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Tseng, M-L, Lim, M, Wong, W-P, Chen, Y-C & Zhan, Y

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A framework for evaluating the performance of sustainable service supply chain management under uncertainty

Abstract

Developing and accessing a measure of sustainable service supply chain management (SSSCM) performance is currently a key challenge. The main contributions of this study are two-fold. First, this paper provides valuable support for SSSCM regarding the nature of network hierarchical relations with qualitative and quantitative scales. Second, this study indicates the practical implementation and enhances management effectiveness for SSSCM. The literature on SSSCM is very limited and performance measures need to have a systematic framework. The purpose of this study is to develop and evaluate the SSSCM importance based on aspects i.e., environmentally conscious design, environmental service operations design and environmentally sustainable design. This paper developed a hierarchical network for SSSCM in a closed-loop hierarchical structure. A generalized quantitative evaluation model based on the Fuzzy Delphi Method and Analytical Network Process were then used to consider both the interdependence among measures and the fuzziness of subjective measures in SSSCM. The results indicate that the top-ranking aspect to consider is that of environmental service operation design, and the top criteria is reverse logistics integrated into service package

Keywords: sustainable design; fuzzy set theory; fuzzy Delphi method (FDM); analytical network process; sustainable service supply chain management.

A framework for evaluating the performance of sustainable service supply chain management

1. Introduction

The Taiwanese electronic industry is vital to the supply of raw materials and economic development worldwide. In recent decades, the industry has responded to challenges by incorporating boundary-spanning activities in green supply chain practices (Zhu et al., 2010; Zhu et al., 2013; Tseng et al., 2014a). Indeed, the transformation of industrialized economies into a service orientation is a continuing process, and the most influential marketing ideas in the business succeed in meeting customer needs (Levitt, 1960; van der Zwan and Bhamra, 2003). Service benefits apply selected best practices from the manufacturing industry, and the differences between the service and manufacturing industries create a need for specific supply chain management of service measures. Still, service supply chain practices must move toward sustainability because as a component of their business evaluation process, contemporary firms review their performance in environmental quality and social benefits as a means to economic prosperity and strive to adopt sustainable services and products to satisfy consumer environmental awareness (Cronin et al., 2011; Keating et al., 2008). Boonitt and Pongpanarat (2011) and Cho et al. (2012) developed a framework for service supply chain performance measurement and emphasized performance measures in addressing the service supply chain processes. Moreover, sustainable service is a component of sustainable plans and operation that could decrease negative environmental impact and provide improved social and environmental benefits to consumers and producers (Kotler et al., 2010; López and Zúñiga, 2014). Nevertheless, there is a lack of literature on sustainable service supply chain management (SSSCM)

In light of the increasing attention on sustainable supply chain management by both practitioners and academics, Azapagic (2004) developed a sustainable framework consisting of economic, environmental, social and integrated indicators that can be used internally (i.e., to identify hot spots) and externally with stakeholders. Abbasi and Nilsson (2012) presented a logistics sustainability systematic structure that efforts in addressing sustainable supply chain management challenges. Inadequate marketing efforts for services are rather unhelpful for manufacturers and do not fully encompass the complex nature of services in supply chain management (Anttonen et al., 2013). Thus, SSSCM material remains rare in the literature. Service supply chains consist as gigantic supportive subsystems in massive sustainable processes and uses of resources, which induce the management to attention and design on their sustainable service development. To realize sustainable design, the firms must create and implement service sustainability measures (Arnette et al., 2014). The view of sustainable service design needs to include the philosophy of design of physical objects, life cycle assessments, the built environment, and services configuration that comply with the sustainable service in their supply chain management (Kimita et al., 2009; Wang et al., 2010; Tseng et al., 2013a).

The complexity of problems and inherent challenges makes SSSCM a priority for action, but design of policy initiatives is quite difficult. A need exists for composing an analytical framework that consider the complexity involved, include the holistic aspects and criteria, and challenge the interdependence of hierarchical relationships. The operationalization of sustainability in service supply chains is another challenge that has emerged from industrial systematic synthesis of the relevant literatures (Löfberg et al., 2010; Wang et al., 2010). Therefore, this study aims to identify the holistic SSSCM attributes that are important in the industry (Lin and Tseng, 2014). Many previous studies have investigated the design for sustainability concept to reduce environmental impact (Tseng et al., 2009a; Zhu et al., 2010; Zhu et al., 2013; Matthews et al., 2014). Wang et al. (2010) suggested that sustainable design occurs through environmental service operations design, environmentally sustainable design and environmentally conscious design (Bovea and Perez-Belis, 2012; Arnette, 2014). Hence, the current study proposes an evaluation framework, and the assessment remains unexplored.

Within the literature, there are rare references to the SSSCM. Hence, the authors of this study believe that certain concepts, frameworks and theories present within SSSCM are of use for academics as well as practitioners in the shift from products and services. This study aims to demonstrate how the SSSCM can contribute to the debate on sustainability and proposes a fuzzy Delphi method (FDM) to screen alternative attributes in the first stage to address the fuzziness of common understanding of expert opinions (Noorderhaben, 1995) and present a hierarchical framework. Additionally, to address the hierarchical framework, the analytical network process (ANP) is used to process interdependent relationships in a complex environment (Tseng et al., 2013b). To address information complexity and uncertainty, this study proposes the use of fuzzy set theory to transform linguistic preferences into comparable crisp values. However, few existing SSSCM reports have presented evaluation of the qualitative and quantitative information together in a hierarchical framework. To this end, this study will answer the following questions:

- What framework and techniques are available within service supply chain management that can aid academics in studying sustainability?
- What are the important aspects and criteria for SSSCM under linguistic preferences and operations information?

The study is organized as follows. Firstly, this work reviews the literature on theoretical determination of sustainable service, sustainable supply chain management, and sustainable service supply chain management and their different approaches. Secondly, this study constructs a framework with a set of aspects and criteria. Thirdly, this study carries out an industrial analysis and proposes the use of the fuzzy Delphi method, fuzzy set theory, and a closed-loop analytical network process. The final section summarizes the main conclusions and results, theoretical and managerial implications, and insights for further studies.

2. Literature Review

This section introduces the concepts of sustainable service, sustainable supply chain management, and the proposed aspects and criteria.

2.1 Sustainable services

Sustainable services are described as "*offerings that satisfy customer needs and significantly improve the social and environmental performance along the whole life cycle in comparison to conventional or competing offers*" (Belz and Frank-Martin, 2009). Firms must be able to clearly show how their services deliver both economic and ecological benefits. This statement is supported by the study of Brindley and Oxborrow (2014) in which suppliers are required to meet sustainable procurement requirements and the organizational challenges of aligning marketing with sustainable supply chain management. Anttonen et al., (2013) indicated that it is crucial to achieve result-oriented material efficiency services among the customers. It is driven by the legislative, market-based and cost-efficiency motivations, which suggested that material efficiency is closely associated with cost-efficiency from the customer operations' perspective. Furthermore, the study noted that mismatches occur between the services supplied and the customer needs. Hence, service supply chain management must properly address this aspect in future studies.

In addition, Prakash (2002) suggested that organizations could become greener at the firm level without attention to the supply chain by adding value and using management systems or at the product level by designing new products or processes. Tseng et al. (2009b) presented a supply chain that emphasizes on multiple customer-supplier dyads, spanning from the raw material extractors to the end customers. However, the level of customer satisfaction plays an important role in compensating on compromises on the value of the products. Kimita (2009) proposed a function parameter model used to express the changes in customer demands resulting from the quality of services and how services can create value continuously throughout the entire lifecycle. Large et al. (2013) showed that five activities improve logistics services and sustainable development, i.e., reduction of transportation intensity and emissions, reduction of the use of land, choice of carrier, permanent improvement of working conditions, and finally, enhancement of employment.

The literature has argued that sustainable service must be understood at an even higher level of analysis, i.e., network or stakeholder analysis. More specifically, this sustainability issue addresses the complex environmental and social consequences of industrial activities, the role of innovation in environmental management and sustainability, and ecosystems based on stakeholders connected through resources. In working towards sustainable supply chains, a lack of engagement by top management makes supply chains environmentally unsustainable due to the number of attributes that must be coordinated in their firms (Murphy Richard, 2003; Preuss, 2009). Sustainable service is always tied to uncertainty. For instance, Inderfurth (2005) argued the uncertainty in returns and demands as an obstacle to following an environmentally benign recycle/reuse/remanufacturing strategy within reverse logistics. Many studies have addressed a number of uncertainties related to services and decision-making, consumer behavior and demands, as well as competitive advantages and strategies (Green et al., 1998; Haake, H. and Seuring, 2009; Lin and Tseng, 2014). In addition, the impression that uncertainty is also a barrier to service is unclear in the literature (Tseng et al., 2009a; Tseng et al., 2010; Tseng et al., 2013b; Tseng et al, 2014b). As mentioned previously, sustainable service suffers from the impression that it must apply the lifecycle assessment for products, control costs in the entire service process, and change approaches to stakeholders (e.g., suppliers, customers and communities).

2.2 Sustainable supply chain management

The principles of sustainable development have been widely debated in the logistics and supply chain field (Carter and Rogers, 2008), and such concepts as sustainable supply chain management (Seuring and Muller, 2008; Lin and Tseng, 2014), green purchasing (Min and Galle, 1997; Green et al., 1998; Prakash, 2002), green supply chain management (Tseng et al., 2011; Tseng et al., 2014c) and reverse logistics (Govindan et al., 2015) have been presented in the literature. Zhu and Sarkis (2004) claimed that the concept of greening the supply chain is primarily a discussion on the assessment of the impact of environment on logistics. Therefore, an increasing awareness exists among consumers on both sustainability issues and actions that the supply chain management has adopted. Sustainable supply chain management is defined as *"the strategic, transparent integration and achievement of an organization's environmental, social and economic goals in the systematic co-ordination of key inter-organizational business processes for improving the long-term economic performance of the individual company and its chains"* (Carter & Rogers, 2008).

In addition, Atasu et al. (2008) emphasized the important characteristics of a remanufactured product, i.e., low cost, lower valuation and supply constraints. In addition to analyzing the profitability of remanufacturing systems for a different cost, technologies and logistics, the structures address the demand-related issues. However, low-cost competition is not the only way to push the products or services into the competitive market, and other alternatives must be considered for tradeoffs in sustainable design (Schwartz et al., 2014; Lin and Tseng, 2014). In contrast, this study aims to achieve an integrated solution to meet customer demands and shifted away from the organization's environmental, social and economic-goals-based servicing. The resulting sustainable supply chain management is able to produce synergies in profit, competitiveness and environmental benefits due to the opportunities that arise from a framework that addresses sustainable service and sustainable supply chain management together.

The best practices from manufacturing and integration between services and manufacturing processes create a need for specific aspects and criteria that reflect sustainable services and sustainable supply chain management practices (Boonitt and Pongpanarat, 2011). Nonetheless, only a few studies have identified service activities under sustainable supply chain management together with a hierarchical structure and uncertainty. A limited understanding of the hierarchical structures has hindered the development of an accepted framework that is able to characterize and categorize design for sustainability in services.

2.3 Sustainable service supply chain management

In industrial practices, tremendous pressures are imposed on both businesses and governments to reduce the environmental impact of their production and consumption, which leads to an increasing awareness of a sustainable future. Belz and Frank-Martin (2009) reported comparison of a number of strategic options, including fostering innovation and technologies, product quality, design for customer needs, cost leadership and delivery time needed to compete through services that enable manufacturers to earn potential profits. Löfberg et al., (2010) stated that the firm's choice of service plan appears to be influenced by its position in the supply chain. Whereas the firms were all characterized as post-sales service providers, the suppliers were viewed as either development partners or owners of a customer service plan. In addition, Hörte and Halila (2008) suggested that eco-service (eco-is a combination of ecology and economy) complexity derives from technology, reorganization of customer relationships, service process and the need for skillful staff. The firms move resources back into production processes, and in wholesale and retail planning of logistics, the facilities and outlets are still focused on innovative services. Previous studies have argued for the benefits of innovative service offerings and more advanced services that focus on customer processes (Gebauer et al., 2004; Tseng et al., 2008; Tseng 2009). The common belief is that a service-oriented manufacturer holds a competitive advantage in the long-term supply chain network that leads to improved performance.

Moreover, effective service management is not easily achieved, and neither integration into a firm, which include the competitive intensity in the product and service fields, the price sensitivity of customers, the strategic choices of customers, the service demands from customers, and market growth. Gebauer et al. (2010) argued that customers demand services that represent product-related service offerings of many firms and must include such customer-related services as preventive maintenance and process-oriented consulting services to stay competitive in the sustainable market. Sustainable and ongoing service improvement must be integrated into the operational process. To do so, the firms must address numerous issues in relation to improvement programs. However, many complicated and uncertain market or service conditions still exist in the industry. For instance, Anttonen et al. (2013) showed that inadequate marketing efforts in certain services are rather passive because of their complex nature. The firms are also cautious in marketing because innovative services are either still in new business development or only targeted for certain customers (Delmas and Montiel, 2009).

In the sustainability literature, the concept of “sustainable development” led to the term “Triple Bottom Line”, which refers to the three E's of ecology (environmental protection), equity (social equity), and economy (economic growth). This term appeared in 1990 and was widely used among professionals in environmental and development circles (Elkington, 1998; Seuring and Muller, 2008; Lin and Tseng, 2014). For instance, Veleva et al. (2001) argued that sustainability should also include economic and social measures and consists of five levels for categorizing the existing indicators relative to the basic principles of sustainability. Tseng (2013c) presented indicators or constraints for sustainable production measures to emphasize the environmental aspects of production and results, i.e., design of green products that can be disassembled (reused or recycled and free from hazardous materials), such that the marketing manager can assist in improving their operations. Still, an increasing number of studies have analyzed and discussed sustainability from the service and supply chain management perspectives. As firms seek to achieve sustainability in their service supply chains, their natural first step is to focus on their direct supplier and customer relationships (Lin and Tseng, 2014; Murphy and Richard, 2003; Tseng, 2009).

Therefore, the objective of this study is to define the SSSCM as “*offering the environmental designs to decrease negative environmental impact while providing improved stakeholders and environmental benefits to consumers and producers along the life cycle assessment in the entire service supply chain network*”. As the role of sustainability in business has grown, the recognition that design for the environment plays a key role to achieving sustainability has become undisputable. Figure 1 presents the sustainable services identified in the supply chain process.

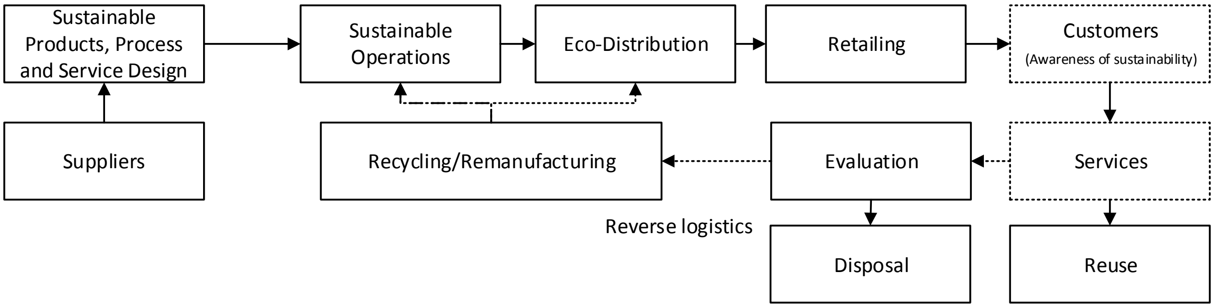

Figure 1. Sustainable service supply chain management

2.4 Proposed aspects and criteria

The original design-for-environment approaches were created as a means of making the operational and production aspects of product creation more eco-efficient and reducing time, cost, and impact on the environment. Moreover, supply chain management originates in part from the concept of minimizing waste because waste reduces economic profitability (Tseng et al., 2009). This study links to design for sustainability in service supply chain management, including operations design, sustainable design and conscious design in the environment, which are adequate to explain the SSSCM (Cronin et al., 2011; Cho et al., 2012; Bovea and Perez-Belis, 2012; Arnette, 2014).

From the viewpoint of environmentally sustainable design, this study is focused on strategic planning for corporate sustainability in improving service during the product eco-design stage for the benefit of the customers, the environment and the firm. This performance will be achieved by annual growth in revenue and service cycle processing time while progressively reducing ecological impacts and resource intensity throughout the supply chain (Tseng et al., 2009a; Tseng 2013). The firm must improve its capabilities in terms of management executives, industrial collaborators for services, and product innovation programs (Kimita et al., 2009) and abide by environmental regulations and policies. In reality, three issues impact eco-products or sustainable services, namely, maintainability (eco- and socio-efficiency increases for economic sustainability), reliability (waste volume decreases) and serviceability (service orientation in products and customer requirements) (Dyllick and Hockerts, 2002). Sustainability design can be considered as the ability of the system to collaborate planning, forecasting, and replenishment with the suppliers. The second approach (incremental waste control throughout the lifecycle) is based on the premise that the current process cycle is impacted by a certain amount of negative impact. This impact can be reduced or cleared up based on selected improvements in technology known as incremental total supply chain cycle time.

In environmental service operations design, we attempt to examine sustainability and design for the environment from different sustainable service and supply chain management points of view. Tseng et al., (2009a) demonstrated that green design in operations and products are important for the firm's continuous improvement in a competitive and sustainable market with a great emphasis on decreasing the generation of toxic and hazardous and carbon emissions in the environment. However, green purchasing and supply activities within dyads involve both one-off and long-term exchanges. Green purchasing and sourcing decisions typically involve internal buying processes that usually associate with direct suppliers (i.e., dyadic relationships, including reverse logistics) (Kannan et al., 2009), supplier selection (Tseng et al., 2009b), environmental certificates, environmental information systems, corporate social responsibility promotion, and employee volunteer hours (Van Weele, 2010; Miemczyk et al., 2012). Sustainable services are needed to satisfy the customer needs and improve social and environmental performance over the entire lifecycle (vs. competitors) to survive in the competitive market (Tseng et al., 2008). In the firm's view, certain products and services offered together have a higher added value and a smaller environmental impact compared with those of rivals. Hence, service quality cost comparison and service output must be improved in the supply chain cycles.

Finally, environmentally conscious design is a view of manufacturing that includes the social, technological and innovative services aspects of design, synthesis, processing, and use of products in continuous or discrete manufacturing industries (Tseng, 2009). Sustainable production means that green products are designed, produced, distributed, used and disposed of with minimal environmental and occupational health damage and maximum use or reuse of resources, activities that include monitoring the product lifecycle assessment in the design supply chain stage (Nunn, 2010). Benefits include safer and cleaner production in the downstream and upstream of the supply chain, improved health and safety of customers and employees, reduced future costs for disposal, employee and customer awareness of environmental issues, improved eco-product quality and services at lower cost, community investment in sustainability, social impact of the business and increased environmental and business performance (Tseng et al., 2014a;c). Environmentally conscious technologies and service design practices allow manufacturers to minimize waste and to turn waste into a profitable product (Zhang et al., 1997). To effectively protect the environment, pollution control must be incorporated into manufacturing technology to promote and integrate the supplier's operational procedures and encourage learning and growth for stakeholders.

In summary, this study proposes SSSCM aspects and criteria to satisfy the needs of sustainable service and sustainable supply chain management using the prior literature and information from operations that points toward eco-effectiveness and socio-effectiveness in the SSSCM. Nevertheless, the majority assumes that a set of well-defined and harmonized aspects and criteria is the only way to make SSSCM measurable (Tseng 2014b). These aspects and criteria are expected to be identified and adjusted through empirical observations.

3. Method

This section reports on the methods and describes how these methods are applied in the study and in the proposed analytical steps.

3.1 Transformation of the quantitative scales

The data from the operational measures are characterized with various units that cannot be directly compared with other scales. Hence, the operational data must be transformed to achieve unit-free criteria and comparable values. The transformed crisp values of T_{ij} are calculated using Eq. (1) (Tseng et al., 2013b).

$$T_{ij} = \left(t_{ij}^N - \min t_{ij}^N\right)/\left(max\ t_{ij}^N - \min t_{ij}^N\right)\ T_{ij} \in (0,1); N = 1,2, \dots n \quad (1)$$

where $\max T_{ij}^N = \max\{t_{ij}^1, t_{ij}^2, \dots . t_{ij}^N\}$ and $\min T_{ij}^N = \min\{t_{ij}^1, t_{ij}^2, \dots .. t_{ij}^N\}$

3.2 Fuzzy Delphi method

Murry et al. (1985) proposed integration of the traditional Delphi Method with fuzzy theory to improve the vagueness of the method. In acknowledging the drawbacks of the traditional Delphi method, many scholars have attempted to improve on this method using a fuzzy environment.

A fuzzy set $\tilde{A}$ in the universe of discourse X is characterized by the membership function $\mu_{\tilde{A}}(\mathrm{x})$ that assigns to each element x in X a real number in the interval [0, 1]. The numerical value of $\mu_{\tilde{A}}(\mathrm{x})$ represents the membership grade of x in $\tilde{A}$ (Triantaphyllou & Lin, 1996; Lu et al., 2007). Table 1 presents the corresponding TFNs with linguistic preferences (Wu et al., 2010).

Table 1. The linguistic scales and the TFNs

Linguistic terms	Linguistic values
Extreme Important	(0.75, 1.00, 1.00)
Demonstrated Important	(0.50, 0.75, 1.00)
Strong Important	(0.25, 0.50, 0.75)
Moderate Important	(0.00, 0.25, 0.50)
Equal Important	(0.00, 0.00, 0.25)

The TFN is based on a three-value judgments: the minimum possible value l_1, the mean possible value m_2 and the maximum possible value u_3. These values depend on the linguistic preferences. We assume that the significance value of a number of j elements given by a number of i experts is $\tilde{x} = (l_{ij}, m_{ij}, u_{ij})$, then $i=1,2,3,\dots.n$ and $j=1,2,3,\dots.m$. The weighting $\tilde{a}_j$ of j elements is $\tilde{x}_j = (l_j, m_j, u_j)$, wherein $l_j = min\{l_{ij}\}$, $m_j = \frac{1}{n}\sum_1^n m_{ij}$ and $u_j = max\{u_{ij}\}$. The definite value $\tilde{R}_j$ is obtained using the simple center of gravity method to defuzzify the fuzzy weight $\tilde{x}_j$..

The proper criteria can be screened from numerous criteria by setting the threshold α. The principles of screening are described as follows: If $\tilde{R}_j \geq \alpha$, the *j* criterion is accepted for the evaluation criteria; if $\tilde{R}_j < \alpha$, then the criterion not accepted.

3.2 Transformation of the qualitative scales

A TFN $\tilde{x}$ is defined by a triangular $\tilde{x} = (l_1, m_2, u_3)$ with the following membership function:

$$\mu_{\tilde{A}}(\mathrm{x}) = \begin{cases} 0, \ x < l_1 \\ (x - l_1)/(m_2 - l_1), l_1 \geq x \geq m_2 \\ (u_3 - x)/(u_3 - m_2), m_2 \geq x \geq u_3 \\ 0, \ otherwise \end{cases}. \tag{2}$$

Next, after defuzzifying the TFN, the approximate weight *Wi* of *Ci* is calculated as follows:

$$W_i = \left[\sum_{j=1}^{n}\left(a_{ij}/\sum_{i=1}^{n} a_{ij}\right)\right]/n \tag{3}$$

3.3 Analytical network process

Assume there are m aspects and *n* number of criteria. For instance, for the criteria denoted as ($C_1, \ldots, C_n$), the pairwise comparison matrix would be denoted as $X=(x_{ij})$ in which X_{ij} represents the relative importance of C_i to C_j. The consistency test of the ANP is designed to ensure the consistency of judgments made by the decision makers throughout the decision-making process. The λ_{max} value is equal to the number of comparisons or $\lambda_{max} = n$. Known as the consistency index (CI),the deviation or degree of consistency is determined using the following formula:

$$\mathrm{CI} = \left(\lambda_{max} - n\right)/(n-1)$$

(4)

The consistency ratio (CR) is defined as the ratio of CI to the mean random consistency index (RI). The CR should be less than 0.1 indicating that the consistency level of the pairwise comparison matrix is acceptable:

$$\mathrm{CR} = \mathrm{CI}/\mathrm{RI}$$

(5)

The ANP uses a supermatrix to address the relationship between feedback and interdependence among the criteria. If there is no interdependent relationship exists among the criteria, the pairwise comparison value is 0. In contrast, if an interdependent and feedback relationship exists among the criteria, then the value will no longer be 0 and an unweighted supermatrix *M* is obtained. The limited weighted supermatrix *M** is based on Eq. (6) and allows for gradual convergence of the interdependent relationships to obtain accurate relative weights among the measures.

$$M^* = \lim_{k\to\infty} M^k \tag{6}$$

3.4 Proposed analytical steps

This study proposes the following steps to carry out hierarchical structure analysis and weighting of the important aspects and criteria of SSSCM.

1. Gather information from the literature review and practical data from the case firm, and consult a group of experts to confirm the reliability of the measures. This step is needed to form an expert group for gathering the professional and academic knowledge required to achieve the evaluation goal.
2. Develop the aspects and criteria, and test the content validity using the expert group. This step is important in order to establish a set of aspects and criteria for FDM evaluation. However, the aspects and criteria have natural complicated relationships within the hierarchical structure. Apply Eq. (4) to aggregate the weights in preparation for the matrices.
3. The operational information (quantitative data) numbers must be transformed using Eq. (1) to produce values that are comparable among the aspects and criteria. By interpreting linguistic information into fuzzy linguistic scales to convert fuzzy numbers into values, the fuzzy assessments are defuzzified using the definitions in Eq. (2) and (3).
4. In testing the consistency of a judgment matrix, the consistency index (C.I.) is obtained using Eq. (4). We acquire the λ_{max} value in the process of decomposing the pairwise comparison matrix. In addition, if $\lambda_{max} = 0$, complete consistency exists within the judgment procedures. If $\lambda_{max} = n$, the consistency ratio (C.R.) of C.I. to the mean random consistency index R.I. is expressed as C.R. using Eq. (5).
5. The crisp values are composed into the weight matrices. The crisp values can be composed into a pairwise comparison matrix, and the matrix can be decomposed with MATLAB to acquire the eigenvector. Moreover, the eigenvector must be normalized to the local priority for the purpose of composing the unweighted supermatrix. To address the problem of interdependence, this study converges the unweighted supermatrix to a weighted supermatrix to arrive at an overall ranking using Eq. (6).

4. Results

This study collected data from electronics manufacturing firms in Taiwan to present the proposed analytical steps. This section is divided into two subsections: industrial background and empirical results.

4.1 Industrial Background

In past decades, focal Taiwanese electronic manufacturing firms have fully evaluated green practices, reduced environmental impacts on supply chain management and increased competencies for sustainable supply chain management. Those firms are focal firms that export electronic products all over the world; they have continuously developed remarkably sustainable products and services that consider social, environmental and economic factors in their supply chain, and eco-products and services are continuously implemented in their supply chain system. However, at present, few studies have discussed sustainable services and sustainable supply chain management together. Therefore, this study proposes a management approach that seeks to construct a SSSCM evaluation framework. There are difficulties involved in building this evaluation framework because the relevant aspects and criteria are rare in the literature, and the aspects and criteria pertain to hierarchical structure and interdependent relationships.

To demonstrate the utility of the proposed evaluation method, the proposed method was applied to the electronics industry. The firms continuously improve their processes, eco-products, best services and environmental activities in their operations. To address the SSSCM, firms propose aspects and criteria for the relevant measures. Moreover, to evaluate the assessment framework, this study uses an expert team consisting of ten professors and twenty management professionals with a minimum of five years of extensive experience in industry settings. Therefore, this study applies the following analytical approach: 1) The FDM is intended to satisfy the requirement for content validity due to the presence of many indicators from ISO9001 and ISO14001, among others, and to eliminate the less important criteria and form the evaluation hierarchical framework. 2) The ANP is used to perform an evaluation of the hierarchical, closed-loop, qualitative/quantitative scales and interdependent relationships. Finally, after a long interview process with the experts, the expert group was confident that they fully understood what FDM and ANP meant to the analysis of the SSSCM for the weighting process. Figure 2 illustrates the proposed approach for this study.

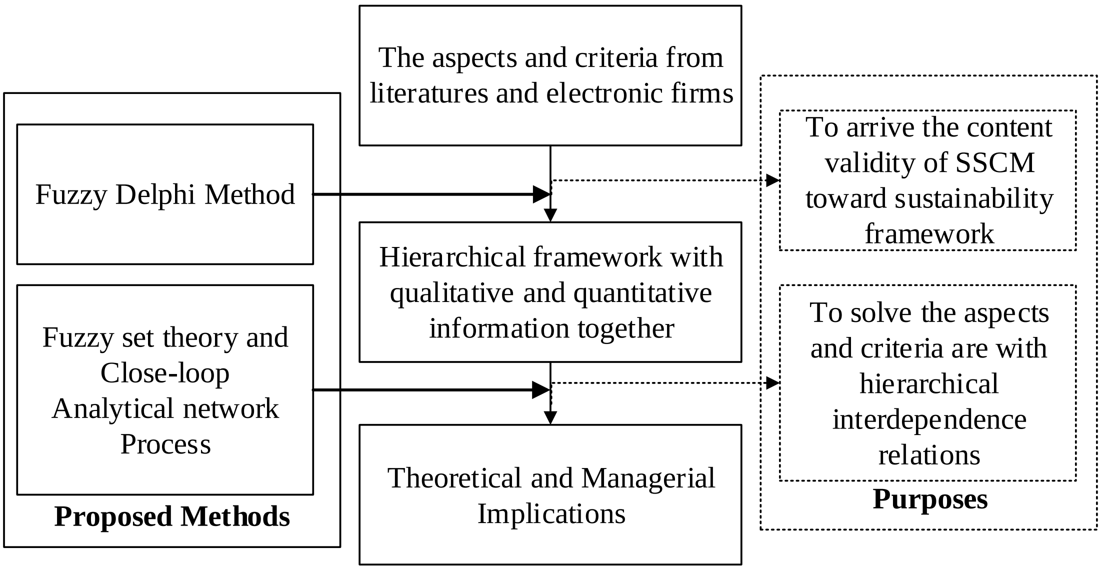

Figure 2. Proposed approach

4.2 Empirical results

1. The initial set of criteria is taken from a literature review, and practical data are collected from the firms. The numerous criteria make this assessment more complex and difficult. Hence, this study consults a group of experts to confirm the content validity through expert members and clarification of the measures. The FDM functions to remove the less important criteria and arrive at the final survey instrument.

Table 2. Measures

Aspects		Criteria	FDM
Environmentally conscious design (AS1)	C1	Evaluates the social impact of the business	0.559
	C2	Health and safety of customers and employees	0.608
	C3	Community investment in sustainability	0.567
	C4	Improved eco-product quality and services at lower cost	0.808
	C5	Safer and cleaner production in downstream and upstream of supply chain	0.597
	C6	Supplier’s booking in operational procedures	0.526
	C7	Life Cycle Assessment performed	0.554
	C8	Employees and customers’ awareness on environmental issues	0.696
	C9	Reduced future costs for disposal	0.762
	C10	Customer service innovation program	0.784
	C11	Updated technology assessment	0.784
	C12	Encourage learning and growth program for stakeholders	0.808
ce oper	C13	Green design in operations services, and products	0.795
	C14	Decrease the generation of toxic and hazardous (Quantitative Scale)	0.680

	C15 Corporate social responsibility promotion	0.674
	C16 Environmental information systems	0.773
	C17 Employee volunteer hours	0.808
	C18 Reduce carbon emissions per quarter (Quantitative Scale)	0.808
	C19 Green purchasing	0.773
	C20 Environmental certificates (ISO 14000, carbon footprint etc)	0.498
	C21 Reverse logistics integration in service package	0.554
	C22 Cost of service quality comparison (Other institutions)	0.573
	C23 Reduce service costs: service costs as percentage of revenue	0.587
	C24 Service output per hour/facilities utilization	0.795
Environmentally sustainable design(AS3)	C25 Total supply chain cycle time (Quantitative Scale)	0.518
	C26 Proportion of disabilities for management executive	0.795
	C27 Collaborative planning, forecasting, and replenishment with suppliers	0.820
	C28 Eco and socio-efficiency increases economic sustainability	0.674
	C29 Waste volume decreases by percentage (Quantitative Scale)	0.577
	C30 Annual growth in revenue	0.567
	C31 Environmental Policy makers eg. Government, management levels etc.	0.917
	C32 Service cycle processing time	0.726
	C33 Strategic planning for corporate sustainability	0.795
	C34 Industrial collaborators for service and product innovation programs	0.623

Note: Threshold value is 0.552

2. Table 2 presents the final aspects and criteria from the FDM result. The threshold α value is 0.552. After removing those FDM results that fell under the threshold value, 34 criteria remain in the study. The framework of this study is presented, containing two levels of hierarchical structure with three aspects and 34 criteria. At this point, the framework is ready for further analysis. However, the data include both quantitative and qualitative measurement scales, and all of the scales must be transformed into comparable values.

Table 3. Fuzzy matrix from experts

	EXPERT 1			EXPERT 2			EXPERT 3			EXPERT 4			….	EXPERT 30		
Criteria	(l,	m,	u)	(l,	m,	u)	(l,	m,	u)	(l,	m,	u)	….	(l,	m,	u)
C1	0.120	0.160	0.160	0.033	0.065	0.098	0.083	0.110	0.110	0.090	0.120	0.120	….	0.075	0.100	0.100
C2	0.080	0.120	0.160	0.098	0.130	0.130	0.055	0.083	0.110	0.060	0.090	0.120	….	0.050	0.075	0.100
C3	0.080	0.120	0.160	0.065	0.098	0.130	0.083	0.110	0.110	0.060	0.090	0.120	….	0.050	0.075	0.100
….	….	….	….	….	….	….	….	….	….	….	….	….	…. …. ….	….	….	….
C14	0.000	**0.445**	0.000	0.000	**0.445**	0.000	0.000	**0.445**	0.000	0.000	**0.445**	0.000	….	0.000	**0.445**	0.000

C15	0.080	0.120	0.160	0.098	0.130	0.130	0.083	0.110	0.110	0.090	0.120	0.120	….	0.075	0.100	0.100
C16	0.080	0.120	0.160	0.098	0.130	0.130	0.055	0.083	0.110	0.030	0.060	0.090	….	0.050	0.075	0.100
C17	0.120	0.160	0.160	0.065	0.098	0.130	0.083	0.110	0.110	0.060	0.090	0.120	….	0.075	0.100	0.050
C18	0.000	0.140	0.000	0.000	0.140	0.000	0.000	0.140	0.000	0.000	0.140	0.000	….	0.000	0.140	0.000
C19	0.080	0.120	0.160	0.065	0.098	0.130	0.055	0.083	0.110	0.060	0.090	0.120	….	0.050	0.075	0.100
C20	0.120	0.160	0.160	0.098	0.130	0.130	0.083	0.110	0.110	0.090	0.120	0.120	….	0.075	0.100	0.100
C21	0.120	0.160	0.080	0.098	0.130	0.130	0.055	0.083	0.110	0.090	0.120	0.120	….	0.050	0.075	0.100
C22	0.080	0.120	0.160	0.065	0.098	0.130	0.083	0.110	0.110	0.090	0.120	0.120	….	0.050	0.075	0.100
C23	0.080	0.120	0.160	0.098	0.130	0.130	0.055	0.083	0.110	0.090	0.120	0.120	….	0.050	0.075	0.100
C24	0.120	0.160	0.160	0.098	0.130	0.130	0.083	0.110	0.110	0.060	0.090	0.120	….	0.075	0.100	0.100
C25	0.000	0.250	0.000	0.000	0.250	0.000	0.000	0.250	0.000	0.000	0.250	0.000	….	0.000	0.250	0.000
C26	0.120	0.160	0.160	0.065	0.098	0.130	0.055	0.083	0.110	0.060	0.090	0.120	….	0.050	0.075	0.100
C27	0.120	0.160	0.160	0.065	0.098	0.130	0.083	0.110	0.110	0.060	0.090	0.120	….	0.050	0.075	0.100
C28	0.120	0.160	0.160	0.065	0.098	0.130	0.055	0.083	0.110	0.060	0.090	0.120	….	0.075	0.100	0.100
C29	0.000	0.128	0.000	0.000	0.128	0.000	0.000	0.128	0.000	0.000	0.128	0.000	….	0.000	0.128	0.000
….	….	….	….	….	….	….	….	….	….	….	….	….	…. …. …. ….	….	….	….
C34	0.120	0.160	0.160	0.033	0.065	0.098	0.083	0.110	0.110	0.060	0.090	0.120	….	0.050	0.075	0.100

Note: The red color is the operational data (quantitative data)

3. Table 3 presents the quantitative and qualitative information from the operations data and interviewees. By interpreting linguistic information into fuzzy linguistic scales to convert fuzzy numbers into values, the fuzzy assessments are defuzzified using the definitions in Eq. (2). The face-to-face interview method was adopted to confirm that the interviewees fully understand the aspects and criteria. The linguistic preferences (qualitative information) are transformed into triangular fuzzy numbers, as shown in Table 2. Using Eq. (1), the operational information (quantitative data) numbers must be transformed to achieve values that are comparable among the aspects and criteria. For instance, the decrease in the generation of toxic and hazardous (decreased by month) (C14) = (0.0652-0.04125)/(0.09512-0.04125)= 0.4458 (see Table 3)

Table 4 .Pairwise comparison of aspects for supermatrix under AS1

AS1	AS1	AS2	AS3	Eigen value	Weights
AS1	1.000	0.886	0.588	0.402	0.250
AS2	1.129	1.000	0.360	0.370	0.230
AS3	1.702	2.781	1.000	0.838	0.521

Table 5 .Pairwise comparison of criteria for supermatrix under C1

C1	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13	C14	C15	C16	C17	C18	C19	C20	C21	C22	C23	C24	C25	C26	C27	C28	C29	C30	C31	C32	C33	C34	Eigen value	Weights
C1	0.240	0.659	0.451	0.539	0.210	0.564	0.390	0.638	0.375	0.206	0.884	0.523	0.214	0.127	0.375	0.206	0.884	0.523	0.214	0.127	0.586	0.267	0.334	0.268	0.299	0.269	0.287	0.273	0.244	0.323	0.254	0.287	0.236	0.262	0.137	0.0245
C2	0.278	0.617	0.481	0.536	0.132	0.602	0.783	0.230	0.540	0.297	0.374	0.221	0.880	0.521	0.540	0.297	0.374	0.221	0.880	0.521	0.314	0.143	0.254	0.215	0.213	0.215	0.218	0.206	0.231	0.192	0.199	0.185	0.194	0.223	0.133	0.0238
C3	0.726	0.726	0.649	0.586	0.535	0.586	0.401	0.796	0.870	0.535	0.726	0.726	0.401	0.649	0.796	0.401	0.401	0.449	0.649	0.756	0.756	0.540	0.647	0.278	0.482	0.485	0.467	0.708	0.640	0.362	0.275	0.388	0.391	0.682	0.214	0.0384
C4	0.305	0.244	0.254	0.210	0.256	0.255	0.264	0.295	0.246	0.256	0.219	0.253	0.245	0.226	0.245	0.213	0.269	0.217	0.253	0.253	0.218	0.225	0.281	0.236	0.245	0.251	0.250	0.223	0.245	0.281	0.235	0.188	0.191	0.250	0.093	0.0166
C5	0.263	0.214	0.226	0.214	0.188	0.237	0.231	0.228	0.176	0.205	0.177	0.220	0.222	0.202	0.216	0.200	0.209	0.184	0.203	0.202	0.193	0.195	0.269	0.221	0.168	0.559	0.620	0.464	0.103	0.733	0.274	0.202	0.149	0.215	0.102	0.0183
C6	0.264	0.208	0.224	0.205	0.221	0.184	0.199	0.221	0.201	0.200	0.167	0.177	0.230	0.201	0.194	0.207	0.216	0.203	0.207	0.210	0.206	0.227	0.298	0.259	0.093	0.268	0.159	0.394	0.234	0.602	0.275	0.224	0.200	0.201	0.090	0.0162
C7	0.726	0.535	0.649	0.586	0.726	0.796	0.401	0.586	0.649	0.535	0.726	0.900	0.649	0.649	0.796	0.649	0.649	0.449	0.649	0.666	0.666	0.519	0.300	0.253	0.256	0.251	0.266	0.256	0.280	0.281	0.207	0.262	0.196	0.231	0.185	0.0331
C8	0.900	0.535	0.401	0.796	0.535	0.586	0.401	0.586	0.870	0.726	0.900	0.535	0.401	0.870	0.586	0.401	0.401	0.730	0.649	0.419	0.419	0.555	0.244	0.210	0.217	0.207	0.223	0.205	0.199	0.221	0.174	0.200	0.162	0.189	0.165	0.0296
C9	0.535	0.900	0.649	0.586	0.726	0.796	0.401	0.586	0.401	0.900	0.726	0.900	0.649	0.649	0.364	0.401	0.649	0.730	0.870	0.485	0.485	0.456	0.619	0.478	0.489	0.369	0.543	0.882	0.492	0.325	0.368	0.209	0.164	0.142	0.202	0.0363
C10	0.726	0.900	0.401	0.796	0.900	0.364	0.649	0.586	0.401	0.535	0.335	0.726	0.401	0.401	0.586	0.649	0.401	0.730	0.649	0.485	0.485	0.657	0.261	0.217	0.230	0.227	0.235	0.243	0.202	0.241	0.178	0.198	0.162	0.236	0.162	0.0289
C11	0.535	0.726	0.870	0.586	0.535	0.586	0.401	0.364	0.649	0.726	0.726	0.900	0.649	0.649	0.586	0.649	0.649	0.730	0.401	0.419	0.419	0.611	0.286	0.289	0.290	0.254	0.289	0.272	0.277	0.271	0.260	0.267	0.488	0.521	0.188	0.0337
C12	0.726	0.535	0.649	0.796	0.335	0.364	0.649	0.586	0.649	0.900	0.535	0.726	0.401	0.870	0.796	0.401	0.870	0.730	0.401	0.666	0.666	0.650	0.186	0.191	0.190	0.165	0.202	0.161	0.209	0.196	0.176	0.182	0.087	0.199	0.171	0.0305
C13	0.535	0.900	0.401	0.796	0.535	0.586	0.649	0.796	0.649	0.535	0.335	0.726	0.649	0.649	0.364	0.649	0.649	0.449	0.401	0.419	0.419	0.775	0.220	0.194	0.198	0.172	0.216	0.207	0.208	0.210	0.216	0.222	0.253	0.324	0.167	0.0298
C14	**0.445**	**0.445**	**0.445**	**0.445**	**0.445**	**0.445**	**0.445**	**0.445**	**0.445**	**0.445**	**0.445**	**0.445**	**0.445**	**0.445**	**0.445**	**0.445**	**0.445**	**0.445**	**0.445**	**0.445**	**0.445**	**0.445**	**0.445**	**0.445**	**0.445**	**0.445**	**0.445**	**0.445**	**0.445**	**0.445**	**0.445**	**0.445**	**0.445**	**0.445**	0.169	0.0303
C15	0.900	0.335	0.401	0.586	0.535	0.586	0.649	0.586	0.401	0.535	0.535	0.900	0.870	0.649	0.586	0.649	0.649	0.730	0.649	0.256	0.256	0.361	0.224	0.198	0.215	0.217	0.225	0.206	0.203	0.202	0.181	0.187	0.546	0.395	0.168	0.0300
C16	0.900	0.900	0.870	0.994	0.900	0.994	0.870	0.994	0.870	0.726	0.726	0.726	0.649	0.649	0.796	0.649	0.649	0.730	0.649	0.649	0.649	0.444	0.260	0.247	0.253	0.211	0.273	0.229	0.277	0.249	0.256	0.263	0.691	0.420	0.220	0.0394
C17	0.529	0.569	0.488	0.487	0.468	0.498	0.521	0.257	0.187	0.186	0.185	0.187	0.837	0.552	0.671	0.812	0.634	0.564	0.694	0.227	0.184	0.192	0.209	0.242	0.244	0.229	0.257	0.222	0.240	0.256	0.204	0.211	0.654	0.853	0.150	0.0269
C18	**0.140**	**0.140**	**0.140**	**0.140**	**0.140**	**0.140**	**0.140**	**0.140**	**0.140**	**0.140**	**0.140**	**0.140**	**0.140**	**0.140**	**0.140**	**0.140**	**0.140**	**0.140**	**0.140**	**0.140**	**0.140**	**0.140**	**0.140**	**0.140**	**0.140**	**0.140**	**0.140**	**0.140**	**0.140**	**0.140**	**0.140**	**0.140**	**0.140**	**0.140**	0.053	0.0095
C19	0.417	0.450	0.229	0.486	0.503	0.284	0.450	0.260	0.194	0.239	0.184	0.244	0.289	0.118	0.398	0.602	0.399	0.460	0.711	0.215	0.201	0.205	0.190	0.199	0.172	0.226	0.217	0.195	0.229	0.215	0.176	0.181	0.487	0.267	0.110	0.0197
C20	0.815	0.331	0.882	0.102	0.749	0.764	0.418	0.246	0.176	0.210	0.165	0.198	0.573	0.389	0.298	0.459	0.382	0.142	0.270	0.168	0.171	0.191	0.222	0.212	0.196	0.161	0.214	0.227	0.215	0.199	0.173	0.181	0.573	0.764	0.128	0.0229
C21	0.351	0.504	0.351	0.290	0.361	0.304	0.402	0.279	0.206	0.225	0.205	0.204	0.504	0.683	0.115	0.532	0.302	0.313	0.230	0.218	0.174	0.221	0.621	0.657	0.587	0.532	0.528	0.478	0.887	0.564	0.467	0.564	0.504	0.289	0.155	0.0277
C22	0.291	0.638	0.427	0.555	0.460	0.120	0.668	0.226	0.178	0.196	0.170	0.207	0.624	0.264	0.770	0.540	0.944	0.588	0.931	0.195	0.191	0.160	0.649	0.534	0.576	0.487	0.435	0.209	0.145	0.197	0.180	0.367	0.624	0.598	0.159	0.0284

C23	0.900	0.711	0.485	0.394	0.516	0.541	0.419	0.631	0.764	0.516	0.711	0.711	0.568	0.666	0.631	0.419	0.626	0.449	0.666	0.764	0.764	0.678	0.656	0.428	0.456	0.482	0.410	0.327	0.410	0.194	0.202	0.317	0.168	0.153	0.192	0.0344
C24	0.900	0.900	0.401	0.586	0.726	0.796	0.649	0.586	0.401	0.726	0.726	0.535	0.649	0.401	0.586	0.649	0.649	0.730	0.649	0.666	0.666	0.654	0.684	0.421	0.439	0.422	0.478	0.590	0.634	0.890	0.923	0.863	0.234	0.169	0.230	0.0411
C25	**0.250**	**0.250**	**0.250**	**0.250**	**0.250**	**0.250**	**0.250**	**0.250**	**0.250**	**0.250**	**0.250**	**0.250**	**0.250**	**0.250**	**0.250**	**0.250**	**0.250**	**0.250**	**0.250**	**0.250**	**0.250**	**0.250**	**0.250**	**0.250**	**0.250**	**0.250**	**0.250**	**0.250**	**0.250**	**0.250**	**0.250**	**0.250**	**0.250**	**0.250**	0.095	0.0170
C26	0.535	0.726	0.401	0.364	0.726	0.796	0.401	0.586	0.649	0.726	0.726	0.900	0.649	0.870	0.586	0.649	0.649	0.730	0.870	0.666	0.666	0.555	0.685	0.368	0.488	0.368	0.455	0.165	0.198	0.298	0.648	0.419	0.313	0.102	0.205	0.0368
C27	0.900	0.535	0.649	0.586	0.535	0.586	0.649	0.586	0.401	0.726	0.726	0.535	0.649	0.649	0.586	0.401	0.401	0.730	0.870	0.568	0.568	0.439	0.665	0.390	0.305	0.412	0.498	0.390	0.381	0.781	0.281	0.844	0.588	0.289	0.211	0.0379
C28	0.726	0.900	0.401	0.364	0.726	0.796	0.401	0.796	0.649	0.900	0.900	0.726	0.649	0.649	0.796	0.649	0.401	0.449	0.649	0.568	0.568	0.510	0.657	0.299	0.422	0.368	0.512	0.207	0.757	0.406	0.676	0.293	0.733	0.802	0.222	0.0398
C29	**0.128**	**0.128**	**0.128**	**0.128**	**0.128**	**0.128**	**0.128**	**0.128**	**0.128**	**0.128**	**0.128**	**0.128**	**0.128**	**0.128**	**0.128**	**0.128**	**0.128**	**0.128**	**0.128**	**0.128**	**0.128**	**0.128**	**0.128**	**0.128**	**0.128**	**0.128**	**0.128**	**0.128**	**0.128**	**0.128**	**0.128**	**0.128**	**0.128**	**0.128**	0.049	0.0087
C30	0.900	0.535	0.401	0.364	0.535	0.796	0.401	0.796	0.649	0.726	0.726	0.726	0.401	0.649	0.796	0.649	0.649	0.730	0.649	0.419	0.419	0.550	0.673	0.484	0.477	0.701	0.546	0.238	0.165	0.293	0.855	0.852	0.231	0.815	0.222	0.0397
C31	0.535	0.535	0.649	0.586	0.726	0.796	0.649	0.586	0.401	0.726	0.726	0.335	0.649	0.401	0.586	0.401	0.401	0.449	0.870	0.666	0.666	0.591	0.658	0.482	0.533	0.621	0.578	0.775	0.391	0.366	0.481	0.375	0.885	0.522	0.218	0.0391
C32	0.335	0.726	0.649	0.796	0.535	0.586	0.870	0.796	0.649	0.900	0.900	0.535	0.401	0.649	0.364	0.649	0.870	0.730	0.649	0.419	0.419	0.511	0.591	0.578	0.398	0.605	0.598	0.133	0.207	0.620	0.236	0.284	0.342	0.194	0.208	0.0372
C33	0.726	0.535	0.401	0.586	0.726	0.586	0.649	0.586	0.401	0.726	0.726	0.726	0.649	0.649	0.586	0.870	0.649	0.449	0.649	0.666	0.666	0.544	0.677	0.601	0.477	0.587	0.623	0.570	0.882	0.629	0.332	0.852	0.347	0.162	0.226	0.0405
C34	0.535	0.535	0.401	0.586	0.535	0.586	0.401	0.796	0.401	0.726	0.726	0.535	0.401	0.649	0.586	0.401	0.401	0.730	0.649	0.419	0.419	0.538	0.627	0.562	0.510	0.542	0.634	0.433	0.358	0.169	0.393	0.268	0.159	0.394	0.184	0.0330

4. This study applied Eq. (3) to aggregate the expert responses for the matrices. Table 4 presents the pairwise comparison of aspects under AS1. The values of $\lambda_{\max}$ =3.481, C.I.= 0.0853 and C.R.= 0.0654 are presented. Similarly, Table 5 presents the pairwise comparison of criteria under C1, and the values $\lambda_{\max} = 7.357$, C.I.= 0.0979 and C.R.= 0.084 are presented. This study repeats this matrix decomposition process in MATLAB 34 times to acquire the weights for the unweighted supermatrix. The C.I. and C.R. are computed for each matrix using Eqs. (4) and (5). The C.I. and C.R. are less than 0.1. Hence, these values satisfy the consistency index and ratio. However, the aspects and criteria contain naturally complicated relationships within the hierarchical structure.
5. To address the hierarchical framework and interdependence relationships, Table 4 lists the aspects of weights under AS1, under AS1 aspects weights (0.250, 0.230, 0.521), Table 5 criteria weights under AS1, under AS1 criteria weights (0.0245, 0.0238, 0.0384, 0.0166, 0.0183, 0.0162, 0.0331, 0.0296, 0.0363, 0.0289, 0.0337, 0.0305, 0.0298, 0.0303, 0.0300, 0.0394, 0.0269, 0.0095, 0.0197, 0.0229, 0.0277, 0.0284, 0.0344, 0.0411, 0.0170, 0.0368, 0.0379, 0.0398, 0.0087, 0.0397, 0.0391, 0.0372, 0.0405, 0.0330); these values are used to compose the unweighted supermatrix, (see the AS1 and C1 columns in Table 6).

Table 6. Unweighted supermatrix

	AS1	AS2	AS3	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13	C14	C15	C16	C17	C18	C19	C20	C21	C22	C23	C24	C25	C26	C27	C28	C29	C30	C31	C32	C33	C34
AS1	**0.2500**	0.3175	0.2870	0.3093	0.3160	0.4510	0.3890	0.2712	0.2068	0.4607	0.2716	0.3690	0.3210	0.3570	0.2570	0.2943	0.4342	0.2403	0.3202	0.4930	0.3032	0.3160	0.4970	0.3320	0.3820	0.3200	0.4520	0.2032	0.2830	0.3810	0.3199	0.3931	0.3690	0.3162	0.4970	0.3320	0.3820
AS2	**0.2300**	0.3356	0.4370	0.3641	0.2740	0.2835	0.3690	0.4750	0.3692	0.3120	0.4760	0.4147	0.4470	0.2950	0.3970	0.4670	0.2448	0.4467	0.4620	0.2803	0.3560	0.2220	0.2640	0.2710	0.3970	0.2230	0.2803	0.4560	0.3220	0.3800	0.2380	0.3569	0.2900	0.3180	0.2640	0.2710	0.3970
AS3	**0.5210**	0.3469	0.2760	0.3266	0.4100	0.2655	0.2420	0.2538	0.4240	0.2273	0.2524	0.2163	0.2320	0.3480	0.3460	0.2387	0.3210	0.3130	0.2178	0.2267	0.3408	0.4620	0.2390	0.3970	0.2210	0.4570	0.2679	0.3408	0.3950	0.2390	0.4421	0.2500	0.3410	0.3658	0.2390	0.3970	0.2210
C1	0.0530	0.0000	0.0000	**0.0245**	0.0150	0.0143	0.0950	0.0128	0.0152	0.0118	0.0700	0.0027	0.0245	0.0219	0.0245	0.0060	0.0207	0.0245	0.0125	0.0137	0.0033	0.0046	0.0033	0.0044	0.0245	0.0245	0.0245	0.0027	0.0245	0.0174	0.0650	0.0320	0.0730	0.0310	0.0245	0.0245	0.0245
C2	0.0780	0.0000	0.0000	**0.0238**	0.0113	0.0980	0.0157	0.0107	0.0173	0.0118	0.0224	0.0156	0.0238	0.0238	0.0238	0.0013	0.0238	0.0238	0.0238	0.0238	0.0127	0.0104	0.0149	0.0088	0.0238	0.0238	0.0238	0.0238	0.0238	0.0083	0.0550	0.0290	0.0450	0.0210	0.0238	0.0238	0.0238
C3	0.0630	0.0000	0.0000	**0.0384**	0.0154	0.0146	0.0185	0.0950	0.0158	0.0182	0.0180	0.0580	0.0384	0.0210	0.0265	0.0065	0.0590	0.0495	0.0224	0.0225	0.0223	0.0239	0.0226	0.0250	0.0227	0.0234	0.0192	0.0207	0.0207	0.0223	0.0225	0.0211	0.0214	0.0200	0.0680	0.0238	0.0490
C4	0.0520	0.0000	0.0000	**0.0166**	0.0910	0.0223	0.0103	0.0780	0.0640	0.0072	0.0107	0.0176	0.0166	0.0166	0.0166	0.0256	0.0150	0.0166	0.0166	0.0150	0.0264	0.0229	0.0281	0.0252	0.0166	0.0166	0.0166	0.0166	0.0166	0.0011	0.0320	0.0190	0.0340	0.0750	0.0264	0.0166	0.0166
C5	0.0950	0.0000	0.0000	**0.0183**	0.0123	0.0780	0.0182	0.0153	0.0235	0.0680	0.0154	0.0850	0.0183	0.0183	0.0183	0.0183	0.0183	0.0183	0.0183	0.0183	0.0140	0.0148	0.0381	0.0397	0.0183	0.0183	0.0183	0.0183	0.0183	0.0077	0.0340	0.0760	0.0187	0.0450	0.0183	0.0183	0.0183
C6	0.0490	0.0000	0.0000	**0.0162**	0.0111	0.0185	0.0175	0.0149	0.0109	0.0156	0.0093	0.0105	0.0162	0.0162	0.0162	0.0148	0.0154	0.0162	0.0150	0.0162	0.0440	0.0435	0.0033	0.0434	0.0162	0.0162	0.0162	0.0162	0.0162	0.0510	0.0410	0.0103	0.0275	0.0230	0.0162	0.0162	0.0162
C7	0.0620	0.0000	0.0000	**0.0331**	0.0178	0.0990	0.0550	0.0185	0.0250	0.0940	0.0116	0.0101	0.0150	0.0630	0.0026	0.0026	0.0331	0.0150	0.0022	0.0331	0.0118	0.0071	0.0160	0.0077	0.0191	0.0161	0.0195	0.0331	0.0331	0.0092	0.0197	0.0286	0.0639	0.0120	0.0331	0.0331	0.0331
C8	0.1190	0.0000	0.0000	**0.0296**	0.0215	0.0300	0.0530	0.0105	0.0256	0.0182	0.0570	0.0114	0.0296	0.0130	0.0296	0.0296	0.0148	0.0296	0.0296	0.0148	0.0104	0.0113	0.0106	0.0089	0.0248	0.0246	0.0218	0.0296	0.0296	0.0380	0.0650	0.0750	0.0185	0.0187	0.0296	0.0296	0.0296
C9	0.0900	0.0000	0.0000	**0.0363**	0.0363	0.0016	0.0245	0.0363	0.0470	0.0144	0.0467	0.0451	0.0150	0.0454	0.0455	0.0464	0.0478	0.0147	0.0461	0.0145	0.0473	0.0480	0.0033	0.0146	0.0214	0.0215	0.0217	0.0147	0.0363	0.0420	0.0530	0.0130	0.0502	0.0199	0.0363	0.0363	0.0363
C10	0.1340	0.0000	0.0000	**0.0289**	0.0289	0.0027	0.0214	0.0289	0.0148	0.0439	0.0429	0.0403	0.0395	0.0400	0.0402	0.0426	0.0441	0.0441	0.0048	0.0520	0.0401	0.0473	0.0476	0.0398	0.0214	0.0219	0.0213	0.0048	0.0289	0.0320	0.0086	0.0130	0.0187	0.0320	0.0289	0.0289	0.0289
C11	0.0960	0.0000	0.0000	**0.0337**	0.0337	0.0116	0.0032	0.0106	0.0322	0.0389	0.0376	0.0367	0.0383	0.0348	0.0356	0.0374	0.0373	0.0353	0.0444	0.0372	0.0387	0.0394	0.0355	0.0140	0.0266	0.0281	0.0269	0.0389	0.0264	0.0243	0.0245	0.0254	0.0223	0.0265	0.0267	0.0337	0.0337
C12	0.1090	0.0000	0.0000	**0.0305**	0.0305	0.0305	0.0305	0.0305	0.0492	0.0436	0.0118	0.0146	0.0046	0.0543	0.0158	0.0046	0.0155	0.0254	0.0496	0.0484	0.0033	0.0048	0.0154	0.0245	0.0219	0.0209	0.0222	0.0150	0.0261	0.0249	0.0282	0.0250	0.0251	0.0219	0.0262	0.0305	0.0305
C13	0.0000	0.0630	0.0000	**0.0298**	0.0298	0.0298	0.0298	0.0298	0.0430	0.0434	0.0361	0.0639	0.0455	0.0415	0.0413	0.0425	0.0434	0.0146	0.0443	0.0143	0.0421	0.0444	0.0150	0.0242	0.0225	0.0223	0.0239	0.0520	0.0204	0.0207	0.0213	0.0204	0.0204	0.0198	0.0174	0.0298	0.0298
C14	0.0000	0.0960	0.0000	**0.0303**	0.0303	0.0107	0.0303	0.0251	0.0438	0.0426	0.0433	0.0376	0.0405	0.0413	0.0483	0.0435	0.0243	0.0391	0.0468	0.0244	0.0418	0.0470	0.0438	0.0468	0.0446	0.0448	0.0150	0.0150	0.0203	0.0211	0.0241	0.0222	0.0196	0.0189	0.0208	0.0303	0.0303
C15	0.0000	0.0850	0.0000	**0.0300**	0.0300	0.0103	0.0300	0.0301	0.0056	0.0154	0.0054	0.0153	0.0479	0.0578	0.0527	0.0600	0.0158	0.0052	0.0564	0.0260	0.0000	0.0118	0.0256	0.0261	0.0057	0.0558	0.0158	0.0158	0.0223	0.0215	0.0216	0.0208	0.0254	0.0227	0.0229	0.0325	0.0300
C16	0.0000	0.0780	0.0000	**0.0394**	0.0394	0.0107	0.0394	0.0016	0.0118	0.0443	0.0427	0.0241	0.0466	0.0363	0.0475	0.0404	0.0486	0.0478	0.0386	0.0141	0.0410	0.0384	0.0141	0.0375	0.0453	0.0420	0.0412	0.0411	0.0239	0.0225	0.0205	0.0234	0.0206	0.0248	0.0246	0.0394	0.0394
C17	0.0000	0.0850	0.0000	**0.0269**	0.0035	0.0046	0.0033	0.0240	0.0243	0.0048	0.0451	0.0050	0.0453	0.0043	0.0384	0.0414	0.0241	0.0449	0.0447	0.0422	0.0428	0.0400	0.0439	0.0477	0.0449	0.0449	0.0498	0.0495	0.0188	0.0202	0.0199	0.0199	0.0204	0.0224	0.0202	0.0269	0.0269
C18	0.0000	0.0570	0.0000	**0.0095**	0.0128	0.0104	0.0149	0.0088	0.0481	0.0252	0.0490	0.0045	0.0120	0.0118	0.0397	0.0419	0.0141	0.0141	0.0050	0.0698	0.0150	0.0475	0.0460	0.0492	0.0485	0.0151	0.0463	0.0461	0.0240	0.0233	0.0255	0.0233	0.0261	0.0233	0.0220	0.0095	0.0095
C19	0.0000	0.0760	0.0000	**0.0197**	0.0208	0.0221	0.0188	0.0239	0.0157	0.0480	0.0046	0.0493	0.0444	0.0049	0.0472	0.0044	0.0719	0.0900	0.0460	0.0141	0.0467	0.0149	0.0457	0.0475	0.0441	0.0434	0.0426	0.0425	0.0230	0.0212	0.0227	0.0210	0.0215	0.0202	0.0195	0.0225	0.0197

C20	0.0000	0.1050	0.0000	**0.0229**	0.0264	0.0229	0.0281	0.0252	0.0136	0.0529	0.0397	0.0250	0.0480	0.0767	0.0487	0.0141	0.0033	0.0397	0.0531	0.0390	0.0254	0.0484	0.0033	0.0033	0.0159	0.0360	0.0593	0.0588	0.0241	0.0232	0.0226	0.0243	0.0206	0.0208	0.0234	0.0229	0.0229
C21	0.0000	0.1150	0.0000	**0.0277**	0.0399	0.0475	0.0381	0.0397	0.0550	0.0590	0.0052	0.0397	0.0118	0.0397	0.0497	0.0564	0.0530	0.0150	0.0439	0.0524	0.0524	0.0052	0.0523	0.0151	0.0152	0.0254	0.0480	0.0480	0.0212	0.0217	0.0215	0.0219	0.0227	0.0210	0.0220	0.0277	0.0277
C22	0.0000	0.0520	0.0000	**0.0284**	0.0440	0.0435	0.0587	0.0434	0.0142	0.0042	0.0429	0.0141	0.0040	0.0407	0.0141	0.0427	0.0340	0.0639	0.0033	0.0347	0.0360	0.0143	0.0422	0.0410	0.0388	0.0433	0.0390	0.0390	0.0143	0.0108	0.0138	0.0108	0.0140	0.0133	0.0115	0.0284	0.0284
C23	0.0000	0.0960	0.0000	**0.0344**	0.0748	0.0713	0.0606	0.0769	0.0243	0.0388	0.0430	0.0141	0.0141	0.0407	0.0170	0.0120	0.0564	0.0391	0.0378	0.0416	0.0354	0.0149	0.0425	0.0434	0.0378	0.0440	0.0396	0.0396	0.0090	0.0344	0.0344	0.0344	0.0344	0.0344	0.0344	0.0344	0.0344
C24	0.0000	0.0920	0.0000	**0.0411**	0.0220	0.0370	0.0420	0.0410	0.0249	0.0190	0.0397	0.0483	0.0411	0.0045	0.0430	0.0428	0.0033	0.0046	0.0145	0.0141	0.0142	0.0378	0.0436	0.0520	0.0469	0.0427	0.0408	0.0411	0.0411	0.0411	0.0490	0.0411	0.0411	0.0411	0.0411	0.0411	0.0411
C25	0.0000	0.0000	0.1180	**0.0170**	0.0106	0.0280	0.0146	0.0140	0.0150	0.0431	0.0462	0.0469	0.0400	0.0033	0.0145	0.0033	0.0247	0.0411	0.0497	0.0249	0.0439	0.0469	0.0382	0.0426	0.0403	0.0476	0.0043	0.0433	0.0815	0.1410	0.0077	0.0128	0.0152	0.0118	0.0700	0.0639	0.0170
C26	0.0000	0.0000	0.1090	**0.0368**	0.0213	0.0250	0.0228	0.0229	0.0120	0.0043	0.0030	0.0414	0.0033	0.0170	0.0404	0.0399	0.0397	0.0290	0.0448	0.0404	0.0443	0.0260	0.0420	0.0357	0.0075	0.0444	0.0146	0.0185	0.0113	0.0198	0.0157	0.0107	0.0173	0.0690	0.0224	0.0156	0.0368
C27	0.0000	0.0000	0.1230	**0.0379**	0.0318	0.0287	0.0260	0.0283	0.0477	0.0047	0.0149	0.0469	0.0640	0.0141	0.0247	0.0830	0.0240	0.0152	0.0147	0.0440	0.0033	0.0465	0.0144	0.0482	0.0405	0.0246	0.0640	0.0060	0.0154	0.0146	0.0185	0.0946	0.0158	0.0950	0.0180	0.0580	0.0379
C28	0.0000	0.0000	0.0650	**0.0398**	0.0500	0.0040	0.0398	0.0398	0.0397	0.0438	0.0218	0.0118	0.0147	0.0456	0.0046	0.0118	0.0420	0.0243	0.0046	0.0389	0.0440	0.0405	0.0445	0.0421	0.0444	0.0367	0.0403	0.0431	0.0910	0.0223	0.0098	0.0780	0.0121	0.0780	0.0107	0.0176	0.0398
C29	0.0000	0.0000	0.0950	**0.0087**	0.0087	0.0087	0.0087	0.0087	0.0474	0.0044	0.0230	0.0468	0.0246	0.0046	0.0463	0.0397	0.0485	0.0413	0.0417	0.0360	0.0471	0.0433	0.0482	0.0145	0.0397	0.0435	0.0383	0.0147	0.0740	0.0782	0.0182	0.0730	0.0950	0.0153	0.0154	0.0854	0.0087
C30	0.0000	0.0000	0.1080	**0.0397**	0.0397	0.0397	0.0397	0.0397	0.0910	0.0430	0.0420	0.0441	0.0125	0.0425	0.0118	0.0431	0.0044	0.0118	0.0200	0.0141	0.0454	0.0423	0.0461	0.0426	0.0500	0.0077	0.0449	0.0373	0.0111	0.0185	0.0175	0.0149	0.0109	0.0149	0.0934	0.0105	0.0397
C31	0.0000	0.0000	0.1050	**0.0391**	0.0391	0.0391	0.0391	0.0391	0.0240	0.0139	0.0391	0.0061	0.0930	0.0391	0.0126	0.0391	0.0139	0.0391	0.0391	0.0391	0.0391	0.0410	0.0391	0.0216	0.0391	0.0102	0.0139	0.0391	0.0178	0.0060	0.0550	0.0185	0.0102	0.0132	0.0116	0.0400	0.0391
C32	0.0000	0.0000	0.0860	**0.0372**	0.0255	0.0205	0.0052	0.0375	0.0115	0.0225	0.0214	0.0219	0.0213	0.0217	0.0188	0.0203	0.0207	0.0242	0.0217	0.0213	0.0195	0.0234	0.0218	0.0209	0.0235	0.0219	0.0234	0.0077	0.0448	0.0476	0.0504	0.0105	0.0560	0.0182	0.0570	0.0114	0.0372
C33	0.0000	0.0000	0.0950	**0.0405**	0.0415	0.0275	0.0145	0.0225	0.0105	0.0215	0.0187	0.0224	0.0220	0.0215	0.0201	0.0197	0.0200	0.0201	0.0213	0.0221	0.0221	0.0242	0.0260	0.0201	0.0236	0.0238	0.0199	0.0446	0.0433	0.0472	0.0148	0.0215	0.0360	0.0226	0.0405	0.0241	0.0405
C34	0.0000	0.0000	0.0960	**0.0330**	0.0330	0.0370	0.0325	0.0160	0.0365	0.0155	0.0196	0.0233	0.0235	0.0222	0.0234	0.0225	0.0252	0.0227	0.0227	0.0232	0.0239	0.0234	0.0231	0.0223	0.0237	0.0240	0.0229	0.0228	0.0469	0.0450	0.0469	0.0147	0.0266	0.0332	0.0233	0.0126	0.0224

Table 7. Weighted supermatrix

Ranking		AS1	AS2	AS3	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13	C14	C15	C16	C17	C18	C19	C20	C21	C22	C23	C24	C25	C26	C27	C28	C29	C30	C31	C32	C33	C34
2	AS1	0.1591	0.1590	0.1590	0.1590	0.1590	0.1590	0.1590	0.1590	0.1590	0.1590	0.1590	0.1590	0.1590	0.1590	0.1590	0.1590	0.1590	0.1590	0.1590	0.1590	0.1590	0.1590	0.1590	0.1590	0.1590	0.1590	0.1590	0.1590	0.1590	0.1590	0.1590	0.1590	0.1590	0.1590	0.1590	0.1590	0.1590
1	AS2	0.1705	0.1704	0.1704	0.1704	0.1704	0.1704	0.1704	0.1704	0.1704	0.1704	0.1704	0.1704	0.1704	0.1704	0.1704	0.1704	0.1704	0.1704	0.1704	0.1704	0.1704	0.1704	0.1704	0.1704	0.1704	0.1704	0.1705	0.1704	0.1704	0.1704	0.1704	0.1704	0.1704	0.1704	0.1704	0.1704	0.1704
3	AS3	0.1720	0.1719	0.1719	0.1719	0.1719	0.1719	0.1719	0.1719	0.1719	0.1719	0.1719	0.1719	0.1719	0.1719	0.1719	0.1719	0.1719	0.1719	0.1719	0.1719	0.1719	0.1719	0.1719	0.1719	0.1719	0.1719	0.1719	0.1719	0.1719	0.1719	0.1719	0.1719	0.1719	0.1719	0.1719	0.1719	0.1719
33	C1	0.0102	0.0102	0.0102	0.0102	0.0102	0.0102	0.0102	0.0102	0.0102	0.0102	0.0102	0.0102	0.0102	0.0102	0.0102	0.0102	0.0102	0.0102	0.0102	0.0102	0.0102	0.0102	0.0102	0.0102	0.0102	0.0102	0.0102	0.0102	0.0102	0.0102	0.0102	0.0102	0.0102	0.0102	0.0102	0.0102	0.0102
28	C2	0.0120	0.0120	0.0120	0.0120	0.0120	0.0120	0.0120	0.0120	0.0120	0.0120	0.0120	0.0120	0.0120	0.0120	0.0120	0.0120	0.0120	0.0120	0.0120	0.0120	0.0120	0.0120	0.0120	0.0120	0.0120	0.0120	0.0120	0.0120	0.0120	0.0120	0.0120	0.0120	0.0120	0.0120	0.0120	0.0120	0.0120
27	C3	0.0123	0.0123	0.0123	0.0123	0.0123	0.0123	0.0123	0.0123	0.0123	0.0123	0.0123	0.0123	0.0123	0.0123	0.0123	0.0123	0.0123	0.0123	0.0123	0.0123	0.0123	0.0123	0.0123	0.0123	0.0123	0.0123	0.0123	0.0123	0.0123	0.0123	0.0123	0.0123	0.0123	0.0123	0.0123	0.0123	0.0123
32	C4	0.0103	0.0103	0.0103	0.0103	0.0103	0.0103	0.0103	0.0103	0.0103	0.0103	0.0103	0.0103	0.0103	0.0103	0.0103	0.0103	0.0103	0.0103	0.0103	0.0103	0.0103	0.0103	0.0103	0.0103	0.0103	0.0103	0.0103	0.0103	0.0103	0.0103	0.0103	0.0103	0.0103	0.0103	0.0103	0.0103	0.0103
20	C5	0.0143	0.0143	0.0143	0.0143	0.0143	0.0143	0.0143	0.0143	0.0143	0.0143	0.0143	0.0143	0.0143	0.0143	0.0143	0.0143	0.0143	0.0143	0.0143	0.0143	0.0143	0.0143	0.0143	0.0143	0.0143	0.0143	0.0143	0.0143	0.0143	0.0143	0.0143	0.0143	0.0143	0.0143	0.0143	0.0143	0.0143
34	C6	0.0089	0.0089	0.0089	0.0089	0.0089	0.0089	0.0089	0.0089	0.0089	0.0089	0.0089	0.0089	0.0089	0.0089	0.0089	0.0089	0.0089	0.0089	0.0089	0.0089	0.0089	0.0089	0.0089	0.0089	0.0089	0.0089	0.0089	0.0089	0.0089	0.0089	0.0089	0.0089	0.0089	0.0089	0.0089	0.0089	0.0089
31	C7	0.0115	0.0115	0.0115	0.0115	0.0115	0.0115	0.0115	0.0115	0.0115	0.0115	0.0115	0.0115	0.0115	0.0115	0.0115	0.0115	0.0115	0.0115	0.0115	0.0115	0.0115	0.0115	0.0115	0.0115	0.0115	0.0115	0.0115	0.0115	0.0115	0.0115	0.0115	0.0115	0.0115	0.0115	0.0115	0.0115	0.0115
11	C8	0.0163	0.0163	0.0163	0.0163	0.0163	0.0163	0.0163	0.0163	0.0163	0.0163	0.0163	0.0163	0.0163	0.0163	0.0163	0.0163	0.0163	0.0163	0.0163	0.0163	0.0163	0.0163	0.0163	0.0163	0.0163	0.0163	0.0163	0.0163	0.0163	0.0163	0.0163	0.0163	0.0163	0.0163	0.0163	0.0163	0.0163
17	C9	0.0150	0.0150	0.0150	0.0150	0.0150	0.0150	0.0150	0.0150	0.0150	0.0150	0.0150	0.0150	0.0150	0.0150	0.0150	0.0150	0.0150	0.0150	0.0150	0.0150	0.0150	0.0150	0.0150	0.0150	0.0150	0.0150	0.0150	0.0150	0.0150	0.0150	0.0150	0.0150	0.0150	0.0150	0.0150	0.0150	0.0150
3	C10	0.0182	0.0182	0.0182	0.0182	0.0182	0.0182	0.0182	0.0182	0.0182	0.0182	0.0182	0.0182	0.0182	0.0182	0.0182	0.0182	0.0182	0.0182	0.0182	0.0182	0.0182	0.0182	0.0182	0.0182	0.0182	0.0182	0.0182	0.0182	0.0182	0.0182	0.0182	0.0182	0.0182	0.0182	0.0182	0.0182	0.0182
14	C11	0.0153	0.0152	0.0152	0.0152	0.0152	0.0153	0.0152	0.0152	0.0152	0.0153	0.0152	0.0152	0.0152	0.0152	0.0152	0.0152	0.0153	0.0152	0.0152	0.0153	0.0152	0.0152	0.0153	0.0152	0.0152	0.0152	0.0153	0.0152	0.0152	0.0152	0.0152	0.0152	0.0152	0.0152	0.0153	0.0152	0.0152
19	C12	0.0148	0.0148	0.0148	0.0148	0.0148	0.0148	0.0148	0.0148	0.0148	0.0148	0.0148	0.0148	0.0148	0.0148	0.0148	0.0148	0.0148	0.0148	0.0148	0.0148	0.0148	0.0148	0.0148	0.0148	0.0148	0.0148	0.0148	0.0148	0.0148	0.0148	0.0148	0.0148	0.0148	0.0148	0.0148	0.0148	0.0148
25	C13	0.0132	0.0132	0.0132	0.0132	0.0132	0.0132	0.0132	0.0132	0.0132	0.0132	0.0132	0.0132	0.0132	0.0132	0.0132	0.0132	0.0132	0.0132	0.0132	0.0132	0.0132	0.0132	0.0132	0.0132	0.0132	0.0132	0.0132	0.0132	0.0132	0.0132	0.0132	0.0132	0.0132	0.0132	0.0132	0.0132	0.0132
8	C14	0.0163	0.0162	0.0162	0.0162	0.0162	0.0162	0.0162	0.0162	0.0162	0.0162	0.0162	0.0162	0.0162	0.0162	0.0162	0.0162	0.0162	0.0162	0.0162	0.0162	0.0162	0.0162	0.0162	0.0162	0.0162	0.0162	0.0162	0.0162	0.0162	0.0162	0.0162	0.0162	0.0162	0.0162	0.0162	0.0162	0.0162
21	C15	0.0138	0.0138	0.0138	0.0138	0.0138	0.0138	0.0138	0.0138	0.0138	0.0138	0.0138	0.0138	0.0138	0.0138	0.0138	0.0138	0.0138	0.0138	0.0138	0.0138	0.0138	0.0138	0.0138	0.0138	0.0138	0.0138	0.0138	0.0138	0.0138	0.0138	0.0138	0.0138	0.0138	0.0138	0.0138	0.0138	0.0138
13	C16	0.0149	0.0149	0.0149	0.0149	0.0149	0.0149	0.0149	0.0149	0.0149	0.0149	0.0149	0.0149	0.0149	0.0149	0.0149	0.0149	0.0149	0.0149	0.0149	0.0149	0.0149	0.0149	0.0149	0.0149	0.0149	0.0149	0.0149	0.0149	0.0149	0.0149	0.0149	0.0149	0.0149	0.0149	0.0149	0.0149	0.0149
15	C17	0.0147	0.0147	0.0147	0.0147	0.0147	0.0147	0.0147	0.0147	0.0147	0.0147	0.0147	0.0147	0.0147	0.0147	0.0147	0.0147	0.0147	0.0147	0.0147	0.0147	0.0147	0.0147	0.0147	0.0147	0.0147	0.0147	0.0147	0.0147	0.0147	0.0147	0.0147	0.0147	0.0147	0.0147	0.0147	0.0147	0.0147

29	C18	0.0115	0.0115	0.0115	0.0115	0.0115	0.0115	0.0115	0.0115	0.0115	0.0115	0.0115	0.0115	0.0115	0.0115	0.0115	0.0115	0.0115	0.0115	0.0115	0.0115	0.0115	0.0115	0.0115	0.0115	0.0115	0.0115	0.0115	0.0115	0.0115	0.0115	0.0115	0.0115	0.0115	0.0115	0.0115	0.0115	0.0115
18	C19	0.0144	0.0144	0.0144	0.0144	0.0144	0.0144	0.0144	0.0144	0.0144	0.0144	0.0144	0.0144	0.0144	0.0144	0.0144	0.0144	0.0144	0.0144	0.0144	0.0144	0.0144	0.0144	0.0144	0.0144	0.0144	0.0144	0.0144	0.0144	0.0144	0.0144	0.0144	0.0144	0.0144	0.0144	0.0144	0.0144	0.0144
6	C20	0.0167	0.0167	0.0167	0.0167	0.0167	0.0167	0.0167	0.0167	0.0167	0.0167	0.0167	0.0167	0.0167	0.0167	0.0167	0.0167	0.0167	0.0167	0.0167	0.0167	0.0167	0.0167	0.0167	0.0167	0.0167	0.0167	0.0167	0.0167	0.0167	0.0167	0.0167	0.0167	0.0167	0.0167	0.0167	0.0167	0.0167
1	C21	0.0180	0.0180	0.0180	0.0180	0.0180	0.0180	0.0180	0.0180	0.0180	0.0180	0.0180	0.0180	0.0180	0.0180	0.0180	0.0180	0.0180	0.0180	0.0180	0.0180	0.0180	0.0180	0.0180	0.0180	0.0180	0.0180	0.0180	0.0180	0.0180	0.0180	0.0180	0.0180	0.0180	0.0180	0.0180	0.0180	0.0180
30	C22	0.0115	0.0115	0.0115	0.0115	0.0115	0.0115	0.0115	0.0115	0.0115	0.0115	0.0115	0.0115	0.0115	0.0115	0.0115	0.0115	0.0115	0.0115	0.0115	0.0115	0.0115	0.0115	0.0115	0.0115	0.0115	0.0115	0.0115	0.0115	0.0115	0.0115	0.0115	0.0115	0.0115	0.0115	0.0115	0.0115	0.0115
5	C23	0.0175	0.0175	0.0175	0.0175	0.0175	0.0175	0.0175	0.0175	0.0175	0.0175	0.0175	0.0175	0.0175	0.0175	0.0175	0.0175	0.0175	0.0175	0.0175	0.0175	0.0175	0.0175	0.0175	0.0175	0.0175	0.0175	0.0175	0.0175	0.0175	0.0175	0.0175	0.0175	0.0175	0.0175	0.0175	0.0175	0.0175
7	C24	0.0167	0.0167	0.0167	0.0167	0.0167	0.0167	0.0167	0.0167	0.0167	0.0167	0.0167	0.0167	0.0167	0.0167	0.0167	0.0167	0.0167	0.0167	0.0167	0.0167	0.0167	0.0167	0.0167	0.0167	0.0167	0.0167	0.0167	0.0167	0.0167	0.0167	0.0167	0.0167	0.0167	0.0167	0.0167	0.0167	0.0167
4	C25	0.0191	0.0191	0.0191	0.0191	0.0191	0.0191	0.0191	0.0191	0.0191	0.0191	0.0191	0.0191	0.0191	0.0191	0.0191	0.0191	0.0191	0.0191	0.0191	0.0191	0.0191	0.0191	0.0191	0.0191	0.0191	0.0191	0.0191	0.0191	0.0191	0.0191	0.0191	0.0191	0.0191	0.0191	0.0191	0.0191	0.0191
16	C26	0.0160	0.0160	0.0160	0.0160	0.0160	0.0160	0.0160	0.0160	0.0160	0.0160	0.0160	0.0160	0.0160	0.0160	0.0160	0.0160	0.0160	0.0160	0.0160	0.0160	0.0160	0.0160	0.0160	0.0160	0.0160	0.0160	0.0160	0.0160	0.0160	0.0160	0.0160	0.0160	0.0160	0.0160	0.0160	0.0160	0.0160
2	C27	0.0193	0.0193	0.0193	0.0193	0.0193	0.0193	0.0193	0.0193	0.0193	0.0193	0.0193	0.0193	0.0193	0.0193	0.0193	0.0193	0.0193	0.0193	0.0193	0.0193	0.0193	0.0193	0.0193	0.0193	0.0193	0.0193	0.0193	0.0193	0.0193	0.0193	0.0193	0.0193	0.0193	0.0193	0.0193	0.0193	0.0193
24	C28	0.0143	0.0143	0.0143	0.0143	0.0143	0.0143	0.0143	0.0143	0.0143	0.0143	0.0143	0.0143	0.0143	0.0143	0.0143	0.0143	0.0143	0.0143	0.0143	0.0143	0.0143	0.0143	0.0143	0.0143	0.0143	0.0143	0.0143	0.0143	0.0143	0.0143	0.0143	0.0143	0.0143	0.0143	0.0143	0.0143	0.0143
9	C29	0.0174	0.0173	0.0173	0.0173	0.0173	0.0173	0.0173	0.0173	0.0173	0.0173	0.0173	0.0173	0.0173	0.0173	0.0173	0.0173	0.0173	0.0173	0.0173	0.0173	0.0173	0.0173	0.0173	0.0173	0.0173	0.0173	0.0174	0.0173	0.0173	0.0173	0.0173	0.0173	0.0173	0.0173	0.0173	0.0173	0.0173
10	C30	0.0171	0.0171	0.0171	0.0171	0.0171	0.0171	0.0171	0.0171	0.0171	0.0171	0.0171	0.0171	0.0171	0.0171	0.0171	0.0171	0.0171	0.0171	0.0171	0.0171	0.0171	0.0171	0.0171	0.0171	0.0171	0.0171	0.0171	0.0171	0.0171	0.0171	0.0171	0.0171	0.0171	0.0171	0.0171	0.0171	0.0171
12	C31	0.0167	0.0166	0.0166	0.0166	0.0166	0.0166	0.0166	0.0166	0.0166	0.0166	0.0166	0.0166	0.0166	0.0166	0.0166	0.0166	0.0166	0.0166	0.0166	0.0166	0.0166	0.0166	0.0166	0.0166	0.0166	0.0166	0.0166	0.0166	0.0166	0.0166	0.0166	0.0166	0.0166	0.0166	0.0166	0.0166	0.0166
26	C32	0.0139	0.0139	0.0139	0.0139	0.0139	0.0139	0.0139	0.0139	0.0139	0.0139	0.0139	0.0139	0.0139	0.0139	0.0139	0.0139	0.0139	0.0139	0.0139	0.0139	0.0139	0.0139	0.0139	0.0139	0.0139	0.0139	0.0139	0.0139	0.0139	0.0139	0.0139	0.0139	0.0139	0.0139	0.0139	0.0139	0.0139
23	C33	0.0148	0.0148	0.0148	0.0148	0.0148	0.0148	0.0148	0.0148	0.0148	0.0148	0.0148	0.0148	0.0148	0.0148	0.0148	0.0148	0.0148	0.0148	0.0148	0.0148	0.0148	0.0148	0.0148	0.0148	0.0148	0.0148	0.0148	0.0148	0.0148	0.0148	0.0148	0.0148	0.0148	0.0148	0.0148	0.0148	0.0148
22	C34	0.0148	0.0148	0.0148	0.0148	0.0148	0.0148	0.0148	0.0148	0.0148	0.0148	0.0148	0.0148	0.0148	0.0148	0.0148	0.0148	0.0148	0.0148	0.0148	0.0148	0.0148	0.0148	0.0148	0.0148	0.0148	0.0148	0.0148	0.0148	0.0148	0.0148	0.0148	0.0148	0.0148	0.0148	0.0148	0.0148	0.0148

Table 7 presents the converged and weighted supermatrix. To address the problem of interdependence, this study converges the unweighted supermatrix to arrive at an overall ranking using Eq. (6). Moreover, this study assumes that the framework is a closed-loop framework. The final result is acquired, and the rankings of the aspects are listed as follows: 1) Environmental operation design (AS2), 2) Environmentally conscious design (AS1), and 3) Environmentally sustainable design (AS3). The top five criteria rankings are as follows: 1) Reverse logistic integration in service package (C21); 2) Collaborative planning, forecasting, and replenishment with suppliers (C27); 3) Customer service innovation program (C10); 4) Total supply chain cycle time (C25); and 5) Reduced service costs (i.e., service costs as percentage of revenue).

5. Theoretical and managerial Implications

Sustainable operation design is intended to identify environmental principles for the design and operation of service supply chain functions. It includes in service supply chains that are described together with the operational approaches applied to enhancing environmental and economic performance in the electronic industry. However, to design the environmental and economic performance well it is essential to track on their operational functions of the product consumed and the waste produced and this has to focus on the product lifecycle design and depends on the types of raw materials and the technology applied. The firms must use collaborative planning, forecasting, and replenishment with suppliers and customer service program in the entire SSSCM. In other words, this means the continuous environmental sustainable and operation has to integrate collaborative planning, forecasting, and replenishment with suppliers that applies to services and product design, and operation design to reduce risks for environment in the sustainable supply chain network, but still to consider the economic performance simultaneously. In particular, the appropriate identification of products or services life-cycle stages is necessary for establishment or optimization of environmental policies and performances.

The most important criteria identified are related to the reverse logistics process integrated in SSSCM for improving customer service and meeting environmental pressures. The electronic firms must emphasize on the sustainable products and services, operational planning and controlling for a cost-effective raw materials flow, and the increase of efficiency and effectiveness of green operation processes and related operations (process, services and products) information from the end of product life cycle to the raw material origin for the purpose of remanufacturing or recycling or proper disposal of end life products. These practices include refurbishing used products, reforming operational processes, tracking raw materials to eliminate the operation and material wastes, and choosing toxic-free raw materials and hazardous-free operational and reverse processes. Still, reverse logistics should collaborate in both economic and environmental contexts due to firms are becoming increasingly environmental awareness and focus on their efforts on green operational activities (processes and services) surrounding the return and processing of used/unused products. The service activities are usually ignored by the manufacturers. This study seeks for structuring, organizing, supporting and planning these operational service activities to make more efficient and effective use of resources in SSSCM

Firms should also aim to build an efficient supply chain system for increasing customer interactions and feedbacks. Such interactions and feedbacks give these electronic firms a chance to sense new opportunities for service innovation and product or service value adding, and potentially to include customer co-innovation. Service innovation in SSSCM should be applied in value creation that focuses on service process changes in the firm's view of service innovation or on drawing the service processes guidance. However, the service innovation program presents an organization-wide challenge to the management tasked with their operational and service designs, and therefore, a comprehensive environmental and operational sustainable design is necessary. Especially, information technology and sharing are necessary for better efficiency and effectiveness in operations and services processing that are prevalent to great sustainable services extent to the electronic firms’ supply chain. Still, service process innovation could provide new solutions in customer interaction, environmental distribution methods, novel green technology application in the operations or service processes, new information technology operation and service forms or new ways of organizing and managing the products are required to the SSSCM practices.

The SSSCM is vital to firms that participate in environmentally friendly and green operational activities to ensure that all operations and service processes and products adequately address current environmental concerns while sustaining a profit in the supply chain networks. The firms must deliver products or services to the customers that reduces consumption, wastes, distribution costs, economic concentration and increases the firm’s image to create shareholder value by taking up opportunities and managing risks derived from economic, environmental and social developments. However, enhancement of this SSSCM framework integration occurs by supporting and assisting joint practices with closed supplier relations. Particularly, collaborative planning, forecasting and replenishment leverage joint visibility of products or services innovation throughout the sustainable supply chain networks. In lieu of this, the collaborative planning might go beyond the information shared among suppliers’ aids in planning and satisfying customer demands. This information shared process allows for continuous updating of product and service innovation and upcoming customer satisfaction, and therefore making the service supply chain process more efficient and toward sustainability. This total supply chain time and cost can be determined by the time saving of sustainable product or service process, lower the inventory level, reverse logistics analysis and lower transportation costs, and reducing the pollutions across all supply chains networks.

From a theoretical point of view, the SSSCM offers environmentally conscious design on operations and products or services while providing improved supply chain relationships among stakeholders. This might benefit the customers and suppliers via lifecycle assessment in their supply chain network. To this end, this study discussed various aspects and criteria in the proposed framework for adding value in operational activities related to environmental design of products and services, sustainable operations design, and environmental consciousness design. These proposed sustainable design aspects and criteria have a significant influence on the value-adding, efficiency on operations and effectiveness of the SSSCM configuration. By taking these top-ranked aspects and criteria into account, it is advisable to re-considering, re-structuring, re-organizing, controlling and planning the operations and service activities in SSSCM practices. Re-structuring operational processes allows better cost control in services and operations and total supply chain cycle time. Finally, this study enables management to gain insights from the leading electronic firms' practices and to assess their operations and create coherent SSSCM strategies.

6. Concluding remarks

Although sustainable supply chain management has gained increasing attention in recent decades, the current literature lacks a full treatment of SSSCM. In addition to addressing the social, environment and economic issues, issues remain in the areas of environmental design and reverse logistics. Therefore, researchers should address broad strategic issues that involve service supply chain system design and reverse logistic integration in service packaging, collaborative planning, forecasting, replenishment with suppliers, customer service innovation programs, total supply chain cycle time, and reduced service costs, among others. Therefore, this study provides an incremental step in understanding the firm's sustainable service supply chain management processes by constructing an evaluation framework for SSSCM according to an expert's point of view.

However, many previously ignored SSSCM concerns derive from the sustainable service and sustainable supply chain management outlined in the existing framework (Linton et al., 2007; Seuring and Muller, 2008; Lin and Tseng, 2014; Govindan et al., 2015). Similar to previous green or sustainable supply chain management studies, this study (Zhu et al., 2010; Zhu et al., 2013; Tseng et al., 2014c) focuses on green or sustainable practices and on business performance. A comprehensive analysis of sustainable business operations should simultaneously consider all three aspects of sustainable design, i.e., environmental service operations design, environmentally sustainable design and environmentally conscious design (Tseng et al., 2009; Bovea, M.D., Perez-Belis, 2012; Tseng et al., 2013a; Arnette, 2014). This study integrates innovation and reverse logistics. A service package emerging from this study suggests interesting interactions among the three aspects. In traditional practices, sustainable design was not completely integrated into green or sustainable studies. This study suggests that future studies should more deeply investigate the conceptual domain of design for sustainability to better understand how firms balance all of the proposed aspects.

Finally, additional studies are requiring investigation in decision-making role in a complex hierarchical structure and the use of the proposed SSSCM framework in practice under uncertainty. This study provides practical guidance on how management makes decisions under uncertainty, and in particular, how management uses linguistic information from operations. In the literature, a lack of such SSSCM framework has resulted in unawareness of the sustainable service design and configuring the service process in supply chain management, i.e., product life cycle assessment and service configuration in multiple stages together (Prakash, 2002; Zhu et., 2013). This study provides important insight into an SSSCM framework and the decision-making process. As firms navigate the trade-offs between profits and environmental outcomes and their decisions to provide the opportunity to re-conceptualize the SSSCM framework to develop new green-products and service processes, this might also create additional business opportunities and enhance the long-term competitive advantage in customer satisfaction on the products and services.

To conclude, theoretical frameworks that describe conceptual framework and limitations are essential to advance the use of SSSCM. The proposed theory should incorporate the environmental design goals and take into consideration the stakeholder conditions, relevant operations processes, and desired performance. In certain cases, the proposed framework should explain who, what, when, where, how and why certain phenomena have occurred. This proposed framework should also test the theory in empirical studies, and future studies should gather adequate data to test this framework or conduct a longitudinal study on whether the desired performance results are delivered. Additionally, future studies should determine whether the SSSCM framework is used across industries and is useful and valid to practitioners.

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