Service innovation in sustainable product service systems: improving performance under linguistic preferences

Abstract

Sustainable product service systems enable firms that are operating under resource limitations to deliver the best possible outcomes in terms of social well-being and economic growth. However, prior studies have not yet investigated the function of service innovation in sustainable product service systems or analyzed the convergence of importance and performance weighting in maximizing resource utilization in the supply chain. Moreover, prior studies have not yet integrated and proposed a complex interrelationship-driven hierarchical model including qualitative preferences or identifying weighting under linguistic preferences. This study applied the fuzzy Delphi method, fuzzy importance performance analysis and an analytical network process to analyze an interrelationship-driven hierarchical model of service innovation in sustainable product service systems. Hence, this study provides a set of attributes and a hybrid method to assess the model as well as linguistic preferences to weight the importance and performance measures. The results present four features that are included in the model: sustainable consumption, collaborative advantage, innovation activities and service innovation capabilities. Therefore, when building sustainable product service systems, firms should maintain operations and aim for business synergy in self-generated innovative products/services along with high-quality products/services, collaboration innovation and product and service innovations. Managerial and theoretical implications are discussed.

Keywords: service innovation, sustainable product service systems, fuzzy Delphi method, fuzzy importance and performance analysis, analytical network process

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1. INTRODUCTION

Developing product service systems plays an important role in business strategies by enabling the delivery of the best possible outcomes when exploring solutions to satisfy customer needs and when encouraging firms to adopt product service structures that foster sustainable production and consumption (Chou et al., 2015; Tukker & Tischner, 2006; Lindahl et al., 2014). Hence, developing sustainable product service systems (SPSS) is has increasingly been focused upon as a means by which firms can meet social, economic and environmental expectations (Mont, 2003). The Taiwanese textile industry is striving to shift its business focus from physical productions and sales into offering product-services systems that fulfill customer needs through innovation in the supply chain. By focusing on delivering SPSS, firms might provide a combination of products and services that satisfy a particular customer's demands via innovative interactions among stakeholders in the value production system (Vezzoli et al., 2014; Xing et al., 2013). To

achieve superior performance, the SPSS requires deeper engagement with service operational capabilities, innovation activities, and collaborative advantage. Moreover, it should address the context of sustainable production and consumption (Tukker & Tischner, 2006; Wang et al., 2008; Vittersø & Tangeland, 2015). Thus, a challenge for firms is to combine service innovation with the visions and components of SPSS indicators.

Prior studies have focused on studying the key attributes of SPSS effectiveness (Chou et al., 2015; Vezzoli et al., 2015). Tukker and Tischner (2006) argued that analyzing SPSS might require a deeper discussion of the definition of production and consumption modalities. In fact, Mylan (2014) largely focused on production changes, although consumption patterns also present a significant challenge, which consists of not only evaluating an SPSS but also understanding the contextual conditions in which it is introduced and exploring service innovation and practical attributes (Gallouj and Savona, 2008; Vezzoli et al., 2015). Ceschin (2014) indicated that a lack of understanding continues to permeate innovation activities and sustainable advantage and that these attributes can affect the transition of service innovation. Xing et al. (2013) presented a conceptual model and emphasized value co-production and collaborative advantage, indicating that the key to product service innovation for strong sustainability is the meaningful and complementary cooperation of all stakeholders, which necessitates linking with SPSS. Hence, an empirical study is required to help refine the model and to identify attributes related to service innovation.

In the real world, the attributes must be investigated to clarify the role played by service innovation in SPSS because the attributes are situated in complex (and often hierarchical) interrelationships, which is particularly true when they are presented in the service innovation literature. In this context, the fuzzy Delphi method (FDM) can be applied to visualize the interrelationships among the proposed attributes based on expert preferences (Jassbi et al., 2015). However, it has been argued that FDM is characterized by a lower convergence in generating results, a long process of inquiry and a process that results in the loss of valuable information precisely because of expert preferences (Ishikawa et al., 1993; Kuo & Chen, 2008). Bouzon et al. (2016) used FDM to generate a critical list of attributes that are evaluated by experts and industrial managers and utilized FDM to create better effects for attribute selection. Fuzzy importance and performance analysis (IPA) is required to identify which attributes require more focus and more resources (Deng and Pei, 2009). In addition, a hierarchical model should be developed that includes the complex interrelationships among the attributes. The analytical network process (ANP) is also applied to address these issues. These proposed methods feature the advantage of simplicity, and all the experts' opinions can be included in one study.

Product service systems have also been studied in this context (Aurich et al., 2006; Sakao and Shimomura, 2007). Sousa-Zomer and Cauchick (2016) presented an SPSS business model with a qualitative approach and confirmed that service innovation is important. However, the prior literature merely presented or described important thinking on innovation in SPSS, while few studies presented a measurement model, and even fewer addressed the qualitative information under interrelationships and a hierarchical model. This study's objectives are as follows.

- To define the key role of service innovation in SPSS with linguistic preferences.
- To identify discrepancies between the importance and performance level.
- To determine the important attributes in the interrelationships and in the hierarchical model.

The textile industrial sector requires service innovation in SPSS to decrease negative impacts on the environment, which are a concern in each stage of the product life cycle, from raw material extraction to the production, attention, waste prevention and disposal processes. In fact, service innovation in SPSS provides the industry with a mechanism to enhance its attributes. This study identifies service innovations in SPSS that analyze importance and performance levels. This study can thus provide insights for textile industry management involving the enhancement through service innovation in complex situations. This study is constructed as follows. Section 2 provides a review and discussion of the literature related to SPSS. Section 3 describes the industrial information, expert opinion and the method proposed. Section 4 presents the results of this study. Section 5 discusses the results, providing several managerial and theoretical implications. Concluding remarks and possible future studies are included in the final section.

2. LITERATURE REVIEW

The internal business process is understood here as a series of tasks and functions that must function within a set of attributes and that lead to a result or change the condition. To provide a better understanding with a theoretical basis, the literature and the proposed method and measures are discussed in the following section.

2.1 Service innovation

Traditional service innovation categorizations can be divided into fundamental, incremental and process innovations (Halliday & Trott, 2010; Snyder et al., 2016). Gallouj and Savona (2008) questioned previous categorizations and found a need for new categorizations to better understand the nature of service innovation. Ostrom et al. (2010) identified various interrelated categories of service innovations, that is, different marketing and innovation strategies related to different service innovation categories. However, adopting different categories is challenging because those employing them might experience some difficulties in applying them. Hsieh et al. (2013) argued that employing service innovation categorizations does not result in the delivery of a specific model or framework for different types, notwithstanding the importance of such details. Durst et al. (2015) and Snyder et al. (2016) demonstrated that service innovation is different from traditional innovation features such as changes in customers, internet use or business model. The evidence implies that neglecting the uniqueness of service innovation leads to underestimating the effects of service innovation in the manufacturing sector.

Service innovation became a term that referred to innovation in diverse service situations, including the introduction of new services or incremental improvements to current services (Halliday & Trott, 2010). However, Grönroos (2007) argued that service innovation is an ambiguous term that can be considered both an intangible product and a process. Ostrom et al. (2010) defined service innovation as “creating value for customers, employees, business owners, alliance partners, and communities through new or improved service offerings, service processes, and service business models” and indicated that a study on understanding how to deliver innovative services for manufacturing firms would be highly valued. Melton and Hartline (2010) suggested that integrating the value chain with innovation processes that enables the benefit creation for a firm’s performance and enhances the effects of service innovation through external linkages. Durst et al. (2015) noted service innovation provides an effective means of

creating sustained competitive advantage for a firm. Obviously, although service innovation studies require substantial attention to exploring the effects on performance differentiated between interactive and relational aspects, fewer studies discuss how to deliver service innovation in reaching and sustaining a performance level.

Firms prefer to focus more on adding value for the customer by offering services rather than producing goods because services can provide value without generating negative impacts on the environment or conflicting with the needs of customers (Yoon et al., 2012). Sampson (2012) indicated that firms must emphasize the selection, development and management of service innovation activities and features that focus directly on the customer. Thus, Chen et al. (2016) suggested that service innovation has become an increasingly important consideration for firms, emphasizing innovative service initiatives, adoption and implementation of the market concept and its value-added chains, with the goal of sustainability. In other words, traditional manufacturing firms are therefore starting to provide bundled offerings for completing a product service system to foster sustainability by integrating or combining products and services. Hence, a product service system is potentially a better means of offering services to benefit customers. This study aims to deliver a better understanding of service innovation under an SPSS to address manufacturing firms' need to manage the essentials of innovative service logic.

2.2 Sustainable product service system

Bartolomeo et al. (2003) presented the lack of operational commitment as an added-supply-side attribute affecting success and failure. Accordingly, SPSS are linked with uncertainties in cash flow, which might induce manufacturers to consider such businesses riskier than product-based businesses (European Commission, 2001; Lindahl et al., 2014). Furthermore, Besch (2005) supposed that small and medium-sized firms frequently struggle to finance these types of business models; consequently, they generally encounter a limitation involving financial resources. UNEP (2002) proposed another obstacle—a difficulty in quantifying the savings that arise from combining economic and environmental benefits to promote the innovations to both inside and outside stakeholders or to a firm's strategic partners. Nonetheless, relationships with stakeholders in the value chain and the establishment and deployment of an SPSS entail constructing strong cooperation among the firms (Vezzoli et al., 2015). A potential barrier might develop as a result of firm fears regarding sharing sensitive information involving processes, production and services, which are also considered internal barriers because systems and resources for obtaining profit change (Mont, 2004).

Hence, adopting an SPSS involves more management complexity than the traditional distribution model of simply distributing products. As a consequence, there it is essential to tightly couple the SPSS with the firm for service innovation (Martinez et al., 2010). By contrast, UNEP (2002) indicated that changes in firm mindset and firms are required to support more sustainable innovation- and SPSS-oriented businesses. Mont (2004a) indicated that firms have insufficient knowledge and understanding of SPSS, which might lead to uncertainties with respect to imprecise risks, costs and responsibilities and cause customers to misunderstand the benefits of an SPSS offering. Cook et al. (2006) revealed that receptivity is expected to occur in firms in which service transactions have been executed. Although producing and selling products separately require different managerial capabilities and knowledge, both activities obviously

require firms to develop new competencies, skills and experiences with respect to both management and design activities (Vezzoli et al., 2015). Thus, there is an essential need when running an organization to be proficient at design, manufacturing and distribution; gathering adequate design methods and tools for developing and accessing; obtaining life-cycle costing methods; and addressing performance indicators in evaluating the organization's capability to effectively and efficiently deliver an SPSS (Martinez et al., 2010).

Bartolomeo et al. (2003) indicated that firms also do not have a common understanding regarding life-cycle costs, which challenges them when attempting to recognize potential economic benefits., Mont and Plepys (2008) emphasized that in reality, SPSS have shown that consumer behavior is more complex than must a rational feedback to prices because customers are motivated by diverse internal and external drivers such as psychology, social norms and institutional settings. The primary barrier is the cultural transfer necessary to value an ownerless means of satisfying customers as an alternative to owning the product (Mont, 2002). The problem is that the resolution depends upon access, which clashes with the dominant and well-established norm of ownership, thus causing customers to doubt whether they will receive an ownerless-based resolution (UNEP, 2002). Leonardo et al. (2012) collated evidence and figures in current knowledge forms, revealing in a set of significant findings on both technical and business aspects a search for the interaction of health management and product-service systems in supporting operational decision-making. Wallin et al. (2015) determined that the key requirement when developing products for an SPSS is to design for manufacturing, for use and maintenance by interviewing staff and for analyzing products. However, few studies have connected the SPSS model with interdependence and hierarchical relationships.

2.3 Proposed method

This study finds different types of methodologies in the various approaches to SPSS. Prior studies adopted a quantitative, survey-based approach and a classical statistical method in this context. Wallin et al. (2015) collected and analyzed data over three years from 2009 to 2012, and the results provided an overview of how firms established their innovation capabilities. Ho and Wang (2008) emphasized the need to find a means of addressing large numbers of variables and complex and difficult models. Rexfelt and Hiort af Ornäs (2009) identified situations involving consumer acceptance and developed a methodology through focal groups and individual interviews that details theory from consumer acceptance and innovative adoption literature.

Hence, it is essential to both observe the interdependence among attributes in SPSS and discover a suitable method to approaching those attributes. The wide range of available methods to determine the interdependence among attributes is a complicated issue, and prior studies lack the appropriate information, particularly when a group decision to solve fuzziness with expert perceptions is related to improving firm performance (Glumac et al., 2011). In addition, Sanchez-Lezama et al. (2014) applied an FDM that assists with reducing the uncertainty in improving the accuracy of expert judgments in investigating the characteristics of the survey procedure and ensuring the quality of the survey analysis. To explore the effectiveness of promoting firms' environmental policy, Chang et al. (2011) used the FDM to acquire the critical attributes for assessing hydrogen production technologies. Moreover, this method was applied to discover the key criteria for and to aid in solving the inherent uncertainty of a survey procedure. Ma et al.

(2011) implemented a quantification of experts' attitudes on regional road safety. Jassbi et al. (2015) used the FDM to provide a comprehensive relational model of practice communities and organizational variables affecting communities of practice structures. Tseng et al. (2015) used this method to identify the top-ranking features of considering the stakeholders and to provide practical guidance regarding the top five criteria. For its part, this study applies the FDM to explore relationships involving interdependence among SPSS attributes as a quantified effectiveness assessment model.

Although the FDM presented the interdependence and hierarchical relationships among attributes, there is no study that summarizes and integrates service innovation and SPSS into a measurement framework. The prior studies have presented the FDM application, but few studies have presented and accounted for the interdependence relationships and hierarchical model in the analytical process. For instance, Shi et al. (2016) applied an ANP to improve firm sustainable development using an interdependence hierarchical model. Tseng et al. (2016) proposed an interdependence hierarchical model to evaluate the performance of sustainable service in supply chain management under linguistic preferences. Hence, the ANP is utilized to present the interdependence hierarchical model issues.

2.4 Proposed measures

Studies have proposed several SPSS attributes (Hall, 2009; Camison & Monfort-Mir, 2012; Leßmann and Masson, 2015; Zhu, 2015; Tait et al., 2016). These attributes are presented as five aspects and 21 criteria in the appendix. The five aspects include sustainable production, sustainable consumption, collaborative advantage, innovation activities and service operational capabilities.

An SPSS represents a type of sustainable production and was defined as early as 1998. Kriebel et al. (2001) indicate that sustainable production consists of producing goods using processes and systems that are non-polluting, that conserve energy and natural resources and that yield benefits for employees, communities, and consumers over both the short- and long-term. Thus, engineering techniques have been advanced for sustainable production implementation among firms to achieve a continuous improvement in efficiency, quality and flexibility for production (Zhu, 2015; Tseng et al., 2016). Using energy-saving technologies is a process that involves applying various measures to encourage the concept of saving energy to protect the environment and reduce production costs (Mizuta, 2003). Zhu (2015) established that a strict management system means building a system of recognized and verified systematic methods aimed at smooth functioning through standard processes. The third attribute is price change. Tait et al. (2016) stated that in production, there is a change in price that is affected by many external attributes. Firms must control those attributes to ensure sustainable production, and safety certification is an important attribute in sustainable production that helps guarantee product safety and increase customer trust.

Sustainable consumption contains diverse concepts and has become a core policy target in both national and international domains; moreover, as previously noted, a growing number of major retailers are merging it into their core business strategies (Seyfang, 2006). Verain et al. (2015) determined that sustainable consumption was an important attribute of product choice when customers were shopping for a variety of products. Moreover, Vittersø and Tangeland

(2015) showed that product quality and product benefits also play an important role in sustainable consumption. A typical component in the definition of business is product or service quality, which refers to the level of perception of whether products or services are meeting the expectations of customers when product benefits are the target and the needs of customers can be satisfied by benefits from products. The last attribute in sustainable consumption involves financial problems. Consumers typically focus on the price of products and consider their finances and choose a suitable product (Leßmann & Masson, 2015; Tseng et al., 2016).

Lavie (2006) defined collaborative advantage as the benefit obtained by a group of firms based on cooperation rather than competition. Collaborative advantage refers to creating a synergistic outcome from collaborative activity—an outcome that could not be achieved by any single firm. There are five attributes to collaborative advantage. According to Duffy and Fearne (2004), process efficiency determines the degree of the partnership collaboration process with partners that are cost competitive rather than primary competitors. Next to process efficiency, offering flexibility, business synergy, quality and innovation are important attributes in collaborative advantage (Duffy & Fearne, 2004). Offering flexibility also depends upon the capability of collaborating firms to rapidly change process structures or to adjust the information-sharing process for revising the characteristics of a single product or service. Thus, business synergy is defined as a range of partners integrating, completing and relating resources to reach their co-benefits. Quality refers to a firm with partners that offers a quality product that increases value for customers. In addition, innovation is the extent to which a firm cooperates with its partners to introduce new processes, products and services. Finally, innovation is one of the most important attributes in business activity because an innovative product is more competitive and reaches more markets, leading to potential competition (Vangen & Huxham, 2003).

Innovation activities are activities that aim directly at diffusing an innovation in a narrow sense (study, development and demonstration)—in other words, the activities one would refer to as “doing” or working on the innovation itself (Budde, 2013). In innovation activities, there are four attributes. First, product and service innovations belong to new or significantly improved products and services, such as introducing basic materials, improving intermediate products, designing new components, or transforming new product characteristics (Hall, 2009). Second, process innovations can be understood as changes made “behind the scenes” that aim at enhancing productivity and efficiency, such as creating new equipment or adopting automation, developing effective methods for production, or utilizing new energy sources (Hjalager, 2010). Next, management innovation is related to new methods that apply to a firms' management structure, organization of work, or external relationships, such as new approaches to organizing internal collaborations, directing and empowering staff, career development, and worker compensation. Management innovation was also important in innovation activities (Hall, 2009; Hjalager, 2010). Camison and Monfort-Mir (2012) defined marketing innovation as new marketing methods that involve changes in product design, advertising strategies, and pricing, or exploring new relationships with other parties, such as state and administrative systems, social organizations and specific customers.

Coltman and Devinney (2013) indicated that service operational capabilities involve the ability of an organization to bundle its resource base purposefully to enable execution of the continuing tasks that transform inputs into outputs. Service operational capabilities are

considered valuable when a customer must be more completely satisfied or when a firm fulfills its needs at a lower cost than its competitors. Wang et al. (2008) illustrated that the competitiveness of service innovation involves the intensity of market competition for new services, whereas the second attribute in service operational capabilities is implementing innovative knowledge in demonstrating real practices. The study also proposed using a series of new product/service applications to measure innovation capabilities. Finally, self-generated innovative products/services are a progression in which products/services are developed through a study and development process (Wang et al., 2008).

3. METHOD

This section offers an overview and describes the data collection method utilized in this study. In terms of study methods, the FDM, fuzzy IPA and ANP are addressed in the following sections.

3.1 Industry background

The Taiwanese textile industry developed over the past decade and has now become a worldwide industry worth billions of dollars. Contemporary society widely utilizes all types of textiles; devices constructed in automated or semi-automated manufacturing plants employed by industry textile firms are considered to have great potential to bring substantial benefits to the countries in which they operate. However, along with the growth of the industry, textile services innovation has spread all over a world in which a complex network of participants is linked to multiple end-markets. Therefore, service innovation in firms is facing various challenges such as how to address sustainable operation, uncertain demand, and short product lifecycles. An growing number of firms must configure inside and outside assets but remain compliant with worldwide principles. In the Taiwanese textile industry, firms constitute a highly diversified product service system and are closely linked with upstream and downstream SPSS in the United States, Japan and other southeast Asian countries. The industry is continually developing; many textile firms that had traditionally been recognized as producers of service-related products have now noticeably diversified into rapidly growing service and integrated innovation.

The proposed measures addressing service innovations in SPSS are pertinent and timely issues that are particularly fundamental to the textile industry, which continues to play an important role in the manufacturing sector. This study includes 15 academic experts and 25 industrial professionals for the expert team to assist Taiwanese textile firms in improving their service innovation. This study sought to acquire knowledge of the decisive attributes in SPSS, thereby providing important managerial insights for improving product service systems. This study applied its proposed method to evaluate the importance and performance level of attributes. The analysis outlined in the following section describes the process and is followed by the recommendations provided to the textile industry. This study focuses not only on these processes and recommendations but also on decision-making elements, including numerous studies on a particular type of textile manufacturing that appear to be appropriate for exploring SPSS. The significance of product service to customers, the industry processes, and previous consumer demand makes the textile industry an important focus of study when integrating service innovation into SPSS.

3.2 Fuzzy set theory

Zadeh (1965) proposed fuzzy sets and defined fuzzy intersection, union and fuzzy subset based on fuzzy theory. Several prior studies presented fuzzy logic and relative application approaches. Currently, fuzzy theory is extensively utilized in academia and industry and has been integrated by expert judgments for solving real problems and making decisions (Ho, 2010; Tseng et al., 2015). The membership function is the unit component of fuzzy theory that allows fuzzy sets to be transferred into precise figures and processes that can be mathematically analyzed. Accordingly, an important step for solving problems and making decisions based on fuzzy theory is to explore the proper membership function for defuzzification.

(INSERT TABLE 1 HERE)

The function of triangular fuzzy numbers (TFN) is applied to transform the cognitions of experts based on questionnaire assessments. $T(\alpha) = (x, y, z)$ represents the value of the membership function; therefore, x means the lower limit, y presents the middle value, and z is the upper limit of the original cognition value. Experts have been requested to assess using five levels of linguistic terms by means of questionnaire assessments, which implies the degree of importance. Correspondingly, the mentioned levels are used for TFN transformation, as shown in Table 1. The process of fuzzy computation is accepted to address the judgments of k experts, who are considered study subjects. Furthermore, the simple center-of-gravity method is adopted for defuzzification (Zhao & Govind, 1991; Chou et al., 2008).

(INSERT Figure 1 HERE)

Supposing (x, y, z) is a TFN of T set, and $\tilde{T}$ expresses the defuzzification value through the center-of-gravity method. The procedure of defuzzification is meant to transform the fuzzy number into a clear and precise value.

$$\tilde{T} = [(z - x) + (y - x)]/3 + x \quad (1)$$

3.3 Fuzzy Delphi method

The traditional Delphi method is applied as a hybrid incarnation to solve a critical issue by reaching general agreement among the experts. This method not only allows experts to exchange thoughts several times based on their experiences, knowledge and recommendation anonymously but also unravels a complicated problem using a series of questionnaires until consensus is reached. This type of group decision-making method enables reaching rapid convergence of forecasting opinions, helping decision makers shorten the time required to make decisions. Although the method can collect ideas from a wide geography, it still suffers in terms of overcoming linguistic differences. In addition, the study process for experts for achieving general agreement is a complex and time-consuming procedure (Green et al., 1990; Murry & Hammons, 1995). Hence, the FDM combines with the fuzzy concept to overcome the weakness of the traditional Delphi method. Doing so has the following advantages: first, it reduces the number of interviews and the investigation time; second, it offers a more complete expression

of opinions from experts; third, fuzzy theory can be applied to convert the knowledge of experts into precise figures to fulfill demand; and, finally, it can generate additional benefits in relation to decision-making time and cost (Hsu et al., 2010; Chen & Lee, 2013).

1. Transform the assessment score for alternative attributes' importance from experts' judgment by adopting linguistic variables within questionnaires.
2. Establishing TFN by computing the TFN based on an assessment score for each of the aspects and criteria judged by the experts and searching the important TFN for alternative attributes. The geometric mean approach is adopted in this study for gathering the general agreement of the group decision. The procedure is as follows:
   Assuming the assessment score of importance for the a^{th} element, which is judged by the b^{th} expert of k experts is $\alpha_{ab} = (x_{ab}, y_{ab}, z_{ab}), a = 1,2,\cdots, j, b = 1,2,\cdots, k$. Thus, the fuzzy weight of the a^{th} element can be expressed as $\alpha_a = (x_a, y_a, z_a), a = 1,2,\cdots, j$,
   $x_a = Min_a(x_{ab}), y_a = \left(\sum_{a=1}^{j} y_{ab}\right)/k\,, z_a = Min_a(z_{ab})$ (2)
3. Defuzzify the fuzzy weight α_a for each alternative element using a simple center-of-gravity approach for gathering the precise value $\widetilde{\alpha}_a$.
4. Screen out and obtain the acceptable attributes by setting up the threshold value β. When $\widetilde{\alpha}_a \geq \beta$, the a^{th} attribute is accepted as an assessment indicator; otherwise, the a^{th} attribute must be deleted from the indicator list.

3.4 Fuzzy importance performance analysis

Martilla and James (1977) initially proposed the IPA method. This method adopts a two-dimensional matrix to present the analysis result, which enables ranking the performance on the importance and quality of a product or service shown to customers (Sampson & Showalter, 1999; Deng and Pei, 2009).

1. Collect experts' consciousness of the importance and performance of each accepted attribute. Experts have been requested to judge the satisfaction for each criterion on a 1 to 5 linguistic scale. The fuzzy set of performance for the a^{th} element judged by the b^{th} expert of k experts can be presented as $\mathcal{P}_{ab} = (\mathcal{P}x_{ab}, \mathcal{P}y_{ab}, \mathcal{P}z_{ab}), a = 1,2,\cdots, j, b = 1,2,\cdots, k$ (shown in Figure 1). Therefore, the fuzzy weight of the a^{th} element is $\mathcal{P}_a = (\mathcal{P}x_a, \mathcal{P}y_a, \mathcal{P}z_a), a = 1,2,\cdots, j$.
2. Defuzzify the fuzzy weight $\mathcal{P}_a$ by adopting a simple center-of-gravity method for transferring each alternative element into a clear value $\tilde{\mathcal{P}}_a = \{[(\mathcal{P}z_a - \mathcal{P}x_a) + (\mathcal{P}y_a - \mathcal{P}x_a)]/3\} + \mathcal{P}x_a, a = 1,2,\cdots, j$. The importance of $\tilde{\jmath}_a$ can be obtained by repeating the above procedure.
3. Compute the means for importance and performance. The entire mean for the importance and performance weight can be obtained separately using $\tilde{\jmath}'_a = \left[\sum_{a=1}^{j}(\tilde{\jmath}_a)/j\right]$, $\tilde{\mathcal{P}}'_a = \left[\sum_{a=1}^{j}(\tilde{\mathcal{P}}_a)/j\right]$.
4. Arrange the IPA matrix into four quadrants by adopting the means of importance and performance weight $\left(\tilde{\jmath}'_a, \tilde{\mathcal{P}}'_a\right)$. Importance value is considered the horizontal axis and performance value the vertical axis, which enables mapping individual elements into two dimensions. In addition, employing four quadrants uses a visual analysis to present the level of importance and performance of each aspect and criterion. Quadrant I represents the aspect and criterion of higher-level and better performance; hence, the firm should maintain

these features of work, which are essential resources for the competiveness of the firm. If the aspect and criterion is located in quadrant II, the function has a lower level of importance with higher performance and is thus a secondary resource for firm competitiveness. In other words, these areas are of lesser importance in the current operation, and the firm focuses only slightly on investment in this area. An aspect and criterion falling into quadrant III represents a secondary weakness of the firm, with a lower level of importance and insufficient performance. If the firm is under a resource limitation, such areas can be improved when the firm has the necessary resources. Quadrant IV possesses the feature of higher-level importance with lower performance, which means that the firm must prioritize investing resources to improve.

3.5 Integrating the importance and performance weights

There are two weights in this analysis, i.e., $\omega_{\tilde{J}'_a}$ is the importance weight and $\omega_{\tilde{P}'_a}$ is the performance weight. This study assumes that the importance and performance weights are equally important in management. The weights (ω_t) are computed as follows:

$$\omega_t = (\omega_{\tilde{J}'_a} + \omega_{\tilde{P}'_a})/2 \tag{3}$$

Suppose there are m aspects and n attributes. ω_t represents the relative unconverged weights as ω_{ta} to ω_{tb}. The converged process uses a supermatrix to address the hierarchical model with interdependence relationships. Then, the unconverged supermatrix S is obtained. The converged supermatrix S^* is based on Eq. (4) and allows for a gradual convergence of the interdependence relationships to obtain accurate relative weights for the attributes.

$$S^* = \lim_{i\to\infty} S^i \tag{4}$$

4. RESULTS

This section is based on the proposed analytical steps to conduct an analysis using the FDM; the IPA diagram and the converged ANP supermatrix to present the results.

4.1 FDM results

The initially proposed 5 aspects and 21 criteria are presented in the appendix. The FDM results are shown in Table 2, where the minimum value is 0.462. Eq. (1) defuzzifies the TFN. Eq. (2) shows the TFN (Lowest, medium, Highest value) and uses the mathematical average method to acquire the threshold value. This study computed the threshold value of 0.545; all evaluation values of all items are required to be greater than this threshold. However, based on fuzzy FDA analysis, IAs 1 (0.462) has a value of less than the threshold value; therefore, it will be removed from the initially proposed aspects.

(INSERT TABLE 2 HERE)

Following Eqs. (1) and (2), Table 3 shows the threshold value is 0.643. The results indicate that the IC1, IC2, IC9, and IC15 have values less than the threshold value. Hence, these criteria are removed from the initial proposed criteria.

(INSERT TABLE 3 HERE)

Table 4 presents the reliable measures from the FDM results. Four aspects and 15 criteria remain in the attributes. The aspects are Sustainable consumption (AS1), Collaborative advantage (AS2), Innovation activities (AS3) and Service operational capabilities (AS4). The remaining criteria are the most related and important for the service innovation in SPSS and enhance the reliability and credibility of the measurement attributes.

(INSERT TABLE 4 HERE)

4.2 Fuzzy IPA results

Table 5 shows the results of the IPA for the aspects, where the (I-P) means that the importance weight is greater than the performance weight. The (I-P) of AS1, AS2 and AS3 are positive; only AS4 is negative. AS4 means that performance weight is greater than the importance weight. Figure 2 presents the IPA diagram to allocate the aspects into four quadrants.

(INSERT TABLE 5 HERE)

(INSERT Figure 2 HERE)

The IPA of the criteria is shown in Table 6. However, there were slight differences between the mean value of importance (0.691) and the mean value of performance (0.664). The results imply that the importance for each evaluation item is significantly higher than the performance, indicating that some of the items suffer poor performance and urgently need improvement. The IPA diagram in Figure 3 shows that the decision makers over-invested resources in AS2. Over-concentrating on an aspect should be decreased, as raising overall competitiveness might otherwise be impossible.

(INSERT TABLE 6 HERE)

(INSERT Figure 3 HERE)

There are five criteria located in this high performance and importance quadrant that are the strength and pillar of firms (C4, C9, C12, C14 and C15). Those criteria considered the pride of the firms are shown to have positive effects on firm performance and should thus be maintained such that the firm can “keep up the good work” to create sustainable advantages. These criteria were designed to emphasize the importance of products/services developed through study and development in the firm, the importance of self-generated innovative products/services (C15), several new product/service applications (C14) and the intensity of market competition for new services by joining service innovation competitiveness (C12). Moreover, a product can satisfy the tacit needs and wants of its target customers by generating product benefits (C4), thus significantly affecting the firm and maintaining continuous improvement. The results can help the firm increase its sustainable competitiveness in the marketplace. In addition, introducing new materials, intermediate products, new components, or new product features by working on product and service innovations (C9) might change the current rival situation and assist firms in exploring its new competitiveness.

Meanwhile, three criteria (C6, C8 and C10) fall in the “possible overkill” quadrant. The discrepancy between the levels of low importance and high performance indicates a possible overuse of resources that can be reduced. Firms are allocating resources for high performance. However, those criteria are not deemed exceptionally important to the firm when management innovations (C10) are determined to be related to new positive methods employed by management and works or when external relationships are pursued in search of new means of organizing internal collaborations, managing and authorizing staff, developing careers and

compensating workers. Business synergy (C6) refers to the scope of associated complementary partners in terms of utilizing resources efficiently to achieve co-benefits. Collaborative innovation (C8) encourages a firm to work jointly with its partners to introduce new processes, products, or services into the market.

Three criteria (C3, C11 and C13) fell into the "low priority" area. These criteria are not particularly important and pose no threat to the firms, and resources are thus not being channeled toward them. As a result they should remain untouched. Hence, the marketing innovations (C11) do not significantly affect firm performance due to its new marketing methods, a point that relates to changes in the product design, advertising strategies, pricing, and new relationships with other parties, including the status of administrative systems, public organizations or particular customers. Conversely, the quality of products or services involves the degree of consciousness that fulfills customer's expectations; however, the product service system is generally ignored when measuring quality. This omission suggests that firms might have a low awareness of product quality (C3), and this result implies that the actual use of innovation knowledge was illustrated innovative knowledge (C13), which does not affect firms' service innovation.

From four criteria (C1, C2, C5 and C7), it can be inferred that managers should "concentrate here" more to improve firm performance. Those criteria are very important with low performance to the firm and thus represent key areas that must be improved as a top priority. The customer focuses on the price of products and considers its finances when choosing a suitable product. Hence, firms should focus more on product choice (C1) and any financial problems (C2) of the potential customer. Offering flexibility (C5) means cooperating with firms in shifting process structures or shaping the information-sharing process to revise the characteristics of the product or service. Consequently, Quality (C7) pertains to the firm associating with partners to provide a quality product that leads to customer satisfaction with higher value.

4.3 Integrated and converged importance and performance weights

Table 7 expresses the average weights for the importance and performance involved in constructing an unconverged supermatrix using Eq. (3). The ranking sequence is stated as follows: Sustainable consumption (As1), Collaborative advantage (As2), Innovation activities (As3) and Service operational capabilities (As4).

(INSERT Table 7 here)

Applying Eq. (4) yields the results in Table 8 and generates the converged supermatrix. The top five criteria are Business synergy (C6), Self-generated innovative products/services (C15), Product and service innovations (C9), Product and service quality (C7) and Collaborative innovation (C8).

(INSERT Table 8 here)

5. IMPLICATIONS

This study integrated service innovation with SPSS by employing the FDM, Fuzzy IPA and ANP concepts. The implications provide theoretical and practical insights for management in the industrial sector.

5.1 Managerial Implications

Industrial management can incorporate the findings into their strategic development of service innovation in an SPSS model, with close consideration of prevailing social, economic, and environmental conditions based on the FDM. The model should be associated closely with the attributes that are critical to firm performance. Hence, industrial management focuses on service innovation in SPSS. Moreover, reallocating resources and efforts from unimportant aspects and criteria from unnecessary activities can lead to costly expenditures. This study shows that product or service choice is key to improved SPSS. Currently, the technological development, consumers demand not only quality products but also product or service diversification. Consumers always have several alternatives in choosing products or services. Variety in products is shown in functions, price and design. Diversity in products or services also attracts more consumers. Selection of products or services plays an important role in orienting production because consumers choose some types of products or services in accordance with place of origin, production processes or producer.

Firms should focus on surveys to understand consumers' functional or design needs and then develop products or services accordingly. In addition, firms can learn to innovate and combine existing products or services to improve their service or design product processes. Service innovation in SPSS means product and service innovation. Product and service innovation is a situation in which resources are involved in firms' operational processes such as managerial, technology, product and process innovation (Wu et al., 2015; Tseng et al., 2016). In particular, in choosing available products or services on the market, consumers are concerned not only with diversification of products or services but also with price; they choose suitable products or services depending upon their finances. To satisfy customers, firms should market products or services with reasonable prices and functions. Therefore, firms can take the following steps to reduce product or service costs. First, firms should consider approaches to using waste to create other products or services rather than sending it to recycling, reuse or disposal. In addition, tracking and measuring operational efficiency is used to adjust and optimize the use of available resources. Setting performance targets reflects the efficiency and effectiveness goals.

To improve service in SPSS is to develop self-generated innovative products/services in the firms' system, which is quite closely related to business synergy among partners. Hence, flexibility leads to an environment in which the partners examine work and needs using a balanced approach to self-generated innovative products/services that is mutually beneficial, particularly insofar as collaborative innovation is concerned. Collaborative innovation allows a firm to be more adaptive and creative in a changing environment and allows its partners to thoughtfully respond to such product or service changes rather than react in ways that might damage firms in longer-term relationships. Hence, firms can be flexible in their operational processes and work with self-generated innovative products/services. Collaborative innovation involves a product or service catering to the consumer market. The consumer is satisfied with basic features, but seeks

added valuable functionalities. Hence, business synergy offers the maximum value to the supply chain partners. Establishing and communicating collaborative innovation to achieve business goals, then performing the self-generated innovative products/services is the key criterion for success.

Collaboration in service innovation in SPSS is typically meant to address problems with product or service innovation processes during innovative operational processes. Hence, a strong collaboration often breeds innovation with respect to problem solving, and interaction facilitates innovation by providing a place to suggest and to perform review to enhance service innovation in SPSS. Collaboration among firms in the industry is typically associated with increases in their customer satisfaction and contributes to firm performance, encouraging firms to exchange knowledge with others in a collaboration process. Firms can share analytics and insights with collaborators to support shared initiatives, allowing collaborators to increase their efficiency and effectiveness together.

5.2 Theoretical Implications

This study contributes to the literature by exploring the attributes of service innovation in SPSS, thereby gaining better insights. This study provides evidence suggesting that sustainable operations and sustainable consumption should be the priority premises; collaborative advantage is also acknowledged as a critical role for improving service innovation in SPSS. The findings of this study suggest how service innovation criteria integrate into SPSS. These findings are consistent with several previous studies that also found a positive relationship between service innovation and SPSS (Snyder et al., 2016; Xin et al., 2013).

The results suggest that having sustainable operations is an important attribute of SPSS. Inside sustainable operations is a pattern that provides socially beneficial, economically viable and environmental friendly results over the entire life cycle (Fuchs & Lorek, 2005). The SPSS is a concept through which businesses can improve their economic and environmental performance. Hence, this concept demands high levels of innovation in products by analyzing the demands of customers for products or services to satisfy their perceptions and gathering the results as the foundation of innovation. Sustainable products help meet consumer demands by considering the reduction of environmental and social impacts (Seuring & Müller, 2008). Currently, with the development of technology and awareness, sustainable production plays an important role in SPSS when satisfying the consumer without producing rebound effects that erode potential environmental and social benefits or their economic attractiveness. As a result, firms should not only be concerned with the design and price of products but also focus on environmental and social problems to achieve sustainability in production.

This study has provided integrated attributes of service innovation in SPSS. Obviously, service innovation is a key component in SPSS that has minimal impact on the environment or egalitarian society and is economically viable, all while meeting the basic needs of consumers worldwide (Clark, 2007; Tseng et al., 2016). Sustainable consumption not only is suited to each individual but also crosses all regions and all countries, from the public to governments and multinational conglomerates. The proposed hierarchical model extends beyond the environmental optimization of products and processes and requires fundamental and creative thinking to reduce environmental impacts by setting a series of attributes while maintaining an acceptable

level of quality for products and services. SPSS and sustainable consumption are essential concepts for achieving sustainability. Therefore, enhancing awareness regarding consumption for each consumer is necessary. A true assessment of consumption of a product or service can bring benefits for both customers and firms for the environment and society.

6. CONCLUSIONS

From a theoretical perspective, this study presents the influences of service innovation in SPSS and provides a set of empirical features and criteria related to service innovation in SPSS; in so doing, it fosters an evaluation of the importance and performance of each attribute to sustainable advantages. To explore such a complex phenomenon, this study applied the FDM, which was adopted to filter the professional competencies of top management (Horng and Lin, 2013). The results presented a set of attributes for the assessment model. Prior studies have not had such precise evaluation attributes. Moreover, the fuzzy IPA distributed importance and performance weights to assess the complicated situation; thus, decision makers could identify those important attributes that required improvement. Although previous studies have used the IPA to demonstrate that these items enable the achievement of good performance without requiring extensive improvements or investing excessive amounts of resources, qualitative attributes remain that require further discussion. Prior studies have rarely addressed these qualitative preferences. Importantly, the literature does not employ integrated and converging weights on the attributes. Hence, this study integrated the methods to address those dilemmas from prior studies.

The findings confirm that service innovation integrates SPSS, implying that sustainable consumption and innovation activities should be prioritized over other features of management decision-making. These aspects have the potential to improve the SPSS and affect service innovation. Specifically, sustainable consumption was found to be the feature that could maintain the work by management. In addition, innovation activities might lead to the development of a sustainable firm as a result of service innovation sustainability. Notably, applying sustainable consumption practices delivers several benefits. Furthermore, sustainability must become a superior principle in firms to lead them from weak to robust sustainable consumption (Lorek and Spangenberg, 2014). Both product selection and financial problems have generated great concern with respect to how consumers could be influenced to develop markets in sustainable textile products. Innovation activities in an SPSS can create synergy for development. Diversified innovation activities are incorporated in a firm via product and service innovation, assisting the firm in rapidly responding to market changes and customer needs.

A practical contribution of this study is that it identifies the importance and performance of service innovation in SPSS and highlights what a firm should emphasize as it undertakes sustainable operations. In addition, the results provide evidence for how to improve service innovation in SPSS in terms of the textile industry. This study highlights self-generated innovative products/services along with a number of new product/service applications, service innovation competitiveness, product benefits, and product and service innovations. Those criteria that are determined to be strengths of the firms are shown to have positive effects on a sustainable firm at significant levels in terms of both importance and performance; thus, firms should maintain these strengths to create and maintain sustainable advantages. Moreover, firms should focus

more attention on business synergy, self-generated innovative products/services, product and service innovation, product and service quality and collaborative Innovation. Those criteria that fall into this concentrated quadrant, which have high importance to the firm but low performance, represent key areas that must be enhanced with a high priority.

This study is encountered the limitations. The findings are applicable to the textile industry and might not be generalizable to other industries. The relevant industry studies are quite rare, possibly resulting in insufficiency of the study model due to the textile industry has not reached a mature developmental phase in some countries. This study provides some significant suggestions for using the FDM, fuzzy IPA and ANP concept hybrid method. The related number of collected respondents is small; however, the respondents are experts and professionals in the field. Future studies are suggested to further explore feasible and reliable methods to reach outstanding performance in each dimension of the study model or to discover sustainable advantages overlooked by the study, which would lead to a broader scope of study and a complete discussion of the cross-country textile industry. This study focused exclusively on the SPSS literature on overall sustainable competitiveness in the Taiwanese textile industry and might lack other necessary details. Therefore, follow-up study is suggested on certain features such as service innovation cooperation in the supply chain.

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APPENDIX. The initial attributes

Initial aspects		Initial criteria	References
Sustainable production (IAs1)	IC1	Use energy-saving technologies	Zhu (2015)
	IC2	Establish strict management system	
	IC3	Price change	Tait et al. (2016)
	IC4	Safety certified	
Sustainable consumption (IAs2)	IC5	Product choice	Verain et al. (2015)
	IC6	Financial problems	Leßmann & Masson (2015)
	IC7	Product quality	Vittersø & Tangeland (2015)
	IC8	Product benefits	
Collaborative advantage (IAs3)	IC9	Process efficiency	Duffy & Fearne, (2004)
	IC10	Offering flexibility	
	IC11	Business synergy	
	IC12	Quality	
	IC13	Innovation	
Innovation activities (IAs4)	IC14	Product and service innovations	Hall (2009); Hjalager (2010)
	IC15	Process innovations	
	IC16	Management innovations	Camison & Monfort-Mir (2012)
	IC17	Marketing innovations	
Service operational capabilities (IAs5)	IC18	Service innovation competitiveness	Wang et al. (2008)
	IC19	Application of innovative knowledge	
	IC20	Number of new products/services applications	
	IC21	Self-generated innovative products/services	

Figures

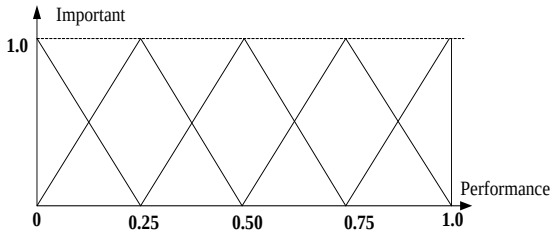

Figure 1. The relationship of the membership of fuzzy linguistic terms

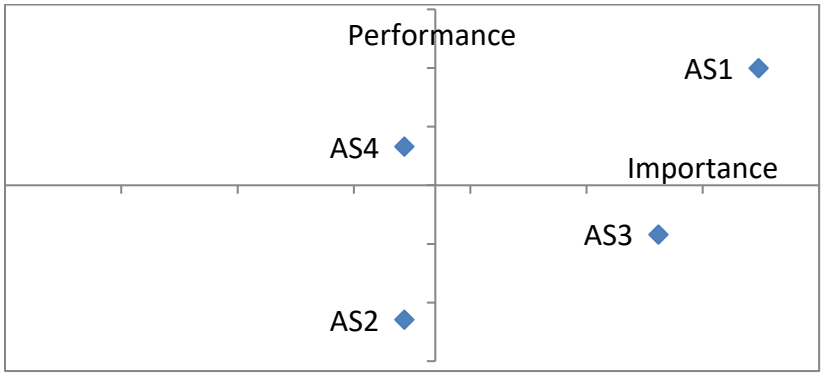

Figure 2. IPA result for aspects

Figure 3. IPA result for criteria