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Development of a Holistic Assessment Framework for Industrial Organizations

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Abstract: The evaluation and selection among the best production practices beyond the conventional linear models is, nowadays, concerned with those holistic approaches drawn toward environmental assessment in industry. Therefore, researchers need to develop an analysis that can evaluate the performance of industrial organization in the light of their environmental viewpoint. This study implemented a pilot co-integrated scheme based on an innovative in-house Holistic Assessment Performance Index for Environment (HAPI-E) industry tool while assimilating the principles of circular economy through the Eco-innovation Development and Implementation Tool (EDIT). For the latter, nine qualitative indicators were motivated and enriched the weighting criteria of the questionnaire. The decomposition of the complexity and preferences mapping was accompanied by a multi-criteria holistic hierarchical analysis methodology in order to synthesize a single index upon a need-driven scoring. This multi-criteria decision approach in industry can quantify the material and process flows, thus enhancing the existing knowledge of manipulating internal resources. The key-criteria were based on administrative, energy, water, emissions, and waste strategies. Subsequently, the HAPI-E industry tool was modeled on the food industry, being particularly focused on pasta-based industrial production. Then, the parameters of this tool were modeled, measured, and evaluated in terms of the environmental impact awareness. The magnitude of necessary improvements was unveiled, while future research orientations were discussed. The HAPI-E industry tool can be utilized as a precautionary methodology on sustainable assessment while incorporating multifaceted and quantification advantages.

Keywords: holistic assessment framework; proactiveness; environmental indicators; sustainable development; sustainable production schemes; circular economy

1. Introduction

Today, environmental awareness is considered a multifaceted issue that attracted the scientific interest worldwide. Such an integrated framework upon environmental consciousness of products' risk has been developed from Khan et al. [1]. In this framework the participative roles of product designers, manufacturing engineers, environmental analysts, and risk experts were examined in designing and developing environmental awareness in association with varied product design choices [1]. In another holistic framework, the environmental perspective of designing was associated with the architectural accessibility, the interior design, and the interactive technologies [2]. Under this framework, citizen housing was promoted as healthy and enjoyable ways to be utilized by clients.

Earlier research studies examined the pronounced role of sustainability as the key-notion of a prosperous social, economic and environmental development. Specifically, sustainability can be taken into consideration toward future longevity, energy consumption, and environmental protection upon the contexts of the built environment [3], marine environment [4], and regulatory legislation system [5]. The interrelationship between the entities of environment and sustainability was developed in the literature under the three interlinked framework of environmental indicators (EI) at the industrial and manufacturing contexts, sustainable production (SP) schemes, and sustainable development (SD) of environmental indicators.

In the viewpoint of environmental indicators (EI) at the sectors of industry and manufacturing, Villard et al. [6] standardized an environmental analysis of microelectronic products upon the main indicators of resource depletion, eutrophication, water stress, and local electrical consumption, along with the features of time-sensitivity and the processes-driven microelectronic industry and its products [6]. Another critical issue of perception environmental indicators is the decision-making problem at the industrial and manufacturing contexts, especially at cases of incomplete or vague information [7]. Such human decision-making processes in uncertain situations are also attributed to an individual perception about pollution. Supplier selection for an environmentally friendly product is an important issue, since environmental impact can be an important criterion for supplier selection. Particularly, Sinha and Anand [7] introduced the following five-steps environmental analysis of (1) supply, (2) logistic, (3) process analysis, (4) use, and (5) recycle. Under the methodology applied, supplier's environmental metrics upon energy, water, emissions, and hazardous wastes were gathered and applied under a fuzzy preference modeling. The environmental impact for products was valuated under the following distinct types of global warming, ozone depletion, photochemical ozone creation, acidification, nutrient enrichment, and volatile organic compounds [7]. At this study a multi-preference fuzzy relationship model was developed and the environmental performance of the best supplier was based on fuzzy preference approach, to handle the supplier selection problem [7].

In the viewpoint of sustainable production (SP) schemes, Ercan and Tatari [8] stressed out that environmentally friendly features of transportation are that of electricity and hybrid modes of fuelling. Particularly, Ercan and Tatari [8] stressed that weighted criteria of evaluation environmentally friendly and cost-effective transportation fuels can be considered by transportation policy-makers in conjunction with multi-criteria tools of decision making and the cost-driven indicators of electricity mix and fuel economy [9].

In the viewpoint of product users' perception in favour of environment product sustainability is challenging aspect since it enables product designers, manufacturers, and environmentalists to follow a new product development (NPD) pattern.]. By identifying attributes on the selection of proper suppliers among a pool of suppliers, researchers can develop an index of sustainable suppliers available, enabling the to evaluate the sustainability features among the most suitable suppliers selected [9].

In the viewpoint of sustainable development (SD) of environmental indicators, Mariouryad et al. [10] investigated the multifaceted adoption of health, safety, and environmental indicators and noted positive but slow changes regarding health, safety, and environmental indicators in the Iranian pharmaceutical industry. Therefore, these indicators have to be evaluated at regular time-intervals [10]. Besides, Dobes et al. [11] framed the management of production systems in alignment with sustainable production schemes upon resource efficiency, as follows: (i) administrative measures, (ii) eco-design of products and services, (iii) introduction of resource efficient processes and appliances, (iv) application of new and innovative business models [11].

This study presents a systematic literature review on the evolution of the main environmental assessment tools for industry. The theoretical background upon the available environmental assessment tools for industry has been deployed at Section 2. The development of the in-house HAPI-E industry tool proposed by authors is analyzed in Section 3. In Section 4, a case study in the pasta production industry is described. The underlying environmental performance took into account the management decisions on the efficiency of resources and the outputs such as energy, water, emissions, and waste strategy;

all were measured and compared with the proposed improvements in alignment with environmental impact minimization. In Section 5, the research results are discussed, along with the magnitude of the improvements, and further research orientation are deployed. Section 6 summarized the main conclusions, stressing that the HAPI-E industry tool can be a feasible methodology for resource efficiency potential assessment and has the potential to incorporate multi-level and quantification advantages.

The novelty of this study resides on the fact of a need-driven multi-criteria decision analysis evaluation in industry, under which the Analytical Hierarchy Process (AHP) aims to assign a weight to all contributing parameters while following logical and well-structured decision processes in order to avoid possible confusion. The main objective of this study was to identify measurable aspects of the AHP as well as vulnerability aspects of the EDIT [12]. This will enable policy makers to take appropriate measures to reduce alarming problems and to prevent environmental depletion and sustainability degradation in the examined industrial plant. Therefore, the proposed joint methodological approach of AHP and EDIT [12] is a novel approach that has not previously been developed in the relevant literature, as far as we (the authors) know. The joint implementation of AHP and EDIT [12] makes possible its use at the multi-business level, the quantification of data, and the external support and capacity building, which are proven developmental factors [11].

2. Literature Overview on Environmental Assessment Tools for Industry

2.1. Analytical Hierarchy Process (AHP)

In the literature, the pronounced contribution of Analytical Hierarchy Process (AHP) in the industrial sector has been demonstrated. AHP is especially effective in applying multiple decision criteria to technologically driven decision-making problems. Under this research orientation, Siew et al. [13] denoted that moulding is a critical process in the manufacturing of semiconductors, which protect silicon chip and wire interconnects. These authors determined priority weights of the most essential decision criteria for preferred machine-tool selection in the moulding process in the semiconductor industry in Malaysia by ranking all the identified decision criteria using AHP. The authors concluded that cost is the most essential decision criteria in machine-tool selection, followed by productivity, safety, user friendliness, maintainability and serviceability, and installation easiness and compatibility.

Another research context of AHP was examined by Motamedi et al. [14], who stressed that diversified industrial applications of nanotechnology including electronics, pharmaceuticals, and biomaterials. Contrarily, the upstream oil industry showed low adoption of emerging technologies due to high investments involved at the relevant industrial sector. At the case of nanotechnology benefiting at the upstream oil industry, the relevant importance of a spectrum of decision-making criteria was judged by a pool of experts. All information was gathered and compiled in prioritizing investment alternatives with respect to sort out all criteria in a raw numbering format, while the application of a dynamic AHP can route to customized investment policies [14].

Among the most prevalent applications of the AHP is the risk assessment of industrial parks (Liang and He [15]) as well as at the plant location of manufacturing industries [16]. Particularly, Liang and He [15] examined the risk control of chemical industrial parks as one of the most important managerial goals of chemical enterprises. Since chemical industry parks are very complex systems, the risk control involves many complexities, and it is necessary to consider the relative importance of each index. Among the feasible methods to practically evaluate the risk control in chemical industrial parks is AHP, being a classical multiple attribute decision-making method that has been structured on the key construction of a judgment matrix to determine the success or failure of the procedural analysis. In a similar industrial context, Gothwal and Saha [16] introduced an AHP that can simplify complex decision problems into simpler hierarchies, having flexibly incorporated financial and non-financial factors that determine the decision alternatives in a systematic way upon consensus. These authors structured an AHP modeling to examine a real case study under which industrial manufacturing plant to be valued and selected.

At another noteworthy study Rahman and Ali [17] evaluated the intangible factors of innovative ideas, new service attributes, learning principles, and self-service technologies to improve services' and resources' allocation. Under this framework, Rahman and Ali [17] adopted an AHP to establish a multi-criteria decision-making approach where local and global hierarchical priorities were assigned upon relative weights among available categories of service quality. Therefore, the improvement of service quality can be resulted from empirical illustration, managerial reorganization, and resources' allocation [17].

In a similar study, Talib and Rahman [18] investigated and categorized the determining aspects of a Total Quality Management (TQM) program, such as barriers and relative importance at the service industry. The targeted barriers were divided into categories and ranked as a multi-criteria decision-making process. Under the framework of priority weights, these authors stressed out the determining roles of the aspects "managerial issues", "people-oriented issues", and "organizational issues".

In the relevant literature, Krajnc and Glavic [19] proposed AHP along with a case study application of sustainability assessment. The composite sustainability index enabled comparison of companies in specific sectors of sustainability performance—specifically, economic-driven indicators about the well-being of all company's stakeholders and the traditional measures upon financial accounting. Besides, environmental-driven indicators of companies impacted living and nonliving ecosystems. Moreover, societal-driven of indicators are related to companies attitude on employees', suppliers', and customers' treatment. Overall, the aforementioned model can reduce these indicators by aggregating them into a composite sustainable development index, being proven effective for the assessment of one company or more companies together [19]. Shukla et al. [20] denoted that AHP can support solving of complex decision problems, such those aroused at the industrial sector. Specifically, there is a wide spectrum of manufacturing aspects, such as those related to eco-, process-, and product-design, while further consideration has to be given environmental hazards and excessive costs of manufacturing [20]. In a similar study, Jayamani et al. [21] developed a multi-criteria decision-making AHP approach which was jointly executed by MATLAB software in comparing two engine hood designs and achieving fuel efficiency upon weight reduction of vehicular components [21].

AHP has been extensively and jointly used with extreme learning machine (AHP-ELM) to obtain effective process characteristics [22]. Moreover, San Martin et al. [23] utilized AHP combined with Geographic Information System (GIS) as a supporting decision making supporting tool to evaluate the main parameters involved in the valorisation of food waste management strategies [23]. The AHP has also been utilized with fuzzy integrated scale to evaluate the risk in supply chain safety [24–26] and with interval fuzzy Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) towards: safety supervision of sport foods while ranking different alternatives of suppliers [27], solving supplier selection problem through multi-choice goal programming for supplier selection [9], and evaluating critical green maintenance aspects at the design stage, such as that of sustainability risk at a mechanical system [28].

In the research orientation upon joint-evaluated techniques, an extended Holistic Assessment Performance Index for Environment analysis was developed within the industrial context (HAPI-E industry tool), which was based on the AHP and methodologically incorporated the EDIT [12]. The former, as an in-house developed tool, has been modified under the latter's environmental qualitative concept to adapt to industrial need–driven benchmarking.

2.2. Life Cycle Assessment (LCA) and Global Reporting Initiative (GRI)

Environmental indicators to the industrial context are the different concepts of Life Cycle Assessment (LCA), which have been developed all over the world, e.g., the Society of Environmental Toxicology and Chemistry—Environmental Protection Agency (SETAC-EPA) LCA and Economic Input Output (EIO) LCA models [29]. Under this framework, environmental indicators were investigated in the green procurement activities at the sectors of industry and tourism [30]. Such indicators at plastic industry include monitoring of the amount of residues retained on the sieves, water consumption, and electricity consumption [31]. In the industrial context, De los Rios and Charnley [32] argued that the use of LCA tools is the key methodology of assessment the life costs of a product and then to achieve its ecological optimization while managing material choices. Such designing features are suiting to ease of disassembly, material separation, and reassembly for circular products [32]. In parallel, design strategies for climate change necessitate descriptive classifications to aid forthcoming stages of the research. Such an integrated taxonomy on sustainable industry is represented in Table 1, where definitions and guidelines are related to designing processes and products, aiming to segment strategies upon holistically sustainable design [32].

Table 1. An integrated taxonomy on sustainable industry. Adapted from De los Rios and Charnley [32], p. 111.

Approach—Design For (DfX):	Managerial—Focus On:	Strategy—Design For (DfX):	Methods—Design For (DfX):
Life Cycle	Extended Life and Longer Lifecycles	Reliability	Quality
		Maintenance	Repair and Refurbishment
		Reuse	Upgrading
	End-of-Life, including Multiple Lifecycles and "Cradle to Cradle" approaches	Component recovery	Remanufacturing
		Material recovery	Recycling
			Cascaded use
Whole Systems	Sustainable Systems	Radical innovation toward sustainability	
		Reduced environmental backpacks	Supply Chain
			Manufacturing and Assembly
Environment, toward preventive policies	Energy Conservation	Clear energy consumption	Biomimicry
	Material Conservation	Material selection toward sustainability	

Among the most important tools for environmental appreciation of LCA is the Global Reporting Initiative (GRI) index. Particularly, the Global Reporting Initiative (GRI) index is considered the largest catalogue of environmental indices and provides the latest references for sustainability focused on the environment, the economy, and society. The principles of environmental assessment and the framework of an LCA analysis are both described at the ISO 14040 standard [33,34]. Particularly, LCA methodology is applied to water footprint calculation in order to quantify the whole product's life cycle phases and environmental impact [35–41]. Under the multifaceted appreciation of business performance, like most subjective norms on public relations or intangible benefits, social bottom line can be difficult to measure. However, the (aforementioned) GRI index has developed guidelines to enable businesses to report and measure their social impact [42].

2.3. Triple Bottom Line (TBL)

The triple bottom line (TBL) concept upon sustainability in supply chain environment was primarily introduced by Eklington in 2018. The TBL method is an out-of-the-box holistic approach that foresees beyond the traditional bottom line of a business, being concerned with the social, environmental, and financial profits made by this business. Indeed, all three factors are determining business to generate a profit, since no single bottom line can sustain a business alone [42].

Moreover, business operability under the TBL method enable policy makers and managerial teams to determine how sustainable their business is and how profitably it is actually performed. Besides, the TBL enables business to understand its current economic status and its future prosperity. TBL, utilize the following categories of analysis: Governance, Staff, Society, Environment, and Business model (all referred to the B-Impact Assessment), as well as Economic Sustainability, Natural Resources Management, and Society Welfare (all referred to the Triple bottom line). TBL methodology was also overviewed under the Economic-Environmental-Social aspects [42] or the People-Planet-Profit aspects [43].

2.4. Eco-Innovation Development and Implementation Tool (EDIT)

The environmental viewpoint of industrial methodologies has recently focused on the evolution of GHG emission standards to better assimilate for the carbon footprint calculations, including the Climate Declaration, Publicly Available Specification (PAS) 2050, ISO14000 standard, and GHG Protocol. Among them, a "cradle-to-retail" methodology is a significant tool that takes into account the uncertainty within the different stages, specified in the pasta industry, such as soil cultivation, fertilizers, logistics, and production processes [44].

Another valuable environmental assessment tool is EDIT [12]. EDIT is a holistic tool that analyses the resource efficiency perspectives in industrial plants. EDIT is a need-driven concept that fits to small- and medium-sized enterprises (SMEs), and it supports these SMEs to reveal their orientation as resource-efficient companies [12]. Though the development scheme of such a comprehensive and semi-quantitative analysis is a scientifically robust tool, inhibitors to their becoming fully effective resources in SMEs have been also recognized. The functionality of the EDIT is determined in alignment with efficiency improvement identification [12]. The allocation of the most effective tools and methods in all levels of an enterprise and the planning of crucial interventions can improve the sustainable framework of enterprises. The implementation of an eco-innovation tool in business administration is a conceptual discipline that broadens and enriches the discussion for methodological pluralism in Circular Economy (CE). EDIT [12] constitutes a win-win strategy when applied in a systematic way and integrates the environmental approaches in most companies' internal and external decisions [45]. The systematic assessment of resource efficiency potentials and the consideration of sustainable consumption and production innovations enhance the value of enterprises on products throughout their life cycle processes, the managerial goals, the strategic planning, and the relationship with stakeholders, as implemented and tested in a pilot phase and up-bottom approach below (Table 2) [11].

Dobes et al. [11] developed the EDIT at European SMEs and concluded that this can function as a comprehensive tool for screening audits and detailed analyses, being specially fitting to the needs of the consultant due to its modular framework. Besides, "stakeholder analysis" is a productive managerial opportunity that clarifies companies' priorities and inspire the active participative roles of all stakeholders to develop companies' strategy, insomuch as these companies have already included the approach in their own managerial function. However, the consideration of only a single business level, the lack of quantification of data, the external support, and capacity building are recognized as factors that need improvement [11].

Table 2. The concept of EDIT. Source: Adapted from Dobes et al. [11], p. 294.

<table>
<tr><th colspan="3">SEVEN-LEVELED ANALYSIS OF:</th><th colspan="3">ACTION/STATUS</th></tr>
<tr><td colspan="3">1. Stakeholder</td><td colspan="3">Strategic goals of the enterprise</td></tr>
<tr><td colspan="3">2. Management Systems</td><td colspan="3">State of application</td></tr>
<tr><td colspan="3">3. Input-Output</td><td colspan="3">• Non-product output costs among prioritized inputs
• Determination of inputs and outputs toward product life cycle</td></tr>
<tr><td colspan="6">Life Cycle (outline)</td></tr>
<tr><td>1. Stakeholders</td><td>2. Vision and Goals</td><td>3. Strategy</td><td>4. Management Systems</td><td>5. Production</td><td>6. Products</td></tr>
<tr><td colspan="3">4. Potentials</td><td colspan="3">Improvement potential and importance of selected aspects for SME</td></tr>
<tr><td colspan="3">5. Applications of improvement potentials</td><td colspan="3">Areas of the highest improvement potential</td></tr>
<tr><td colspan="3">6. Cost-Benefit</td><td colspan="3">• Suggestions of further tools and measures
• Priority of applications</td></tr>
<tr><td colspan="3">7. Action Plan</td><td colspan="3">Next steps for the SME proposed</td></tr>
<tr><td colspan="6">IMPLEMENTATION</td></tr>
</table>

On the other hand, the AHP, which has been introduced by Saaty [46], is a robust and widely used multi-criteria methodology that provides some advantages over the aforementioned improvement requirements. AHP is classified as a branch of Operational Research called multi-criteria decision analysis (MCDA). These methods were developed to help decision makers to provide nexus and consistent decisions in problems that incorporate complexity and multi-factor perspectives. Other common processes are the: ELECTRE, PROMETHEE, TOPSIS, Analytical Network Process, Goal Programming, MACBETH [47–52].

Under the functionality of multi-criteria decision analysis (MCDA) technique, Wu et al. [53] signified its suitability to power generation systems, while benefiting energy enterprises toward the sustainable development and operational perspectives of the plant units. Specifically, a probabilistic method explored the sustainability features of the generated AHP weights. The most significant criterion of selection was that of the coal-fired power plant at the national power grid of China, where the selection criteria are abiding to the rules of integrating the selected indicators. Particularly, the following five criteria categories with their own sub-criteria were considered: flexibility (C1), economic (C2), environmental (C3), reliability (C4), and the technical criterion (C5); each one of these criteria is higher or lower scored under the sustainability assessment, thus implying varied importance at the aforementioned coal-based power units in China [53].

3. HAPI-E Industry Tool—Tool Description

The modified HAPI-E industry tool used AHP supports simple and straight forward postulates in treating multi-criteria decision problems. Nevertheless, AHP is developed under a pair wise analysis of parametric attribution of weights that is based on the scale of their relative importance, but their variations should not exceed a certain threshold. Then, scaling of significance was arranged from a lowest–to-highest value. Specifically, the highest value is referred to absolute importance, while reciprocal of all scaled ratios are entered in the transpose position. Again, the lowest value is referred to the absolute triviality. Subsequently, the complete comparison matrix is formulated when the weights of the factors are calculated under normalizing the respective eigenvector by the cumulative eigenvector. Dispersion of the weight of the decision factor is allocated through the equal-interval ranging technique to different classes' suited.

In this study, the proposed framework of industrial environmental evaluation by joint implementation of HAPI-E industry tool and EDIT is depicted at Figure 1. This framework follows deductive logic, under which is the general process of interlinks and motivation drivers in industry (general premises given at step a) is followed by the joint applicability of the EDIT and HAPI-E industry tool (reasoning given at step b), thus reaching the logically certain conclusion of functionality in a typical pasta industry (specific conclusion drawn upon this proposed circular framework).

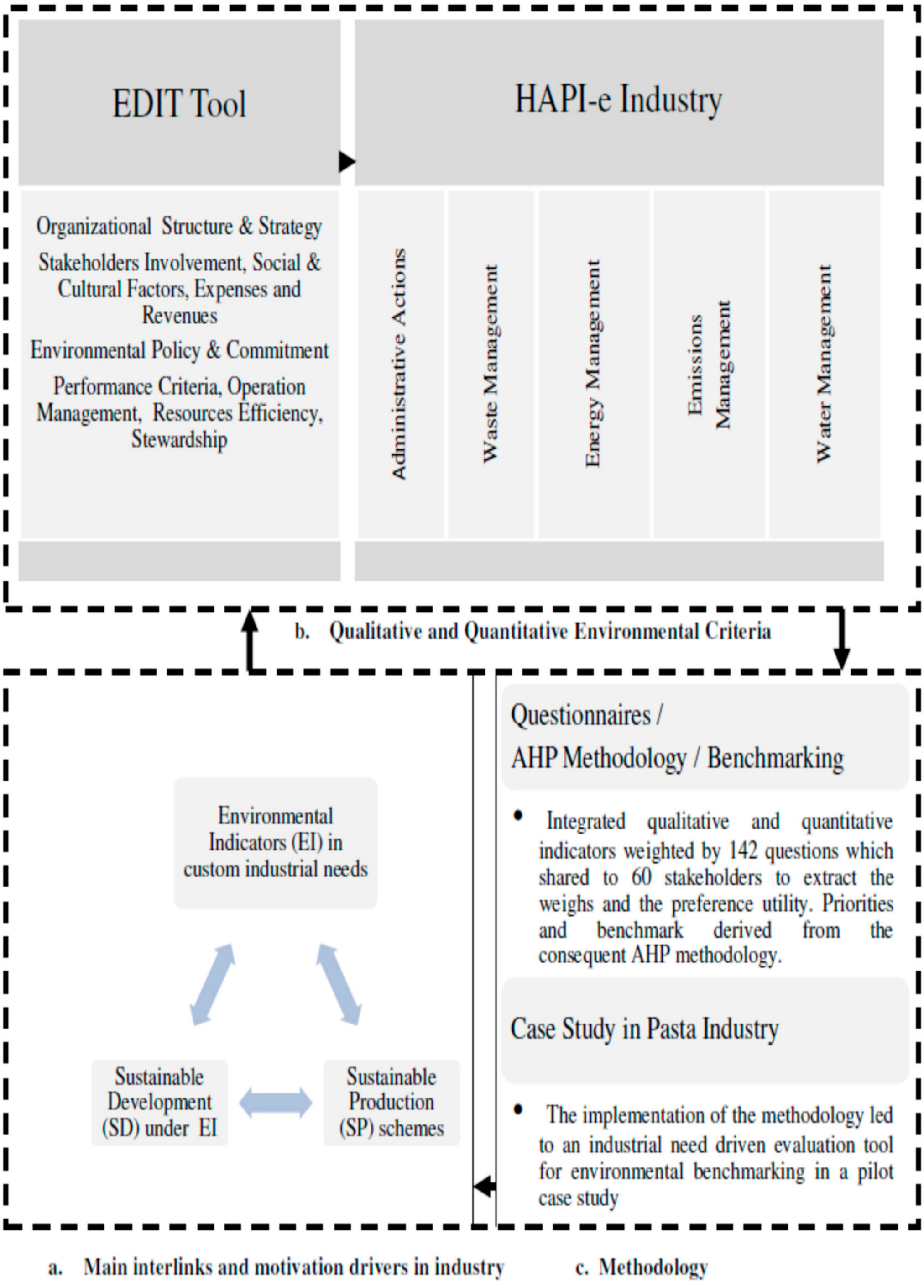

Figure 1. Proposed framework of industrial environmental evaluation by joint implementation of HAPI-E industry tool and EDIT [12] with need driven feedback (authors own study).

3.1. Questionnaires

Prior to the implementation of AHP, it is necessary to select the criteria, place them in the hierarchy levels, and formulate the pair wise comparison matrix (PCM). The core of the process is the estimation of the weights. The measurements were done by the questionnaires, in a two-stage analysis, according to the specific features in the industry and the nine EDIT indicators, in order to embed them in the HAPI-E weighting criteria.

The first stage is referred to the Table A1 (Appendix A) and the EDIT qualitative concepts classification in the three motivation drivers of the study. The assessment took place through weights stipulated by the distributed questionnaires. The considered qualitative criteria setting are: The EI under industry and manufacturing contexts; the SP is related with Stewardship, Operation Management, and Resources Efficiency Performance Indicators Criteria, while the SD of Environmental Indicators better related with the Organizational Structure and Strategy, Stakeholders Involvement, Social and Cultural Factors, Environmental Policy and Commitment, and Expenses and Revenues in Environmental Sponsorship and Donations. The main characteristics of the HAPI-E industry tool considering the motivation drivers are presented in Table 3.

Table 3. HAPI-E Industry criteria and SD of EI and SP schemes Characteristics.

Criteria of HAPI-E Industry Tool	Administrative Actions	Waste Management	Energy Management	Emissions Management	Water Management
Stewardship	X	X	X	X	X
Stakeholders Involvement	X	-	-	-	-
Expenses and Revenues in Environmental Sponsorship and Donations	X	-	-	-	-
Performance Criteria	X	X	X	X	X
Environmental Policy & Commitment	X	-	-	-	-
Operation Management	X	X	X	X	X
Resources Efficiency	X	X	X	X	X
Social & Cultural Responsibility (SCR)	X	-	-	-	-
Organizational Structure & Strategy	X	-	-	-	-
Use	SD, SP	SP, EI	SP, EI	SP, EI	SP, EI

Notes: EI: Environmental Indicators under the Industry and Manufacturing Contexts; SP: Sustainable Production Schemes; SD: Sustainable Development under Environmental Indicators.

Following Table 3, the second stage of the procedure refers to Table A2 (Appendix A), which is constituted by joint indicators, based on 142 questions distributed to the upper administration and the technical staff level via Google forms, while the analysis of the perceptions has taken into account the Table 4 scale. In Appendix A, the basic questionnaire of this modified HAPI-E industry tool is depicted, including the qualitative indicators that were derived from the EDIT [12].

3.2. AHP Principles and Consistency Test

The fundamental AHP is depicted in the lines below. The development of AHP is based in the following four simple axons: reciprocal judgments, homogeneous comparisons, network structures and synthesis in a hierarchical manner, and meeting the desirable expectations [46]. One of the key factors of the method is to estimate the priorities in terms of consistency and consideration of the principal or the largest eigenvector. Consistency means that the decision maker is exhibiting coherent judgment in specifying the pair wise comparison of the criteria or alternatives. Mathematically, it was defined that the comparison matrix **A** is consistent if

$$a_{ij}a_{jk} = a_{ik}\ for\ any\ i, j\ and\ k \tag{1}$$

That property requires all columns and rows of the comparison matrix to be linearly dependent. The consistency ratio of the aggregate matrix is defined as

$$CR = \frac{(n_{max} - n)}{(n-1)RI} \tag{2}$$

where RI stands for a random index of consistency

$$RI = \frac{1.98 \times (n-2)}{n}, \tag{3}$$

and n derives from the size of the matrix. According to Saaty (1980), the CR is accepted when it is less than 0.1 in order for the matrix to be consistent. If $CR > 0.1$, the decision maker has to revise the elements of a_{ij} to realize better consistency in the pair wise comparison matrix (PCM).

3.3. Weight Calculation

The relative weights (w) were found by dividing each element of the matrix with the sum of the column were it is placed. Then, the average sum of each row calculates the relative weight for each sub-criterion ($\overline{w}$) regarding to the consistency ratio of the corresponding main criterion. Following this procedure and according to the Equations (1)–(3), above, the pair wise comparison matrix and the relative weights of the main criteria were obtained. Since, $A\overline{w} = n_{max}\overline{w}$, with $n_{max} > n$ and the i equation is, $\sum_j^n a_{ij}\overline{w}_{ij} = n_{max}\overline{w}_i$, $i = 1, 2, \ldots, n$, then

$$\sum_{i=1}^{n}(\sum_{j=1}^{n} a_{ij}\overline{w}_j) = n_{max}\sum_{1}^{n}\overline{w_i} = n_{max}. \tag{4}$$

That means that the n_{max} value equals to the sum of the elements of the vector column $A\overline{w}$. Following the relative weights, an AHP was used in order to quantify the weights and to indicate the main objectives of the solution, namely the tree structure of the criteria definition and its pair-wise comparison, also taking into account the reciprocal property ($a_{ij} = 1/a_{ij}$) for each single pair. The analysis of the questionnaires and the data obtained for all criteria, normalized and the Pairwise Comparison Matrix (PCM) was developed according to Saaty [54]. Particularly, Saaty [54] classified the scale for pair-wise comparisons into 9 intensity of importance components, varying from intermediate importance (intensities 2, 4, 6, and 8), equal importance (referring to the equal contribution of two elements to the objective), moderate importance (referring to the slightly favour of one element between that of: experience or judgement, over another), up to extreme importance (referring to favouring evidence of one element over another, it is of the highest possible order of affirmation). Moreover, there are many scale functions to translate the judgments into ratios [55].

4. Case Study in Food Industry, Especially in Pasta

The following analysis is crucial to customize the necessity of the research study to the production process and the quality features in order to specify the key factors that influence the environmental performance and the questionnaire filling regarding the process particularities of the product. According to the analysis, HAPI-E industry tool incorporated the EDIT methodology [12] to include the triple bottom line orientation in the industry sector, providing resilient and flexible functionality. This approach captured the needs of the food-pasta industry by repeating the two-stage analysis by in site visit and evaluation, which now reflects the different aspects of the specific food industry and the environmental scenario capacity.

4.1. Food IndustrySpecial Characteristics

The food industry, due to its leading business character, is expected to impact the drivers for sustainable production and consumption through the effective implementation of innovative and resource-efficient practices. The complex solutions associated with the non-linearity of the production functions beside the requirements optimized practices make the handling of each instance a challenging decision-making process. The food industry has recently attracted research interest in their nutrient value, management accounting practices, product novelty, and abiding health policies' promotion as commercial food products [56–58]. An interesting research development has been oriented in attracting young adults who are a desirable target population in the field of energy-dense, nutrient-poor (EDNP) food and beverage marketing. This shift to young adulthood is notable because this target group of consumers has an influential role on health and eating behavior [59]. Generally, in this research study, the pronounced role of social media and advertising upon the food and beverage marketing was also stressed out.

In the food industry, the role of cost-efficient policies—both at central government and at local SMEs—to energy reduction and eco-green quality improvement of the agro-food system in the Italian marketplace was also reported [60]. Even though the advancements in food and beverage marketing are dynamic and astonishing, societies' evolution sustains cultural boundaries [61]. These cultural boundaries cannot be undermined, nor be strictly economics-driven, but these have to consider the nutrition habits, cultural traits, and production capabilities of tradable goods in an international marketplace [61]. In this context, awareness of product claims upon "no added sugars" is favoured to reduce sugars claims, and there is a perception of changing sugar to other sweeteners and ingredients [62].

Another social attribute of food and drink consumption was fully investigated by Spence and Shankar [63]. These authors conducted a methodological approach and revealed that human sensations like hearing can play a determining role on consuming perceptions of food and drink. The positive response of human sensations, as well as the auditory stimuli to influence people's consumption rates, their preference ratings, and their flavor preferences to test and smell in the mouth, are directly associated to the oral texture, temperature, viscosity, and the sound-like reflections (particularly on noisy foods, such as crisps, celery, and carrots) when we eat or drink, as it was also reported by Zampini and Spence [64].

4.2. Pasta Production Process Specifications and Attributes

Serrano et al. [65] signified the associated potential risk in health issues related with different production processes in pasta industry, e.g., mycotoxins due to contamination by enniatins (ENs) in different steps in pasta processing. The authors concluded that the effect of the medium-high temperatures allowed a considerable mycotoxin reduction and high portion of ENs removal from durum wheat semolina during pasta processing (Table 4).

In this study, an in-house tool for industry, HAPI-E industry tool, was examined for a first time. The combined scientific robustness of the AHP and the EDIT methodology [12] provided the basis for an integrated approach in the specific industry that can be used as a signaling index of environmental reflection and wider sustainability accomplishment.

Table 4. Meta-analysis in process specifications in pasta production and attributes. Source: Adapted from Mercier et al. [66], p. 689.

Procedural Specifications			
Type of wheat and ingredients/additives	Method of shaping including diameter and thickness of extrusion die	Drying	Dough hydration
Attributes of Quality			
Proximate	**Cooking**	**Drying**	**Dough**
• Protein content (ingredient and wheat) • Dietary fiber content of the dough	• Time • Losses • Weight (increase) • Volume (increase)	• Thickness and diameter after extrusion • Water content • Water effective diffusion coefficient	• Time • Stability • Water absorption • Gelatinization temperature • Gluten properties
Materials	**Colour**	**Sensory**	**Mechanical**
• Enrichment of ingredients • Additives • Suppliers: Exclusivity; Transportation of raw materials; Packaging/Storage conditions of processed goods	• Chromatic parameters of cooked and uncooked past	• Flavour • Texture • Appearance • Quality	• Firmness • Elasticity • Stickiness

4.3. Modelling Industrial Process of Pasta Production

A procedural modelling, Figure 4, is pictorially represented as an integrated model of milling operation and pasta production. According to Owens [67], these modelling components are as follows: (1) receipt and storage of raw materials, mill operation, (2) wet mixing process, (3) extrusion and cutting, (4) drying process, and (5) pasta storage-packaging.

The main production steps/processes in this case study consists of two discrete production lines referring to mill operation and to the pasta production process. These two discrete production lines are that of Figure 2.

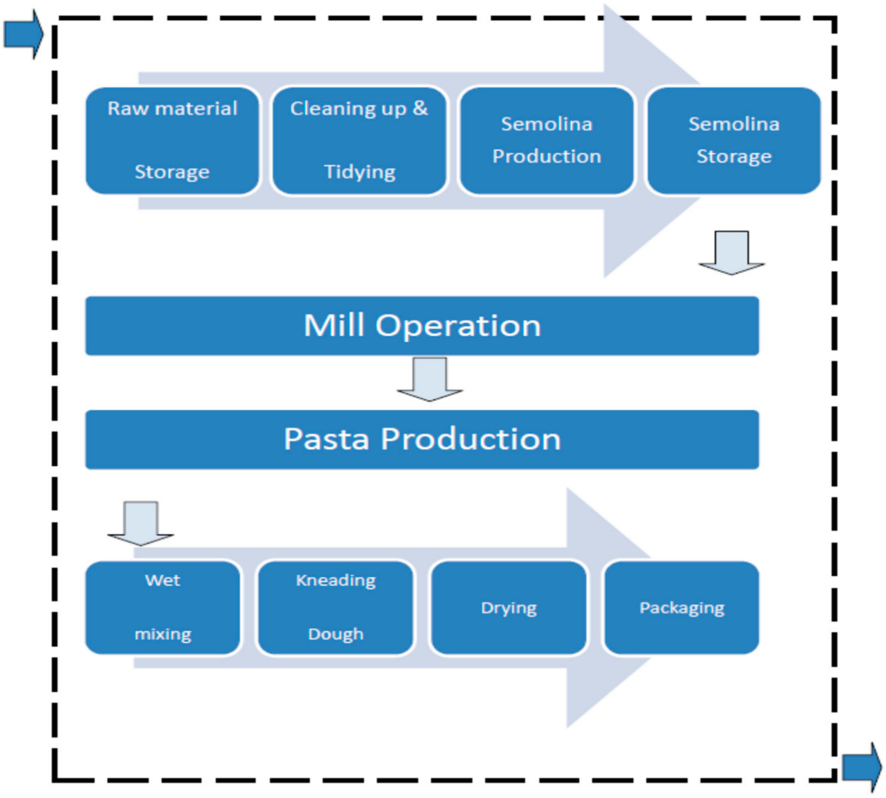

Figure 2. Flow chart of the integrated mill operation and pasta production process.

4.4. Profile of Energy and Thermal Needs

Pasta production is determined by various forms of primary resources—such as electric energy and thermal energy—that are environmentally impacting the overall process through air, water, and solid phases. The energy-oriented units that are operated in the industrial plant are that of mixing/blending; drying; cleaning up, tidying, and decontamination; forming, moulding, and extruding; and packing and filling. Particularly, thermal energy is applied to the pasteuriser and to the dryer. The first one uses natural gas in boilers, while the dryer uses hot water that, through coils located on the top of the cabinet, heat the drying airflow. The hot water is produced by a methane boiler [68]. In environmental terms, the environmental-sensitive processes in pasta industry are referred to cleaning, blending, mixing, forming, drying, and packing [68]. It was reported that the portion of CO_2 emissions that are related to electricity consumption in the pasta industry is almost one fifth of CO_2 emissions that are accompanied the thermal energy produced [68]. Besides, it is noted that less than 10% of the total thermal energy is finally absorbed by the final product at the pasteurisation process, whereas the remaining 90% is disposed to both kill off microbes and to prolong the shelf-life of the final pasta products. Moreover, the main amount of energy consumed is mainly eliminated as saturated vapour and wasted in the environment [68].

Pasta production entails a mature technological background, being accompanied by a well-developed market in which the final product is disposable. Nonetheless, several issues still constrain the technical and economic optimization of different stages production line as well as of the product's life cycle. Moreover, reconciling new lifestyles and ideas require adaptive actions in the process, are many times contradicted with the health and safety standards, as well as against quality and consumption preferences.

The complexity of the processes in food industry, the multi-level dimensions, the discreteness, and the non-linear properties make the AHP a proper methodology to identify the key characteristics that may be used in early stages of signalling and warning. The latter is proven the main advantage of the method that incorporates ideas, senses, and preference functionalities in proactive behavior attitudes. The usefulness of the early stage assessment, along with the recognition and the integration of solutions, enhance the capability of the industry and play a significance role in cost effectiveness and the market competitiveness [69].

5. Results and Discussion

The abundant approaches to sustainability have been explored for the manufacturing industry, but despite efforts that foster carbon footprint reduction, the majority of enterprises continue to operate in the traditional linear model of production and consumption which is conceptualized under the take-make-dispose rationale. Consequently, the rapid exploitation of global resources necessitates the effective use of global natural resources to sustain human activities in the future. In parallel, the implementation of holistic sustainability strategies is interlinked with products' and services' design, playing an influential role on the way the entire value chain is constructed and managed [32].

The conception of the case study conducted was to investigate the adopted methodology in practice. In this research framework, an in situ visit to the factory plant in a province of Greece was made, and the questionnaire was delivered. Three visits by two persons were conducted in site to select general and process data. The results elaboration has been proceeded by using the "Business Performance Management Singapore—BPMSG AHP Excel template with multiple inputs" [55], and the ranking (Rk) of criteria are presented at the following Table 5, showing the HAPI-E industry tool main criteria weights and scoring. Subsequently, data collected and evaluation upon all this primary material were gathered and evaluated using the HAPI-E industry tool (Table 5 and Figure 3).

Table 5. Weight calculations and individual scoring of the HAPI-E industry tool categories.

Criterion	Weights (Contribution, in %)	Individual Scoring
1. Administrative actions	18.70	14.95
2. Waste management	28.50	32.64
3. Energy management	20.00	8.94
4. Emissions (greenhouse gases) management	18.70	3.30
5. Water resources management	16.40	5.07
Final score		64.90

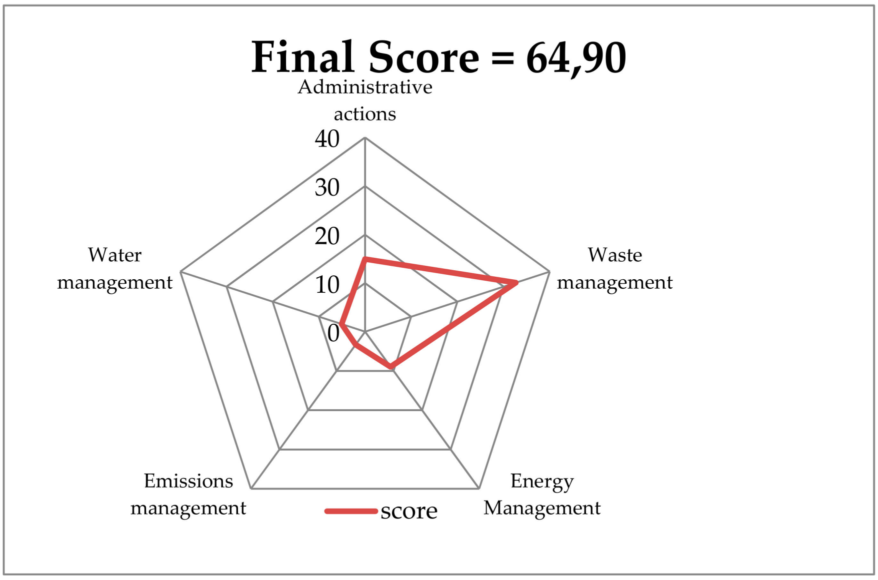

Figure 3. Industrial assessment of the representative pasta industry.

Data manipulation revealed that the HAPI-E industry tool is especially fitting to SMEs since it supports company personnel to unveil potential weaknesses as well specific potentials for wider company development. Subsequently, while noting threads of companies' development, the research outcomes could also serve policy makers and company managers to stress the stakeholders' values and to foster those corporate strategies and management tools toward mission and vision and processes to be followed upon products design and delivery. The main advantageous features of the HAPI-E industry tool directly benefit companies to be adaptable to the proposed changes that incorporate both technology and management. Moreover, collected quantitative and qualitative data support company personnel to expand the companies' perspectives on new ways that monitor and reinforce resource efficiency, thus increasing awareness and strengthening commitment for sustainable manufacturing systems.

The valuable features of the existing methodologies can be integrated into a new holistic, prevention-oriented, need-driven system to make quantitative diagnosis to promote resources' efficiency among SMEs. Apart from SMEs, consultancy service providers can benefited by establishing initial relationships with clients toward high-quality and need-driven services. The system is also especially supportive for multipliers/intermediaries—including SME associations—being a decisive means of identifying opportunities and fostering maximum returns of investment according to: time, money, human health, and ecological benefits.

It is also noteworthy that the high environmental policy of the pasta industry is burdened by the waste management. Indeed, these categorical indicators are proven of utmost importance among the industry professionals, according to the answers received in the questionnaire. Pasta industry can recycle, reuse, and re-sell a high portion of its waste produced. Particularly, the 30% wheat in the fermentation process is disposed as a byproduct in fodder, which then can be sold. The remaining 70% on fermentation becomes semolina, being a 100% recoverable product. Moreover, the pasta industry sustains collaborative and approved partners for paper and cellophane. From 2015 on, paper and plastic were fed recycling materials, whereas wood pallets can be repaired and reused. Finally, the oils are disposed of by the Greek Environmental Technology, where the industry studied also utilized recyclable packaging on its marketable products.

Another crucial parameter of evaluation is energy management. In the examined pasta industry, each production line is considered as autonomous since it supports its own management system (being specially focused on energy and drying). Besides, the boiler room has been facilitated with set-points of automation, whereas each machine has functioned autonomously. In parallel, the industry plant installed new-generation and low-energy consumption air conditioners, and adopted a frequent (biannual) maintenance on them and a periodic (per four months) maintenance on boilers as well as a periodic air bleeding of the radiators in working areas in order to accomplish a higher thermal efficiency.

It is also noteworthy that low scoring was reported at the categories "water management" and "emissions of gases." In the category of "water management," the industry was highly rated in alignment with the maintenance of the plumbing, water use reduction via battery heads with fitting low flow of water and flow restricting taps, novel technologies applied for water and energy savings, effective use and pressure regulation on the grid by operating pressure stabilizers, and water use reduction in vacuum pumps. At the category of "emissions of gases," the industry was highly rated due to the fact of natural gas usage, being the sole fuel type for the production line and for electric vehicle motion. Besides, external associates are devoted to the marketable products transferring to and from the industry, thus indirectly affecting the gases emissions. Moreover, other externalities have not been included in calculation due to their intangible and non-countable nature. Such aspects should be the protective framework in competitive markets as well as a plethora of alternative best practices that could be exploited in processes.

6. Limitations and Future Research Perspectives

The main limitations of this study are the subjectivity in evaluating multi-criteria decision methods, the complexity of the analysis by increasing the number of experimental-designed attributes and the uncertainty of the AHP. Specifically, the proposed multi-criteria decision methods using hybrid weights may be only validated by the theoretical analysis of the case study results but not verified in a practical way. Therefore, in order to figure out whether the research outcomes work well, a long-term tracking study can be valuable, while other shortcomings—such as prejudiction, knowledge incompleteness, and uncertainty of AHP-derived assessment—can be handled by stochastic methods [53].

Under the context of such alternative practices, administrative actions play a decisive role in energy management evaluation. Indeed, the examined pasta industry operates with a competent administrative body in order to better qualify its raw materials. Such an industrial sector supports neither an autonomous environmental department nor corporate social responsibility (CSR) policies, while there is no provision of continuing environmental education among the workforce. However, it has developed a sound collaboration partnership with an environmental consultancy office for environmental licensing, as well as research orientation toward environmental innovations. Moreover, internal audits and regularly conducted inspections can unveil potential non-compliance with the setting environmental protection standards.

Another administrative constraint that moderate the coordination among supplier selection attributes from sustainability perspective, is the subjectivity, impreciseness, and vagueness to assign score value to attributes. Indeed, while selecting the proper supplier from a pool of suppliers, the subjectivity, impreciseness, and vagueness can be reduced to a large extent by applying tools like fuzzy methodology. Another limitation is the increase of attributes included and the complexity of the analysis. To this end, Sinha and Anand [9] introduced the concept of matrix factorization that can be utilized at industrial-based scenarios entailing the development of new products. The applicability of this framework includes a wide spectrum of industrial sectors including that of manufacturing, pharmaceutical, and automobile [9]. Therefore, future research frameworks could enable the participation of a wider consortium of product designers, manufacturers, and environmentalists toward effective decision making upon suppliers' selection.

7. Conclusions

Based on this study, it is noteworthy that multi-criteria decision analysis methods and tools are proven effective decision support solutions to address complex problems dealing with opposite objectives and interests, uncertainties, and non-harmonised data. The inclusion of multifaceted dimensions (technical, economic, environmental, social, and institutional) can be taken into account as a set requirement for consideration by future researchers. The proper criteria selected in the sustainability assessment of energy systems, system designers, manufacturers, risk analysts, environmentalists, and businesses ensure that the conceptual in a system design will be free from any cognitive weakness from sustainability risk point of view [28], can play a key role in the subsequent selection and reporting of the best alternative [70], have to be proven useful for designers and practicing engineers to compare various alternatives of a product from the life-cycle design point of view [71] and not undermine the socio-economic determinants of sustainability accomplishment through alternative energy sources for energy production, and energy consumption especially among energy-intensified developed economies [72–74].

Under the framework of this analysis, the novel HAPI-E industry tool was developed as a proactive environmental tool within the industrial context. It can provide early stage signaling in the inter-organizational framework, which is always less costly funded to correction actions than the post treatment. Moreover, the embedding EDIT methodology [12] at the in-house multi-criteria tool (HAPI-E industry) expanded the functionality of the former (EDIT) by increasing the business levels, quantifying the materials, the energy, and the mass flows to specify the improvements in particular SMEs and to decrease the external technical assistance and capacity building since it utilizes internal resources, knowledge, and a robust hierarchical expertise.

Conclusively, the HAPI-E industry tool is proven an effective application in the food industry, especially in pasta production. The effectiveness of this research approach is particularly fitting to the specifications of multi-parametric industrial environments, in which the procedural complexity can be perceived and adapted to the norms, principles, and regulations of circular economy.

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Appendix A

Questionnaires used to carry out a census of all indicators for the joint implementation of HAPI-e Industry and EDIT value tool.

Table A1. Indicate the intensive scale (High:1, Medium:2, Low:3) for the following qualitative indicators thatbest describes the three contexts (EI, SP, SD).

Indicators	EI	SP	SD
Stewardship			
Stakeholders Involvement			
Expenses and Revenues in Environmental Sponsorship and Donations			
Performance Criteria			
EnvironmentalPolicy & Commitment			
Operation Management			
Resources Efficiency			
Social & Cultural Factors			
Organizational Structure & Strategy			

Note: EI: Environmental Indicators under the Industry and Manufacturing Contexts; SP: Sustainable Production Schemes; SD: Sustainable Development under Environmental Indicators.

Table A2. Indicate the intensity scale for the following qualitative and quantitative indicators regarding the implementation in your organization.

	Indicators	Strongly Agree	Agree	Equal	Disagree	Strongly Disagree
Administrative Actions	Environmental System Certification					
	Annual publicity of environmental targets					
	Dedicated environmental section within the organization					
	Awareness and employee training					
	Selection of suppliers—partners according their environmental performance					
	Sponsorship—Donations to Environmental organizations					
	Sustainable Development under Environmental Indicators context					
	Sustainable Production (SP) schemes					
Waste management	Waste selection, separation and recycling					
	Green suppliers selection					
	Measures for chemical constraints					
	Minimization of materials flow policies					
	Sustainable Production schemes					
	Environmental Indicators under the Industry context					
Energy Management	Monitoring of consumption					
	Renewable energy production					
	Energy improvement measures					
	Energy Conservation measures					
	Sustainable Production schemes					
	Environmental Indicators under the Industry context					

Table A2. *Cont.*

	Indicators	Strongly Agree	Agree	Equal	Disagree	Strongly Disagree
Emissions Management	Annual CO_2 production					
	Measurements on carbon footprint reduction					
	Policy for the reduction of transportation					
	Sustainable Production schemes					
	Environmental Indicators under the Industry context					
Water management	Annual water consumption per employee					
	Measurements for the water savings					
	Sustainable Production schemes					
	Environmental Indicators under the Industry context					

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