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An integrated sustainable production and consumption approach

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Abstract

Purpose – The purpose of this paper is to identify how organizations can evaluate the green product deletion decision within an environmentally sustainable consumption and production environment through a hybrid multistage multiple criteria evaluation approach.
Design/methodology/approach – This paper proposes a decision-making model by integrating "soft computation" using neighborhood rough set theory, fuzzy cluster means, and cumulative prospect theory. Literature is used to identify various factors for the decision environment. An illustrative problem provides insights into the methodology and application.
Findings – The results indicate that green products can be evaluated from both their relative environmental burdens and benefits. Sustainable consumption and production factors that play a role in this multifactor decision are identified. The results show that a comprehensive evaluation can capture an effective overall picture on which green product(s) to delete.
Research limitations/implications – The opaqueness of the proposed methodology may cause less acceptance by management. The methodology made a number of assumptions related to the data. An actual application of the tool rather than just an illustrative example is needed.
Originality/value – The main contribution of this study is the novel integration of supply chain perspectives, both upstream (supply and production) and downstream (demand/usage), with green product deletion decision making. The hybrid multistage technique has advantages of being able to incorporate many factors that have a variety of quantitative and qualitative characteristics to help managers address green product deletion issues as well as its impact on greening of supply chains and organizational environmental sustainability. This paper adds value to product deletion, supply chain management, and sustainable production and consumption literatures.

Keywords Sustainability, Supply chain management, Cumulative prospect theory, Fuzzy cluster means (FCM), Green product deletion, Rough set theory (RST)
Paper type Research paper

1. Introduction

Organizations have focused a significant amount of effort and resources on product innovations and product introductions in the product life cycle. This focus has also occurred when introducing new "green" or environmentally sound products. Almost every product has a life cycle which will eventually end with its decline and ultimately its deletion from an organization's product portfolio.

Product deletion is as critical as new product introduction to many organizations. Deletion of a product has operational and strategic implications for the organization that need to be carefully considered (Shah *et al.*, 2016/2017). Green products add more layers of complexity to this decision. While deleting green products, environmental sustainability dimensions play a much broader role and incorporate social and regulatory dimensions and considerations in a way that other products do not. For example, when deleting a product based only on business decisions, customers and stakeholders may understand the financial motivations to keep the organization healthy. Green products typically will carry more

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emotional and social weight. If a company decides to delete a green product there may be cries of greenwashing or the potential perceptions of greater harm to the environment. The broader social implications of these goods, which may or may not occur as extensively in regular products, makes the decision more complex. Green product deletion has very rarely, if at all, been investigated in the literature.

A green product may be green for different reasons. For example, the product may have been produced, in the upstream supply chain, using green materials and processes. Yet, its usage may not be very green. For example, recycled paper and packaging may still be used in an environmentally unsustainable way although it was produced in a green way. Alternatively, some products, such as photovoltaic solar panels, may be green because they are consumed in a green manner, although production may not have been very green. Thus, if an organization is to consider which green product to delete, a broader perspective is required.

In this paper, using a general systems theoretical lens, a comprehensive set of factors affecting the green or regular product deletion decision is considered. The factors focus on environmental performance, but also include business, consumer, and overall product deletion decision-specific characteristics. Clearly many soft computational tools can aid in this complex systems decision process (Devezas, 2005; Gupta, 1999). In the context of product deletion, a three-step hybrid multiple criteria decision process to help evaluate the green product deletion decision is introduced.

The major contribution of this paper is introducing green product deletion decisions as an important area for investigation by researchers in the supply chain management field. This is implemented from a unique sustainable production and consumption (SPC) perspective in this paper. This joint perspective is a better balance for product decisions, especially product deletion decisions, and is relatively neglected in the literature. This approach gets closer to the environmental life cycle perspective that is recommended when evaluating products and materials, with a linkage to supply chain sustainability. Another important contribution is the integration of environmental sustainability, business, and product deletion metrics into the decision. Although each methodological soft computation stage of the decision approach in this paper has been developed in the literature, the contribution is the unique way they are integrated to help organizations arrive at a decision. The hybrid multiple criteria soft computational approach utilizes neighborhood rough set theory (NRST) to help develop relative importance weights of the attributes (factors). The second stage of the hybrid approach is the use of fuzzy cluster means (FCM) methodology to determine reference points and their probabilities. This information is generated for use in a cumulative prospect theory (CPT) process that calculates the final evaluation of green product performance on all the attributes.

The remainder of this paper provides theoretical background that helps provide an overview of factors in the supply chain, including SPC, for consideration in the green product deletion decision. General business related and organizational product deletion decision factors are also introduced. These factors are used in the hybrid multiple criteria soft computing methodology. The methodological tools including NRST, FCM, and CPT are then introduced. How these soft computing tools can be used together and synergistically is described with a detailed illustrative example of a green product deletion decision. The results are discussed from the perspective of an overall evaluation (i.e. integrating SPC factors) and partial factors (i.e. isolating SPC factors) evaluation. The conclusion discusses research limitations and directions for future research.

2. Background

In this section, a number of related topics are reviewed to set the theoretical foundation for making green product deletion decisions. These topics include a brief review of product deletion in general, SPC, green products and factors influencing green product deletion including building sustainability into supply chains.

Theoretically, there are a number of activities within organizations and their supply chain influenced by the production deletion decision. Supply chain sustainability from both upstream (production) and downstream (consumption) perspectives are critical in this examination. Systems theory, and its offshoot complex systems theory, is an underlying theoretical framework that helps to understand the implications of decisions in this realm (Chang *et al.*, 2017; Rotmans and Loorbach, 2009). Systems theory, from the broader sustainability perspective, seeks to understand various natural, social, technological and organizational systems and their interactions. In this situation, the various systems include natural systems through environmental impact; social systems through social sustainability dimensions and consumer consumption; technological systems through product deletion decisions within organizations; and organizational systems that focus on materials and product flows across and within organizational boundaries. These interactions are not trivial or simple, and thus need for consideration of complexity; and the use of soft computing methodologies (Devezas, 2005).

2.1 Product deletion

Product deletion (elimination or pruning) is defined as discontinuing or removing a product from an organization's product portfolio (Avlonitis and Argouslidis, 2012). Firms consider products for deletion when they become weak, are poorly fitting, or suffer from underperformance on various financial and strategic parameters (Argouslidis *et al.*, 2015). Such weak products exhaust firms' resources and amplify the complexity of internal processes across functional areas, such as external sourcing, logistics, marketing, and human resources (Putsis and Bayus, 2001; Thonemann and Brandeau, 2000). Deleting these products alleviate operational costs and augment organizational profits (Bayus and Putsis, 1999). Firms can re-channel the resources released from deleted products to other stronger products in their product portfolio, or in improving their sustainability facets (Stadtler, 2015).

Several organizational, financial, operational, marketing, and strategic benefits can be gained from deleting underperforming products. However, product deletion is also a challenging and complex decision with critical consequences (Argouslidis *et al.*, 2014). For example, if product deletion is not executed appropriately, there could be customer dissatisfaction, loss of market share and revenue, poorer operational activities, and loss of competitiveness (Harness and Mackay, 1997; Shah, 2017a, b). For green products, which require extra resources and considerations for design, materials selection, manufacturing, processing, transportation, service, and end-of-life management, and a broader base of stakeholders to consider, this decision becomes even more daunting. Therefore, important strategic and operational factors need to be meticulously incorporated into the green product deletion process (Maniatis, 2016).

The product deletion process encompasses four stages: identification of candidates for elimination, analysis and revitalization/modification, evaluation and decision making, and implementation (Avlonitis and Argouslidis, 2012). The proposed model presented in this paper facilitates the evaluation and decision-making phase. Eight important product deletion evaluation factors tested by Avlonitis (1984, 1985) namely., capital reallocation, release of executive time, full-line strategy, corporate image, competitive moves, sales, profitability, and fixed and working capital are included in the proposed model. These factors are explained in detail in Section 2.3.3.

2.2 SPC

Businesses fuel economic growth, employment, social prosperity, and improving peoples' lives by providing good quality affordable products and services (Kindström and Kowalkowski, 2014). However, though businesses create value for various stakeholders, their activities are also damaging the environment and depleting Earth's natural resources (Lehmann and Joseph, 2015). Therefore, it has become imperative to meet economic and social needs keeping in mind the capacity constraints of our planet. This requires not only businesses to use processes and deliver products with lower environmental impact but also calls for consumers to make sustainable choices. All facets of the system of production and consumption must be critically evaluated to help meet environmental sustainability goals (Hallstedt, 2017; McDonagh *et al.*, 2012).

The UN Commission on Sustainable Development defined SPC as the production and consumption of products and services that satisfy essential needs and provide a better quality of life, while decreasing consumption of natural resources, emissions of toxic substances and wastes throughout their life cycles, with the goal of causing less damage to natural resources, and thereby ensuring that the demands of future generations will be met (Jonkutė and Staniškis, 2016; Welford *et al.*, 1998). There have been several initiatives to improve resource efficiency and sustainable production however, "despite the improvement in results of environmental practices of many individual producers, an increase in the amount of general consumption often exceeds the achieved progress (the so-called 'rebound' effect) […]" (Jonkutė and Staniškis, 2016). It is clear that for sustainability development, sustainable production systems alone are not enough; consumer choices and actions are also crucial (Kjaerheim, 2005; Spangenberg, 2013; Stevens, 2010; Tseng *et al.*, 2013).

However, SPC can not only be achieved through eco-innovation, eco-design, sustainable procurement, or closed-loop production but also through deletion of products that are either not ecologically produced or not sustainably consumed (Shah, *et al.*, 2016-17).

In the proposed model, nine important factors influencing sustainable production/distribution and six critical factors affecting sustainable consumption are included to evaluate the product deletion decision. These factors are explained in detail in the next section.

2.3 Factors influencing green product deletion

This paper identifies three major dimensions of factors that might affect an organization's green product deletion decision (Table I). These dimensions are specifically from sustainable supply chain (incorporating SPC) and product deletion perspectives. Two divisions of supply chains are discussed in detail separately, including upstream supply chain (production and distribution supply chain) and downstream supply chain (consumption supply chain). Three major categories of product deletion strategic factors involve impact on organizational resources, impact on strategy, and financial impact. The forthcoming sections will present; 23 factors within these three major dimensions that influence an organization's green product deletion decision. These 23 factors are grounded in previous literature and are selected to represent the breadth and comprehensiveness of the type of quantitative and qualitative factors that should be considered in the context of product deletion.

2.3.1 Production/distribution supply chain. Upstream supply chain processes transform material and energy to products or services (Mentzer *et al.*, 2001). This upstream supply chain generally includes extraction, production, and distribution of products or services to end users (Giunipero and Aly Eltantawy, 2004). Production and distribution supply chain factors include inputs, such as activities and costs associated with energy, raw material, logistics, labor, marketing and research and development (R&D), design, and outputs, such as useable materials, components, products, and non-desirables such as solid waste and air emissions. Energy costs are those garnered in the product's manufacturing and distribution processes (Gold and Seuring, 2011; Mirhedayatian *et al.*, 2014; Zhu and Geng, 2013). For example, electricity consumed in the factories and petrol used in transportation and delivery. Material cost includes costs associated with acquiring raw material resources,

Dimension	Factors	Definition	Sources	Measurement and boundaries
Production/ distribution supply chain	Energy (E1)	Energy cost that is used in the product's production and distribution process, such as electricity, gas, and water	Mirhedayatian *et al.* (2014), Gold and Seuring, (2011), Zhu and Geng (2013)	Cost, $ (1,10) 1 represents very less money associated; and 10 represents very high money amount associated
	Material (M)	Material cost that is used in the product's production process	Mirhedayatian *et al.* (2014), Beamon (1998), Min and Zhou (2002)	
	Logistics (L)	Logistics related costs involved in the product's distribution to consumers, including warehousing and transportation	Mirhedayatian *et al.* (2014), Cooper and Ellram (1993), Mentzer *et al.* (2008)	
	Labor (La)	Labor cost in the product's production and distribution processes	Mirhedayatian *et al.* (2014), Vidal and Goetschalckx (1997), Liang (2008)	
	Marketing (MKT)	Marketing investment in promoting the product's value proposition to consumers	Mirhedayatian *et al.* (2014), S. Min and Mentzer (2000), Gimenez and Ventura (2005)	
	R&D	Research and development cost in the product's production and distribution processes	Mirhedayatian *et al.* (2014), Lambert *et al.* (1998), Stank *et al.* (2001)	
	Design (D)	Design cost in product and process development, such as eco-design and distribution network design	Tseng *et al.* (2013), Mirhedayatian *et al.* (2014), Tukker *et al.* (2008)	
	Solid waste (SW1)	Solid waste in the product's production and distribution processes, such as trash or garbage	Zhu and Geng (2013), Beamon (1999a), Srivastava (2007)	Weights allocation (1,5) 1 represents very less waste and emissions of output; 5 represents very high waste and emission
	Air emissions (AE1)	Air emissions in the product's production and distribution processes, such as CO_2	Zhu and Geng (2013), Beamon (1999a), Srivastava (2007)	

(*continued*)

Table I.
Factors used in green product deletion evaluation model

Dimension	Factors	Definition	Sources	Measurement and boundaries
Consumption supply chain	Solid waste (SW2)	Solid waste in the product usage process, such as trash or garbage	McCarty and Shrum (1993), Otoniel *et al.* (2008), Salhofer *et al.* (2008)	
	Air emissions (AE2)	Solid waste in the product usage process, such as such as CO_2	Peters (2008), Peters and Hertwich (2008), Munksgaard *et al.* (2000)	
	Energy (E2)	Energy consumed in the product usage process	Mirhedayatian *et al.* (2014), Young *et al.* (2010), Lenzen (1998)	Cost, $ (1,10) 1 represents very less money associated; and 10 represents very high money amount associated
	Perceived product effectiveness (PPE)	A consumer's perceived product effectiveness, including the purchase and consumption convenience, as well as confidence in its functionality	Tsiotsou (2006), Souder *et al.* (1998), Berger and Corbin (1992)	Level assessment (1,100) 1 represents low level; 100 represents high level
	3Rs	Level of reduce, reuse, recycle of a product from all its components	Barchers (2010), Winans *et al.* (2017)	
	Customer utility (CU)	Customer's overall utility level of consuming a product, including satisfaction and perceived quality and service	Tukker *et al.* (2008), Beamon (1999b), Hennig-Thurau and Klee (1997)	
Product deletion strategic factors	Capital reallocation (CR)	Human, physical, and financial resources committed to a product on overall supply chain processes which will need to be reallocated to other products after product deletion	Avlonitis and Argouslidis (2012), Avlonitis (1984, 1985), Avlonitis *et al.* (2000)	Weights allocation (1,10) 1 represents very less contribution to the overall firm strategic decision; 5 represents very high contribution to the overall firm strategic decision
	Release of executive time (RET)	Executive time committed to a product on overall supply chain processes that will be released due to product deletion	Avlonitis (1984, 1985), Avlonitis *et al.* (2000)	

Table I. (*continued*)

Dimension	Factors	Definition	Sources	Measurement and boundaries
	Full-line strategy (FLS)	An organizational strategy attempting to enhance product line depth by carrying a high number of variations of similar products in order to satisfy a wide range of different customer desires	Matsubayashi *et al.* (2009), Avlonitis *et al.* (2000), Avlonitis and Argouslidis (2012)	
	Corporate image (CI)	Company's identity, intended image, construed image, and reputation	Brown *et al.* (2006), Avlonitis *et al.* (2000), Avlonitis and Argouslidis (2012), Shah (2015)	
	Competitive moves (CM)	A firm's tendency to employ mimetic behavior, i.e., when they observe that their main competitors are engaging in particular behaviors, they also tend to engage in similar behaviors	Varadarajan *et al.* (2006), Avlonitis *et al.* (2000), Avlonitis and Argouslidis (2012), Shah (2015)	
	Sales (S)	A product's sales volume	Avlonitis *et al.* (2000), Saunders and Jobber (1994), Alexander (1964)	
	Profitability (P)	The degree to which a product yields profit or financial gain	Avlonitis *et al.* (2000), Quelch and Kenny (1994), Hamelman and Mazze (1972)	
	Fixed and working capital (FWC)	Fixed and working capital tied to a product, which can be tangible asset, such as a building, or an intangible asset, such as an intellectual property	Avlonitis *et al.* (2000), Quelch and Kenny (1994), Hamelman and Mazze (1972)	

Table I.

intermediate materials, and semi-finished products necessary for the production process of a product (Beamon, 1998; Min and Zhou, 2002; Mirhedayatian *et al.*, 2014). Non-energy materials may include wood, metals, chemicals, crude oil, and cotton.

Logistics is defined as the organizational management processes of planning, implementing, and controlling product flows from point-of-origin to point-of-consumption (Cooper *et al.*, 1997). Logistics costs refer to the investment associated with such logistics activities. Warehousing and transportation are included (Cooper and Ellram, 1993). The cost of labor is the sum of money paid to employees involved in the production and distribution supply chain, including the cost of employee benefits, such as insurance, and payroll taxes (Liang, 2008; Vidal and Goetschalckx, 1997). Marketing associated expenses are dissimilar in costs to investments that are in facilities and inventories, marketing funds are typically value oriented (Gimenez and Ventura, 2005; Seggie *et al.*, 2007). Marketing cost is identified in this paper as funds of promoting the product's value proposition to consumers (Foster and Gupta, 1994).

Spending on R&D and design is also critical for products (Audretsch and Feldman, 1996). For example, companies that offer green products to the market are found to invest millions on eco-design, such as green packaging and green technology in recyclable material; and environmental management standards, such as ISO 14000. The inputs mentioned thus far, are measured in dollars and represented on a scale of 1-10 in the methodology calculation, where 1 means very limited cost involved and 10 means very high cost associated. These measures are exemplary, and a relative transformation can be completed easily from actual data. They are provided in this way since some of these measures may be based on managerial experience and perception.

Two major outputs from production and distribution supply chains include solid waste (Beamon, 1999a; Zhu and Geng, 2013) (i.e. landfilled material) and air emissions (Srivastava, 2007; Zhu and Geng, 2013) (i.e. CO_2). Both of these outputs are measured by weights allocation and represented on a scale of 1-5[1], where 1 means very little waste and emissions involved and 5 means very high level of waste and emission resulted in the production and distribution process. Actual products generated as output are not included since they will also be considered as inputs into the consumption stages and could be measured by utilities of consumers and sales in the other factor groupings provided below.

Product deletion decisions, from a systems theoretic perspective, are influenced and measured by both input and output factors within production and distribution supply chains. When a green product is deleted, certain input costs including energy, material, and labor associated with the green product will be released and could be shifted to other products within an organization. Investments on eco-design and green technology can be diverted to other products and projects. Some of these factors are captured in product deletion strategic factors (Section 2.3.3).

2.3.2 Consumption supply chain. The downstream supply chain is more closely aligned with actual sale of products to end users including other businesses or individuals (Christopher, 2016; Vachon and Klassen, 2006). Typically, the downstream supply chain is within the purview of marketing departments in a given organization, although distribution and logistics issues do arise. The type of end users may vary depending on the characteristics of products. Regardless of the industry type or product category, the downstream process has direct interaction with customers and consumers through finished products. This process and its interactions with end users can be defined as the consumption portion of the supply chain. Although consumption may occur anywhere along the supply chain, this characterization will be used to incorporate consumption characteristics into the decision for green product deletion (Vachon and Klassen, 2006).

Related environmentally oriented factors in the consumption supply chain include input of energy and outputs including solid waste and air emissions. For green product deletion, another set of environmentally oriented factors that can likely play a role in the decision-making process are the "3Rs" (i.e. reduce, reuse and recycle) (Carter and Ellram, 1998). Consumer perceived product effectiveness (PPE) and utility are used to capture some of the business concerns associated with consumption (Berry *et al.*, 2017; Brown and Dacin, 1997; Creyer and Ross, 1996); although this factor can also be extended to include stakeholder perceived effectiveness of outputs and products (Kirchoff *et al.*, 2011).

Energy input represents energy required and consumed in the product usage process, both by the product providers and end users (Lenzen, 1998; Young *et al.*, 2010). The categories of waste and emissions output are similar to the production and distribution supply chain, but focus on the output generation from the end user product usage process.

PPE represents a consumer's perceived product accessibility, including the purchase and consumption convenience, as well as confidence in its functionality and quality (Lin and Chang, 2012; Tsiotsou, 2006). PPE is a critical criterion for evaluating products. For instance, studies found consumers in general value green or environment-friendly products to be less effective in functionality but more effective in quality than regular products (Lin and Chang, 2012). Utility is one measure of customer preferences over products or services; it represents one's satisfaction level of product experience. Utility is a critical measurement in economic theories, including rational choice theory and game theory. In those theories, utility can be revealed by user's level of willingness to pay for certain products or services (Green and Devita, 1975; Tukker *et al.*, 2008).

Level of 3Rs (reduce, reuse and recycle) is another factor that could affect green product deletion; it can be representative of a product's environmental sustainability criterion (Pandey *et al.*, 2017; Laosirihongthong *et al.*, 2013). Reduce stands for reduction of resource usage in sourcing or manufacturing processes, in this case it represents reduction of waste in end-of-life or post-purchase service stages. Reuse represents reuse of resource and material input in a product's manufacturing and remanufacturing processes and reuse of a product or its components after its life cycle. Recycle includes the process of converting output waste to applicable input in product manufacturing and remanufacturing processes, especially after consumption. These 3Rs consist of factors within corporate environmental sustainability management dimension that might influence which green product to delete based on the level of reduce, reuse and recycle of a product and its components on supply chains (Lin *et al.*, 2001). PPE, 3Rs and utility are evaluated by level assessment on a scale of 1 to 100, where 1 represents lowest level and 100 the highest level, and may utilize actual data or perceived information from managers and experts.

2.3.3 Product deletion strategic factors. Strategic factors related to product deletion can be categorized into three groups, i.e., impact on firm's resources, impact on firm's strategy, and impact on firm's financial performance (Avlonitis, 1984, 1985).

Firms invest several human, physical, and financial resources in developing and managing products. When making a product deletion decision, managers will have to decide what, when, and how the dedicated resources from the deleted product could be released to various other business activities and other products within the organization. This consideration will include: reallocating capital resources and facilities to other products; and releasing management and employee time devoted to the deleted products to other products (Avlonitis, 1984, 1985).

Managers also incorporate organizational strategic factors into a product deletion decision. Such strategic factors consider the firm's full-line strategy, firm's corporate image, and competitive moves. Companies that attempt to achieve a full-line strategy will be hesitant to delete products. They will sacrifice potential benefits from deletion and expand offerings to satisfy wide and dynamic market demand. In this perspective, if a product deletion decision occurs, the product portfolio will be streamlined influencing the overall full-line strategy.

Corporate image is another strategic aspect. Products help to define, support, and maintain an organization's intended image, customer perception, and market reputation (Brown *et al.*, 2006). When a company aims at pro-social and environmental-friendly image, deletion of certain green products hurt its intended green image and reputation. Furthermore, companies that intend to employ mimetic behavior as their strategy, their product deletion decisions will occur by following to moves of their competitors or major market players (Varadarajan *et al.*, 2006).

Companies generate profits from products; developing and managing products requires significant financial investment. If a product no longer positively contributes to overall financial performance of the firm, it might be reasonable for managers to consider it for deletion in order to minimize the financial loss (Shah, 2017a). Deleting a green product can influence several financial performance metrics of an organization including product sales, product profitability, and fixed and working capital associated with the product (Avlonitis, 1984, 1985).

All product deletion strategic factors are measured by weights allocation on a scale of 1-10, where 1 represents very less (minimal) contribution to the overall strategic factors of a firm; 5 represents very high contribution to the overall strategic factors of a firm.

2.4 Decision tools for green product deletion

Helping organizations make decisions that incorporate these 23 factors is something that various soft computing and multiple criteria decision-making approaches can manage. Many tools can be utilized, each with their advantages and disadvantages. For example, the factors can be grouped into various categories and a hierarchy of decisions can be made, such as with the analytical hierarchy or network process (AHP/ANP) (Saaty, 1980). The advantages and limits of AHP/ANP are well known. AHP/ANP can help simplify the decision structure and provides elemental pairwise comparisons to help arrive at weights that can be aggregated to make a decision. However, the technique requires significant inputs from managerial perceptions and preferences. In addition, the consideration of multiple alternatives (beyond 5-7) becomes cumbersome.

Many other discrete multiple criteria decision techniques can also be used such as TOPSIS, VIKOR, data envelopment analysis, or Electre. Each can be applied to this problem, and researchers are encouraged to investigate their applicability. A review of these and other techniques for quantitative (soft computing) applications to sustainability and supply chains and general application to a set of various decision factors has been provided (see Brandenburg *et al.*, 2014; Sarkis and Sundarraj, 2000). The reader is steered to these reviews to help them decipher various advantages and disadvantages of decision tools for multiple criteria evaluation.

In this paper, authors use the multistage approach integrating NRST, FCM, and CPT. The capabilities of these tools are synergistic. This is the first time these three tools have been utilized together as a soft computation methodology. Other tools and techniques that utilize competing approaches can be utilized and experimentation is recommended for these other techniques.

3. A hybrid multiple criteria decision support methodology

This section provides a general background and notation for CPT, NRST and fuzzy clustering means (FCM). These methodologies will be used within the hybrid multiple criteria evaluation for a product deletion decision based on SPC factors.

3.1 CPT

CPT (Kahneman and Tversky, 1979; Tversky and Kahneman, 1992), is a model for descriptive decisions under risk, crisis and uncertainty (Bai and Sarkis, 2017; Liu *et al.*, 2014). CPT uses rank-dependent expected utility theory (EUT). EUT provides a relative comparison between riskless and risky prospects, aiding decision makers to achieve better decisions (Rabin, 2000).

CPT assumes decision makers tend to think of possible outcomes relative to a certain reference point rather than to a final status. It also assumes that decision makers have different risk propensities when it comes to gains (i.e. outcomes above the reference point) and losses (i.e. outcomes below the reference point). The theory postulates that they are worried more about potential losses than potential gains (loss aversion). CPT is a popular behavioral decision theory and this is the first time it is integrated into a green products deletion decision analysis.

In CPT, an alternative (x, p), is composed of $m+n+1$ possible outcomes $x_{-m} < \ldots < x_0 < \ldots < x_n$, which occur with probabilities $p_{-m}, \ldots, p_0, \ldots, p_n$. In this context x_0 is introduced as the reference point. People are risk averse when outcomes (x_i) are framed as gains relative to a reference point (x_0) and risk seeking when outcomes (x_i) are framed as losses. Thus, the cumulative prospect value of an alternative is calculated, as given in the following equation:

$$P(x,p) = \sum_{i=0}^{n} \pi_i^+ \varphi(x_i) + \sum_{i=-m}^{-1} \pi_i^- \varphi(x_i) \quad (1)$$

where the cumulative prospect value of the alternative includes two dimensions, the value function $\varphi(x_i)$ defining the subjective value of outcome x_i and the cumulative weighting function π_i^+ of potential gain, and the cumulative weighting function π_i^- of potential loss. Reference points, which are subjective and related to decision maker's beliefs and preconceived notions, influence a decision maker to take certain actions under risk and crisis (Kaluszka and Krzeszowiec, 2012). The value function $\varphi(x_i)$ of outcome x_i is treated separately for gains and losses as shown in the following expression (Kahneman and Tversky, 1979):

$$\varphi(x_i) = \begin{cases} (\Delta x)^\alpha, & \Delta x = x_i - x_0 \geqslant 0 \\ -\lambda(-(\Delta x))^\beta, & \Delta x = x_i - x_0 < 0 \end{cases} \quad (2)$$

λ is the loss aversion parameter; the parameters $0 < \alpha,\ \beta < 1$ are the coefficients of sensitivity for gains and losses, respectively. For α, the value function $\varphi(x_i)$ exhibits risk aversion over gains; for β, the value function $\varphi(x_i)$ exhibits risk seeking over losses. The larger the value of α, β, the more sensitive decision makers are to risk. A value of parameter $\lambda \geqslant 1$, represents loss aversion where individuals are more sensitive to losses than gains (Bai and Sarkis, 2017).

The probability p of EUT is transformed into cumulative decision weights $\pi(p)$ in CPT using expressions (in the given equations):

$$\pi_i^+(p_i) = w^+(p_i + \cdots + p_n) - w^+\left(p_{i+1} + \cdots + p_n\right) 0 \leqslant i \leqslant n \quad (3)$$

$$\pi_{-j}^-\left(p_{-j}\right) = w^-\left(p_{-m} + \cdots + p_{-j}\right) - w^-\left(p_{-m} + \cdots + p_{-j-1}\right) - m \leqslant -j \leqslant 0 \quad (4)$$

where $w^+(p_i)$ and $w^-(p_i)$ denote the probability weighting functions $w(p)$ for gains and losses, respectively and:

$$w^+(p_i) = \exp(-\gamma(-\ln(p_i)^\varphi)) \quad (5)$$

$$w^-\left(p_{-j}\right) = \exp\left(-\delta\left(-\ln\left(p_{-j}\right)^\varphi\right)\right) \quad (6)$$

where p_i denotes the probability of potential outcome x_i, $0 < \gamma,\ \delta,\ \varphi < 1$ are model parameters. The parameters in this study are set to $\alpha = \beta = 0.88$, $\lambda = 2.25$, $\gamma = \delta = 0.8$, and $\varphi = 1$ (see Kahneman and Tversky, 1979; Prelec, 2000 for justification of these parameters based on their experimentation).

Although CPT is a well-established behavioral decision theory, a limitation is that it requires significantly more data as inputs including probabilities, the reference point, and the weight of attributes. This additional information will be approximated using FCM and NRST from existing information. This will allow for more effective implementation for CPT application. FCM and NRST are now reviewed.

3.2 NRST

NRST is used in this study to determine attribute weights. Rough set theory classifies objects into equivalence classes where objects are indiscernible if their attribute values are identical to each other (Bai and Sarkis, 2013; Pawlak, 1982). NRST extends equivalence classes using a neighborhood distance relationship, allowing it to be more flexible by allowing continuous and discrete data types (Kusi-Sarpong *et al.*, 2015; Bai *et al.*, 2012).

In NRST, let NDS $= (U, C)$ be a neighborhood decision system, where U is a nonempty sample set of objects $U = \{x_1, x_2 \ldots, x_n\}$, called a universe (in this paper green products to be considered for deletion); C is a nonempty set of attributes $C = \{c_1, c_2, \ldots, c_m\}$ to characterize the objects:

Definition 1. Given arbitrary object x_i, $x_k \in U$ and attributes $B \subseteq C$, the neighborhood $\delta_B(x_i)$ of x_i in attributes B is defined as:

$$\delta_B(x_i) = \left\{x_j \,\middle|\, x_k \in U, \Delta^B(x_i, x_k) \leqslant \delta\right\}, \tag{7}$$

where δ is a threshold value, and Δ is a distance function $\Delta^B(x_i, x_k) = (\sum_{j \in B} |v_{ij} - v_{kj}|)$.

3.3 FCM

FCM (Dunn, 1973; Bezdek, 1981) uses a fuzzy degree of membership for clustering purposes. FCM generates data object subset clusters so that objects in each cluster are more similar to each other than to objects in other clusters (Bai *et al.*, 2014; Bai *et al.*, 2016; Izakian and Abraham, 2011).

The degree of membership in the clusters depends on the closeness of the objects to the cluster centers and is quantified by a value in the interval [0, 1]. A larger membership degree value represents greater association between that object and a particular cluster. FCM partitions a set of n objects $X = \{x_1, x_2, \ldots, x_n\}$, real-number space into c $(1 < c < n)$ fuzzy clusters with $H = \{h_1, h_2, \ldots, h_c\}$ cluster centers. The fuzzy clustering of objects is described by a fuzzy matrix U defined by n rows and c columns. The FCM algorithm objective seeks to minimize the equation given below:

$$\min J(U, H) = \sum_{i=1}^{n} \sum_{k=1}^{c} u_{ik}^{m} \left(\| x_i - h_k \| \right)_A, \tag{8}$$

where the element u_{ik} in fuzzy matrix U is the membership function of the ith object within the k^{th} cluster. The characteristics of u_{ik} are defined in the expressions given below:

$$u_{ik} \in [0, 1] \quad \forall i = 1, 2, \ldots, n; \quad \forall k = 1, 2, \ldots, c; \tag{9}$$

$$\sum_{k=1}^{c} u_{ik} = 1, \quad \forall i = 1, 2, \ldots, n; \tag{10}$$

$$0 \leqslant \sum_{i=1}^{n} u_{ik} \leqslant n \quad \forall k = 1, 2, \ldots, c; \tag{11}$$

The cluster centers are obtained through an iterative process using the following expressions:

$$h_{i,t} = \frac{\sum_{k=1}^{n} (u_{ik})^m x_k}{\sum_{k=1}^{n} (u_{ik})^m}, \quad i = 1, 2, \cdots, c; \tag{12}$$

$$u_{ik,t} = \left[\sum_{j=1}^{c} \left(\frac{\left\| x_k - h_{i,t-1} \right\|_A}{\left\| x_k - h_{j,t-1} \right\|_A} \right)^{2/(m-1)} \right]^{-1}, i \neq j \tag{13}$$

where t represents iteration number; $m > 1$ is a cluster fuzziness scalar term, and $\|\cdot\|_A A = I$ is the Euclidean distance between an object x_i and cluster center h_k.

FCM is used to mine data to determine the reference points (cluster centers) and the probability of each reference point (the probability that an object belongs to this cluster) for use in CPT.

4. An illustrative production deletion evaluation using a hybrid multicriteria evaluation

The hybrid multiple criteria approach for product evaluation and deletion in an SPC environment is now illustrated. The proposed methodology is composed of nine steps that generally include setting up the decision environment, normalizing the data, determining weights, reference points, and then arriving at a decision.

The product deletion decision process typically has a number of stages (Muir and Reynolds, 2011): (1) recognition of deletion candidates; (2) analysis and vitalization; (3) evaluation and decision making; and (4) implementation. In this example, the scenario is that steps (1) and (2) are complete. The focus this study is on step 3 the evaluation and decision involved in considering a set of 40 potential green products for deletion. The illustrative problem here is hypothetical with numbers that are randomly generated to help exemplify the feasibility of the methodology in this decision environment.

Step 1: develop a decision system for products.

Develop a decision system, $T = (G, C, V)$, for products based on various product deletion and SPC elements. $G = \{g_1, g_2, \ldots, g_n\}$ is a set of i green product alternatives to be deleted. $C = \{c_1, c_2, \ldots, c_m\}$ is a set of m environmental sustainability and product deletion attributes. $V = \{v_{ij}, i = 1, \ldots, n, \text{ and } j = 1, \ldots, m\}$ are the values associated with deleting a product g_i on attribute c_j.

A total of 40 potential green products for deletion are considered in this illustrative evaluation, that is, $G = \{g_i, i = 1, 2, \ldots, 40\}$. The overall performance level of each green product is evaluated on 23 attributes $C = \{c_j, j = 1, 2, \ldots, 23\}$. All attributes are listed in Table I and based on literature related to SPC factors and product deletion business influences.

Organizational decision makers or data can be used to evaluate each product situation. In this situation either degree variables (discrete data) can be applied to calculate specific factors or normalize the data to fall within a given range; further normalization is completed in the next stage as well. The measurement and boundaries for each attribute appear in Table I. For example, for the energy cost attribute the numerical data range is from 1-10. A value of 1 represents very much less energy cost, and a value of 10 represents very much more energy cost. These are relative values. Table II shows a completed table of green level assignments. This data is illustrative and used to demonstrate the specific application of the proposed the method.

Step 2: normalize the decision system

Further normalization is also completed at this stage. Due to incremental data and variations in data importance (e.g. decreasing values are better), a normalization process is needed for consistency in calculations. Normalization of attributes is completed to make all values range from 0 to 1. After the normalization process, all attributes will become incremental data representing "increasing value is better". Normalization across all attributes allows for the latter calculations to have similar scale ranges and better show the gains and losses in CPT.

Normalization of the incremental data (improves as values increase) is completed using the following expression:

$$x_{ij} = \frac{v_{ij} - Lower_j}{Upper_j - Lower_j} \tag{14}$$

where v_{ij} is the initial green level of product g_i for attribute c_j, $Upper_j$ is the max value of attribute c_j, $Lower_j$ is the min value of attribute c_j .

Normalization of the decreasing data is completed using the following expression:

$$x_{ij} = \frac{Upper_j - v_{ij}}{Upper_j - Lower_j} \tag{15}$$

For example, the product g_1 energy cost is decreasing is better data with a value of 5. The normalization, using expression (15), is: $x_{1,1} = (10-5)/(10-1) = 0.556$. The PPE of product g_1 is incremental data with a value of 63. The normalization, using expression (14), is: $x_{1,13} = (63-3)/(99-3) = 0.625$.

The normalized decision system is shown in Table III.

Next, in steps 3 and 4, NRST is used to compute the information content of the attributes. The information content will be used to determine the relative attribute importance weights.

Step 3: compute relationships among the green products using attribute valuations

The distances between the green products using the attribute values are first determined. This calculation will result in 23 (23 attribute matrices) 40×40 distance matrices. The distance calculation between products uses expression (7).

For example, for energy cost the neighborhood distance between product g_1 and $\Delta(x_{1,1}, x_{2,1}) = \sqrt{(0.556-0.556)^2} = 0$.

Green product relationships for each attribute are further determined. For this illustrative example a neighborhood size of $\delta = 0.2$ is given. The relationship matrix ($Mc_j(n)$) of attribute c_j, n is the total number of green products, is defined by the following equation:

$$M_{c_j}(n) = (r_{ik})_{n \times n},$$

where:

$$r_{ik} = \begin{cases} 1, & \Delta_{c_j}(x_i, x_k) \leqslant \delta \\ 0, & otherwise \end{cases} \tag{16}$$

For example, for energy cost $r_{12} = r_{21} = 0$ because $\Delta c_1(x_1, x_2) = 0 < 0.2$. The total energy cost relationship matrix, $M_{c_1}(40) = (r_{ik})_{40 \times 40}$, is shown in Table IV.

	Production/distribution supply chain										Consumption supply chain							Product deletion strategic factors						
Product	E1	M	L	La	MKT	R&D	D	SW1	AE1	SW2	AE2	E2	PPE	3Rs	CU	CR	RET	FLS	CI	CM	S	P	FWC
1	5	2	6	6	9	6	7	3	3	1	3	2	63	29	87	6	5	2	5	9	6	10	2
2	5	6	9	10	4	8	10	4	5	1	3	7	3	25	69	2	2	5	9	4	1	8	8
3	7	9	1	1	2	9	3	2	5	2	1	1	34	65	67	3	9	8	4	10	7	1	1
4	7	4	4	3	9	8	8	3	1	4	4	8	61	56	19	3	10	3	6	8	3	6	10
5	5	7	8	5	3	8	2	4	2	3	1	5	82	96	62	5	7	8	4	9	10	6	1
6	10	9	9	10	9	6	2	4	4	3	1	8	64	28	95	4	10	2	1	5	10	3	5
7	5	4	3	10	9	10	4	4	4	2	4	7	10	46	70	7	8	6	9	6	8	5	2
8	4	3	1	3	4	8	1	2	4	5	2	8	22	25	78	8	7	2	6	6	4	2	7
9	1	5	2	7	5	2	3	4	2	5	1	8	20	84	54	10	1	5	3	5	1	6	5
10	3	7	3	6	6	4	9	2	3	3	2	6	3	37	19	6	1	10	9	2	10	3	8
11	2	7	10	7	6	7	10	1	2	2	4	7	17	69	20	9	7	8	7	5	4	5	6
12	9	10	1	9	1	5	10	1	5	5	2	1	29	64	40	10	10	7	9	7	9	6	2
13	2	4	9	4	8	10	3	1	3	4	5	4	57	2	92	4	9	7	2	9	9	4	3
14	3	10	9	3	5	5	10	4	3	2	2	7	42	9	56	6	9	1	1	4	9	6	8
15	7	2	2	8	5	1	5	4	2	4	4	2	22	57	19	8	10	6	6	7	7	2	2
16	10	7	3	9	2	5	8	5	4	4	3	6	40	34	85	1	3	1	3	3	4	6	9
17	5	5	10	2	5	6	3	4	2	2	5	3	43	50	92	7	4	6	4	1	6	7	3
18	6	3	10	5	8	1	6	2	2	5	1	10	10	66	40	1	6	5	9	2	9	7	5
19	3	1	10	1	5	10	4	3	3	4	2	10	90	3	90	7	3	5	9	9	1	7	9
20	10	7	5	9	4	5	1	2	5	2	5	2	67	98	42	8	8	5	5	6	1	8	1
21	8	3	1	5	7	6	6	2	1	2	1	3	32	98	7	6	5	10	4	6	8	9	3
22	6	5	7	5	5	4	6	1	2	2	4	4	56	46	65	7	6	1	3	4	10	5	4
23	1	6	9	7	1	3	10	1	3	1	3	10	83	46	17	2	2	7	2	7	1	5	10
24	2	8	8	4	7	2	8	2	2	1	5	4	88	39	16	2	8	5	5	5	7	1	6
25	8	9	8	5	5	7	2	4	3	3	1	3	40	11	49	5	8	6	3	6	4	5	8
26	5	9	8	6	9	5	4	4	3	3	2	1	29	3	93	9	6	3	10	6	3	9	4
27	3	3	4	5	1	8	1	1	2	1	2	7	11	74	43	5	8	1	4	3	4	7	5
28	2	9	10	6	4	10	9	1	1	3	3	1	48	97	55	10	7	9	5	9	2	3	7
29	6	5	2	4	4	4	7	1	2	2	5	5	20	98	100	5	9	1	8	1	7	1	1
30	1	2	8	1	5	7	3	3	1	1	4	2	88	66	53	9	7	10	9	5	7	10	9
31	8	7	1	9	1	1	8	4	5	1	2	9	42	62	55	3	9	1	10	9	5	5	1
32	7	9	1	10	10	7	7	1	2	5	2	10	85	91	60	6	5	9	10	8	4	1	10

(*continued*)

Table II.
The decision system for all green products

Product	E1	M	L	La	MKT	R&D	D	SW1	AE1	SW2	AE2	E2	PPE	3Rs	CU	CR	RET	FLS	CI	CM	S	P	FWC
	Production/distribution supply chain									Consumption supply chain						Product deletion strategic factors							
33	6	2	9	10	7	1	3	4	1	5	2	7	44	35	8	1	1	1	6	1	6	8	7
34	1	1	1	7	6	5	9	2	5	2	2	10	19	86	54	3	7	1	4	6	8	2	6
35	2	3	10	2	7	1	3	4	3	5	5	7	95	75	69	3	5	6	9	2	6	7	10
36	1	1	10	9	2	3	2	2	1	1	1	10	44	10	3	4	5	5	10	6	4	9	3
37	9	10	8	7	1	10	10	1	4	3	2	8	12	62	76	9	9	4	6	2	8	3	4
38	2	10	3	3	6	9	10	4	2	1	1	6	66	91	21	7	1	6	10	6	8	7	10
39	8	5	2	10	1	2	7	2	1	3	5	5	99	59	49	6	7	1	9	6	7	3	9
40	7	8	6	4	7	2	1	4	4	4	3	3	70	34	68	5	7	2	2	4	5	6	3

Table II.

	Production/distribution supply chain										Consumption supply chain				
Product	E1	M	L	La	MKT	R&D	D	SW1	AE1	SW2	AE2	E2	PPE	3Rs	CU
1	0.556	0.889	0.444	0.444	0.111	0.444	0.333	0.500	0.500	1.000	0.500	0.889	0.625	0.281	0.866
2	0.556	0.444	0.111	0.000	0.667	0.222	0.000	0.250	0.000	1.000	0.500	0.333	0.000	0.240	0.680
3	0.333	0.111	1.000	1.000	0.889	0.111	0.778	0.750	0.000	0.750	1.000	1.000	0.323	0.656	0.660
4	0.333	0.667	0.667	0.778	0.111	0.222	0.222	0.500	1.000	0.250	0.250	0.222	0.604	0.563	0.165
5	0.556	0.333	0.222	0.556	0.778	0.222	0.889	0.250	0.750	0.500	1.000	0.556	0.823	0.979	0.608
6	0.000	0.111	0.111	0.000	0.111	0.444	0.889	0.250	0.250	0.500	1.000	0.222	0.635	0.271	0.948
7	0.556	0.667	0.778	0.000	0.111	0.000	0.667	0.250	0.250	0.750	0.250	0.333	0.073	0.458	0.691
8	0.667	0.778	1.000	0.778	0.667	0.222	1.000	0.750	0.250	0.000	0.750	0.222	0.198	0.240	0.773
9	1.000	0.556	0.889	0.333	0.556	0.889	0.778	0.250	0.750	0.000	1.000	0.222	0.177	0.854	0.526
10	0.778	0.333	0.778	0.444	0.444	0.667	0.111	0.750	0.500	0.500	0.750	0.444	0.000	0.365	0.165
11	0.889	0.333	0.000	0.333	0.444	0.333	0.000	1.000	0.750	0.750	0.250	0.333	0.146	0.698	0.175
12	0.111	0.000	1.000	0.111	1.000	0.556	0.000	1.000	0.000	0.000	0.750	1.000	0.271	0.646	0.381
13	0.889	0.667	0.111	0.667	0.222	0.000	0.778	1.000	0.500	0.250	0.000	0.667	0.563	0.000	0.918
14	0.778	0.000	0.111	0.778	0.556	0.556	0.000	0.250	0.500	0.750	0.750	0.333	0.406	0.073	0.546
15	0.333	0.889	0.889	0.222	0.556	1.000	0.556	0.250	0.750	0.250	0.250	0.889	0.198	0.573	0.165
16	0.000	0.333	0.778	0.111	0.889	0.556	0.222	0.000	0.250	0.250	0.500	0.444	0.385	0.333	0.845
17	0.556	0.556	0.000	0.889	0.556	0.444	0.778	0.250	0.750	0.750	0.000	0.778	0.417	0.500	0.918
18	0.444	0.778	0.000	0.556	0.222	1.000	0.444	0.750	0.750	0.000	1.000	0.000	0.073	0.667	0.381
19	0.778	1.000	0.000	1.000	0.556	0.000	0.667	0.500	0.500	0.250	0.750	0.000	0.906	0.010	0.897
20	0.000	0.333	0.556	0.111	0.667	0.556	1.000	0.750	0.000	0.750	0.000	0.889	0.667	1.000	0.402
21	0.222	0.778	1.000	0.556	0.333	0.444	0.444	0.750	1.000	0.750	1.000	0.778	0.302	1.000	0.041
22	0.444	0.556	0.333	0.556	0.556	0.667	0.444	1.000	0.750	0.750	0.250	0.667	0.552	0.458	0.639
23	1.000	0.444	0.111	0.333	1.000	0.778	0.000	1.000	0.500	1.000	0.500	0.000	0.833	0.458	0.144
24	0.889	0.222	0.222	0.667	0.333	0.889	0.222	0.750	0.750	1.000	0.000	0.667	0.885	0.385	0.134
25	0.222	0.111	0.222	0.556	0.556	0.333	0.889	0.250	0.500	0.500	1.000	0.778	0.385	0.094	0.474
26	0.556	0.111	0.222	0.444	0.111	0.556	0.667	0.250	0.500	0.500	0.750	1.000	0.271	0.010	0.928
27	0.778	0.778	0.667	0.556	1.000	0.222	1.000	1.000	0.750	1.000	0.750	0.333	0.083	0.750	0.412
28	0.889	0.111	0.000	0.444	0.667	0.000	0.111	1.000	1.000	0.500	0.500	1.000	0.469	0.990	0.536
29	0.444	0.556	0.889	0.667	0.667	0.667	0.333	1.000	0.750	0.750	0.000	0.556	0.177	1.000	1.000
30	1.000	0.889	0.222	1.000	0.556	0.333	0.778	0.500	1.000	1.000	0.250	0.889	0.885	0.667	0.515
31	0.222	0.333	1.000	0.111	1.000	1.000	0.222	0.250	0.000	1.000	0.750	0.111	0.406	0.625	0.536
32	0.333	0.111	1.000	0.000	0.000	0.333	0.333	1.000	0.750	0.000	0.750	0.000	0.854	0.927	0.588
33	0.444	0.889	0.111	0.000	0.333	1.000	0.778	0.250	1.000	0.000	0.750	0.333	0.427	0.344	0.052

(*continued*)

Table III. The normalized decision system for all green products

Table III.

34	1.000	1.000	1.000	0.333	0.444	0.556	0.111	0.750	0.000	0.750	0.750	0.000	0.167	0.875	0.526
35	0.889	0.778	0.000	0.889	0.333	1.000	0.778	0.250	0.500	0.000	0.000	0.333	0.958	0.760	0.680
36	1.000	1.000	0.000	0.111	0.889	0.778	0.889	0.750	1.000	1.000	1.000	0.000	0.427	0.083	0.000
37	0.111	0.000	0.222	0.333	1.000	0.000	0.000	1.000	0.250	0.500	0.750	0.222	0.094	0.625	0.753
38	0.889	0.000	0.778	0.778	0.444	0.111	0.000	0.250	0.750	1.000	1.000	0.444	0.656	0.927	0.186
39	0.222	0.556	0.889	0.000	1.000	0.889	0.333	0.750	1.000	0.500	0.000	0.556	1.000	0.594	0.474
40	0.333	0.222	0.444	0.667	0.333	0.889	1.000	0.250	0.250	0.250	0.500	0.778	0.698	0.333	0.670

	Product deletion strategic factors							
Product	CR	RET	FLS	CI	CM	S	P	FWC
1	0.556	0.444	0.111	0.444	0.889	0.556	1.000	0.111
2	0.111	0.111	0.444	0.889	0.333	0.000	0.778	0.778
3	0.222	0.889	0.778	0.333	1.000	0.667	0.000	0.000
4	0.222	1.000	0.222	0.556	0.778	0.222	0.556	1.000
5	0.444	0.667	0.778	0.333	0.889	1.000	0.556	0.000
6	0.333	1.000	0.111	0.000	0.444	1.000	0.222	0.444
7	0.667	0.778	0.556	0.889	0.556	0.778	0.444	0.111
8	0.778	0.667	0.111	0.556	0.556	0.333	0.111	0.667
9	1.000	0.000	0.444	0.222	0.444	0.000	0.556	0.444
10	0.556	0.000	1.000	0.889	0.111	1.000	0.222	0.778
11	0.889	0.667	0.778	0.667	0.444	0.333	0.444	0.556
12	1.000	1.000	0.667	0.889	0.667	0.889	0.556	0.111
13	0.333	0.889	0.667	0.111	0.889	0.889	0.333	0.222
14	0.556	0.889	0.000	0.000	0.333	0.889	0.556	0.778
15	0.778	1.000	0.556	0.556	0.667	0.667	0.111	0.111
16	0.000	0.222	0.000	0.222	0.222	0.333	0.556	0.889
17	0.667	0.333	0.556	0.333	0.000	0.556	0.667	0.222
18	0.000	0.556	0.444	0.889	0.111	0.889	0.667	0.444
19	0.667	0.222	0.444	0.889	0.889	0.000	0.667	0.889
20	0.778	0.778	0.444	0.444	0.556	0.000	0.778	0.000
21	0.556	0.444	1.000	0.333	0.556	0.778	0.889	0.222
22	0.667	0.556	0.000	0.222	0.333	1.000	0.444	0.333
23	0.111	0.111	0.667	0.111	0.667	0.000	0.444	1.000
24	0.111	0.778	0.444	0.444	0.444	0.667	0.000	0.556
25	0.444	0.778	0.556	0.222	0.556	0.333	0.444	0.778

(continued)

26	0.889	0.556	0.222	1.000	0.556	0.222	0.889	0.333
27	0.444	0.778	0.000	0.333	0.222	0.333	0.667	0.444
28	1.000	0.667	0.889	0.444	0.889	0.111	0.222	0.667
29	0.444	0.889	0.000	0.778	0.000	0.667	0.000	0.000
30	0.889	0.667	1.000	0.889	0.444	0.667	1.000	0.889
31	0.222	0.889	0.000	1.000	0.889	0.444	0.444	0.000
32	0.556	0.444	0.889	1.000	0.778	0.333	0.000	1.000
33	0.000	0.000	0.000	0.556	0.000	0.556	0.778	0.667
34	0.222	0.667	0.000	0.333	0.556	0.778	0.111	0.556
35	0.222	0.444	0.556	0.889	0.111	0.556	0.667	1.000
36	0.333	0.444	0.444	1.000	0.556	0.333	0.889	0.222
37	0.889	0.889	0.333	0.556	0.111	0.778	0.222	0.333
38	0.667	0.000	0.556	1.000	0.556	0.778	0.667	1.000
39	0.556	0.667	0.000	0.889	0.556	0.667	0.222	0.889
40	0.444	0.667	0.111	0.111	0.333	0.444	0.556	0.222

Table III.

Table IV.
The relationship for the energy cost attribute among green products

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	SUM
1	1	1	0	0	1	0	1	1	0	0	0	0	0	0	0	0	1	1	0	0	0	1	0	0	0	1	0	0	1	0	0	0	1	0	0	0	0	0	0	0	11
2	1	1	0	0	1	0	1	1	0	0	0	0	0	0	0	0	1	1	0	0	0	1	0	0	0	1	0	0	1	0	0	0	1	0	0	0	0	0	0	0	11
3	0	0	1	1	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0	0	1	1	0	0	1	0	0	0	1	0	1	1	1	0	0	0	0	0	1	1	13
4	0	0	1	1	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0	0	1	1	0	0	1	0	0	0	1	0	1	1	1	0	0	0	0	0	1	1	13
5	1	1	0	0	1	0	1	1	0	0	0	0	0	0	0	0	1	1	0	0	0	1	0	0	0	1	0	0	1	0	0	0	1	0	0	0	0	0	0	0	11
6	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	5
7	1	1	0	0	1	0	1	1	0	0	0	0	0	0	0	0	1	1	0	0	0	1	0	0	0	1	0	0	1	0	0	0	1	0	0	0	0	0	0	0	11
8	1	1	0	0	1	0	1	1	0	1	0	0	0	1	0	0	1	0	1	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	11
9	0	0	0	0	0	0	0	0	1	0	1	0	1	0	0	0	0	0	0	0	0	0	1	1	0	0	0	1	0	1	0	0	0	1	1	1	0	1	0	0	11
10	0	0	0	0	0	0	0	1	0	1	1	0	1	1	0	0	0	0	1	0	0	0	0	1	0	0	1	1	0	0	0	0	0	0	1	0	0	1	0	0	11
11	0	0	0	0	0	0	0	0	1	1	1	0	1	1	0	0	0	0	1	0	0	0	1	1	0	0	1	1	0	1	0	0	0	1	1	1	0	1	0	0	15
12	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0	1	0	0	0	1	1	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0	1	0	1	0	9
13	0	0	0	0	0	0	0	0	1	1	1	0	1	1	0	0	0	0	1	0	0	0	1	1	0	0	1	1	0	1	0	0	0	1	1	1	0	1	0	0	15
14	0	0	0	0	0	0	0	1	0	1	1	0	1	1	0	0	0	0	1	0	0	0	0	1	0	0	1	1	0	0	0	0	0	0	1	0	0	1	0	0	11
15	0	0	1	1	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0	0	1	1	0	0	1	0	0	0	1	0	1	1	1	0	0	0	0	0	1	1	13
16	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	5
17	1	1	0	0	1	0	1	1	0	0	0	0	0	0	0	0	1	1	0	0	0	1	0	0	0	1	0	0	1	0	0	0	1	0	0	0	0	0	0	0	11
18	1	1	1	1	1	0	1	0	0	0	0	0	0	0	1	0	1	1	0	0	0	1	0	0	0	1	0	0	1	0	0	1	1	0	0	0	0	0	0	1	15
19	0	0	0	0	0	0	0	1	0	1	1	0	1	1	0	0	0	0	1	0	0	0	0	1	0	0	1	1	0	0	0	0	0	0	1	0	0	1	0	0	11
20	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	5
21	0	0	1	1	0	0	0	0	0	0	0	1	0	0	1	0	0	0	0	0	1	0	0	0	1	0	0	0	0	0	1	1	0	0	0	0	1	0	1	1	11
22	1	1	1	1	1	0	1	0	0	0	0	0	0	0	1	0	1	1	0	0	0	1	0	0	0	1	0	0	1	0	0	1	1	0	0	0	0	0	0	1	15
23	0	0	0	0	0	0	0	0	1	0	1	0	1	0	0	0	0	0	0	0	0	0	1	1	0	0	0	1	0	1	0	0	0	1	1	1	0	1	0	0	11
24	0	0	0	0	0	0	0	0	1	1	1	0	1	1	0	0	0	0	1	0	0	0	1	1	0	0	1	1	0	1	0	0	0	1	1	1	0	1	0	0	15
25	0	0	1	1	0	0	0	0	0	0	0	1	0	0	1	0	0	0	0	0	1	0	0	0	1	0	0	0	0	0	1	1	0	0	0	0	1	0	1	1	11
26	1	1	0	0	1	0	1	1	0	0	0	0	0	0	0	0	1	1	0	0	0	1	0	0	0	1	0	0	1	0	0	0	1	0	0	0	0	0	0	0	11
27	0	0	0	0	0	0	0	1	0	1	1	0	1	1	0	0	0	0	1	0	0	0	0	1	0	0	1	1	0	0	0	0	0	0	1	0	0	1	0	0	11
28	0	0	0	0	0	0	0	0	1	1	1	0	1	1	0	0	0	0	1	0	0	0	1	1	0	0	1	1	0	1	0	0	0	1	1	1	0	1	0	0	15
29	1	1	1	1	1	0	1	0	0	0	0	0	0	0	1	0	1	1	0	0	0	1	0	0	0	1	0	0	1	0	0	1	1	0	0	0	0	0	0	1	15
30	0	0	0	0	0	0	0	0	1	0	1	0	1	0	0	0	0	0	0	0	0	0	1	1	0	0	0	1	0	1	0	0	0	1	1	1	0	1	0	0	11
31	0	0	1	1	0	0	0	0	0	0	0	1	0	0	1	0	0	0	0	0	1	0	0	0	1	0	0	0	0	0	1	1	0	0	0	0	1	0	1	1	11
32	0	0	1	1	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0	0	1	1	0	0	1	0	0	0	1	0	1	1	1	0	0	0	0	0	1	1	13
33	1	1	1	1	1	0	1	0	0	0	0	0	0	0	1	0	1	1	0	0	0	1	0	0	0	1	0	0	1	0	0	1	1	0	0	0	0	0	0	1	15

(*continued*)

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	SUM
34	0	0	0	0	0	0	0	0	1	0	1	0	1	0	0	0	0	0	0	0	0	0	1	1	0	0	0	1	0	1	0	0	0	1	1	1	0	1	0	0	11
35	0	0	0	0	0	0	0	0	1	1	1	0	1	1	0	0	0	0	1	0	0	0	1	1	0	0	1	1	0	1	0	0	0	1	1	1	0	1	0	0	15
36	0	0	0	0	0	0	0	0	1	0	1	0	1	0	0	0	0	0	0	0	0	0	1	1	0	0	0	1	0	1	0	0	0	1	1	1	0	1	0	0	11
37	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0	1	0	0	0	1	1	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0	1	0	1	0	9
38	0	0	0	0	0	0	0	0	1	1	1	0	1	1	0	0	0	0	1	0	0	0	1	1	0	0	1	1	0	1	0	0	0	1	1	1	0	1	0	0	15
39	0	0	1	1	0	0	0	0	0	0	0	1	0	0	1	0	0	0	0	0	1	0	0	0	1	0	0	0	0	0	1	1	0	0	0	0	1	0	1	1	11
40	0	0	1	1	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0	0	1	1	0	0	1	0	0	0	1	0	1	1	1	0	0	0	0	0	1	1	13

Table IV.

Step 4: determine the weight of each green attribute

This step is divided into two sub steps.

Sub-step 1: determine the information content for each green attribute using expression given below of NRST:

$$I(c_j) = 1 - \frac{1}{|G|^2} \sum_{i=1}^{|G|} |X_i^{c_j}| \tag{17}$$

where $I(c_j)$ is the information content for each green attribute c_j. $|G|$ is the cardinality of the universe of green products, which is 40 in this illustrative example. $|X_i^{c_j}|$ is the number of members with similar attributes levels across the attribute (c_j) for green product g_i.

For example, the number of members for the Energy cost attribute and the evaluation of $|X_{01}^{Energy}|$ are identified. The rows of $M_{c_1}(40)$ are summed at this time. For green product g_1, $|X_{01}^{Energy}| = 11$. The information content for the Energy cost attribute is determined based on the number of members for all green products, which appears as the last column in Table IV, using expression (17): $I(c_1) = 1 - (\frac{1}{|40|^2}(11 + 11 + \ldots + 13)) = 1 - \frac{468}{1600} = 0.7075$.

Sub-step 2: each green attribute weight is calculated using the following normalization expression:

$$w(c_j) = \frac{I(c_j)}{\sum_{j=1}^{m} I(c_j)} \tag{18}$$

For example, the aggregated information content of all attributes is equal to $\sum_{j=1}^{m} I(c_j) = 16.289$. The information content for the energy cost is $I(c_1) = 0.7075$, which results in a normalized weight of $w(c_1) = (0.7075)/(16.289) = 0.0434$.

An analogous approach is used to calculate the information content and weights of all attributes with results shown in Table V. The weights of all product attributes will be used step 9.

FCM is next used in steps 5 and 6 to classify green products for each attribute, to determine reference points and the probabilities of each reference point (for use within CPT).

Step 5: compute reference points and membership values using FCM

Green products are now classified into different clusters using FCM fuzzy memberships. A cluster center with characteristics of this cluster is first determined. The cluster center is used as a reference point for the CPT analysis. The number of clusters is initially assigned to be $c = 3$ for each attribute. This number of clusters can represent a good reference point, a medium reference point, and a poor reference point, respectively.

After FCM clustering, three cluster centers (reference points) $H_j = \{h_{1j}, h_{2j}, h_{3j}\}$, for each attribute c_j, for each attribute are summarized in Table VI. Each green product will be given a membership value u_{ik} of each cluster for each attribute separately. The Energy cost c_1 attribute and membership values for each green product considered for deletion is displayed in Table VII. This step is completed by utilizing expressions (8) to (14).

Step 6: computing reference point probability

Product membership degrees have values in the range [0, 1]. A product is assigned to a cluster for which it has the highest membership value in Table VII. The probability of each reference point is calculated by the number of products belonging to this cluster divided by the total number of products.

For the illustrative case, for example, the membership value of green product g_1 based on the Energy cost c_1 for the three clusters are 3.4, 94.3, and 2.4 percent respectively; thus green

Division	Factors	Information content	Weights
Production/distribution supply chain	Energy (E1)	0.708	0.0434
	Material (M)	0.723	0.0444
	Logistics (L)	0.690	0.0424
	Labor (La)	0.713	0.0437
	Marketing (MKT)	0.693	0.0425
	R & D	0.725	0.0445
	Design (D)	0.716	0.0440
	Solid waste (SW1)	0.724	0.0444
	Air emissions (AE1)	0.784	0.0481
Consumption supply chain	Solid waste (SW2)	0.794	0.0487
	Air emissions (AE2)	0.784	0.0481
	Energy (E2)	0.723	0.0444
	Perceived product effectiveness (PPE)	0.643	0.0394
	3Rs	0.671	0.0412
	Customer utility (CU)	0.638	0.0391
Product deletion strategic factors	Capital reallocation (CR)	0.701	0.0431
	Release of executive time (RET)	0.685	0.0421
	Full-line strategy (FLS)	0.696	0.0427
	Corporate image (CI)	0.684	0.0420
	Competitive moves (CM)	0.673	0.0413
	Sales (S)	0.714	0.0438
	Profitability (P)	0.685	0.0421
	Fixed and working capital (FWC)	0.726	0.0446
SUM		16.289	1

Table V. Information content and weight for each green attribute

	Production/distribution supply chain									Consumption supply chain					
Reference points	E1	M	L	La	MKT	R&D	D	SW1	AE1	SW2	AE2	E2	PPE	3Rs	CU
Good	0.902	0.854	0.930	0.851	0.954	0.954	0.843	0.998	0.844	0.913	0.995	0.860	0.860	0.940	0.883
Medium	0.490	0.462	0.542	0.483	0.555	0.555	0.370	0.727	0.488	0.509	0.692	0.373	0.458	0.580	0.544
Poor	0.143	0.092	0.100	0.065	0.174	0.174	0.044	0.249	0.070	0.068	0.111	0.038	0.134	0.164	0.132

	Product deletion strategic factors							
Reference points	CR	RET	FLS	CI	CM	S	P	FWC
Good	0.888	0.891	0.883	0.918	0.870	0.831	0.860	0.898
Medium	0.535	0.578	0.502	0.473	0.517	0.405	0.535	0.487
Poor	0.150	0.085	0.048	0.158	0.111	0.035	0.121	0.107

Table VI. The reference points for each green attribute

product g_1 is best assigned to a medium reference point. The final members of medium reference point are g_1 g_2 g_3 g_4 g_5 g_7 g_8 g_{15} g_{17} g_{18} g_{22} g_{26} g_{29} g_{32} g_{33} and g_{40}. The number of products with a medium reference point is 16. The medium reference point probability for energy cost c_1 is (16)/(40) = 40.0%. The probability of each reference point for energy cost is in the last row of Table VII.

Step 7: calculate the value function of each green product

The value function of green product g_i, for attribute c_j is determined using CPT. For a reference point r of green attribute c_j, x_j^r, the value function z_{ij}^r is calculated by the expression given below:

$$z_{ij}^r = \varphi_r(x_{ij}) = \begin{cases} \left(x_{ij} - x_j^r\right)^{\alpha}, & x_{ij} \geqslant x_j^r \\ -\lambda\left(-\left(x_{ij} - x_j^r\right)\right)^{\beta}, & x_{ij} < x_j^r \end{cases} \tag{19}$$

where α, β and λ are similar to those in expression (2).

Products	Good	Medium	Poor
1	3.4%	94.3%	2.4%
2	3.4%	94.3%	2.4%
3	4.3%	56.9%	38.7%
4	4.3%	56.9%	38.7%
5	3.4%	94.3%	2.4%
6	2.3%	7.7%	90.0%
7	3.4%	94.3%	2.4%
8	33.6%	59.6%	6.8%
9	95.2%	3.5%	1.2%
10	81.7%	15.2%	3.1%
11	99.9%	0.1%	0.0%
12	0.2%	0.7%	99.1%
13	99.9%	0.1%	0.0%
14	81.7%	15.2%	3.1%
15	4.3%	56.9%	38.7%
16	2.3%	7.7%	90.0%
17	3.4%	94.3%	2.4%
18	1.0%	96.8%	2.2%
19	81.7%	15.2%	3.1%
20	2.3%	7.7%	90.0%
21	1.2%	7.9%	90.9%
22	1.0%	96.8%	2.2%
23	95.2%	3.5%	1.2%
24	99.9%	0.1%	0.0%
25	1.2%	7.9%	90.9%
26	3.4%	94.3%	2.4%
27	81.7%	15.2%	3.1%
28	99.9%	0.1%	0.0%
29	1.0%	96.8%	2.2%
30	95.2%	3.5%	1.2%
31	1.2%	7.9%	90.9%
32	4.3%	56.9%	38.7%
33	1.0%	96.8%	2.2%
34	95.2%	3.5%	1.2%
35	99.9%	0.1%	0.0%
36	95.2%	3.5%	1.2%
37	0.2%	0.7%	99.1%
38	99.9%	0.1%	0.0%
39	1.2%	7.9%	90.9%
40	4.3%	56.9%	38.7%
Sum	15	16	9
Probability	37.5%	40.0%	22.5%

Table VII. The degree of membership values of green products for energy cost c_1

For example, the energy cost has three reference points, a good reference point 0.902 (normalized value), a medium reference point 0.490, and a poor reference point 0.143 (see Table VI). The value function z_{11}^1 for green product g_1, attribute c_1 based on a good reference point can be calculated using the following losses process: $z_{11}^1 = -\lambda\left(-\left(x_{1,1} - x_1^{r=1}\right)\right)^\beta = -1.180$. This result shows that this product's energy performance is well below the good reference point. The value functions for green product g_i with respect to the good reference point are shown in Table VIII. Due to space constraints, the value function of green product g_i for the medium reference point and poor reference point are shown, but can be calculated using a similar process.

Table VIII. The value function of each green product for good reference point

	Production/distribution supply chain										Consumption supply chain				
Product	E1	M	L	La	MKT	R&D	D	SW1	AE1	SW2	AE2	E2	PPE	3Rs	CU
1	−1.180	0.052	−1.588	−1.359	−2.580	−1.657	−1.658	−1.623	−1.174	0.116	−1.615	0.044	−0.838	−2.077	−0.085
2	−1.180	−1.367	−2.515	−2.603	−1.000	−2.278	−2.581	−2.322	−2.585	0.116	−1.615	−1.706	−2.627	−2.192	−0.737
3	−1.825	−2.309	0.097	0.187	−0.270	−2.580	−0.271	−0.878	−2.585	−0.609	0.010	0.177	−1.736	−0.989	−0.803
4	−1.825	−0.687	−0.926	−0.301	−2.580	−2.278	−1.972	−1.623	0.195	−2.091	−2.314	−2.019	−0.904	−1.272	−2.242
5	−1.180	−1.689	−2.212	−1.026	−0.650	−2.278	0.067	−2.322	−0.375	−1.379	0.010	−1.053	−0.165	0.058	−0.964
6	−2.739	−2.309	−2.515	−2.603	−2.580	−1.657	0.067	−2.322	−1.898	−1.379	0.010	−2.019	−0.806	−2.105	0.090
7	−1.180	−0.687	−0.571	−2.603	−2.580	−2.877	−0.651	−2.322	−1.898	−0.609	−2.314	−1.706	−2.430	−1.576	−0.704
8	−0.839	−0.311	0.097	−0.301	−1.000	−2.278	0.196	−0.878	−1.898	−2.770	−0.869	−2.019	−2.087	−2.192	−0.431
9	0.130	−1.035	−0.180	−1.681	−1.334	−0.270	−0.271	−2.322	−0.375	−2.770	0.010	−2.019	−2.144	−0.344	−1.214
10	−0.478	−1.689	−0.571	−1.359	−1.657	−1.000	−2.279	−0.878	−1.174	−1.379	−0.869	−1.385	−2.627	−1.843	−2.242
11	−0.066	−1.689	−2.813	−1.681	−1.657	−1.971	−2.581	0.005	−0.375	−0.609	−2.314	−1.706	−2.231	−0.860	−2.214
12	−2.440	−2.610	0.097	−2.302	0.067	−1.334	−2.581	0.005	−2.585	−2.770	−0.869	0.177	−1.883	−1.021	−1.636
13	−0.066	−0.687	−2.515	−0.678	−2.278	−2.877	−0.271	0.005	−1.174	−2.091	−2.986	−0.706	−1.032	−2.840	0.051
14	−0.478	−2.610	−2.515	−0.301	−1.334	−1.334	−2.581	−2.322	−1.174	−0.609	−0.869	−1.706	−1.496	−2.645	−1.152
15	−1.825	0.052	−0.180	−1.995	−1.334	0.067	−1.001	−2.322	−0.375	−2.091	−2.314	0.044	−2.087	−1.241	−2.242
16	−2.739	−1.689	−0.571	−2.302	−0.270	−1.334	−1.972	−2.994	−1.898	−2.091	−1.615	−1.385	−1.557	−1.931	−0.169
17	−1.180	−1.035	−2.813	0.056	−1.334	−1.657	−0.271	−2.322	−0.375	−0.609	−2.986	−0.333	−1.466	−1.455	0.051
18	−1.507	−0.311	−2.813	−1.026	−2.278	0.067	−1.335	−0.878	−0.375	−2.770	0.010	−2.627	−2.430	−0.957	−1.636
19	−0.478	0.184	−2.813	0.187	−1.334	−2.877	−0.651	−1.623	−1.174	−2.091	−0.869	−2.627	0.067	−2.812	0.023
20	−2.739	−1.689	−1.263	−2.302	−1.000	−1.334	0.196	−0.878	−2.585	−0.609	−2.986	0.044	−0.706	0.085	−1.576
21	−2.136	−0.311	0.097	−1.026	−1.971	−1.657	−1.335	−0.878	0.195	−0.609	0.010	−0.333	−1.795	0.085	−2.579
22	−1.507	−1.035	−1.903	−1.026	−1.334	−1.000	−1.335	0.005	−0.375	−0.609	−2.314	−0.706	−1.064	−1.576	−0.868
23	0.130	−1.367	−2.515	−1.681	0.067	−0.650	−2.581	0.005	−1.174	0.116	−1.615	−2.627	−0.123	−1.576	−2.299
24	−0.066	−2.002	−2.212	−0.678	−1.971	−0.270	−1.972	−0.878	−0.375	0.116	−2.986	−0.706	0.040	−1.785	−2.327
25	−2.136	−2.309	−2.212	−1.026	−1.334	−1.971	0.067	−2.322	−1.174	−1.379	0.010	−0.333	−1.557	−2.589	−1.366
26	−1.180	−2.309	−2.212	−1.359	−2.580	−1.334	−0.651	−2.322	−1.174	−1.379	−0.869	0.177	−1.883	−2.812	0.065
27	−0.478	−0.311	−0.926	−1.026	0.067	−2.278	0.196	0.005	−0.375	0.116	−0.869	−1.706	−2.401	−0.694	−1.547
28	−0.066	−2.309	−2.813	−1.359	−1.000	−2.877	−2.279	0.005	0.195	−1.379	−1.615	0.177	−1.313	0.072	−1.183
29	−1.507	−1.035	−0.180	−0.678	−1.000	−1.000	−1.658	0.005	−0.375	−0.609	−2.986	−1.053	−2.144	0.085	0.151
30	0.130	0.052	−2.212	0.187	−1.334	−1.971	−0.271	−1.623	0.195	0.116	−2.314	0.044	0.040	−0.957	−1.244
31	−2.136	−1.689	0.097	−2.302	0.067	0.067	−1.972	−2.322	−2.585	0.116	−0.869	−2.326	−1.496	−1.084	−1.183
32	−1.825	−2.309	0.097	−2.603	−2.877	−1.971	−1.658	0.005	−0.375	−2.770	−0.869	−2.627	−0.032	−0.063	−1.027
33	−1.507	0.052	−2.515	−2.603	−1.971	0.067	−0.271	−2.322	0.195	−2.770	−0.869	−1.706	−1.436	−1.902	−2.551

(*continued*)

Table VIII.

34	0.130	0.184	0.097	−1.681	−1.657	−1.334	−2.279	−0.878	−2.585	−0.609	−0.869	−2.627	−2.173	−0.269	−1.214
35	−0.066	−0.311	−2.813	0.056	−1.971	0.067	−0.271	−2.322	−1.174	−2.770	−2.986	−1.706	0.130	−0.661	−0.737
36	0.130	0.184	−2.813	−2.302	−0.270	−0.650	0.067	−0.878	0.195	0.116	0.010	−2.627	−1.436	−2.617	−2.690
37	−2.440	−2.610	−2.212	−1.681	0.067	−2.877	−2.581	0.005	−1.898	−1.379	−0.869	−2.019	−2.373	−1.084	−0.501
38	−0.066	−2.610	−0.571	−0.301	−1.657	−2.580	−2.581	−2.322	−0.375	0.116	0.010	−1.385	−0.739	−0.063	−2.186
39	−2.136	−1.035	−0.180	−2.603	0.067	−0.270	−1.658	−0.878	0.195	−1.379	−2.986	−1.053	0.177	−1.178	−1.366
40	−1.825	−2.002	−1.588	−0.678	−1.971	−0.270	0.196	−2.322	−1.898	−2.091	−1.615	−0.333	−0.605	−1.931	−0.770

	Product deletion strategic factors							
Product	CR	RET	FLS	CI	CM	S	P	FWC
1	−1.138	−1.475	−2.388	−1.554	0.031	−0.965	0.177	−2.428
2	−2.402	−2.410	−1.451	−0.133	−1.734	−2.549	−0.333	−0.463
3	−2.097	−0.012	−0.412	−1.870	0.166	−0.612	−2.627	−2.728
4	−2.097	0.142	−2.082	−1.228	−0.368	−1.938	−1.053	0.135
5	−1.466	−0.805	−0.412	−1.870	0.031	0.209	−1.053	−2.728
6	−1.785	0.142	−2.388	−2.782	−1.414	0.209	−2.019	−1.495
7	−0.795	−0.441	−1.122	−0.133	−1.083	−0.227	−1.385	−2.428
8	−0.430	−0.805	−2.388	−1.228	−1.083	−1.623	−2.326	−0.826
9	0.146	−2.710	−1.451	−2.180	−1.414	−2.549	−1.053	−1.495
10	−1.138	−2.710	0.152	−0.133	−2.353	0.209	−2.019	−0.463
11	0.003	−0.805	−0.412	−0.890	−1.414	−1.623	−1.385	−1.167
12	0.146	0.142	−0.779	−0.133	−0.738	0.081	−1.053	−2.428
13	−1.785	−0.012	−0.779	−2.484	0.031	0.081	−1.706	−2.124
14	−1.138	−0.012	−2.688	−2.782	−1.734	0.081	−1.053	−0.463
15	−0.430	0.142	−1.122	−1.228	−0.738	−0.612	−2.326	−2.428
16	−2.702	−2.105	−2.688	−2.180	−2.047	−1.623	−1.053	−0.046
17	−0.795	−1.794	−1.122	−1.870	−2.653	−0.965	−0.706	−2.124
18	−2.702	−1.147	−1.451	−0.133	−2.353	0.081	−0.706	−1.495
19	−0.795	−2.105	−1.451	−0.133	0.031	−2.549	−0.706	−0.046
20	−0.430	−0.441	−1.451	−1.554	−1.083	−2.549	−0.333	−2.728
21	−1.138	−1.475	0.152	−1.870	−1.083	−0.227	0.044	−2.124
22	−0.795	−1.147	−2.688	−2.180	−1.734	0.209	−1.385	−1.813
23	−2.402	−2.410	−0.779	−2.484	−0.738	−2.549	−1.385	0.135
24	−2.402	−0.441	−1.451	−1.554	−1.414	−0.612	−2.627	−1.167
25	−1.466	−0.441	−1.122	−2.180	−1.083	−1.623	−1.385	−0.463

(*continued*)

26	0.003	−1.147	−2.082	0.111	−1.083	−1.938	0.044	−1.813
27	−1.466	−0.441	−2.688	−1.870	−2.047	−1.623	−0.706	−1.495
28	0.146	−0.805	0.011	−1.554	0.031	−2.247	−2.019	−0.826
29	−1.466	−0.012	−2.688	−0.532	−2.653	−0.612	−2.627	−2.728
30	0.003	−0.805	0.152	−0.133	−1.414	−0.612	0.177	−0.046
31	−2.097	−0.012	−2.688	0.111	0.031	−1.300	−1.385	−2.728
32	−1.138	−1.475	0.011	0.111	−0.368	−1.623	−2.627	0.135
33	−2.702	−2.710	−2.688	−1.228	−2.653	−0.965	−0.333	−0.826
34	−2.097	−0.805	−2.688	−1.870	−1.083	−0.227	−2.326	−1.167
35	−2.097	−1.475	−1.122	−0.133	−2.353	−0.965	−0.706	0.135
36	−1.785	−1.475	−1.451	0.111	−1.083	−1.623	0.044	−2.124
37	0.003	−0.012	−1.771	−1.228	−2.353	−0.227	−2.019	−1.813
38	−0.795	−2.710	−1.122	0.111	−1.083	−0.227	−0.706	0.135
39	−1.138	−0.805	−2.688	−0.133	−1.083	−0.612	−2.019	−0.046
40	−1.466	−0.805	−2.388	−2.484	−1.734	−1.300	−1.053	−2.124

Table VIII.

Step 8: calculate the decision weights of the value function

In this step, the value function cumulative decision weights $\pi(p^r)$ of a reference point can be calculated using the value function z_{ij}^r and the probability p^r. Due to a decreasing rank order of reference point with $r = \{1, 2, \ldots, c\}$, the value functions z_{ij}^r are increasing rank orders. For example, the ranking result is $z_{ij}^1 \leqslant \ldots \leqslant z_{ij}^r \leqslant 0 \leqslant z_{ij}^{r+1} \leqslant \ldots \leqslant z_{ij}^c$. Thus, according to expressions (3)-(6), the decision weights $\pi^+(p^r)$ or $\pi^-(p^r)$ can be determined.

For example, the Energy cost of green product g_1 has three values $z_{1,1}^1 = -1.180$, $z_{1,1}^2 = 0.091$, and $z_{1,1}^3 = 0.459$ corresponding to the three reference points from Table VIII. To calculate decision weights, an increasing rank order is $z_{1,1}^1 < 0 < z_{1,1}^2 < z_{1,1}^3$. Correspondingly, the probability of p are noted as p^1, p^2, $p^3 = 37.5\%$, 40%, 22.5%. Using Prelec (2000), the values of $\gamma = \delta = 0.8$, and $\varphi = 1$ as assigned as a baseline case in this illustration. According to expressions (3)-(6), the cumulative decision weights $\pi(p^r)$ are calculated by $\pi^-(p^1) = w^-(p^1) = \exp((-0.8)*(-\ln(0.375))^1) = 0.456$, $\pi^+(p^2) = w^+(p^2+p^3) - w^+(p^3) = 0.383$, $\pi^+(p^3) = w^+(p^3) = 0.303$. The cumulative decision weights are shown in Table IX.

Step 9: calculate the cumulative prospect value for each green product

Using the value function z_{ij}^r, decision weights π_r^+ or π_r^-, and the relative importance weight w_j of each attribute (from step 4, expression (18)), the cumulative prospect value of each green product g_i can be calculated by expression (20).

$$\varphi(w, z, p) = \sum_{j=1}^{m} w_j \left(\sum_{z_{ij}^r \leqslant 0} z_{ij}^r \pi_i^- + \sum_{z_{ij}^r > 0} z_{ij}^r \pi_i^+ \right) \tag{20}$$

For example, the Energy cost of green product g_1 has a three value function $z_{1,1}^1 = -1.180$, $z_{1,1}^2 = 0.091$, and $z_{1,1}^3 = 0.459$ corresponding to three reference points; three cumulative prospect values, $\pi_{1,1}^1$, $\pi_{1,1}^2$, and $\pi_{1,1}^3$ are 0.456, 0.383 and 0.303 and a relative importance weight $w_1 = 0.0434$. Using expression (20), the prospect value $\varphi(w, z, p)$ of green product g_1 is calculated as $\varphi(w,\ z,\ p) = 0.0434 \times ((-1.180 \times 0.456) + (0.091 \times 0.383) + (0.459 \times 0.303) + \sum_{j=2}^{m} w_j(\cdots) = -0.127$.

The cumulative prospect values of all green products are shown in Table X.

With a score of −0.281 for the cumulative prospect value for green attributes inclusive of varying reference points, green product g_{16} is the worst performing green product based on production, consumption, and product deletion factors from amongst all green products in the original set.

5. Discussion and analysis

5.1 Results analysis

The results of the methodology show that the technique culminating in a final decision guides managers in a green product deletion decision-making process. The initial results show that the green product g_{16} is the worst performing from a product deletion perspective. A nuanced analysis of the results can provide some insights into the decision situation. First, by looking at the cumulative prospect ($\varphi(w, z, p)$) values shown in Table X, value $\varphi(w, z, p)$ represents the possible loss or gain value on green product performance when compared to the reference values. Almost all the $\varphi(w, z, p)$ values are negative. This result indicates that each product, except green product g_{40}, will likely have a worse than necessary outcome in meeting environmental regulations and business requirements. This issue may be very serious from a competitive and regulatory perspective since none of the green product deletions are likely to meet decision makers' reference expectations. The decision maker's mind reference expectations may be too high, especially on environmental measures. If the organization is

	Production/distribution supply chain							Consumption supply chain							
Product	E1	M	L	La	MKT	R&D	D	SW1	AE1	SW2	AE2	E2	PPE	3Rs	CU
1	0.456	0.313	0.456	0.303	0.330	0.356	0.528	0.330	0.551	0.403	0.597	0.313	0.330	0.330	0.330
2	0.456	0.456	0.456	0.303	0.330	0.356	0.528	0.330	0.551	0.403	0.597	0.456	0.330	0.330	0.330
3	0.456	0.456	0.313	0.184	0.330	0.356	0.528	0.330	0.551	0.551	0.449	0.313	0.330	0.330	0.330
4	0.456	0.313	0.313	0.184	0.330	0.356	0.528	0.330	0.403	0.551	0.597	0.456	0.206	0.330	0.330
5	0.456	0.456	0.456	0.303	0.330	0.356	0.380	0.330	0.551	0.551	0.449	0.456	0.330	0.206	0.330
6	0.456	0.456	0.456	0.303	0.330	0.356	0.380	0.330	0.551	0.551	0.449	0.456	0.330	0.330	0.206
7	0.456	0.456	0.456	0.303	0.330	0.356	0.528	0.330	0.551	0.551	0.597	0.456	0.330	0.330	0.330
8	0.456	0.456	0.313	0.303	0.330	0.356	0.380	0.330	0.551	0.551	0.597	0.456	0.330	0.330	0.330
9	0.313	0.456	0.456	0.303	0.330	0.356	0.528	0.330	0.551	0.551	0.449	0.456	0.330	0.330	0.330
10	0.456	0.456	0.456	0.303	0.330	0.356	0.528	0.330	0.551	0.551	0.597	0.456	0.330	0.330	0.330
11	0.456	0.456	0.456	0.303	0.330	0.356	0.528	0.330	0.551	0.551	0.597	0.456	0.330	0.330	0.330
12	0.456	0.456	0.313	0.303	0.206	0.356	0.528	0.206	0.551	0.551	0.597	0.313	0.330	0.330	0.330
13	0.456	0.456	0.456	0.303	0.330	0.356	0.528	0.206	0.551	0.551	0.597	0.456	0.330	0.330	0.206
14	0.456	0.456	0.456	0.303	0.330	0.356	0.528	0.330	0.551	0.551	0.597	0.456	0.330	0.330	0.330
15	0.456	0.313	0.456	0.303	0.330	0.227	0.528	0.330	0.551	0.551	0.597	0.313	0.330	0.330	0.330
16	0.456	0.456	0.456	0.303	0.330	0.356	0.528	0.330	0.551	0.551	0.597	0.456	0.330	0.330	0.330
17	0.456	0.456	0.456	0.184	0.330	0.356	0.528	0.330	0.551	0.551	0.597	0.456	0.330	0.330	0.206
18	0.456	0.456	0.456	0.303	0.330	0.227	0.528	0.330	0.551	0.551	0.449	0.456	0.330	0.330	0.330
19	0.456	0.313	0.456	0.184	0.330	0.356	0.528	0.330	0.551	0.551	0.597	0.456	0.206	0.330	0.206
20	0.456	0.456	0.456	0.303	0.330	0.356	0.380	0.330	0.551	0.551	0.597	0.313	0.330	0.206	0.330
21	0.456	0.313	0.313	0.184	0.330	0.356	0.380	0.206	0.403	0.403	0.449	0.313	0.330	0.206	0.330
22	0.456	0.313	0.456	0.184	0.206	0.227	0.380	0.206	0.403	0.403	0.597	0.313	0.206	0.330	0.206
23	0.313	0.456	0.456	0.303	0.206	0.356	0.528	0.206	0.551	0.403	0.597	0.456	0.330	0.330	0.330
24	0.456	0.456	0.456	0.303	0.330	0.356	0.528	0.330	0.551	0.403	0.597	0.456	0.206	0.330	0.330
25	0.456	0.456	0.456	0.303	0.330	0.356	0.380	0.330	0.551	0.551	0.449	0.456	0.330	0.330	0.330
26	0.456	0.456	0.456	0.303	0.330	0.356	0.528	0.330	0.551	0.551	0.597	0.313	0.330	0.330	0.206
27	0.456	0.456	0.456	0.303	0.206	0.356	0.528	0.206	0.551	0.403	0.597	0.456	0.330	0.330	0.330
28	0.456	0.456	0.456	0.303	0.330	0.356	0.528	0.206	0.403	0.551	0.597	0.313	0.330	0.206	0.330
29	0.456	0.456	0.456	0.303	0.330	0.356	0.528	0.206	0.551	0.551	0.597	0.456	0.330	0.206	0.206
30	0.313	0.313	0.456	0.184	0.330	0.356	0.528	0.330	0.403	0.403	0.597	0.313	0.206	0.330	0.330
31	0.456	0.456	0.313	0.303	0.206	0.227	0.528	0.330	0.551	0.403	0.597	0.456	0.330	0.330	0.330
32	0.456	0.456	0.313	0.303	0.330	0.356	0.528	0.206	0.403	0.551	0.449	0.456	0.206	0.206	0.206
33	0.456	0.313	0.456	0.303	0.330	0.227	0.528	0.330	0.403	0.551	0.597	0.456	0.330	0.330	0.330

(*continued*)

Table IX. The cumulate decision weights of the value function for good reference point

Table IX.

34	0.313	0.313	0.313	0.303	0.330	0.356	0.528	0.330	0.551	0.551	0.597	0.456	0.330	0.330	0.330
35	0.456	0.456	0.456	0.184	0.330	0.227	0.528	0.330	0.551	0.551	0.597	0.456	0.206	0.330	0.330
36	0.313	0.313	0.456	0.303	0.330	0.356	0.380	0.330	0.403	0.403	0.449	0.456	0.330	0.330	0.330
37	0.456	0.456	0.456	0.303	0.206	0.356	0.528	0.206	0.551	0.551	0.597	0.456	0.330	0.330	0.330
38	0.456	0.456	0.456	0.303	0.330	0.356	0.528	0.330	0.551	0.403	0.449	0.456	0.330	0.330	0.330
39	0.456	0.456	0.456	0.303	0.206	0.356	0.528	0.330	0.403	0.551	0.597	0.456	0.206	0.330	0.330
40	0.456	0.456	0.456	0.303	0.330	0.356	0.380	0.330	0.551	0.551	0.597	0.456	0.330	0.330	0.330

	Product deletion strategic factors							
Product	CR	RET	FLS	CI	CM	S	P	FWC
1	0.330	0.456	0.276	0.456	0.184	0.551	0.163	0.407
2	0.330	0.456	0.276	0.456	0.303	0.551	0.276	0.407
3	0.330	0.456	0.276	0.456	0.184	0.551	0.276	0.407
4	0.330	0.313	0.276	0.313	0.184	0.551	0.163	0.270
5	0.330	0.456	0.276	0.456	0.184	0.403	0.276	0.407
6	0.330	0.313	0.276	0.456	0.303	0.403	0.276	0.407
7	0.330	0.456	0.276	0.456	0.303	0.551	0.276	0.407
8	0.330	0.456	0.276	0.456	0.303	0.551	0.276	0.407
9	0.206	0.456	0.276	0.456	0.303	0.551	0.276	0.407
10	0.330	0.456	0.163	0.456	0.303	0.403	0.276	0.407
11	0.206	0.456	0.276	0.456	0.303	0.551	0.276	0.407
12	0.206	0.313	0.276	0.456	0.303	0.403	0.276	0.407
13	0.330	0.456	0.276	0.456	0.184	0.403	0.276	0.407
14	0.330	0.456	0.276	0.456	0.303	0.403	0.276	0.407
15	0.330	0.313	0.276	0.456	0.303	0.551	0.276	0.407
16	0.330	0.456	0.276	0.456	0.303	0.551	0.276	0.407
17	0.330	0.456	0.276	0.456	0.303	0.551	0.276	0.407
18	0.330	0.456	0.276	0.456	0.303	0.403	0.276	0.407
19	0.330	0.456	0.276	0.456	0.184	0.551	0.276	0.407
20	0.330	0.456	0.276	0.456	0.303	0.551	0.276	0.407
21	0.206	0.456	0.163	0.456	0.184	0.403	0.163	0.407
22	0.206	0.456	0.276	0.456	0.303	0.403	0.276	0.407
23	0.330	0.456	0.276	0.456	0.303	0.551	0.276	0.270
24	0.330	0.456	0.276	0.456	0.303	0.551	0.276	0.407
25	0.330	0.456	0.276	0.456	0.303	0.551	0.276	0.407
26	0.206	0.456	0.276	0.313	0.303	0.551	0.163	0.407

(*continued*)

27	0.330	0.456	0.276	0.456	0.303	0.551	0.276	0.407
28	0.206	0.456	0.163	0.456	0.184	0.551	0.276	0.407
29	0.330	0.456	0.276	0.456	0.303	0.551	0.276	0.407
30	0.206	0.456	0.163	0.456	0.303	0.551	0.163	0.407
31	0.330	0.456	0.276	0.313	0.184	0.551	0.276	0.407
32	0.206	0.456	0.163	0.313	0.184	0.551	0.276	0.270
33	0.330	0.456	0.276	0.456	0.303	0.551	0.276	0.407
34	0.330	0.456	0.276	0.456	0.303	0.551	0.276	0.407
35	0.330	0.456	0.276	0.456	0.303	0.551	0.276	0.270
36	0.330	0.456	0.276	0.313	0.303	0.551	0.163	0.407
37	0.206	0.456	0.276	0.456	0.303	0.551	0.276	0.407
38	0.330	0.456	0.276	0.313	0.303	0.551	0.276	0.270
39	0.330	0.456	0.276	0.456	0.303	0.551	0.276	0.407
40	0.330	0.456	0.276	0.456	0.303	0.551	0.276	0.407

Table IX.

Products	All attributes Cumulative prospect value	Rank	Production/distribution supply chain Cumulative prospect value	Rank	Consumption supply chain Cumulative prospect value	Rank
1	−0.127	30	−0.179	17	−0.026	36
2	−0.273	2	−0.370	2	−0.202	15
3	−0.116	32	−0.153	19	0.023	40
4	−0.171	13	−0.159	18	−0.305	2
5	−0.085	38	−0.150	20	0.020	39
6	−0.245	3	−0.381	1	−0.099	33
7	−0.192	8	−0.284	5	−0.230	12
8	−0.145	25	−0.035	35	−0.293	4
9	−0.15	23	−0.030	36	−0.205	14
10	−0.159	21	−0.128	25	−0.265	7
11	−0.168	15	−0.201	14	−0.256	9
12	−0.142	27	−0.258	6	−0.180	19
13	−0.168	14	−0.134	23	−0.288	5
14	−0.192	7	−0.247	8	−0.175	21
15	−0.137	29	−0.080	31	−0.270	6
16	−0.281	1	−0.301	4	−0.211	13
17	−0.16	20	−0.130	24	−0.141	26
18	−0.172	12	−0.114	28	−0.297	3
19	−0.145	24	−0.135	22	−0.233	10
20	−0.175	10	−0.222	12	−0.106	30
21	−0.054	39	−0.054	33	−0.043	35
22	−0.109	34	−0.044	34	−0.106	31
23	−0.182	9	−0.112	29	−0.195	16
24	−0.161	19	−0.116	27	−0.185	17
25	−0.167	16	−0.233	9	−0.125	28
26	−0.161	18	−0.248	7	−0.127	27
27	−0.096	37	0.022	40	−0.117	29
28	−0.117	31	−0.195	15	−0.054	34
29	−0.143	26	−0.025	37	−0.144	25
30	0.014	40	−0.017	38	−0.025	37
31	−0.173	11	−0.224	11	−0.102	32
32	−0.156	22	−0.229	10	−0.174	22
33	−0.244	4	−0.140	21	−0.322	1
34	−0.163	17	−0.120	26	−0.162	23
35	−0.137	28	−0.088	30	−0.258	8
36	−0.107	35	−0.008	39	−0.231	11
37	−0.22	5	−0.328	3	−0.175	20
38	−0.097	36	−0.218	13	−0.002	38
39	−0.109	33	−0.074	32	−0.184	18
40	−0.198	6	−0.183	16	−0.154	24

Table X. The cumulative prospect values for each green product

unable to find green products that may be deleted that can meet the decision maker's mind reference expectations, than other factors, such as profitability and other competitive reasons, will need to take precedence in deletion decisions. Next, green product g_{40} is greater than 0, which represents a unique positive value of from all green product that will be considered for deletion; and when evaluated based on the reference values. This result indicate that the green product g_{40} will have a better than reference point outcome.

5.2 Methodology analysis

The comprehensive evaluation shows that using green product deletion alternatives reference points, probability information, and weights of factors for CPT can be used as a multiple criteria decision evaluation approach. CPT is based on behavioral aspects of decision making and risk propensity of decision makers. Using NRST and FCM, more objective weights and probabilities are arrived at using data that may or may not require inputs from actual decision makers and managers. Modeling uncertainty in this environment makes the problem more realistic. The techniques, when integrated together, can help complete this modeling of a green product deletion decision through a more objective approach that can incorporate weighting and uncertainty. Achieving more objectivity is an important aspect of multiple criteria decision modeling with uncertainty (Durbach and Stewart; 2012).

5.3 Sensitivity analysis

The results of this technique show that green products targeted for deletion can be effectively determined ranked. Sensitivity analysis was also conducted to investigate whether the decision varies, and by how much, if only some factors of SPC are considered instead of all. To determine the sensitivity of the solution, and provide a caveat for researchers and managers, an analysis with two subsets of factors is conducted. This subset of factors includes either upstream (production) factors or downstream (consumption) factors. This breakdown may roughly show differences in results between supply chain/ operations managers and their decisions vs marketing personnel and their decisions. Table X shows the results of these two additional evaluations.

The results of this analysis show that there are significant differences. In fact, when looking at the top five prospects to delete (products 2, 6, 7, 16, and 37) if only production factors are considered and the top five prospects to delete (products 4, 8, 13, 18, and 33) if only consumption factors are considered, no overlap exists. Thus, it is very likely that if only one subset of factors is considered the decision can be very different or sensitive. Overall, when all factors are considered, the deletion decision overlaps more with the production factors (four product overlaps) than with the consumption factors (one product overlap) in this specific scenario.

Another analysis could occur for those products a firm definitely plans to retain (lowest rankings). In this situation, one product (product 30) appears in the last five products to be considered for deletion (ranked 36-40) for both the production and consumption factors. Overall, it is confirmed that green product 30 is ranked as the last product to be considered for deletion when all the factors are considered. Managers can be confident that this product should remain in the product portfolio as it adds value to business and SPC factors.

A variety of sensitivity analyses can be conducted by altering other parameters and weights. The technique implicitly incorporates behavioral and risk propensities in the evaluation using the various CPT parameters. Changing risk expectations, a parameter alteration, may occur due to managerial, industrial, and market characteristics. Since this data is illustrative, there is no information related to the various decision environment elements and this provides opportunity for future investigation.

5.4 Theoretical and managerial implications

In this section we summarize and slightly expand on some theoretical and managerial implications of this study.

First, this study further advances the relationship between soft computing methods and sustainability research. It also further supports the feasibility of applying soft computing and systems theoretic perspective. Systems theory takes into consideration of the interaction of various systems. In this case green product deletion can be effectively evaluated within the broader systems, sustainable supply chain (production and consumption perspective). Natural, organizational, social, and technological systems interact in this study.

The technical feasibility contribution of this study is evident; further research related to the effectiveness of this tool needs to consider behavioral theoretic perspectives. For example, CPT is based on behavioral aspects of decision making and risk propensity of decision makers. How well and to what level of sensitivity can the behavioral aspects be captured. Given the complexity of the situation, capturing various elements of risk propensity becomes difficult. Also, risk propensity may vary across factors and individuals. This technique may be evaluated from these perspectives.

Theoretically, systems theory is a very general theory; more nuanced theoretical aspects may also be contributing to this environment. There are many levels of theories that can be investigated. Supply chain level theories such as relational theory (e.g. Fu *et al.*, 2017); marketing and consumer behavior theory such as the theory of planned behavior (e.g. Paul *et al.*, 2016); organizational theory such as institutional theory (e.g. Sarkis *et al.*, 2011); and individual organizational behavior theory such as motivation for proenvironmental behaviors (e.g. Graves *et al.*, 2013); can all play a role of informing researchers within the broader systems theory paradigm. Integrating and evaluating soft computing, product deletion, and SPC are important theoretical aspects that will be related to our findings here.

Managerial implications exist within this study. Some of these implications are related to the factors and behaviors that the tools attempt to incorporate. Given the complexity of the decision environment, will managers be overwhelmed with the opaqueness of the decision tools involved? This practical is a general managerial concern with all applications of soft computing. Acceptance of the tool in this decision environment is an important managerial consideration. Part of this acceptance is to validate the effectiveness of such a tool. Unfortunately, there is no easy way to determine the effectiveness and validity of perceptually and behaviorally based multiple criteria soft computing tools; the work in this area continues (Wu and Tiao, 2017). Soft computing is advantageous for practical settings in that it can get closer to real world situations that are not always easily quantifiable and scored, but it is also a weakness. These concerns overlap both theoretical and managerial implications.

One evident managerial implication derives from the sensitivity analysis completed in this study. Clearly, what factors and aspects of the production and consumption evaluation of production deletion decision can greatly influence the final decision. This calls for a comprehensive evaluation. Yet, building a comprehensive decision situation requires multiple decision makers from across internal and external organizational boundaries; and multiple levels of decision makers. This additional complexity may lengthen the amount of time necessary for such evaluations; and may build mistrust if applied inappropriately.

Careful methodology and decision environment implementation and application is needed. Muir and Reynolds (2011) mention that in practice managers still utilize informal approaches with a lack of a formal process to arrive at product deletion decisions. Using the methodology to help structure the decision environment and inform the decision makers is a major benefit of this, and other soft computing tools. Thus, it is not always the final decision that should be the goal of these real world decision environments, but a goal should be to help decision makers make sense of complex decision environments and provide a more formalized and systematic decision-making process.

6. Conclusion and future directions

This paper introduces product deletion, and specifically green product deletion, to the soft computing, SPC, and decision-making research community. It addresses an issue that has seen minimal scrutiny, but can have significant impact on the greening of supply chains and organizational environmental sustainability. The soft computing aspects relate to the integration of a number of multiple criteria decision evaluation approaches together to derive a ranking that helps decide which product to delete. This is the first time that NRST, FCM, and CPT have been integrated together in the context of green product deletion in a supply chain setting. This hybrid multistage technique has advantages of being able to incorporate many factors that have a variety of quantitative and qualitative characteristics.

CPT with its risk based decision approach can prove helpful for evaluating a decision replete with uncertainty and risk. However, it requires estimations of reference points, probability, and weighting of factors. With little need for additional decision maker input, NRST is capable of providing factor or attribute weightings; FCM can provide reference point valuations and probabilities that can be utilized in CPT. This integration provides a foundation for other techniques that can be utilized to help generate similar inputs to CPT and have broader implementation of the CPT methodology for research and decision-making purposes. Thus, there are both theoretical and methodological contributions offered by this paper.

The methodologies introduced here may be replaced by other techniques that can help generate weights and probabilities (e.g. data envelopment analysis; and other clustering approaches). Investigating the results under differing competing methodological scenarios can be completed.

Further, no model is perfect and this model has its limitations too. First, the use of multiple, and relatively complex, approaches may require some significant simplification and explanation to managerial decision makers. This complexity may be shielded by development of decision support systems, but requires that the techniques become a "black box." The opaqueness of this complex approach may cause lessened acceptance by management, even with the advantages of the technique. Thus, an actual application of the tool rather than just an illustrative example will be necessary to determine the level of acceptance. This can be an important avenue for future research.

The methodology made a number of assumptions related to the data; first it assumed that a complete set of data is available. There are a number of instances of missing data, especially with a new decision environment of green product deletion. How the technique works in an environment with missing and more perceptual data needs further investigation.

Another limitation exists from the factors that were used in this study. Although a number of factors were used from literature, the product deletion situation in the real world may involve more complex sets of factors. For example when deleting any product (green or otherwise), there are operational activities that may be influenced, for example, the leanness of organizations (e.g. inventory management). How lean practices are affected, as are technological and supply chain changes, can be further investigated and integrated in this model. Although feasibility of the technique is evident; further validation and effectiveness research is needed.

Given that, this is one of the initial papers to consider evaluating the green product deletion decision, there is ample room for additional investigation in the future. It is hoped that the readership (researchers and/or practitioners), can see the value in developing decision support mechanisms from a soft computing perspective for this understudied business and sustainability concern.

Note

1. These scale numbers are exemplary. Different scales are used because: the information may be derived from different units within the organizations; relatedly, we wish to show that even with different scales, the normalization procedure can be applied to aggregate these diverse scales within the soft computing methods; and these different scales exemplify a lack of a consensus set of scales for these factors within the related literature.

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