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Sustainable product-package design in a food supply chain: A multi-criteria life cycle approach

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This paper presents a multi-criteria decision-making approach for the selection of a sustainable product-package design, accounting for the different actors within a food supply chain. The study extends the focus of sustainable packaging design to the collective of all supply chain actors. Decision criteria are identified via a literature review, and current product-package alternatives are collected via interviews. With the inputs of these criteria and the alternative designs, a multi-criteria decision-making problem is formulated and solved using Best Worst Method (BWM). BWM finds the weights of the criteria. Using these weights, the ranking of the alternatives is found. The implementation of the analysis took place for three selected products of the Kraft Heinz Company. Data on the preferences of the supply chain members of these selected products were collected, and the optimal package designs were selected. It is shown through sensitivity analysis that modifying the weights that decision makers assign to the preferences of the supply chain members and the importance of the dimensions of sustainability have an effect on the selection of the optimal design.

KEYWORDS

BWM, food packaging, multi-criteria decision-making, best worst method, sustainability, sustainable packaging, sustainable supply chain management

1 | INTRODUCTION

The rising environmental concerns of consumers have brought the value of sustainability to the forefront of the corporate agenda. In recent years, the focus of research in sustainability has shifted from the corporate level to that of the whole supply chain.[1] Considering sustainability in a supply chain implies making all the decisions more sustainable. The focus of this study is packaging design, an essential decision in a supply chain of a product. Azzi et al[2] identified five specific aspects in packaging design that are of high importance, one of which being "packaging design for sustainability." Considering sustainability in food-related products has been found a very important topic by several researchers.[3,4] This paper analyses the supply chain of a company in the food-packaging industry and aims to develop and apply a method for deciding about improving the sustainability of the package design. This objective is achieved by creating a decision-making tool that improves the choice between alternative package designs, from a sustainability perspective. Additionally, the focus on the supply chain implies that the assessment of a product's design should not be according to product or company-specific sustainability criteria but rather according to criteria that ensure the sustainability of the whole supply chain. To ensure this comprehensive scope of sustainability, the preferences of all members in the supply chain have to be accounted for, even if the specific sustainability objectives of each individual supply chain actor may differ.

The packaging level under study is the primary or consumer packaging. This level of packaging is the last piece of packaging between the product and the consumer. As, in this study, we would like to take into account the perspective of the consumer in consort with the perspective of all the other supply chain actors, we chose this level of packaging. Even though the main task of packaging is to protect and distribute the right product to the right end user in a safe, cost-efficient and user-friendly way, it is often regarded as a burden for the environment. However, several assessments of this kind have indicated that the environmental impacts of packaging are relatively small compared with the environmental impacts of the packed food products that they contain. The most severe environmental consequences of packed foods can be attributed to food losses that are mainly caused by overproduction and excess portion quantities.[5] The challenge in selecting the optimal package design is finding the perfect balance between the product and the packaging. As a result, in this paper, the product-package perspective is adopted, or in other words, product-package combinations are studied instead of solely the packages.

This paper has several contributions. Firstly, research in the field of sustainable packaging in the food packaging industry is enhanced with the creation of a sustainable packaging criteria list, which incorporates a triple bottom line (TBL, see further in the text) perspective on sustainability, adopts the product-package perspective, and takes into account the complete life cycle of the product-package combination, which has been neglected in existing literature.[6] Secondly, a decision-making tool is created that can be used by product-package manufacturers in the food-packaging industry when selecting an optimal package design among alternatives. This tool can be used in various stages of new product development, either in the beginning when selecting the minimum requirements of the product to be packed or in the end when validating the selected package alternative before the actual design process can be initiated. Apart from assigning the relative scores of the packages towards the criteria, the decision-maker should also strategically select the weights that will be assigned to the three dimensions of sustainability and to the preferences of the supply chain members.

The rest of the paper is organized as follows. In the next section, a review of literature is provided to feed into a conceptual framework for sustainable package design selection in supply chains. Section 3 describes the methodology used in this study for applying the framework. Analysis and results are presented in Section 4. The paper concludes in Section 5 with some future research directions.

2 | LITERATURE REVIEW

First, some basic definitions are given. The existing literature is separated in the four main pillars of this paper, starting from the most general towards the most specific as follows: the value of sustainability, sustainable supply chain management (SSCM), sustainable packaging, and sustainability in the food-packaging industry.

2.1 | Basic definitions

2.1.1 | TBL of sustainability

The TBL is a term that was first used by Elkington. The perspective of TBL claims that sustainable development has three dimensions, an economic, an environmental, and a social one. The TBL suggests that at the intersection of the dimensions are activities that positively affect the natural environment and society and also result in long-term economic benefits and competitive advantages for the firm.

2.1.2 | Sustainable supply chain management

In the 1980s, the concept of SSCM was born. Seuring and Müller[7] refer to SSCM as "the management of material, information and capital flows as well as cooperation among companies along the supply chain while taking goals from all three dimensions of sustainable development such as economic, environmental and social, into accounts which derive from customer and stakeholder requirements." This definition serves as a milestone for the enhanced version of the definition of SSCM that was given by Carter and Rogers[8] later in 2008, and refer to SSCM as "the strategic, transparent integration and achievement of an organization's social, environmental and economic goals in the systemic coordination of key inter-organizational business process for improving the long-term economic performance of the individual company and the supply chain." The selection of the package design, in this paper, will take place according to these three dimensions of sustainable development.

2.1.3 | Packaging

Packaging should be considered as a system comprising three levels[9]: the first level is referred to as the primary one, or *consumer packaging*, and has the aim of protecting the product. The next level is the secondary one, known as *transport packaging*, and is designed to contain and group together several primary packages. The third level is the *tertiary packaging*, which involves several primary or secondary packages grouped together on a pallet or a road unit. In this paper, when referring to the package or the packaging, the first level is implied. Apart from three hierarchical levels, packaging also serves three different functions[10]: the *marketing function* that is designed to select alternatives in graphic design and formats for adapting to the current legislation and customer requirements, the *logistics or flow function* designed to facilitate purchases, production, or packing and distribution, and lastly, the *environmental function*, which is related to reverse logistics. In order for these functions to be put together, the separation of packaging into the three aforementioned levels is essential.

2.1.4 | Sustainability in the food-packaging industry

The history of modern food packaging is believed to have begun in the 19th century with the invention of canning. Since then, the industry has seen great advances, which have led to improved food quality and safety. These advances were mostly driven by changing consumer preferences, which, in turn, have led to rising attention towards sustainable packaging, an increase in the use of the packaging value chain relationships for competitive advantage, and the introduction of the evolving role of food service packaging. The most commonly used approach that has been followed in estimating sustainability in the food packaging industry is the complete Life Cycle Assessment (LCA). It is an analytical method that is used to evaluate the resource

consumption and environmental burdens associated with a product, process, or activity.[11] In their paper, Heller and Keoleian[11] assess the sustainability of the US food system and suggest ways of how this complex system can be improved. They suggest that a product life cycle approach provides a framework for studying the links between satisfying societal needs, the natural and economic processes that are used for this reason, and lastly, their corresponding environmental consequences. They separate the life cycle of a product in the food industry in five stages, from the beginning to the end of the supply chain. For each stage, they incorporate the stakeholders that take part in the supply, the manufacturing, and the distribution process of the product and also those who are affected by its commercialization and ownership. Furthermore, for each life cycle stage, a number of key performance indicators are presented, separated among the TBL of sustainability. These indicators describe how sustainability can be assessed according to the economic, social, and environmental effects of the food product under study. This approach to sustainability aims at *reforming* current practices of supply chain management, instead of *transforming* them. A distinction that is framed in terms of "weak" versus "strong" sustainability,[12] of which the latter form of sustainability can be recognized in ideas about the so-called "circular economy."[13] However, such radical transformational ideas do not inform how to improve existing practices of supply chain management, as they suggest discarding such practices altogether. As such, the TBL approach is considered to be more appropriate route towards developing SSCM.

2.2 | Integration of the four pillars

In this section, the four main pillars discussed in Section 2.1 are integrated. By expanding sustainability to all the operations of a firm in the food-packaging industry, it can be implied that sustainability stretches the concept of SSCM to look at optimizing operations from a broader perspective.[14]

The criteria according to which a product is characterized as sustainable have already been documented. There are different approaches to these criteria. Three major ones are published by the European Organization for Packaging and the Environment (EUROPEN) in Europe, the Sustainable Packaging Coalition (SPC) in the United States,[15] and the Sustainable Packaging Alliance (SPA) in Australia.[16] The package design could be chosen according to these criteria that are depicted in Table 1. The problem statement can be underlined by the fact that these criteria are partly product-specific and do not incorporate or ensure the sustainability of the whole supply chain. After the criteria have been formulated, they will be compared with the ones published by the EUROPEN (www.europen-packaging.eu), the SPC, and the SPA.

In this paper, the supply chain sustainability criteria are found based on a comprehensive literature review and the ones published by EUROPEN, SPC, and SPA.

The definition of TBL, as presented in the beginning of Section 2.1, is judged as incomplete by many authors.[17] They suggest that the terms of risk management, transparency, strategy, and culture should be added in the graph of TBL as it is depicted in Figure 1. Risk management includes all the risk factors that a firm should strive to minimize as part of its sustainable development. Transparency relates to the opening of a company's operations to greater-public scrutiny. Strategy and organizational culture should comply, coexist, and coevolve with the sustainable practices of the firm. The intersection with a question mark symbolizes the fact that solely environmental and social activities are costly undertakings, and competitive firms do not engage in them unless it fits their strategic and financial objectives.[17] This framework of SSCM is used in this paper, since it is a more complete version of TBL.

The unit of analysis of this study is the product package. As a result, the company under study is not only the package converter

TABLE 1 Three schools of sustainable packaging criteria

Existing sustainable packaging criteria		
According to European Organization for Packaging and the environment (EUROPEN)	**According to sustainable packaging coalition (SPC)**	**According to sustainable packaging Alliance (SPA)**
1. Packaging should be designed holistically with the product in order to optimize overall environmental performance	1. Packaging should be beneficial, safe, and healthy for individuals and communities throughout its life cycle	1. Effective: packaging should have social and economic benefit
2. Packaging should be made from responsibly sourced materials	2. Packaging should meet market criteria for performance and cost	2. Efficient: packaging should be based on "doing more with less"
3. Packaging should be designed to be effective and safe throughout its life cycle, to protect the product	3. Packaging should be sourced, manufactured, transported, and recycled using renewable energy	3. Cyclic: packaging should optimize recovery
4. Packaging should meet market criteria for performance and cost	4. Packaging should optimize the use of renewable or recycled source materials	4. Clean/safe: packaging should contain nonpolluting and nontoxic materials
5. Packaging should meet consumer choice and expectations	5. Packaging should be manufactured using clean production technologies and best practices	
6. Packaging should be recycled or recovered efficiently after use.	6. Packaging should be made from materials healthy throughout the life cycle	
	7. Packaging should be physically designed to optimize materials and energy	
	8. Packaging should be effectively recovered and utilized in biological and/or industrial closed loop cycles	

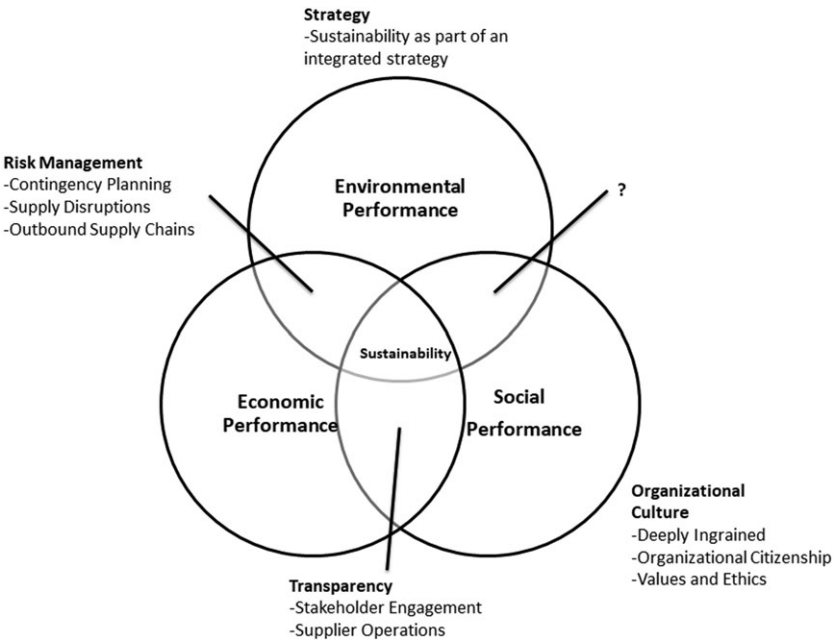


FIGURE 1 Sustainable supply chain management framework[17]

but also the one who produces the contained product. This actor is also the decision-maker who has to incorporate in the product design, those characteristics that satisfy to the maximum degree possible the needs of the rest of the supply chain members. After considering the specific needs of the food-packaging industry and the five stages proposed by Heller and Keoleian,[18] it was decided to separate the supply chain into six main members. These can be seen in Figure 2 and are, namely, the raw-material suppliers, the packaging-material suppliers, the product-package manufacturers, the retailers, the consumers, and the end-of-life companies. It has to be mentioned that even though the raw-material suppliers and the packaging-material suppliers often have parallel roles in the supply chain, they have been placed in the respective sequence since in certain cases, the latter serve the role of the copacker for the company under study.

2.3 | Sustainable packaging criteria selection

The content analysis that follows is based on the idea that from a methodological point of view, literature reviews can be comprehended as content analysis, where quantitative and qualitative aspects are mixed to assess structural and content criteria.[7] The process contains four main steps, namely, the material collection step, the descriptive analysis step, the category selection step, and lastly, the material evaluation step. For the last two steps of the process, where material analysis takes place, Seuring and Müller[7] designed a framework that contains a feedback loop for the revision of the structural dimensions and analytic categories.

This content analysis was modified and used as a development process for a conceptual framework more recently by Wan Ahmad et al[19] elaborating on the contextual factors of SSCM practises in the oil and gas (O&G) industry. Even though the relation with the food-packaging industry is scarce, the approach taken in this paper is highly correlated to the perspective of Wan Ahmad et al,[19] since it takes into account all three dimensions of sustainability. Furthermore, the contextual factors described therein derive strictly from literature regarding O&G industry because of lack of related sources but rather from literature dedicated to sustainable development in the supply chain of various industries.

Regarding the material collection step, studies and scientific articles related to the integration of the four pillars of literature review were collected. The identification of the relevant studies was more detailed than in the general literature review, since in this part, the context from which the criteria would be derived was investigated. The studies were identified through a structured keyword search (ie, "sustainable," "supply chain," "package," "food," "criteria,"and "factors") in four electronic databases, namely, Emerald, Elsevier, Springer, and Wiley. Furthermore, the Google Scholar was used as complementary search engine in this part of the process, and publications related to sustainable packaging were also used. Next, a selection procedure was followed for the literature that was searched. Each individual study had to belong to at least two of the four pillars of the main literature review, namely, "the value of sustainability," "sustainable supply chain management," "sustainable packaging," and "food packaging industry." In other words, each study should individually contribute to the integration of the four pillars of literature review. The sources

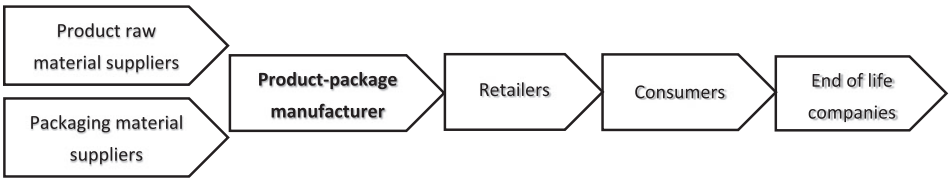


FIGURE 2 The supply chain members in the food packaging industry

used for the creation of the criteria list and the conceptual framework were 30 in total number, composed of 26 scientific papers regarding the four pillars of literature review and 4 publications of sustainable packaging organizations.

The next step in the development process of the conceptual framework is dedicated to the separation of the identified criteria along the TBL. Certain criteria could belong to more than one dimension; however, assumptions were made some criteria were placed in their intersections. The complete list of criteria is presented in Tables 2A-2C, while in Figure 3, the criteria are depicted in their respective dimensions and their intersections.

After having listed the respective criteria, the framework with the contextual factors of the food-packaging industry could be mapped. The framework that is created is then revised by experts at the case company, Kraft Heinz Company, and academics taking into account three criteria: everyone agrees that the contextual factors have all been mapped, the criteria are relevant to selecting a product-package combination, and there are no studies that would add any more sustainable packaging criteria to the list. A feedback loop is added to the conceptual framework development process so as to ensure that the process is done in a correct way until the targets are met.

Here, we explain the reasons of putting some of the criteria on the intersections of the sustainability dimensions.

Starting with the intersection between the environmental and economic performance, the criteria "manages environmental risk" and "physically designed to optimize materials and energy" are located. The first one was placed there because it is related to corporate risk management, since minimizing the ecological impact contributes in reducing variation of unexpected outcomes. The second one was placed in the intersection because while a firm may reap the financial benefits of optimization in the use of materials and energy, it also contributes in enhancing its environmental performance.

In the intersection between the economic and social performance, four criteria are placed. Starting with the criterion "cooperation with supply chain members," it is evident that fairness in the distribution of profits among the members is closely related with the social practices of the firm. This criterion is also closely related to "transparency," since by operating with clarity, a firm strengthens the relationship with its partners in the supply chain, which can, in turn, lead to higher success in the introduction of the product package in the market. Moreover, "maximizing consumer value" not only shows respect regarding the consumer's income but also encourages the end consumers to select the firm's products in the competitive market. Similarly, the criterion "manages reputational risk" was also placed in this intersection since effective mitigation of risk also boosts the selling capability of the product package. Finally, in the intersection between the environmental and social performance, the criteria of "product integrity" and "suppliers and carriers are certified" are placed even though in the framework of Carter and Rogers[17] that space was left empty. The reason that the first criterion was placed there is due to the fact that

TABLE 2A Environmental criteria for packaging

Environmental criteria	References
Sourced in an environmentally friendly way	Other studies[11,15,19-21]
Manufactured in an environmentally friendly way	Other studies[5,11,15,19,22,23]
Transported in an environmentally friendly way	Other studies[5,11,15,19,22,24]
Recycled, reused, and disposed in an environmentally friendly way	Other studies[5,15,20,25]
Uses recycled, renewable, and reused sourced materials	Other studies[5,11,15,19-24,26,27]
Recovered and utilized in industrial closed loop cycles	Other studies[7,8,15,21,24,27-30]
Manages environmental risk	Other studies[1,5,7,17,19,21,28-32]
Integration with the environmental management system	Other studies[1,19,26,28,33,34]
Product stewardship	Other studies[19,28,34]
Uses healthy sourced materials	Other studies[5,11,20,21,24,27]
Avoids packaging and raw material waste	Other studies[5,11,19,21-24,27,29,33,35]

TABLE 2B Economic criteria for packaging

Economic criteria	References
Performance meets market needs	Other studies[1,5,7,15,16,19-21,25,29-34,36,37]
Sourcing, manufacturing and distribution, and recycling costs	Other studies[5,7,15,20,21,29,33,35,38,39]
Physically designed to optimize materials and energy	Other studies[1,5,15,16,19,21-24,26,27,35]
Gain employee's and top management commitment	Other studies[1,19,26,31,37,40,41]
Aligned with company's characteristics	Other studies[1,7,17,19,31,34,38,40,42]
Continuity	Other studies[1,5,7,19,28,34,36]
Boosts competitiveness	Other studies[1,7,21,37,39]
Cooperation with supply chain members	Other studies[1,7,11,19,23,26,28,34,39-41,43]
Profitability	Other studies[1,7,17,19,21,28,30,31]
Product protection	Other studies[5,21,24,29,35,36,43]
Package functionality	Other studies[5,21,24,25,27,36,43]
Product integrity	Other studies[5,11,21,24,29,35,36,43]

TABLE 2C Social criteria for packaging

Social criteria	References
Beneficial for individuals and the community	Other studies[15,16,21]
Healthy and safe for individuals and the community	Other studies[5,11,16,19,20,23,24,26,35,36]
Aligned with the organization's corporate social responsibilities	Other studies[1,11,21]
Manages reputational risk	Other studies[1,7,17,19,30-32]
In accordance with governmental policies and regulations	Other studies[1,5,7,11,21,24,36-39]
Transparency	Other studies[7,17,19,21,30,31,33,34,40]
Employee's quality of life	Other studies[7,11]
Maximize consumer value	Other studies[11,21,25]
Suppliers and carriers are certified and pass the environmental and social criteria	Other studies[7,11,19,22,23,26,28,30,34,39]

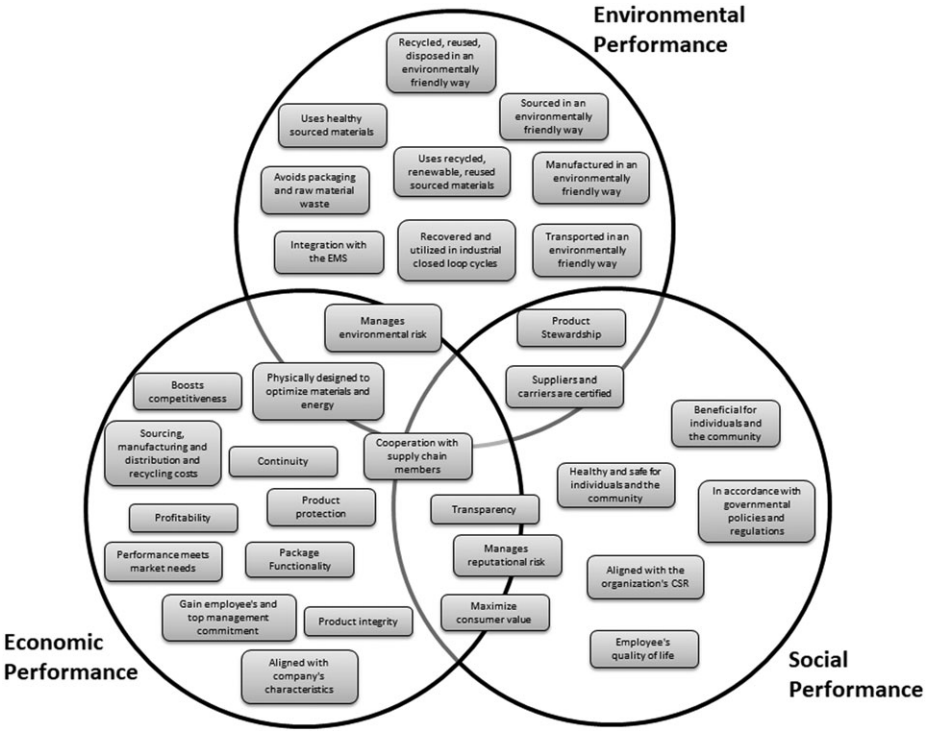


FIGURE 3 Criteria categorization along the triple bottom line

having a traceable product package whose sustainability can easily be assessed is beneficial for individuals and the community and also contributes in building an accurate green image of the firm that will prohibit non-governmental organizations from raising any opposition. Regarding the certification of the suppliers and carriers, together with the social certifications that they should hold, they should also pass certain environmental criteria. However, Carter and Rogers,[17] in their article, claimed that no firm is involved in sustainability practises strictly because of environmental and social concerns. If those two criteria were totally neglected by a firm, then, it would probably face indirect financial consequences because of the heavy competition in the food industry.

3 | METHODOLOGY

The research investigates the way that the sustainable packaging factors of the whole supply chain affect the design of the package in the food-packaging industry. As explained above in the process of the creation of the criteria list, these factors need to be translated to certain quantifiable criteria. According to these criteria, various package design alternatives are evaluated, and the optimal one is selected. As a process of taking a decision is involved and various criteria have an impact on the decision, we conclude that it can be formulated as a multi-criteria decision-making (MCDM) problem. Furthermore, because of the existence of six members in the supply chain, it is also a multi-actor problem. This implies that the best package design is selected taking into account the preferences of the whole supply chain members.

Three lists of criteria for the three dimensions of sustainability criteria were presented in Tables 2A-2C. The process followed from here included a number of steps. Expert opinions were used to rank these criteria and reduce their number by selecting the most important from them. Next, structured interviews were conducted to select a number of product-package combinations and their alternative package designs. Then, relative scores were assigned to each design alternative according to the decision-maker through a structured interview once again. Finally, the members of the supply chain were asked to complete a survey to identify weights of the criteria. An explanation of the aim of the study and the evaluation criteria are provided for all the respondents. The data obtained from the survey were used to calculate the weights of the criteria.

We explain the operationalization of the MCDM approach in the next subsections.

3.1 | Multi-criteria decision-making

MCDM is a subdiscipline of operations research. In an MCDM problem, a number of alternatives are evaluated with respect to a number of criteria in order to select the best alternatives.[44] There exist several MCDM methods, such as the weighted sum model (WSM), weighted product model (WPM), and the analytic hierarchy process (AHP).[44] The method used in this paper is the Best Worst Method (BWM), which was recently developed by Rezaei.[45] The primary advantages of BWM, and thus, the reasons behind selecting it are that in comparison with other existing MCDM methods the BWM requires less comparison data and leads to more consistent comparisons. Furthermore, this paper aims to expand the spectrum of applications of this particular method by applying it in a multi-actor setting of the food-packaging industry. The implementation of BWM has been the topic of several scientific papers with objectives of supplier selection,[46-48] the evaluation of power grid enterprise,[49] evaluating the quality of scientific

outputs,[50] evaluating R&D performance of firms,[51] evaluating the social sustainability of supply chains,[52] evaluating airports and airline services,[53-55] technology battles,[56,57] and measuring quality of transit nodes[58] and logistics performance index indicators[59] among others.

3.2 | Best worst method

The steps of the BWM that are used in deriving the weights of the criteria are presented below[45,60]:

1. Determine a set of decision criteria. In this step, the decision-maker identifies n criteria $\{c_1, c_2, \cdots, c_n\}$ that are used to make a decision.
2. Determine the *best* and the *worst* criteria. The best criterion is the most important (or the most desirable or the most contributing) criterion, while the worst criterion is the least important (or the least desirable, or the least contributing) one.
3. Determine the preference of the *best* over all the other criteria, using a number between 1 and 9, with 1 indicating equal importance between two criteria, 2 indicating that one criterion is slightly more important than the other,..., and 9 indicating that one criterion is extremely more important than the other. The resulting best-to-others (BO) vector would be: $A_B = (a_{B1}, a_{B2}, \cdots, a_{Bn})$, where a_{Bj}indicates the preference of the best criterion B over criterion j.
4. Implement a similar approach for the *worst*. The resulting others-to-worst (OW) vector would be: $A_W = (a_{1W}, a_{2W}, \cdots, a_{nW})^T$, where a_{jW} indicates the preference of the criterion j over the worst criterion W.
5. Find the optimal weights $(w_1^*, w_2^*, \cdots, w_n^*)$. The aim is to determine the optimal weights of the criteria such that the maximum absolute difference $|w_B - a_{Bj}w_j|$ and $|w_j - a_{jW}w_W|$ for all j is minimized. This can be translated to the following model:

$$\begin{aligned} &\min \ \max_j \left\{ |w_B - a_{Bj}w_j|, |w_j - a_{jw}w_w| \right\} \\ &\text{subject to} \\ &\sum_j w_j = 1 \\ &w_j \geq 0, \text{ for all } j. \end{aligned} \tag{1}$$

Model (1) is equivalent to the following linear programming model:

$$\begin{aligned} &\min \xi^L \\ &\text{subject to} \\ &|\, w_B - a_{Bj} \times w_j \,| \leq \xi^L \\ &|\, w_j - a_{jw} \times w_w \,| \leq \xi L \\ &\sum_j w_j = 1 \\ &w_j \geq 0, \text{ for all } j. \end{aligned} \tag{2}$$

By solving model (2), the optimal weights $(w_1^*, w_2^*, ..., w_n^*)$ and the optimal value of ξ, called ξ^* are obtained. The ξ^* is an indicator of the consistency ratio of the comparison system. The consistency ratio means that the closer ξ^* is to zero, the more consistent the comparison system provided by the decision-maker is. With these weights and the normalized scores of the alternatives on the different criteria x_{ij}^{norm}; the final score per alternative, V_i; can be calculated using the following:

$$V_i = \sum_{j=1}^{n} w_j x_{ij}^{norm}, \tag{3}$$

where

$$x_{ij}^{norm} = \begin{cases} \dfrac{x_{ij}}{\max\{x_{ij}\}}, \text{ if } x \text{ is positive (such as quality)} \\ 1 - \dfrac{x_{ij}}{\max\{x_{ij}\}}, \text{ if } x \text{ is negative (such as price)} \end{cases}. \tag{4}$$

4 | ANALYSIS AND RESULTS

In this section, the various steps described in the BWM implementation framework are undertaken. First, the number of criteria (Tables 2A-2C) is reduced, then, the selection of the product packages and their alternative package designs takes place, then, the supply chain members are identified, and the criteria weights are calculated, and finally, relative scores are assigned to the package alternatives. After selecting the optimal package design, two what-if scenarios are evaluated in order to discuss the results.

4.1 | Reducing the number of criteria

In the initial list, there were 32 sustainable packaging criteria in total, 11 for the environmental performance (Table 2A), 12 for the economic (Table 2B), and nine for the social (Table 2C). In order to create a user-friendly BWM survey, increase the discrimination power of the criteria, and increase the response rate, the number of criteria in each dimension had to be reduced. By requesting the opinion of the experts in the field of packaging and the environment, the most important criteria in each dimension were selected for the application of the method.

The sample of experts was formed by people in academia and the food packaging industry. Firstly, members of the academic community of the Delft University of Technology were approached that were either teaching courses related to sustainability and the environment or had previously conducted research in the field of sustainable packaging. Secondly, structured interviews were conducted with packaging developers and strategic material-planning managers in the case company, Kraft Heinz Company. In both cases, the respondents were asked to fill in a survey by selecting the five most important packaging criteria in each of the three dimensions of sustainability. Furthermore, they had to rank these five most important criteria by assigning a grade from 1 to 5. A grade of 5 was used for the most important criterion of the selected five and a grade of 1 for the least important criterion. In the end, the summation of the respective criteria grades of all respondents was calculated for each of the three dimensions of sustainability. Regarding the respondents of the academia, five were completed. Regarding the experts from the Kraft Heinz Company, two 1-hour meetings were scheduled with the head of Packaging Europe and the Strategic Material Planner Manager. Since the final total number of respondents was seven, the selection rule that was

applied stated that if a criterion had a summation of grades equal or greater than seven, then, it would be included in the implementation of the BWM. By applying the aforementioned rule, the criteria were reduced to the list presented in Table 3.

As the ultimate job of the criteria, here, is to make a ranking among the alternative designs, we think that there should not be that much value in the discarded criteria. In other words, even if we consider some value for the discarded criteria, we expect little or no change in the final scores of the alternatives and almost certainly no change in the ranking. This is a common practice in MCDM field as, by reducing the criteria, we increase the discrimination power of the method.

4.2 | Selection of product packages and alternative package designs

During the structured interviews with the head of Packaging Europe and the Strategic Material Planner Manager of Kraft Heinz Company, a discussion was made regarding the products that would be selected. In the end, the three products that were chosen are the Heinz Tomato Ketchup, the Heinz Seriously Good Mayonnaise, and the Heinz Beans. These products and their corresponding alternative package designs are depicted in Figure 4.

The criteria according to which these products were selected are elaborated in this section. First of all, the products had to be produced in one of the factories in Europe because the responsible managers that would be interviewed had to be located in the Netherlands, either in the European Supply Chain Hub in Zeist, Utrecht area, or the European Innovation Centre 57 in Nijmegen. Another reason for selecting the products from the European factories was the fact that the members of their supply chain would most likely also be located in the same continent. Furthermore, a criterion was also set for the nature of the product-package combinations. Two of the three products, namely, the ketchup and the mayonnaise, were intentionally chosen to be of the same food type of sauces, sharing the same form and qualities, and thus, sharing the same alternative package designs and having the same packaging material suppliers in their chains. The third product, the beans, was selected for having little in common with the other two. A third criterion that was established and led to the selection of these three products was the number of distinct alternative package designs. The ketchup and the mayonnaise have six different packages, while the beans have three. Each package alternative is designed for a specific use and for serving specific needs. It has to be underlined that in these package alternatives, the different variations in the amount of the contained product are not taken into account. The last criterion that was taken into account was the selection of products that are globally known and are the "cash cows" of the Kraft Heinz Company. These products prevail in the competition in their respective markets; in this way, the real-world impact of the new approach would be relatively large, while a generalization of the findings for other similar products would be feasible.

4.3 | Calculation of criteria weights

In this section, the results for each dimension of sustainability are shown.

For the BWM, data has been collected from all six members of the supply chain (the raw material suppliers [seven suppliers], the packaging material suppliers [seven suppliers], the product-package manufacturer [Kraft Heinz Company: the main decision-maker], the retailers [two retailers], the consumers [35 consumers], and the end-of-life companies [two companies] (to see an example of the BWM questionnaire, one might visit www.bestworstmethod.com). The weights for all members of each level of the supply chain was calculated, and the mean value presented. For our data collection, depending on their accessibility, both online surveys (for the raw material suppliers, the packaging material suppliers, and the retailers) and structured interviews (for the other supply chain members) have been used, in which the same list of questions has been presented to our respondents. As the respondents should provide pairwise comparisons using a structured approach (BWM), the two data collection methods are the same in terms of reliability.

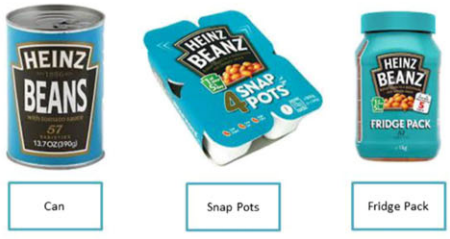
To begin with the environmental dimension, the respective criteria weights are shown in Figure 5. In the end, the most dominant criterion in this dimension was proved to be ecoefficient production with a weight of 23%. Ecoefficiency strategies seek to reduce

TABLE 3 Reduced criteria list

Selected sustainable packaging criteria		
Environmental performance	**Economic performance**	**Social performance**
1. Transported in an environmentally friendly way	1. Performance meets market needs	1. Beneficial for individuals and the community
2. Manufactured in an environmentally friendly way	2. Sourcing, manufacturing, distribution, and recycling costs	2. Healthy and safe for individuals and the community
3. Recycled, reused, and disposed in an environmentally friendly way	3. Physically designed to optimize materials and energy	3. Manages reputational risk
4. Uses recycled, renewable, reused sourced materials	4. Continuity	4. In accordance with governmental policies and regulations
5. Recovered and utilized in industrial closed loop cycles	5. Cooperation with supply chain members	5. Employee's quality of life
6. Avoids packaging and raw material waste	6. Profitability	6. Suppliers and carriers are certified
	7. Package functionality	

(A) Heinz Ketchup alternative package designs

(B) Heinz Mayonnaise alternative package designs



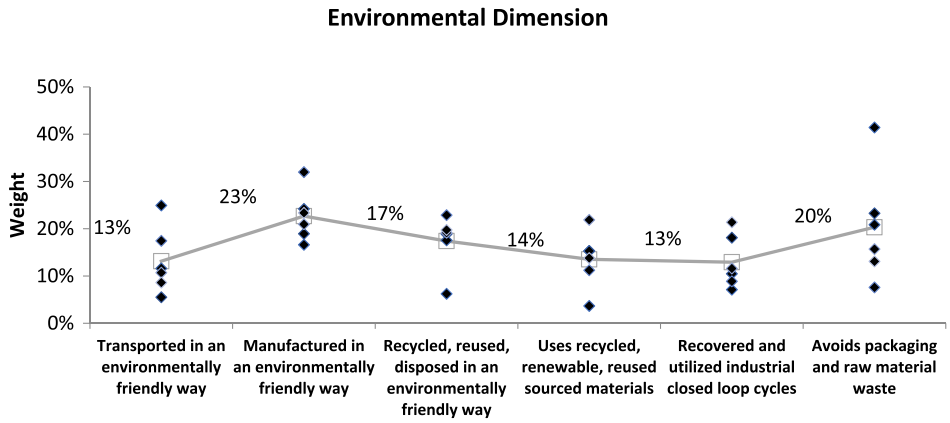
(C) Heinz Beans alternative package designs

FIGURE 4 A, Heinz ketchup alternative package designs B, Heinz mayonnaise alternative package designs C, Heinz beans alternative package designs

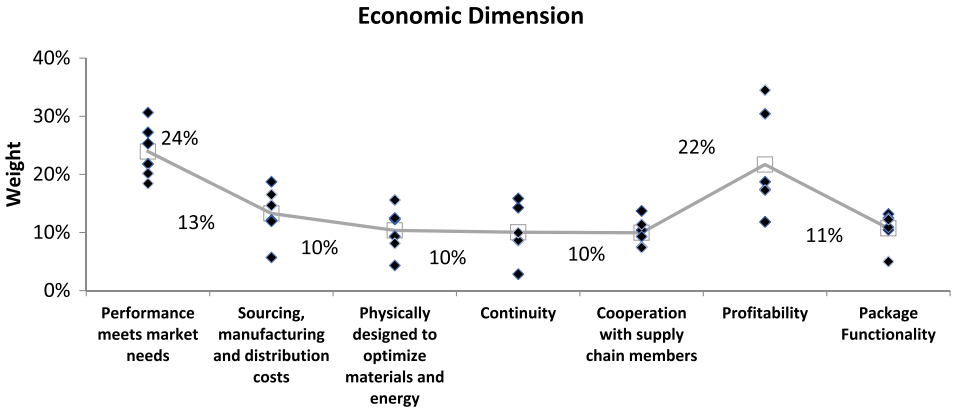
emissions, energy use, and waste during the manufacturing of the product package. The second most important criterion was the elimination of raw and packaging material waste with a weight of 20%. It refers to the conservation of packaging and raw materials during the complete life cycle. A criterion that should not be neglected by the decision-maker is regarding the final stage of the product life cycle and more specifically of how the product package is recycled, reused, or disposed, since it acquired a final weight of 17%.

Moving on to the economic dimension of Figure 5B, the criterion that acquired the highest grade was "performance meets market needs." Having a weight of 24%, it is clear that all members in the supply chain highly value the degree to which the end consumers are satisfied. With the second criterion being "profitability," it is evident that the supply chain members believe that having a sustainable business means maintaining a high-profitability ratio and not focusing solely on short-term profits. The rest of the criteria in this dimension are fluctuating at around 10%.

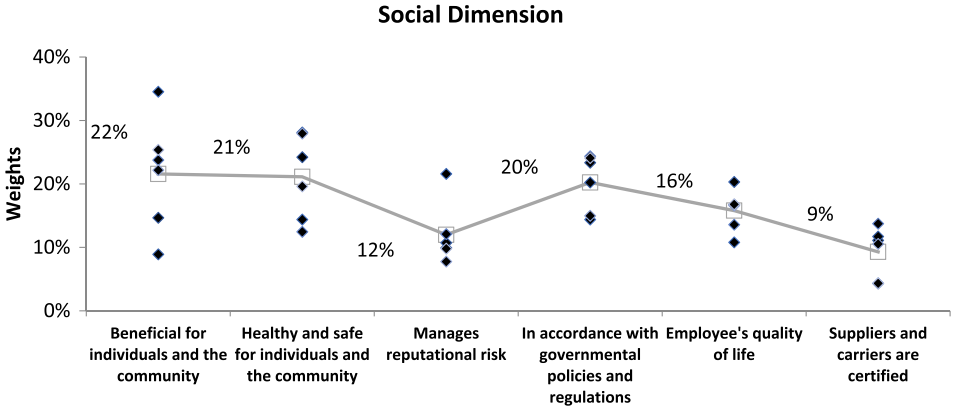
Ending with the social dimension of sustainability in Figure 5C, the two criteria that prevailed with 22% and 21% were those related to the consumer's well-being and safety. The first refers to the



(A) Total environmental dimension criteria weights



(B) Total economic dimension criteria weights



(C) Total social dimension criteria weights

FIGURE 5 A, Total environmental dimension criteria weights B, Total economic dimension criteria weights C, Total social dimension criteria weights

benefits of packaging to individuals and communities that can vary from the creation of meaningful, stable employment, to the protection, preservation, safety, and transport of food products. The second criterion not only ensures that no harmful substances are released to the environment during its production phase but also that no toxic substances are present through its use and end-of-life phases.[19] Only 1% behind is the criterion regarding regulatory and compliance-related risks that are caused by changes in laws and regulations. Another criterion that is highly valued by the supply chain members with a weight of 16% is regarding the respect of the working rights and conditions of all the employees involved in the various stages along the complete life cycle of the product.

4.4 | Scores of alternative package designs

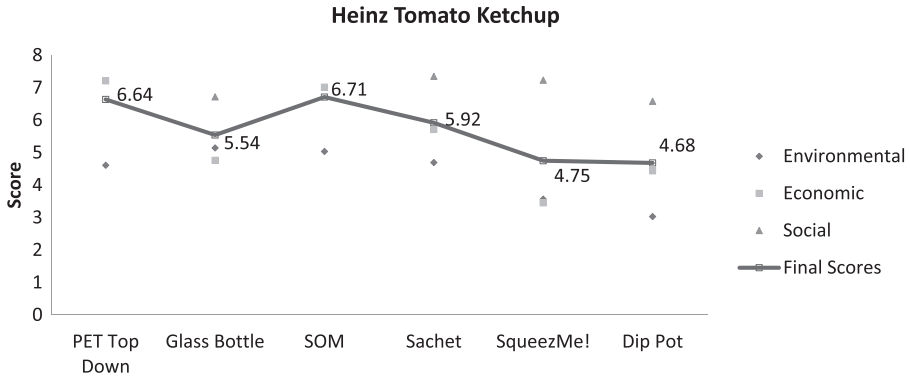
In the previous section, the final sustainable criteria weights were estimated for the environmental, economic, and social performances. In this section, the various alternative package designs are ranked according to the identified sustainable criteria. The person that was chosen to

evaluate the packages was the head of Packaging Europe. Through a 1-hour structured interview that took place in the European Innovation Centre 57 of the Kraft Heinz Company in Nijmegen, he was asked to fill in the matrix with the relative scores of the package designs.

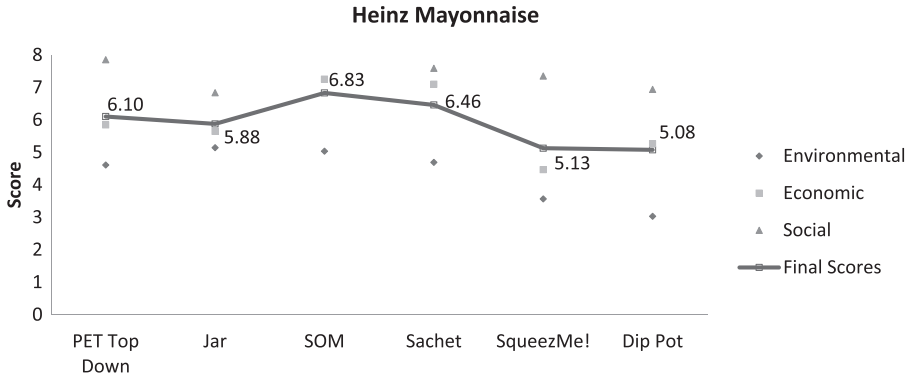
The scaling that was used for the relative scores of the packages and the criteria was from 1 to 9. However, the use of the scale is different from the one that was used in the BWM survey. The highest score of 9 represents the maximum performance that a package design can have in regard to the respective criterion. Similarly, a score of 1 indicates the worst possible performance. The decision-maker evaluated the performance of each package alternative of each one of the three products. Since the decision-maker holds one of the top positions in the hierarchy of the packaging technology department of the Kraft Heinz Company in Europe, he can be regarded as adequate for the implementation of BWM in order to select the optimal package design.

4.5 | Selection of optimal package designs

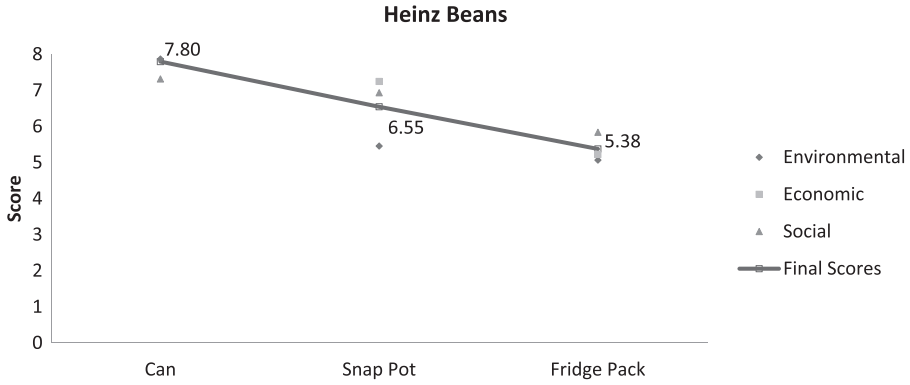
After having collected both the final weights of the sustainable packaging criteria and the relative scores of the package alternatives, the calculation of the final scores that are used for the comparisons is feasible. These final scores are calculated for each package alternative and for each of the three dimensions of sustainability by simply



(A) Final scores for the alternative package designs of Heinz Tomato Ketchup



(B) Final scores for the alternative package designs of Heinz Mayonnaise



(C) Final scores for the alternative package designs of Heinz Beans

FIGURE 6 A, Final scores for the alternative package designs of the Heinz Tomato Ketchup B, Final scores for the alternative package designs of the Heinz Mayonnaise C, Final scores for the alternative package designs of the Heinz Beans.

multiplying the scores with the respective criteria weights. In Figure 6A-C, these results are depicted for each of the three products separately. In each figure, the respective scores of each dimension of sustainability are depicted with a marker of different shape. Along the line, the perceived total sustainability scores are shown for each package alternative as the average of the relative scores in each dimension.

In Figure 6A, the perceived total sustainability scores for the most valued brand of the Kraft Heinz Company, the Heinz Tomato Ketchup, are presented. The package design with the highest total score is the Sauce–O–Mat (SOM), which achieved a score of 6.71. The SOM is a high-quality branded sauce dispensing solution for front-of-house use, and its main advantages are the easiness in cleaning, its durability and its great visual impact that acts as a marketing tool in restaurants.[61] The high-perceived total sustainability score lies in its unique qualities regarding avoiding raw and packaging material waste and package functionality, because of its refilling capability with the use of 2.5 or 5-kg plastic bags of ketchup. Furthermore, another quality of the SOM is its conformity to the environmental regulations. Closely behind the SOM is the package with the largest sales volume, the PET Top Down bottle with a score of 6.64. The advantages of the PET bottle lie in the high-profitability score, the ecoefficient transportation process, and the low-operational costs that it entails. It lags behind the SOM for the low score that was assigned to it regarding the most important economic criterion, that of performance meeting the needs of the market.

The second product under study is the Heinz Seriously Good Mayonnaise and the respective perceived total sustainability scores are presented in Figure 6B. The reason that this product was selected for the implementation of BWM was that it also belongs in the same food category as the Ketchup and the fact that they share the same alternative package designs. The package design with the highest score was, in this case, also the SOM with a score of 6.83. This result can be used as a premise in proving that for two products of the same food type, the optimal package design does not differ. However, the second highest score was achieved by the Sachet and not the PET bottle for the case of the Mayonnaise. The sachet shares similar benefits as the SOM, but scores lower because of its inability to contain large quantities and optimize materials and energy. However, the Sachet scores higher than the PET bottle in the case of the Mayonnaise since due to the nature of the product, the scores changed relative to the Ketchup regarding its market performance, package functionality, and the management of the reputational risk.

In Figure 6C, the perceived total sustainability scores for the alternative package designs of the Heinz Beans are presented. The superiority of the Can over the Snap Pot and the Fridge Pack is underlined in the linear trend that is present in the graph. The reason behind its superiority regarding the environmental performance lies in the environmentally friendly way that the tin can is manufactured and recycled, in the use of recycled sourced materials and its recovery in industrial closed loop cycles. Regarding the economic and social performance, the tin can has significant benefits in terms of low sourcing, manufacturing and distribution costs, in terms of maintaining a sustainable profitable business, and in being beneficial and healthy for individuals and the community.

4.6 | Sensitivity analysis: Effects of dimension weights on selection process

In the previous section, the optimal package designs were selected for each of the three product packages that were studied. Equal importance is given to the three dimensions of sustainability. Thus, the perceived total sustainability score was calculated from the average of the three sustainability scores as it is depicted in Figure 6A-C. In this section, it is investigated whether a change in the weight of each dimension affects the selection process of the optimal package design. The effect of the varying weights of the three dimensions on the selection process are presented with the creation of a what-if scenario. A pyramid chart is used in order to highlight which two package alternatives compete for being optimal for each product. A sensitivity analysis is then performed that shows the limits that the weights could reach without having a change in the selection process.

For the case of the Heinz Tomato Ketchup, the pyramid chart can be seen in Figure 7. Even though the SOM had the highest perceived total sustainability score, it is the Glass Bottle that prevails regarding the environmental performance. Having an easily recycled packaging material boosts the relative criteria scores in comparison to the plastic ones. However, because of its poor performance relative to the rest of the criteria, the weight of environmental performance has to be at 96% so as the Glass bottle to be chosen over the SOM. Regarding the economic and social performance of sustainability, the Ketchup package alternative that prevails is the PET Bottle, Because of its operational effectiveness. However, in order for the PET Bottle to be chosen as the optimal package design, the weight of environmental performance would have to be lower than 20%, while maintaining equal weights in the economic and social dimensions at over 40%. It can be observed from Figure 7 that the prevailing package alternatives are the SOM and the PET Bottle.

In order to investigate even further the effect that varying the weight of the dimensions has in the selection between the SOM and PET Bottle for the Ketchup, sensitivity analysis was conducted. The dimensions were analysed in pairs, while keeping each time the third

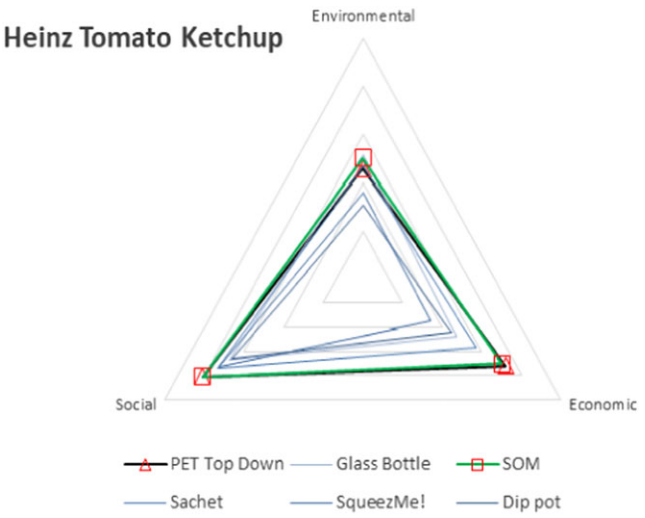
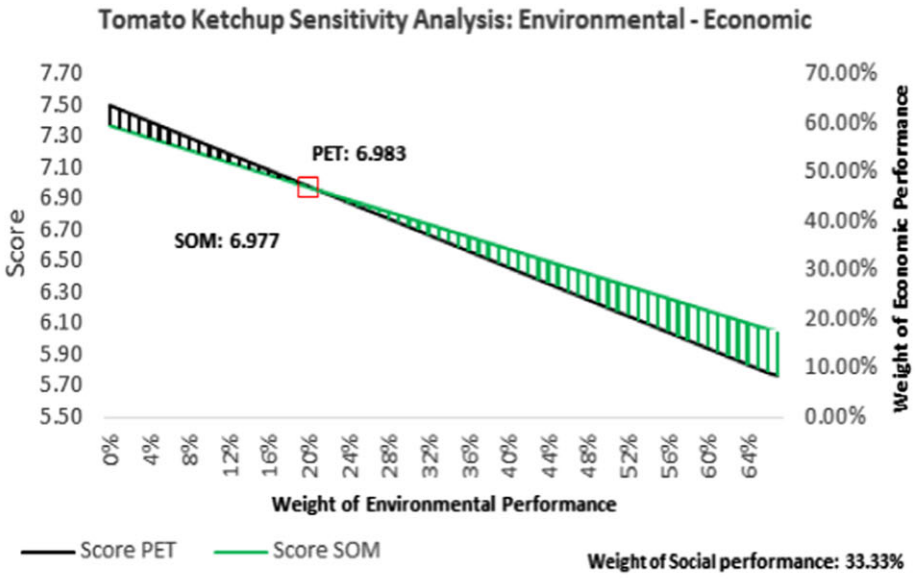
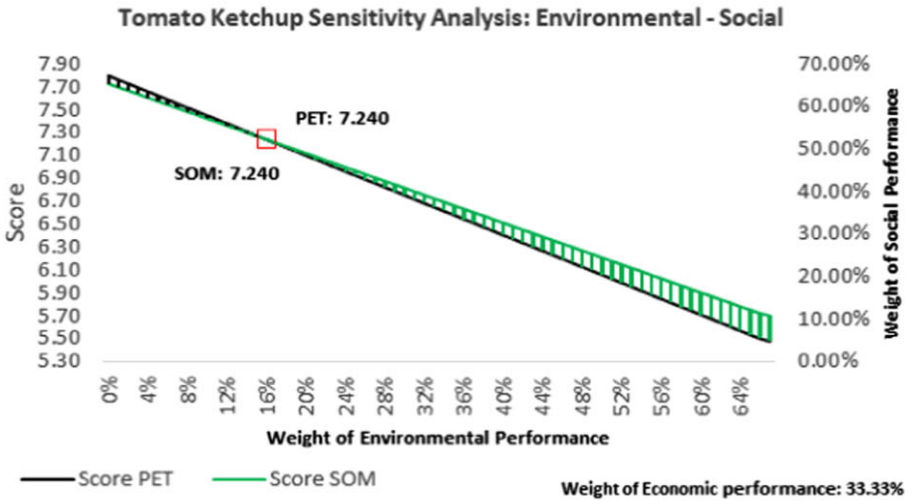


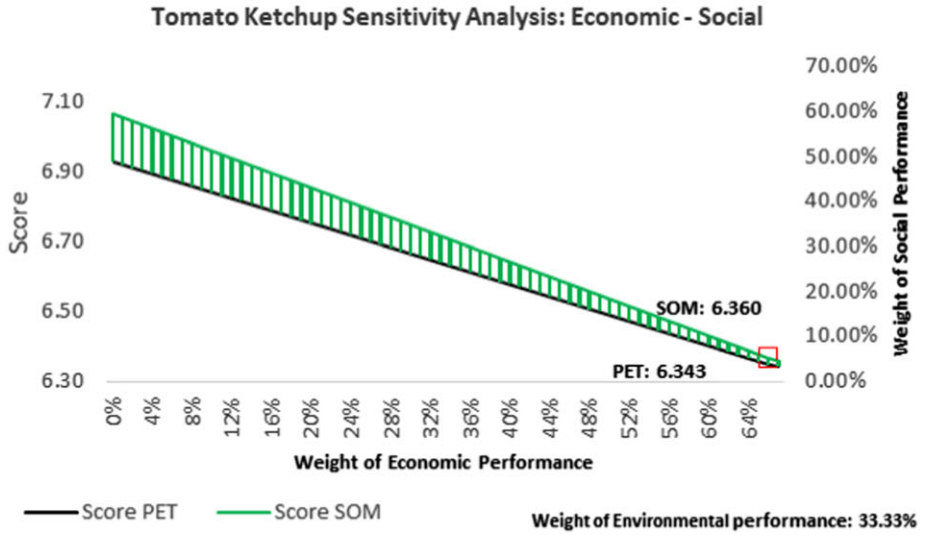
FIGURE 7 Pyramid chart for the prevailing alternatives of ketchup



(A) Sensitivity analysis for ketchup between environmental and economic performance



(B) Sensitivity analysis for ketchup between environmental and social performance

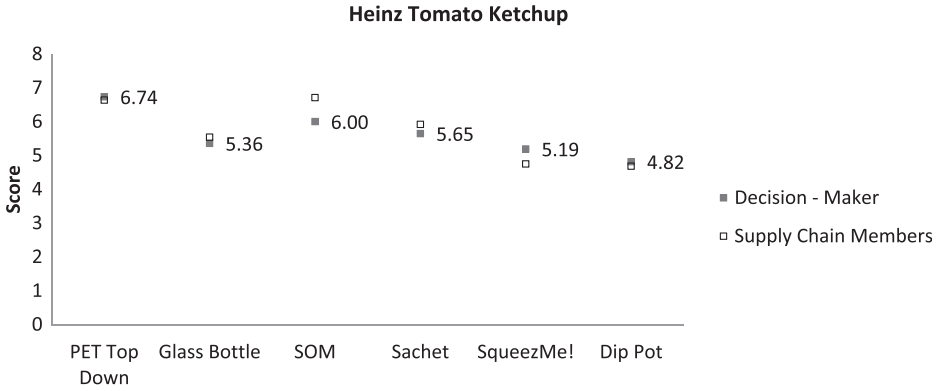


(C) Sensitivity analysis for ketchup between economic and social performance

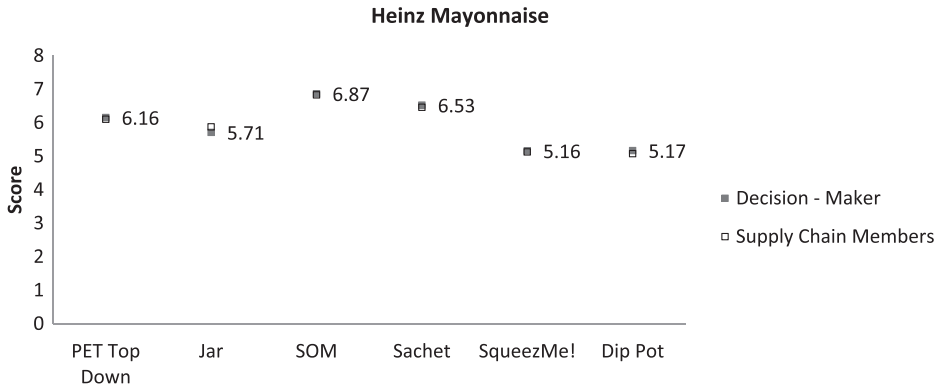
FIGURE 8 A, Sensitivity analysis for ketchup between environmental and economic performance B, Sensitivity analysis for ketchup between environmental and social performance C, Sensitivity analysis for ketchup between economic and social performance

dimension stable at 33.33%. The results of the sensitivity analysis are presented in Figure 8A-C. From Figure 8A, it can be observed that while the weight of environmental performance is between 0% and 20%, then, the PET Bottle prevails over the SOM. It is supposed that in this case economic performance, weight varies from 0% to 66.67%, while social performance weight is stable at 33.33%. Next, in Figure 8B, by keeping at constant levels the weight of economic performance, environmental performance weight would have to be lower than 16% in order for the PET Bottle to be selected. In this second case, social performance weight varies from 0% to 66.67%. Lastly, in Figure 8C, by investigating the relationship between the weights of economic and the social dimensions, it can be observed that no matter how much the weight of economic performance is reduced, the PET Bottle never scores higher than the SOM. In this last case, social dimension weight varies from 0% to 66.67%, while the environmental weight remains stable.

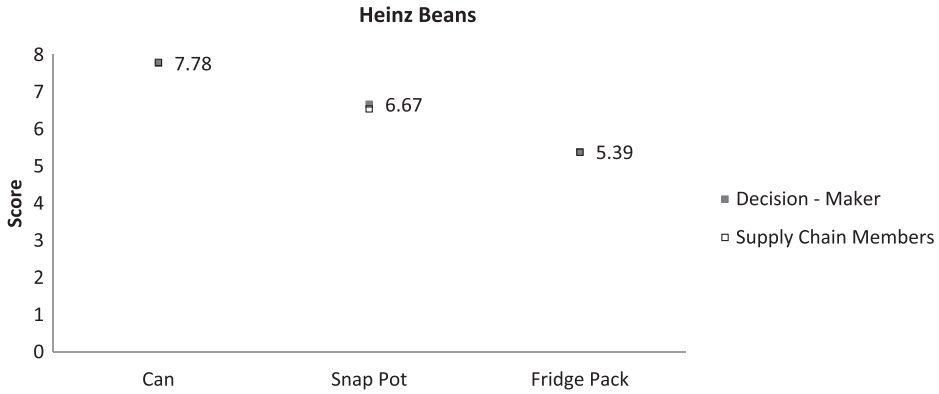
Regarding the package designs of the Heinz Seriously Good Mayonnaise, the one that achieved the highest perceived total sustainability score was the SOM. However, also in this case regarding the environmental sustainability, the package material that is made out of glass was the one that prevailed. Even though the Jar of Mayonnaise achieved the same score as the Glass Bottle of Ketchup in the environmental performance, the weight of the other two dimensions for the Mayonnaise had to be less than 0.5% in order to prevail. In



(A) Scenario scores for the alternative package designs of Heinz Tomato Ketchup



(B) Scenario scores for the alternative package designs of Heinz Mayonnaise



(C) Scenario scores for the alternative package designs of Heinz Beans

FIGURE 9 A, Scenario scores for the alternative package designs of the Heinz Tomato Ketchup B, Scenario scores for the alternative package designs of the Heinz Mayonnaise C, Scenario scores for the alternative package designs of the Heinz Beans

other words, in order for the Jar to be chosen as the optimal package design, the weight of environmental performance had to be over 99%. In contrast with the Ketchup, no matter how low the weight of environmental performance would fall or how high the other two weights would be modified at, the SOM of Mayonnaise would be the optimal package design since it is superior to any other alternative the last two dimensions.

Lastly, regarding the Heinz Beans, from Figure 8C, it is evident that the Can always prevails no matter what the relative weights of the dimensions are. Thus, sensitivity analysis was not conducted.

Although this study neglects the different needs that the consumer has for each type of package alternative, the optimal package designs that are selected in this paper could be modified regarding the volume of the contained product and the different kinds of consumers' needs that they serve.

4.7 | Sensitivity analysis: Effects of preference weights on selection process

In Section 4.5, the optimal package designs were selected by assigning equal weights to the preferences of the six supply chain members. This way, all six members reap the benefits of the introduction of the selected package design. In practice, however, this would not be the case always since the manufacturing firm that actually selects the design strives to satisfy its own needs first. Thus, since the created tool is targeted for the decision-maker, the Product-package Manufacturer, in order to assist them with selecting a package design, their preferences should have the highest weight. For this reason, a what-if scenario was created that assigns a 50% weight to the preferences of the Product-package Manufacturer and another 50% to the preferences of the remaining five members of the supply chain.

In Figure 9A-C, the final scores for the package alternatives for the scenario, which are depicted with the black frame, are compared with the final scores of Section 4.6, which are depicted with a solid rectangle. The labels correspond to the final scores of the scenario. As it can be observed from Figure 9A, the optimal package design for the Heinz Tomato Ketchup is now the PET Bottle, which scored 6.74 and overpassed the SOM. The reason behind the change of the optimal solution lays in the superiority of the PET Bottle over the SOM in the economic dimension of sustainability. In turn, this superiority is due to the high-relative score of the PET Bottle over the SOM regarding the low sourcing, manufacturing, and distribution costs. In the scenario where the weight of decision-maker was 50%, the weight of this criterion increased from 13% to 15%. The 2% difference in the weight is responsible for the change in the optimal solution, since the PET Bottle had a relative score of 8 while the SOM only had a score of 6 relative to the operational costs.

It is remarkable that the optimal package designs for the Mayonnaise (Figure 9B) and the Beans (Figures 9C) did not change. However, in the conclusion of Section 4.6, it was implied that the difference of the nature of the product had no effect in the selection of the package designs and that only the scores of the alternative package designs mattered. As a result, it is expected that the PET Bottle would also prevail in the case of the Mayonnaise for the what-if scenario. Nevertheless, this was not the case since the superiority of the SOM was maintained due to the fact that the PET Bottle for the Mayonnaise in comparison with that of Ketchup scores 1 point less regarding profitability and 4 points less regarding functionality. On the contrary, the relative scores for the SOM do not change between the Mayonnaise and the Ketchup. For the case of the Beans, the changes in the criteria weights were not sufficient so as to provoke a change in the package design.

5 | CONCLUSION, MANAGERIAL IMPLICATIONS, AND FUTURE RESEARCH

In this study, a comprehensive literature review was conducted to find the relevant sustainable criteria for food package design. A novel MCDM method, BWM, was used to find the importance of a shortened list of criteria considering all the supply chain members of a food company. The optimal package designs were selected according to the identified criteria and to the respective weights that the supply chain members assigned to them according to their preferences. What-if scenarios were created that measure the effect that variable weights have on selecting the optimal package design.

5.1 | Contribution

The first point that differentiates this paper with other sustainable research projects conducted in the food-packaging industry is the incorporation of three unique perspectives in the selection process. Firstly, not only is the social dimension incorporated in the product design but it is also assigned an equal weight to the environmental and economic dimensions. In this, it needs to be acknowledged that sustainability remains a contentious concept that may be substantiated in different ways, leaving room for some degree of subjectivity—not only regarding meaning but also scope and ambition. Having said that, our framework covers the elements that are key to sustainability and allows for an uptake that is practical from a managerial perspective, and as such can figure as a productive vehicle towards increased levels of sustainability. Another point that differentiates this study is the adoption of a supply chain perspective in product design. The preferences of all members in the supply chain of products in the food-packaging industry along the total life cycle are incorporated in product design. Referring to the product-package perspective, in this paper, the package and the contained product are not regarded separately but rather as one entity, as a product-package combination sharing mutual qualities. Although, considering all the members in designing sustainable packaging might not be new, incorporating these three perspectives together in the selection process of the optimal package design in the food-packaging industry is a novel idea.

The inclusion of the three perspectives in the analysis made feasible the introduction of a second point in the contribution of the paper. This is the creation of a supply chain level sustainable criteria list. The full list contains 32 criteria, while through expert opinions, the number of criteria along the TBL was reduced, and a more practical version was created with 19 criteria.

The final contributing point is regarding the creation of a decision-making tool that can be used by package manufacturers when

evaluating the sustainability of alternative package designs in the food-packaging industry.

5.2 | Managerial recommendations

In this study, a decision-making tool is created that can be used by package manufacturers when evaluating the sustainability of alternative package designs in the food-packaging industry. This tool can be used by R&D managers who are responsible for evaluating alternative food package designs.

Modifying the weights that the decision-maker assigns to the three dimensions of sustainability and the preferences of the six supply chain members, the selection process of the optimal package design is altered. As a result, apart from assigning the relative scores of the packages towards the criteria, the decision-maker should also strategically select the weights that will be assigned. The product-package manufacturer first attempts to incorporate their own interests in the design in order to keep up to the expectations of the stakeholders and then tries to satisfy to the maximum degree possible the preferences of the rest of the supply chain members.

The decision-making tool that was developed in this study is presented to the head of Packaging Europe of the Kraft Heinz Company, with the aim of using it when evaluating alternative food package designs. The managers of the company are very happy with the results and recommendations. This company is the actual decision-maker with knowledge and experience in designing the package. The company is concerned about the sustainability of different designs, which is why they are willing to incorporate the opinion of all the other actors in measuring the sustainability level of each alternative. But, this function (designing the packaging) is out of the authority, knowledge, and experience of the other actors.

5.3 | Future research directions

Future research could use the proposed framework of the sustainable package design criteria in other food companies. In this study, we used the three dimensions of sustainability, namely, economic, environmental, and social. Future research could use this approach and compare the traditional approach of considering merely the economic criteria. Furthermore, we think this study can be considered as an example of considering the whole supply chain in an important decision-making problem. Most supply chain studies focus on bilateral relationships, which cannot capture the view of the other partners that have an impact on the decisions made by each and every member of a supply chain. Also, from a technical perspective, the sensitivity study proved to be a valuable contribution and is worthy of further elaboration from both a case study perspective and from a methodological BWM perspective. Finally, it would be interesting to consider the role of power structure in making such decisions. In that regard, it would be interesting to see how a partner with an important power source could influence the final decision made.

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