sum of values of the rows and columns of the interrelationship matrix by applying the following equations:

$$\alpha = [\textstyle\sum_{a-1}^{n} r_{ab}]_{n\times n} \quad = [r_a]_{n\times 1} \quad (9)$$
$$\beta = [\textstyle\sum_{b-1}^{n} r_{ab}]_{n\times n} \quad = [r_b]_{1\times n} \quad (10)$$

The attributes are positioned in a cause-and-effect diagram by using $[(\alpha+\beta, (\alpha-\beta)]$ for the horizontal and vertical axes. If $(\alpha-\beta)$ is positive, the attribute belongs to the cause group; if the value is negative, it belongs to the effect group.

4. Results

This section reveals the valid barriers based on the proposed attributes, and the analytical results are shown in the following table.

4.1. FDM

This study collected the initial aspects and criteria from the literature (Appendix 1) and used equations (1) and (2) to screen out those that were less important. Table 2 shows that 26 criteria depending on 9 aspects were accepted with the threshold value $\gamma = 0.426$, as shown in Table 3.

(INSERT TABLE 3)

4.2. Fuzzy DEMATEL method

To stratify important levels of expert perceptions and judgments regarding the interrelationships among the remaining criteria, experts were interviewed by providing linguistic preference scales ranging from VLI to VHL, as shown in Table 4.

(INSERT TABLE 4)

The FDEMATEL method results were converted into linguistic preferences, as shown in Table 1. Equations (3)-(6) obtained and accumulated crisp values and transformed them into the fuzzy direct relationship matrix. Defuzzification was then performed to build the average initial direct relationship matrix, which is presented in Table 5.

(INSERT TABLE 5)

Equations (7)-(8) are the crisp values in the interrelationship matrix, and the total interrelationship matrix is shown in Table 5. In the total interrelationship matrix of aspects, values between 1.016 and 1.155 denote a weak interrelationship, values between 1.155 and 1.252 denote a moderate interrelationship, and values between 1.252 and 1.348 denote a strong interrelationship.

(INSERT TABLE 6)

Equations (9)-(10) compute a cause-and-effect diagram of the aspects based on the vertical axis $(\alpha - \beta)$ and horizontal axis $(\alpha + \beta)$, as shown in Table 7.

(INSERT TABLE 7)

SFS implementation is carried out by introducing a visual map that uses a hierarchical structure. To explain this, quantitative results are translated into linguistic terms to achieve an SFS and effective results. Based on the coordinates $(\alpha - \beta)$ and $(\alpha + \beta)$, a causal interrelationship diagram was drawn, as shown in Figure 1, by mapping valid aspects. The dominant influencing aspects in the causal group are governance (A5), production assessment (A4), behavioral change (A1) and distribution and storage (A3). In contrast, the affected group consists of green food consumption (A2), quality assessment (A6), food waste (A7), production regulation (A8) and technological capability (A9). A1, A2, A3, A6, A7, A8 and A9 are affected by A5 and A4, especially A4 to A9. A2, A3, A6, A7, A8 and A9 are influenced by A1, and A1, A2, A6, A7, A8 and A9 are influenced by A3 and strongly affected by A9.

(INSERT FIGURE 1)

To obtain the driving and dependence power for the criteria of the total interrelationship matrix, this study performed the procedures (see appendix 2). The cause-and-effect diagram of the criteria was generated based on the driving and dependence power of the criteria, as shown in Figure 2. Therefore, a healthy lifestyle (C6), product design (C11), packaging material (C12), product labeling (C13) and prices (C16) are the top five causal criteria for an SFS. C7, C9, C15, C4, C21, and C20 are dependence factors; C6, C11, C12, C13, and C16 are linkage factors; C2, C3, C8, C14, C17, C18, C22, C23, C25, and C26 are independent factors; and C1, C5, C10, C19, and C24 are autonomous factors.

(INSERT FIGURE 2)

5. Discussion

This section discusses theoretical and managerial implications and contributions regarding the relationships between aspects and important criteria for an SFS to respond to social, economic and environmental impacts under uncertainties. Previous studies have empirically demonstrated the relationship between the food system and sustainability; therefore, this study contributes to and sheds new light on the discussion on SFSs.

5.1. Theoretical contributions

In an SFS, the causal aspects are behavioral change (A1), distribution and storage (A3), production assessment (A4) and governance (A5). The imbalanced perspectives between firms and consumers are the main challenges, and overcoming them is a daunting task given the different reactions to SFSs, particularly production regulations and technological capability. The food industry is highly regulated, and myriad standards have been developed to meet heterogeneous consumer demands. SFS implementation is expected to ultimately affect food production regulations. Under uncertainties, technological capability plays an important role in enabling ly supply-chain players to enter the food system. In other words, technological capability potentially provides positive outcomes for food production activities, with a special focus on lessening the environmental impact. In Thailand, the cocreation of a middle point between technological capability and social effectiveness is argued to be the most effective approach to achieving sustainability goals. Despite the promise of technological capability in achieving an SFS, it is still unevenly distributed across the areas of production assessment and distribution and storage, and from the firm perspective, green technology is in continuously high demand.

Behavioral change (A1) consists of changing individuals' and/or organizations' decision-making and is identified through a different appropriate reaction to the entire SFS (Hoek et al., 2021). Behavioral change is the indicator of how well information that enhances SFS knowledge is being communicated. A high awareness of the SFS will influence social and moral sense, affecting consumer judgments regarding food purchasing and consumption (Lago et al., 2020). In an SFS, the social sense of customer behavioral changes is driven by a healthy lifestyle that is consistent with recommended nutritional guidelines and environmental awareness, and it provides economic benefits through a productive workforce (Hafez and Elakkad, 2020). Consumers are more concerned about health; however, their sustainable consumption strengthens environmental concerns. In contrast, the absence of behavioral change to more sustainable consumption reduces the effectiveness of sustainability efforts even with regulations in place. Behavioral change is the core of social effectiveness in an SFS and affects green food consumption. Rather than commodities moving farther along the supply chain, food production has emerged to meet consumer demands. Thus, the social efficiency of an SFS is argued to be the ability of food manufacturers to sustainably produce food that meets the requirements of sustainable consumption. In addition, economics related to government regulations affect costs, and the purchase state is an important controller of behavioral change, green food consumption, distribution and storage, quality assessment, food waste, production regulation and technological capability.

Importantly, consumer anxiety is the service quality provided by the delivery time of food manufacturers in distribution and storage activities (A3) (Sigurdsson et al., 2017; Sigurdsson et al., 2020). Customers expect to be served appropriately and to receive their orders within a short period of time without delays due to unforeseen circumstances. Innovative technology can maximize service quality under uncertainties. The introduction and popularization of innovative technology under uncertainties have caused changes and fluidity in consumer perceptions. For instance, the COVID-19 pandemic has led to the rapid emergence of distribution and storage in Thailand, such as O2O. However, the new procedures and production flows of organizations have the possibility of disrupting the technologies that have been developed to address environmental issues. On a positive note, enhancing service quality during times of uncertainty may result in better technological capability (Ali et al. 2021). Environmental impact concerns, among other concerns related to consumer perceptions, push organizations to improve their service quality, activities, and strategies to optimize the SFS. Management service quality with the application of technology in organizations needs to change to have less environmental impact. In summary, an SFS aims to ensure customer satisfaction and to result in economic benefits and social effectiveness. Although organizations are in charge of innovative technology with some outsourcing practices to improve service quality, product assessment and food production governance are still key to balancing the demands of the TBL in an SFS.

In production assessment (A4), food production suffers from food waste and food loss despite food insecurity. Food production is complicated, as products are not modular once processed. The SFS problem is predominantly related to the environmental impacts and economic benefits, where a reduction in food waste and zero hunger are sustainability goals and hence universal aims (Herrero et al., 2021; Boer et al., 2021). Specifically, food quality is an important measure because consumers are commonly concerned with notions of food safety. In addition, increasing health concerns have shifted consumers' focus to food hygiene, pushing firms to enhance the effectiveness of their development process, design, and operational performance to meet consumer demand (Bisht et al., 2017). Nevertheless, product assessment requires some couplings to address sustainability, such as the implementation of innovative technology in production processes, innovative packaging material and more eco-friendly product design that boosts green food consumption.

Governance (A5) is a framework and process related to decision-making, accountability, control and action by a responsible party both within and beyond factory walls. In an SFS, governance is viewed as a mechanism used by firms and bodies that control food production to comply with specific rules and regulations that can be extended to sustainability efforts. Recently, a large number of food firms have taken strong responsibility for long-term products and sustainability by transforming the principle of strategic planning into sustainability. For example, the decision of top management to invest in more advanced technological capability is commonly a result of external pressure exerted by consumers, regulatory and certification bodies and competitors. Following this argument, firms' economic measures consider the value added resulting from such investment. Good governance by regulatory bodies and top management helps firms in the food industry implement sustainability strategies across the supply chain and its ecosystem via strengthened relationships and accountability to stakeholders, reflecting the TBL (Galli et al., 2020; Batat, 2020). In the food system, governance enhances health security not only through food consumption but also through reduced environmental impact. In addition, the governance embodied in food regulations ensures that food production is carried out according to health standards and meets consumer demands/dietary needs, which may also fall within the SFS concept. Governance also creates a positive sense of environmental impact and increases cost savings since the action plan is designed by managers who are concerned about environmental impact. Thus, cooperating in governance simultaneously helps firms and increases shareholders' satisfaction with promoting an SFS.

5.2. Industrial implications

In terms of practical improvements, the top five weighted criteria are product labeling (C13), product design (C11), packaging material (C12), a healthy lifestyle (C6), and product prices (C16). Product labeling (C13) is provided by food manufacturers to facilitate customers' understanding by presenting product information through logos and descriptive information. The information available on food packaging influences customers' trust in their purchasing decisions. Consumers' decisions regarding food product purchasing positively impact the environment, indicating the importance of the information that is conveyed by labeling. A lack of information on product labels may make consumers decide to act in an unsustainable manner that is harmful to the environment. This is because food purchasing behavior is caused by culture and habitually lies within society, where the inclination to purchase the least environmentally harmful products cannot be acted on absent labeling of more sustainable products. Appropriate product labeling represents an opportunity for firms to communicate sustainable production to and educate society regarding different sustainable consumption patterns. Enhancing individuals' sustainable consumption may have a snowball effect on the market at large. Hence, to deliver concrete product information and reduce unsustainable product consumption, product labeling is essential.

Product design (C11) should stem from sustainability concerns through innovative business modes in the food industry via reusable resources to lessen environmental impact. Product design with discarded materials is showing increasing value in the marketplace, especially among niche communities with sustainability knowledge and health concerns. Moreover, there is a huge opportunity and potential for the recirculation of materials through recycling, reuse and remanufacturing in production lines within firms when innovative technology is deployed. The approach of using discarded materials in indirect food products such as packaging during product design not only reduces negative environmental impacts but also optimizes recycling practices, minimizes the resources used, and minimizes waste from production activities. The idea that food products can be reused and recycled may sound overly optimistic, but maximizing the sustainability of indirect food products, through such measures as biodegradable packaging, prolonging the shelf life of food products, using advanced food technology to preserve bioactive compounds, and focusing on functional food, can be regarded as steps towards sustainable food production and consumption and, ultimately, an SFS. In short, SFSs can benefit from the high potential of food product design by attempting to deliver sustainable food products that embrace recycling practices that are able to minimize and reduce the amount of resources used while meeting socioeconomic needs.

Food product packaging material (C12) is argued to be one of the most effective ways to implement sustainability. Nonreusable food material from production output has increased, both damaging the phenomenal growth of the environment and affecting human well-being. Established sustainability practices seek product material considerations that are appropriate to minimize the environmental footprint. Since the food supply chain is long and complex, the entire supply chain, i.e., from farm to fork, should use sustainable product packaging as a best practice, and organizations should use natural or biodegradable packaging material. The physical flow of materials in the multiple layers of the food supply chain is enormous, and sustainable product packaging can further assist organizations' business models in being less harmful to the environment. Implementing biodegradable material sourcing from natural resources to replace chemical materials will create a wide range of cradle-to-cradle conceptions from a consumer perspective and influence consumer attitudes. Furthermore, such efforts may lead to the greatest breakthroughs with regard to customers' opinions and awareness, as product packaging is the interface between products and consumers. Therefore, remodeling and searching for materials that have characteristics related to care for nature and the environment are needed to address environmental issues and promote sustainability through low-energy-intensive activities that have little impact on the atmosphere and the environment.

A healthy lifestyle (C6) has been a growing trend among consumers, and changing lifestyles and perceptions of health are always associated with food, in addition to exercise. A lifestyle is associated with consumers' experience and behavior in society regarding food products. Young consumers are more concerned about what they eat, and they seek more information related to products. With the assistance of technology and social media, healthier food is gaining in popularity, in addition to the intangible value offered by specific food products such as organic foods, which have lower environmental impacts. To that end, firms must implement technological innovation to offer the demanded products and incorporate the long lead-time natural resources that are extended into a complete SFS. For instance, social media marketing campaigns should be initiated by manufacturers in collaboration with the government and environmentally focused organizations to promote a healthy lifestyle, and it is important to recognize the intersection between food systems and the market demand for healthy products, as a set of dynamic trade-offs may arise. Furthermore, the production regulations in the private sector and community public health agencies facilitate the convergence between social marketing programs for healthy products.

Prices (C16) are the principal factor that customers consider in their purchase decision-making, and they ultimately influence sustainability. Customers' demand for sustainable products is expected if such products are priced at an affordable level. Despite the growing trend of sustainability in society, price is a major factor in customers' purchase decisions, especially in developing countries such as Thailand. A highly sustainable product at an affordable price will have better market penetration. Customers will be willing to spend their money on such a product, boosting satisfaction and loyalty. Firms adopt various strategies to enhance sustainability, but if they do not consider price, sustainability remains invisible and unattractive. The strategy of setting different affordable prices depending on social effectiveness and cultural marketing in individual countries is a good approach to obtaining a holistic SFS. Correspondingly, food product categories are targeted in accordance with the socioeconomic status of the marketplace. The combination of affordable prices and sustainable products increases the probability of obtaining first-time and returning buyers. In summary, by increasing the value offering suggested by affordable prices through society's hot sustainability trend, customers will be more willing to take more responsibility and jump on the environmentally friendly bandwagon, ultimately achieving an SFS.

6. Conclusions

Thailand's food industry must aggressively explore an appropriate way to transform the current food system into a more sustainable one. The current food system suffers from the generation of increasing food waste due to the boom in food services and delivery platforms under the uncertainties caused by the COVID-19 pandemic, causing environmental harm. To transform the food system into an SFS, this study considers the social effectiveness, economic benefit and environmental impact perspectives and obtains 9 aspects and a set of 26 valid criteria. The FDEMATEL method is used to describe the interrelationships among valid measurements. This approach analyzes qualitative information and converts customer preferences into practical outcomes. Qualitative information is collected based on experts' judgments and perceptions of the industry. The interrelationships among attributes, which reflect the contribution of this study to theory and practice, are focused on identifying and seeking ways to achieve an SFS in Thailand.

From a theoretical conceptualization, the interrelationships among the valid aspects in this study strengthen the discussion on SFSs. From the theoretical perspective, these interrelationships include behavioral change, distribution and storage, production assessment and governance. The production assessment and distribution and storage aspects provide the essential motivation to implement technological innovation and enrich the SFS. This study contributes to SFS knowledge and understanding. The cause-and-effect diagram in this study identifies that behavioral change and governance reduce the environmental impact and improve social effectiveness through health concerns by implementing technological innovation. In addition, production assessment and distribution and storage with the implementation of technological capability increase the economic benefits and reduce the harmful environmental impact of food waste. Suitable guidelines are provided for the food industry and organizations to pay close attention to these attributes to quickly and appropriately address unsustainable customer decisions resulting from health concerns to reduce harmful environmental impacts, thus improving the SFS.

The findings of this study on SFSs are necessary for food firms to take responsibility for environmental impacts by enhancing energy conservation and decreasing the destruction of natural resources. Organizations are responsible for producing sustainable products and improving the SFS in the industry by providing appropriate product labeling, product design, packaging material, a healthy lifestyle and prices. Organizations can improve food system practices by improving product labeling to support customers' understanding and awareness of sustainable products and reduced environmental harm through detailed information. Product design is a way to change potential production procedures to respond to environmental concerns by applying technological innovation and system development in organizational production processes. Packaging material helps organizations achieve sustainability through considering product materials to minimize the environmental footprint through the use of energy and money to transform waste into raw materials. Recycling can help reduce environmental impacts, generate economic benefits, and ensure social effectiveness. Setting affordable prices and targeting customers' desire for a healthy lifestyle are important factors in the SFS, considering customers' awareness of health concerns.

The analytical results have several limitations, which may prevent avenues for future research. In this study, the data collection involved only Thailand, and the scope of the industries involved was limited to hospitality. Limited experts were involved in the interviews. They provided fifty-one criteria, and the results showed that the total number of valid attributes was 26, which cannot be generalized to other food industries in other countries. Although this study comprehensively analyzed the literature to select the correct parameters to match the current situation, it was not possible to address all factors in this study. Future studies must obtain more detailed interrelationships among the aspects and collect key criteria and can consider larger numbers of attributes. They may involve more industry experts from other countries so that they can have more precise judgments and reflect subjective preferences. This eory should be enriched by future studies investigating SFSs to provide better solutions to problems in the industry.

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Tables and Figures

Table 1. SFS Attributes

Aspects		Criteria	Description	References
Behavior Change (A1)	C1	Consumer confidence	Confidence in sustainable product	Tseng et al. (2020)
	C2	Environment-friendly attitude	Attitude towards being environmentally sustainable	
	C3	Dependence on traditional market	Reliance on the purchasing of goods from conventional markets	
	C4	Dietary Health	A healthy diet is one that helps maintain or improve overall health	Rohmer et al. (2019)
	C5	Food promotion	As the exchange of messages intended to inform or promote the buying or use of a product or increase brand awareness, it has a significant influence on people's consumption patterns and is a prevalent feature of food environments.	Galli et al. (2020)
Green Food Consumption (A2)	C6	Healthy Lifestyle	Healthy and conscious diet are key attributes for green consumption	Lago et al. (2020)
	C7	Health Concern	Health concern works as a strong driver for green food purchases	
	C8	Knowledge about sustainability	People with a higher level of knowledge about sustainability tend to increase the consumption of green food products	
	C9	Food and Nutritional Security	Association of socio-cultural and sacred aspects of food	Niederle and Schubert (2020)
Distribution an Storage (A3)	C10	Delivery time	Represents the period of time between placing of orders and fulfillment of orders. It has been related to the online shopping experience of customers.	Sigurdosson et al. (2020)
Production assessment (A4)	C11	Product design	Usage of surplus production materials by organization for new goods	Tseng et al. (2020)
	C12	Packaging material	The use of recycled materials by the organization for food packaging	
	C13	Product labelling	The use of a sustainable logo and descriptive packaging details for organization	
	C14	Food Hygiene	The conditions and steps required to ensure food safety from processing to consumption.	Galli et al. (2020)
Governance (A5)	C15	Cost impact in purchase stage	External measure such as value added tax in economic measure	Herrero et al. (2021)
Quality Assessment	C16	Price	Represents the cost of food product in countries own currency	Sigurdosson et al. (2020)

(A6)	C17	Product rating	It shows how the fish product has been classified online by other customers and indicates their overall level of product satisfaction. Consumers with data limitations may use such product ratings as an indication of the preferences of other consumers.	
Food Waste (A7)	C18	Waste reduction	Waste reduction has appreciable effects on the green purchasing consumption	Sigurdosson et al. (2020)
	C19	Package recyclability	Package recyclability potential as an important attribute in green purchases	
	C20	Product Recycling	Sustainable customer intervention by product waste recycling	Tseng et al. (2020)
	C21	Product Reuse	Sustainable customer behavior by reusing existing products	
	C22	Food waste at retail and consumer levels	A prototype tested by experts was developed and then optimized based on the participation of the customer and the evaluation of energy-friendly activities in the usage process.	Sigurdosson et al. (2020)
Production Regulation (A8)	C23	Political engagement	Aesthetic reference of other food movements	Niederle and Schubert, 2020
	C24	General Food Law	The law controls the processing, trade and handling of food products and thus includes the management of the control of food products, the protection of food products, the consistency and related aspects of trade in food products across the whole food chain, from the provision of animal feed to the customer.	Galli et al. (2020)
Technology Capability (A9)	C25	Service design and innovation	The essence of service relationships is more thoroughly discussed in service design: person to human, human to machine, machine to machine and human to nature.	Camarena (2020)
	C26	Changes in technology	Changes in technology will affect the workforce	

Table 2. Linguistic terms

Linguistic terms (performance/importance)	Corresponding triangular fuzzy numbers
Extreme	(0.75, 1.0, 1.0)
Demonstrated	(0.5, 0.75, 1.0)
Strong	(0.25, 0.5, 0.75)
Moderate	(0, 0.25, 0.5)
Equal	(0, 0, 0.25)

Table 3. FDM result for criteria

Criteria		D_b
C1	Consumer confidence	0.512
C2	Environment-friendly attitude	0.528
C3	Dependence on traditional market	0.490
C4	Dietary Health	0.512
C5	Food promotion	0.497
C6	Healthy Lifestyle	0.537
C7	Health Concern	0.512
C8	Knowledge about sustainability	0.528
C9	Food and Nutritional Security	0.491
C10	Delivery time	0.512
C11	Product design	0.512
C12	Packaging material	0.507
C13	Product labelling	0.507
C14	Food Hygiene	0.512
C15	Cost impact in purchase stage	0.537
C16	Price	0.512
C17	Product rating	0.545
C18	Waste reduction	0.512
C19	Package recyclability	0.498
C20	Product Recycling	0.537
C21	Product Reuse	0.537
C22	Food waste at retail and consumer levels	0.512
C23	Political engagement	0.512
C24	General Food Law	0.507
C25	Service design and innovation	0.537
C26	Changes in technology	0.498
Threshold (γ)		0.426

Table 4. Linguistic preference scales from expert 1

R1	A1	A2	A3	A4	A5	A6	A7	A8	A9
A1	1	L	VHI	M	M	HI	HI	L	VL
A2	VHI	1	VL	HI	VL	VL	VHI	VL	M
A3	VL	VL	1	M	M	M	M	HI	VHI
A4	VL	VL	HI	1	HI	HI	VHI	VHI	VHI
A5	VHI	L	HI	M	1	HI	M	HI	M
A6	M	M	M	L	VL	1	VL	M	HI
A7	HI	VHI	HI	M	HI	M	1	HI	M
A8	VHI	L	M	VL	HI	VL	VHI	1	VL
A9	HI	M	VHI	VHI	L	VL	HI	M	1

Table 5. Average initial direct-relation matrix of aspects

	A1	A2	A3	A4	A5	A6	A7	A8	A9	Row
A1	0.841	0.385	0.320	0.354	0.460	0.466	0.517	0.380	0.397	4.121
A2	0.295	0.890	0.320	0.366	0.379	0.359	0.372	0.380	0.416	3.777
A3	0.303	0.417	0.875	0.546	0.419	0.471	0.283	0.412	0.456	4.182
A4	0.342	0.358	0.431	0.863	0.358	0.360	0.423	0.444	0.520	4.100
A5	0.408	0.424	0.410	0.370	0.899	0.449	0.366	0.316	0.422	4.065
A6	0.404	0.355	0.377	0.396	0.279	0.862	0.424	0.294	0.461	3.853
A7	0.310	0.455	0.456	0.040	0.040	0.463	0.877	0.368	0.418	3.426
A8	0.348	0.409	0.468	0.040	0.040	0.219	0.413	0.854	0.282	3.072
A9	0.418	0.417	0.435	0.040	0.040	0.392	0.456	0.429	0.897	3.524
								MAX		4.182

Table 6. Total interrelationship matrix of aspect

	A1	A2	A3	A4	A5	A6	A7	A8	A9
A1	1.183	1.199	1.169	0.836	0.830	1.198	1.241	1.124	1.240
A2	0.943	1.233	1.067	0.771	0.740	1.063	1.093	1.029	1.139
A3	1.059	1.234	1.348	0.919	0.839	1.223	1.196	1.161	1.287
A4	1.039	1.181	1.194	0.967	0.791	1.155	1.202	1.137	1.266
A5	1.063	1.205	1.190	0.844	0.950	1.188	1.189	1.100	1.243
A6	1.001	1.115	1.112	0.800	0.728	1.230	1.139	1.030	1.183
A7	0.845	1.002	0.993	0.592	0.558	0.982	1.114	0.917	1.018
A8	0.083	0.098	0.112	0.010	0.010	0.052	0.099	0.204	0.067
A9	0.100	0.100	0.104	0.010	0.010	0.094	0.109	0.103	0.214

Table 7. Aspect's cause and Effect

	(α)	(β)	$(\alpha+\beta)$ (Casual)	$(\alpha-\beta)$ (Effect)
A1	10.0192	8.7961	18.8153	1.2231
A2	9.0790	10.0710	19.1500	-0.9919
A3	10.2667	9.9800	20.2467	0.2868
A4	9.9327	6.8580	16.7907	3.0746
A5	9.9712	6.5045	16.4757	3.4667
A6	9.3374	9.8325	19.1699	-0.4951
A7	8.0215	10.0889	18.1104	-2.0674
A8	7.0769	9.4106	16.4875	-2.3337
A9	8.2533	10.4163	18.6696	-2.1630

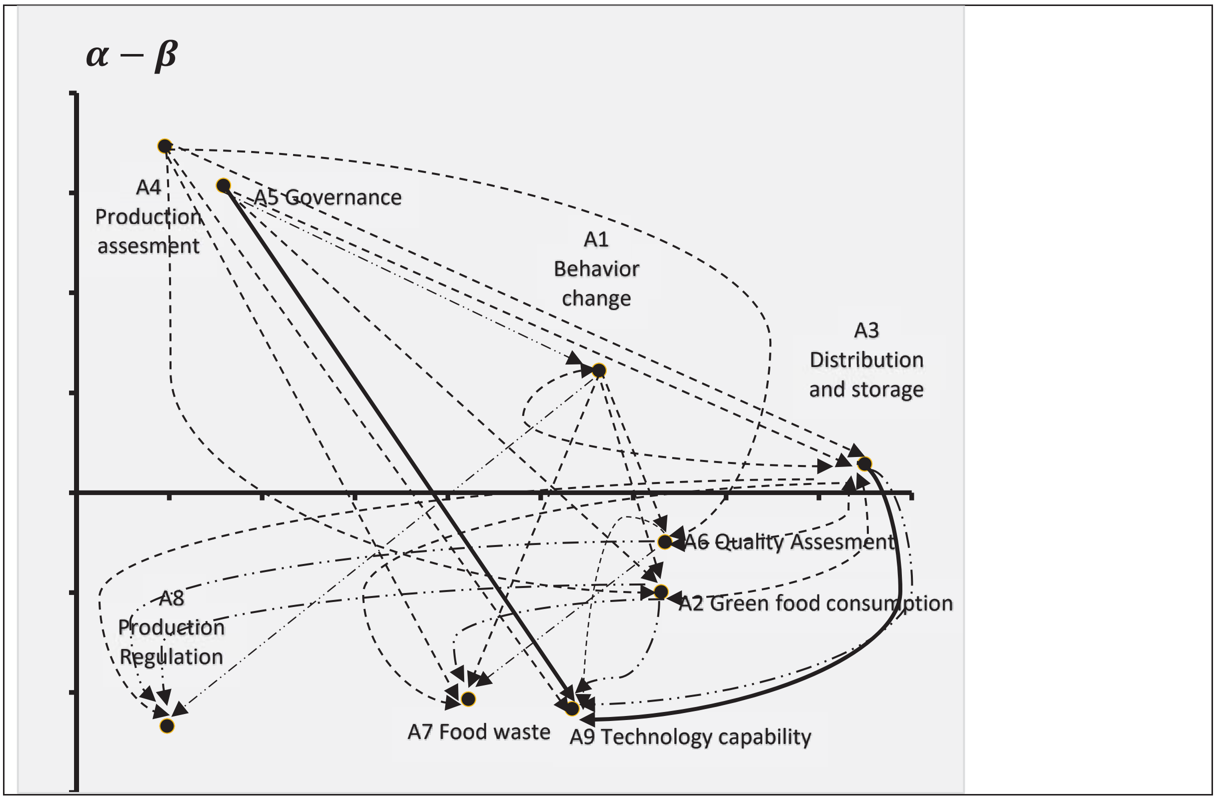

Figure 1. Aspects' causal-effect diagram

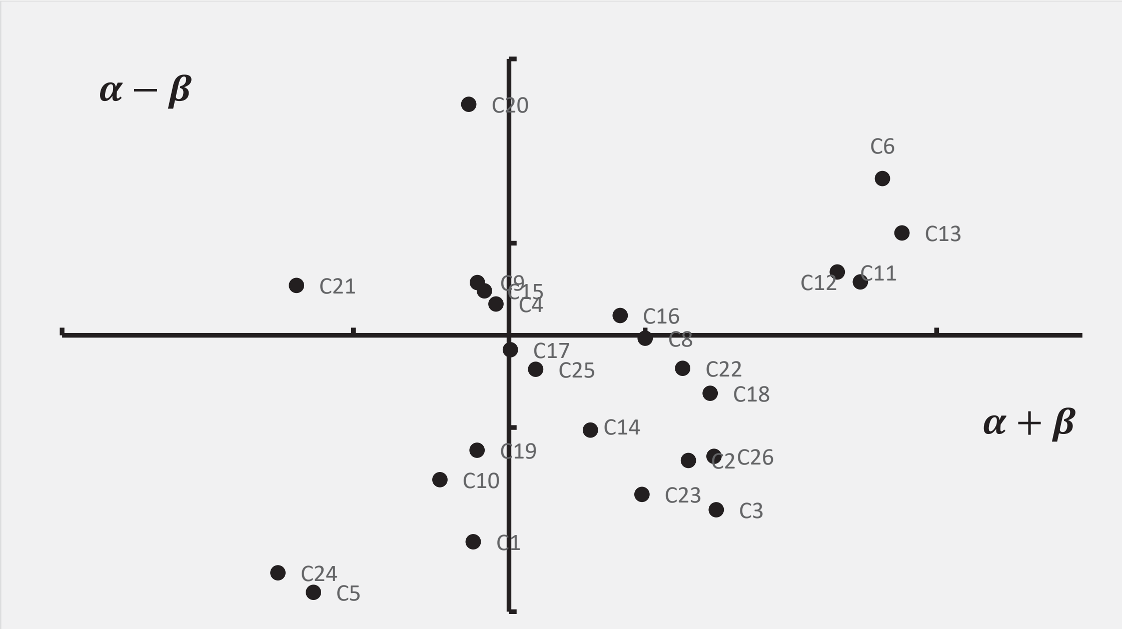

Figure 2. Cause-effect diagram for criteria

Appendix

Appendix 1. Original Table of Measurement

Aspects	Original Criteria		Description	Reference
Behavior Change	OC1	Consumer confidence	Confidence in sustainable product	Tseng et al. (2020)
	OC2	Resource-efficient attitude	Attitude towards successfully leveraging capital to minimize waste	Niederle and Schubert (2020)
	OC3	Environment-friendly attitude	Attitude towards being environmentally sustainable	Camarena (2020)
	OC4	Dependence on traditional market	Reliance on the purchasing of goods from conventional markets	Rohmer et al. (2019)
	OC5	Diet and nutrition	Ingredient substitution to adapt cuisine to local ingredient	Paciarotti and Torregiani (2021)
	OC6	Dietary Health	A healthy diet is one that helps maintain or improve overall health.	Galli et al. (2020)
	OC7	Cultural Diversity	State or fact of portraying all cuisines and cultures as distinct or varying.	Lago et al. (2020)
	OC8	Food promotion	As the exchange of messages intended to inform or promote the buying or use of a product or increase brand awareness, it has a significant influence on people's consumption patterns and is a prevalent feature of food environments.	
	OC9	Corporate Social Responsibility	As this sector has a heavy influence and a high reliance on the market, the climate and culture, it is highly important to food companies.	
	OC10	Food fortification	The addition of nutrients to foods, regardless of whether the nutrients were initially present in the food or not.	
Green Food Consumption	OC11	Healthy Lifestyle	Healthy and conscious diet are key attributes for green consumption.	
	OC12	Health Concern	Health concern works as a strong driver for green food purchases.	
	OC13	Guilt/social pressure	Social pressure exerted by others works as a green consumption driver	
	OC14	Knowledge about sustainability	People with a higher level of knowledge about sustainability tend to increase the consumption of green food products.	
	OC15	Food and Nutritional Security	Association of socio-cultural and sacred aspects of food.	
Distribution and Storage	OC16	Delivery time	Represents the period of time between placing of orders and fulfillment of orders. It has been related to the online shopping experience of customers.	Sigurdosson et al. (2020)
	OC17	Production-consumption reconnection	Sociability and non-market partnerships with providers	Niederle and Schubert, 2020
Production	OC18	Product design	Usage of surplus production materials by	Tseng et al.

assessment			organization for new goods.	(2020)
	OC19	Packaging material	The use of recycled materials by the organization for food packaging.	
	OC20	Product labelling	The use of a sustainable logo and descriptive packaging details for organization.	Sigurdosson et al., 2020
	OC21	Procurement method	Indicates the fish sources of production. The importance of this attribute is demonstrated by study, as a growing number of customers are interested in learning how fish are made. Using this characteristic, consumers prefer to judge the flavor of fish products. Consumers are deeply involved in topics of ecology and ethics.	Galli et al. (2020)
	OC22	Food Hygiene	The conditions and steps required to ensure food safety from processing to consumption.	Paciarotti and Torregiani (2021)
	OC23	True cost Pricing	The discrepancy between a commodities's selling price and the maximum cost to society of the commodity. Normally, the term is used to attract attention to lost or secret expenses that are not found in the retail price, even though it may also potentially refer to hidden gains.	Herrero et al. (2021)
	OC24	Biodiversity strategy	The Biodiversity Plan attempts to avoid the depletion of biodiversity and ecosystem resources.	
Governance	OC25	Food ethics	An interdisciplinary area offering ethical interpretation and instruction in the cultivation, delivery, preparation and use of food for human behavior.	
	OC26	Accountability	Acknowledgment of milestones and success compliance through the application.	
	OC27	Fair trading practices	The price we pay for commodities allows farmers enough for them to afford the necessities of life - such as food, education, and healthcare.	
	OC28	Cost impact in purchase stage	External measure such as value added tax in economic measure.	
Quality assessment	OC29	Environmental concern	Environmental concern is strongly related to green purchases	Lago et al. (2020)
	OC30	Environmental labels	Environmental labels are used by consumers as a proxy to assess product quality	Rohmer et al. (2019)
	OC31	Green pack	Green packaging serves as an opportunity to consume green food.	Sigurdosson et al. (2020)
	OC32	Cleaner production practices	The qualities of green food use are respected by healthier manufacturing practices.	Tseng et al. (2020)

	OC33	Price	Represents the cost of food product in countries own currency.	Niederle and Schubert, 2020
	OC34	Product rating	It shows how the fish product has been classified online by other customers and indicates their overall level of product satisfaction. Consumers with data limitations may use such product ratings as an indication of the preferences of other consumers.	Galli et al. (2020)
	OC35	Item signage	Indicates whether or not the product is listed as the bestselling, the preference of the store, or not. It suggests peer customer purchasing or none of these guidelines for the fish commodity or shop.	Camarena (2020)
	OC36	Purchase state	Represents the fish product's handling conditions as it is imported. This characteristic is used by consumers to determine the inherent consistency, protection, nutritional value, naturalness and essence of the product's food safety.	
Food Waste	OC37	Waste reduction	Waste reduction has appreciable effects on the green purchasing consumption.	
	OC38	Package recyclability	Package recyclability potential as an important attribute in green purchases.	
	OC39	Product Recycling	Sustainable customer intervention by product waste recycling.	
	OC40	Product Reuse	Sustainable customer behavior by reusing existing products.	
	OC41	Food waste at retail and consumer levels	A prototype tested by experts was developed and then optimized based on the participation of the customer and the evaluation of energy-friendly activities in the usage process.	
Production regulation	OC42	Country of origin	Indicates the regional location of the product of the fish. Evidence indicates that it is used by customers to measure the consistency and food safety threats of fish products.	
	OC43	Political engagement	Aesthetic reference of other food movements	
	OC44	General Food Law	The law controls the processing, trade and handling of food products and thus includes the management of the control of food products, the protection of food products, the consistency and related aspects of trade in food products across the whole food chain, from the provision of animal feed to the customer.	
Technology capability	OC45	Designing for systems of smart things	Design of related, immersive devices using approaches focused on systems.	
	OC46	Service design and innovation	The essence of service relationships is more thoroughly discussed in service	

			design: person to human, human to machine, machine to machine and human to nature.
	OC47	Changes in technology	Technology developments will impact the workforce.
Energy Consumption	OC48	Climate Change	Effects of the environmental measure used on the global atmosphere associated with categorized food production.
	OC49	Water use	Effect on food processing-related regional and global waterbodies.
	OC50	Land use	Widely used impacts that are directly linked to food processing on regional environments.
	OC51	Fossil Fuel Depletion	Effect on the primary sector's raw material supplies related to food processing

Appendix 2. Driving and dependence power of criteria

	α	β	α+β	α-β
C1	10.145	11.266	21.411	(1.121)
C2	10.734	11.414	22.148	(0.680)
C3	10.648	11.596	22.244	(0.947)
C4	10.829	10.659	21.488	0.170
C5	9.733	11.129	20.862	(1.395)
C6	11.833	10.982	22.814	0.851
C7	9.952	4.672	14.624	5.280
C8	10.992	11.009	22.001	(0.017)
C9	10.856	10.569	21.425	0.287
C10	10.256	11.040	21.296	(0.783)
C11	11.501	11.158	22.659	0.343
C12	11.514	11.224	22.738	0.290
C13	11.718	11.163	22.881	0.555
C14	10.649	11.163	21.812	(0.514)
C15	10.845	10.603	21.448	0.242
C16	11.011	10.903	21.914	0.107
C17	10.729	10.809	21.538	(0.079)
C18	10.954	11.269	22.223	(0.315)
C19	10.400	11.024	21.424	(0.623)
C20	11.325	10.070	21.395	1.254
C21	10.537	10.267	20.804	0.270
C22	10.975	11.154	22.129	(0.180)
C23	10.562	11.426	21.989	(0.864)
C24	9.726	11.015	20.741	(1.289)
C25	10.720	10.905	21.624	(0.185)
C26	10.790	11.446	22.236	(0.657)
Maximum			22.881	5.280
Minimum			14.624	(1.395)
Average			21.533	(0.000)

Appendix 3. Expert's Demographic

Expert	Position	Education levels	Years of experience	Organization type (academia/practice)
1	Associate Professor, Department of Environmental Engineering	Ph.D.	8	Academia
2	Assistant Professor, Department of Natural Resources	Ph. D	6	Academia
3	Lecturer, Department of Mechanical & Production engineering	Ph. D	5	Academia
4	Lecturer, Department of Mechanical & Production engineering	Ph. D	5	Academia
5	Lecturer, Department of Mechanical & Production engineering	Ph.D.	3	Academia
6	Researcher of food portions reduction	Ph. D	11	Academia
7	Researcher of food portions reduction	Ph. D	9	Academia
8	Researcher of the strategies to reduce food crisis	Master	11	Academia
9	Researcher of the strategies to reduce food crisis	Master	12	Academia
10	Researcher of the strategies to reduce food crisis	Master	6	Academia
11	Assistant manager of Guest Services Associate	bachelor	5	Government office
12	Chief Executive manager	Master	10	Government office
13	General manager of Guest Services Associate	Master	11	Government office
14	Senior Executive manager of Guest Services Associate	Master	9	Practices
15	Senior manager of Café	bachelor	8	Practices
16	Senior manager of Research and Development in Food industry	bachelor	9	Practices
17	Senior manager of Lobby & Lounge	bachelor	10	Practices
18	Senior manager of Research and Development food scientist	Master	10	Practices
19	Manager of production wedding event	Master	9	Practices
20	Manager of Food and Beverage	Master	10	Practices
21	Manager of Guest Services Associate	bachelor	11	Practices
22	Senior manager of Kitchen	bachelor	10	Practices
23	Senior manager of Kitchen	bachelor	11	Practices
24	Flight Attendant	bachelor	4	Practices
25	Flight Attendant	bachelor	5	Practices
26	Staff of Front Dist. Associate in Hotel service	bachelor	2	Practices
27	Project manager of Catering	Master	8	Practices

28	Project manager of Catering	Master	9	Practices
29	Manager of food operation	bachelor	5	Practices
30	Executive kitchen manager	bachelor	9	Practices