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The Assessment of the Green Development of the Tobacco Industry Using a Multicriteria Method

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Abstract

The tobacco industry is heavily regulated due to the significant health implications associated with tobacco use. The industry also involves numerous stakeholders, including farmers, manufacturers, distributors, retailers, regulators, and consumers. The aim of this research is to select the most relevant environmental criteria for the green development of the tobacco industry. This article uses Analytical Hierarchy Process (AHP) methods to create a hierarchical structure of the criteria and subcriteria necessary for green business development, establishing the relative weights of these subcriteria to find the areas in which attention and resources are most urgently required. The assessment of the concordance of expert opinions shows a satisfactory level of agreement. The article advances a more comprehensive view towards the evaluation of green criteria that are significant for the whole industry, seeking to highlight the need to think holistically. According to the views of experts, the most significant sub-criteria for the green development of the tobacco industry are increasing energy efficiency; safeguarding against hazardous wastewater in the environment; reducing the content of hazardous materials used in products; improving air, land, and water quality where economic activity takes place; sustainable forest management; eco-design, especially for efficient material use, biodegradability, and recyclability; and collaboration with suppliers. The entire industry should collaborate in seeking global green development by gradually investing in the improvement of green criteria.

Keywords:
Tobacco Industry;
Green Development;
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1- Introduction

Although the prevalence of smoking continues to decrease globally, the number of smokers is on the rise in the developing world [1, 2]. This increase allows the global tobacco industry to remain stable and even experience growth. However, even though the effect of smoking on individual and public health is well-known and largely understood, the understanding of the impact of the tobacco industry on the environment remains understudied. This deserves more careful examination, especially in light of intensifying efforts to fight climate change following the Paris Agreement. The total annual contribution of the sector to climate change is around 84 Mt CO_2 equivalent. This amounts to approximately 0.2% of the world's total greenhouse emissions, or the same as the contributions of entire countries such as Israel or Peru [3]. In addition to this, the fact that the product itself is hazardous should be taken into account [4].

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The shift from Western markets to the Global South allows tobacco companies to grow complacent when it comes to investing in new, truly eco-friendly products, being more transparent, and renewing infrastructure and work methods across the industry. Pressure for green change is building from all directions: consumers want to be more conscious about the impact of their habits on the environment; activists urge quick action against climate change before it is too late; international organizations like the UN are building coalitions to tackle climate change and the impact of the tobacco industry more specifically; and regulators from the FDA to the EU are pushing for ever more stringent rules. The green transition requires enormous amounts of resources wherever it is implemented, and the tobacco industry—encompassing the global cultivation, processing, production, distribution, and sale of tobacco products—is no exception.

No company in the world has sufficient resources to fully commit to every issue facing its industry. This then requires making choices and distributing attention towards those areas where the most impact can be achieved. There are a significant number of articles analyzing the environmental impact of the tobacco industry [3–8], and discussions surrounding proper assessment criteria are becoming increasingly relevant because of the growing number of 'greenwashing' [9–11] allegations against the industry. In many cases, authors use multicriteria methods to evaluate environmental impact [6, 12]. A substantial body of literature also examines specific green initiatives in the tobacco industry, including emission reduction efforts [13] and advancements in energy efficiency [7, 14–17]. Additionally, studies highlight the industry's focus on waste management practices [18–21], green management strategies that emphasize human resource practices [5], as well as sustainable information systems [22] and logistics operations [23]. Because the tobacco industry only recently began to receive more attention regarding its environmental impact, there is a relative scarcity of research enveloping the entire sector and possible methods for mitigation. Therefore, the development of precise criteria can only be achieved by using piecemeal efforts. However, there is an abundance of literature detailing general principles and criteria for businesses to follow when seeking to be considered 'green' and to lessen their impact on climate change, pollution, and biodiversity loss. The general understanding of the impact of the tobacco industry on the environment is still lacking and deserves more careful examination. To fully understand this phenomenon, the entire industry should be considered—from agricultural cultivation to post-consumer waste [24]. Significant improvements are required to reduce the harmful environmental effects of the tobacco industry and transition it from a traditional to a green business model.

The aim of this study is to select the most relevant environmental criteria for the green development of the tobacco industry. In line with this aim, two goals were specified: to develop a set of environmental criteria for the tobacco industry and to prioritize the selected criteria using a combination of experts' input and mathematical methods. The article uses Analytical Hierarchy Process (AHP) methods to create a hierarchical structure of the criteria and subcriteria necessary for green business development, establishing the relative weights of each subcriterion to find the areas where attention and resources are most keenly required.

This study addresses the critical challenge of identifying key environmental criteria essential for the green development of the tobacco industry, where environmental considerations are frequently overlooked. A primary difficulty in this research involves prioritizing complex environmental criteria specific to the tobacco sector, a task undertaken through rigorous expert assessments and mathematical prioritization methods. This paper contributes to the field by offering a methodological approach that employs a multicriteria framework for prioritizing selected criteria. Our unique contribution is the development of a refined set of prioritized environmental criteria aimed at guiding the tobacco industry towards more sustainable practices and facilitating well-structured environmental strategies. Moreover, the study seeks to advance the existing literature by expanding from a systematic approach to a more holistic perspective.

The paper is structured as follows: sections 2 and 3 provide essential theoretical and methodological insights based on the concepts under study; section 4 describes the main findings of the research; and the final sections discuss and summarize the results, offer concluding remarks, and define possible areas for further study.

2- Literature Review

The main processes in the tobacco industry can be divided into six distinct groups or stages: cultivation; curing; primary processing and trading; manufacturing; distribution; and retail.

Cultivation

Farming, irrigation, and fertilizer use account for more than 70% of all environmental damage in the tobacco industry across most impact categories [3]. When compared to other crops, tobacco also uses huge amounts of water—8 times more than potatoes, for example. Moreover, continuous tobacco plantation farming causes the acidification of soil, so both the quality of the soil and its productivity reduce over time, requiring even more fertilizer, pesticide, and other hazardous materials to maintain the same level of production [8]. Deforestation in order to free up land for tobacco growing and use the resulting wood for curing also accounts for 5% of all deforestation on the planet.

Curing

Curing is the process during which tobacco leaves are dried and prepared for processing. There are three basic methods of curing: sun-curing, air-curing, and flue-curing. The first two use natural ways of drying, but flue-curing uses

heated air to dry the leaves in barns. Since cigarette tobacco requires flue-curing to achieve a high level of quality, most curing is performed via this method. The flue-curing process is a major source of CO_2 emissions: since it involves burning wood or coal, it produces more carbon emissions than all other stages combined—at least 45 Mt CO_2 equivalent globally [3].

Primary Processing and Trading

During primary processing and trading, tobacco leaves are graded by size, color, position of the leaf on the plant, etc. This is generally one of the least impactful stages, in which the main factors to be considered are the use of transport for tobacco distribution and energy use in processing and packaging.

Manufacturing

After cultivation and curing, the most environmentally harmful stage is the industrial manufacture of cigarettes. This involves numerous environmental costs: from the metals used in the manufacture of cigarette-producing machines to the kinds of energy used to direct emissions and waste [25]. According to Zafeiridou et al. [3], the annual CO_2 emissions equivalent of this phase of tobacco production is around 16 Mt. Moreover, cigarette manufacturing is water intensive: around 15 Mt of water is used here, of which almost 9 Mt ends up as wastewater. Additionally, the manufacturing process creates more than 1 Mt of solid waste. These numbers are hugely significant because of the large numbers of different toxic ingredients—flavorings, solvents, plasticizers, etc.—that are used in production [26].

Distribution

The logistics used here include all types of transport—air, sea, and land—and the current lack of electrification (or sustainable fuel use) in these fleets contributes to the total emissions of the industry. Similarly, packaging has a significant impact because plastics are used alongside other forms of packaging, creating more than 2 Mt of waste annually [3]. The growth in the popularity of smokeless forms of tobacco is also causing more and more environmental problems, as they are usually packaged in plastic or non-biodegradable sachets or pouches.

Retail

Retail is the final phase and is where the product reaches the consumer. Evidently, not only the production of cigarettes and other tobacco products pollutes the environment, but also the act of smoking itself: it involves burning and emitting materials that are incorporated in the tobacco and cigarette paper. Since these emissions are toxic, the particles left because of a phenomenon known as third-hand smoke, where these toxic particles gather in dust, on surfaces, and on other objects. Toxic emissions include formaldehyde, nicotine, and various greenhouse gases—CO_2, methane, and nitrous oxides [25]. It has been calculated that tobacco smoke alone emits the equivalent of 0.87 Mt of CO_2 per year [3]. Even more worrying is the number of cigarette butts littering the environment. By different measures, 5.5 to 6 trillion cigarettes are produced each year, and since most come with filters, this amounts to around 4.5 trillion filters deposited in the environment. It is estimated that 0.98 Mt of filters and paper plug wraps ends up as waste each year, a figure expected to rise to 1.2 Mt by 2025 [3, 27, 28]. Tobacco products are among the 10 most commonly found plastics in the world's oceans [27], and by some measures are the single most common form of litter if counted by individual pieces [18].

However, there is a stream of literature detailing general principles and criteria for businesses to follow when seeking to be considered green and to lessen their impact on climate change, pollution, and biodiversity loss. Intergovernmental reports are particularly useful and include EU regulations and the assessment reports of the Intergovernmental Panel on Climate Change (IPCC).

Although, as stated above, individual research has mainly been used for setting up industry-specific criteria, research by Wang et al. can also be mentioned alongside that which provides general criteria as it describes the best way in which to cut emissions in industrial buildings [13]. As the aforementioned paper focuses on tobacco enterprises, it also provides industry-specific insights. Unsurprisingly, Wang et al. found that the most successful method of reducing emissions is improving energy efficiency, a point referenced in almost every body of text discussing reducing impact on climate change, although in this case it is to be achieved specifically by optimizing refrigerating, air handling (AHU), and lighting systems. A further method mentioned is waste heat utilization, which might be feasibly used in other stages of the supply chain, such as curing or tobacco processing. Li et al. studied the tobacco manufacturing process by analyzing the relationship between drying parameters and thermal energy consumption [14]. Other studies in the energy consumption and efficiency field covered issues of the implementation of renewable energy by comparing renewable and non-renewable consumption in the food, beverage, and tobacco industries [15-17].

Falloon & Betts focused on agricultural adaptation and mitigation measures in regard to water management in the face of a changing climate [18]. This is specifically important to the tobacco industry as it uses a lot of water in its

tobacco-growing stage. This is coupled with the high use of fertilizers and pesticides, thus carrying huge risks of soil, groundwater, and marine water contamination. Although Falloon & Betts observe that most measures have both positive and negative outcomes, in relation to water demand (households and enterprises), they mention improvements in water efficiency by reusing wastewater, promoting indigenous practices for water use, the industrial conservation of water (which applies to tobacco manufacturing), and reducing water demand by changing the cropping calendar, using crop mix methods, and changing irrigation systems [18]. Cao et al. also produced industry-specific research, focusing on the curing of tobacco leaves [7]. This is the most CO_2-emitting stage of the entire supply chain—hence, finding ways to limit these emissions is especially significant. The authors found that simply by using electric pumps instead of burning coal/gas or other materials, the energy-saving rate can be increased from 20% to 50%. If this is paired with improvements in barn insulation, the saving rate increases to 60%. Both of these actions are included in the criteria taken forward in this study. The final relevant area of industry-specific research focuses on research regarding tackling cigarette butt littering and pollution. In this case, the research of several authors is relevant and adds to the discussion. Benavente et al. showed that recycling to recover cellulose acetate tow from cigarette filters is possible [19]—this is a valuable polymer that can either be reused in cigarette filter production or used in other industries. The latter point is the focus of research by Moroz et al., who further expanded on the possible uses of recycled cigarette filters, from chemical absorption to the creation of materials, highlighting the potential of cigarette butt recycling systems [20]. Meanwhile, Hoek et al. surveyed respondents, including both smokers and non-smokers, regarding which measures they would favor to reduce cigarette butt pollution [21]. Most measures included governmental action, but from the supply side, it was observed that cigarette companies should create more biodegradable filters to reduce this problem. This factor is included in the criteria in this paper, alongside educational campaigns regarding littering, which were also highlighted by the respondents.

Shoukat et al. highlighted green human resource management as a very important factor for managing sustainability in tobacco companies [5]. Digitalization as a tool for the creation of a green economy is also key. Using the AHP method, the authors provided arguments for the implementation of big data automation and the power of business intelligence tools to enhance wastage management in the tobacco industry [29, 30]. Ahmad et al. revealed that green manufacturing, green purchases, eco-design, and green information are very important aspects for managing companies in a sustainable way, as the impact of cooperation with customers is insignificant [22]. The significance of green logistics practices, such as environmentally friendly transportation and sustainable warehousing, in strengthening supply chain resilience has also been emphasized in other empirical studies [23].

Moving on to criteria derived from regulatory documents, it is first relevant to consult Regulation (EU) 2020/852 of the European Parliament and of the Council, which sets out 6 environmental objectives for any economic activity to reach to qualify as environmentally sustainable. These are climate change mitigation, climate change adaptation, the sustainable use and protection of water and marine resources, the transition to a circular economy, pollution prevention and control, and the protection and restoration of biodiversity and ecosystems. These objectives are then followed by criteria for each objective, but not all criteria are included in this study. Instead, the chosen criteria represent some of the criteria in the regulation but were consolidated into one and were selected based on their applicability to the tobacco industry specifically. From the first objective of climate change mitigation, the following were chosen as criteria for this paper: using renewable energy and improving energy efficiency, increasing clean or climate-neutral mobility, and switching to the use of sustainably sourced renewable materials. For the sustainable use of water resources, the criterion chosen was improving water management and water efficiency. The criteria from the pollution prevention and control objective include cleaning up litter and other pollution and increasing the recyclability of products and waste. Lastly, for the protection and restoration of biodiversity, the criterion chosen was sustainable agricultural practices and forest management, including reforestation and afforestation. The two objectives not mentioned—climate change adaptation and the circular economy—are reasonably covered by the previously mentioned criteria.

The other intergovernmental report used for criteria selection was the Sixth Assessment Report of the IPCC, which provides the global assessment of the climate change mitigation progress. This is a vast document covering various topics, but criteria for this paper were chosen from two chapters in the report: Agriculture, Forestry, and Other Land Uses; and Industry. Again, the word 'efficiency' is key. As criteria from the report, 'material efficiency by designing with less and reducing waste' and 'energy efficiency improvements' were chosen. Related to material efficiency is the next criteria: eco-design, meaning designing products from the start to use less material, use renewable materials, and be easily recyclable or reused. Another criterion from the IPCC report is green procurement—the practice of sourcing materials and services from other environmentally sustainable businesses. A further recurring topic from all research resources is the recyclability and reusability of materials and waste, which is also included as a criterion. Lastly, switching to renewable fuels and the protection, improved management, and restoration of forests and other ecosystems were also chosen as criteria.

The criteria for analysis presented in Table 1 were combined from regulation data and scientific articles, as it was observed that there are no such complex assessments in the tobacco industry.

Table 1. Criteria for green business development in the tobacco industry

Criteria	Subcriteria	Sources
Climate change mitigation (CCM)	Generating or using renewable energy	Cao et al. 2017 [7]; IPCC 2022 [31]; The European Parliament and the Council 2020 [32]; Jebli & Boussaidi 2024 [16]
	Increasing energy efficiency	IPCC 2022 [31]; The European Parliament and the Council 2020 [32]; Wang et al. 2018 [13]; Li et al. 2023 [14]; Derakhshan et al. 2022 [15]
	Increasing clean or climate-neutral mobility	IPCC 2022 [31]; The European Parliament and the Council 2020 [32]
	Increasing use of carbon capture and carbon storage technologies	The European Parliament and the Council, 2020 [32]
	Strengthening land carbon sinks	The European Parliament and the Council, 2020 [32]
	Green building technologies (improved insulation, economical lighting, reusing waste heat, speciality building materials, etc.)	Cao et al. 2017 [7]; ESG Research LLC 2023; The European Parliament and The Council 2020; [32] Wang et al. 2018 [13]
The sustainable use and protection of water and marine resources (WMR)	Safeguarding against hazardous wastewater in the environment	IPCC 2022 [31]; The European Parliament and the Council 2020 [32]
	Reducing the hazardousness of wastewater	IPCC 2022 [31]; The European Parliament and the Council 2020 [32]
	Developing a water management strategy to increase efficiency and reduce water intensity	ESG Research LLC 2023 [33]; Falloon & Betts 2010 [18]; IPCC 2022 [31]; The European Parliament and the Council 2020 [32]
	Sustainable use and protection of marine environments	IPCC 2022 [31]; The European Parliament and the Council 2020 [32]
	Using alternative sources of water	ESG Research LLC 2023 [33]; Falloon & Betts 2010 [18]
The transition to a circular economy (TCE)	Using natural resources more efficiently	IPCC 2022 [31]; The European Parliament and the Council 2020 [32]
	Increasing recyclability of products, especially of cigarette filters	Benavente et al. 2019 [19]; IPCC 2022 [31]; Moroz et al. 2021 [20]; The European Parliament and the Council 2020 [32]
	Reducing the content of hazardous materials used in products	The European Parliament and the Council, 2020 [32]
	Preventing or reducing waste generation	IPCC 2022 [31]; The European Parliament and the Council 2020) [32]; Maulana & Sunitiyoso 2024 [30]
	Re-using and recycling water	Falloon & Betts 2010; [18] The European Parliament and the Council 2020 [32]
	Avoiding or reducing litter	IPCC 2022 [31]; The European Parliament and the Council 2020 [32]
Pollution prevention and control (PPC)	Preventing or reducing pollution other than GHG	The European Parliament and the Council 2020 [32]; Wang et al. 2018 [13]; Cao et al. 2017 [7]
	Improving air, land and water quality where the economic activity takes place	IPCC 2022 [31]; The European Parliament and the Council 2020 [32]; Falloon & Betts 2010 [18]
	Preventing adverse effects of the use or disposal of chemicals	IPCC 2022; [31] The European Parliament and the Council 2020 [32]; Benavente et al. 2019 [19]; Moroz et al. 2021 [20]
	Cleaning up litter and other pollution	IPCC 2022 [31]; The European Parliament and the Council 2020) [32]; Hoek et al. 2020 [21]
The protection and restoration of biodiversity and ecosystems (PRBE)	Nature and biodiversity conservation	IPCC 2022 [31]; The European Parliament and the Council 2020 [32]; Zhang et al. 2016 [8]
	Sustainable land use management	IPCC 2022 [31]; The European Parliament and the Council 2020 [32]; Zhang et al. 2016 [8], Zafeiridou et al. 2018) [3]
	Sustainable agricultural practices	IPCC 2022 [31]; The European Parliament and the Council 2020 [32]; Falloon & Betts 2010 [18]
	Sustainable forest management	IPCC 2022; [31] The European Parliament and the Council 2020 [32]; Zhang et al. 2016 [8]
Green supply chain management (GSCM)	Eco-design, especially for efficient material use, biodegradability and recyclability	Abdallah & Al-Ghwayeen 2020 [34]; Benavente et al. 2019 [19]; Eltayeb et al. 2011 [35]; Hoek et al. 2020 [21]; IPCC 2022 [31]; Moroz et al. 2021 [20]; The European Parliament and the Council 2020) [32]
	Green purchasing, i.e. increasing the use of sustainably sourced services and renewable materials	Abdallah & Al-Ghwayeen [34], 2020; Eltayeb et al. 2011; IPCC 2022 [31]; The European Parliament and the Council 2020) [32]
	Collaboration with customers, through common projects and education campaigns	Abdallah & Al-Ghwayeen 2020 [34]; Eltayeb et al. 2011 [35]; Hoek et al. 2020 [21]
	Collaboration with suppliers	Eltayeb et al. 2011 [35]
	Green human resource management	Longoni et al. 2018 [36]; Molina-Azorin et al. 2021 [37]; Tang et al. 2018 [38], Shoukat et al. 2024 [5]

The criteria outlined in the table represent the vision of directions for green development in the tobacco industry collected from the main regulatory documents and scientific articles related to it. As the EU actively pursues the Green New Deal and related policy documents, second-level taxonomic criteria were chosen to strengthen sustainability reporting across industries. Only climate change adaptation was not separated, as it is more closely related to the social dimension. Instead, green supply chain management was highlighted, following insights from academic articles [5, 19–21, 31, 32, 34, 35]. Each objective has associated criteria specific to the tobacco industry; however, additional sub-criteria, such as soil health, the reduction of chemical inputs, and carbon sequestration, can also be included. In Table 1, the selected criteria represent the consolidation of the analyzed literature.

3- Research Methodology

This article attempts to create criteria by which the green development of the tobacco industry might be constructed. The Analytical Hierarchy Process (AHP) method is used to calculate weights for each of the criteria. AHP was introduced by Saaty [39] and is a method that builds a hierarchical structure and establishes relations within that structure via the pairwise comparison of criteria. Experts in the tobacco industry and green businesses were asked to rate any two criteria on a scale from 1 to 9, with 1 meaning that the criteria are of equal importance, 9 meaning the extreme importance of one criterion over the other, and the other digits representing intermediate values. With this method, a ratio between criteria can be established and weights, or importance, ascribed for each criterion. The first step when using the AHP method is to establish and define the problem. It is also important to determine what kind of knowledge the researcher is seeking [40]. Once these have been distinguished, the next step of the process is to create a hierarchical structure to present that problem. Generally, this means beginning with the main objective of the study as the first level of the structure, originating from the broad perspective, before then moving to the second level of criteria and focusing on specific aspects of the objective. If necessary, sub-criteria are then involved before eventually moving to alternatives that are compared as solutions to the established objective [40, 41]. The structure itself should be complex enough to accurately portray the issue at hand but also simple enough to be flexible and allow for changes along the way. Generally, up to 3 levels are recommended in a structure, and no more than 7 elements in each level [40].

The next step is to construct a matrix of pairwise comparisons of each element in each layer and cluster. The chosen experts were asked to rate each pair of elements on a scale from 1 to 9, thus establishing not only the dominance of one element over the other but also the relative intensity of that dominance. An overview of this scale is shown in Table 2.

Table 2. The list of criteria submitted for expert assessment

Intensity of importance on an absolute scale	Definition	Explanation
1	Equal importance	Two activities contribute equally to the objective
3	Moderate importance of one over another	Experience and judgment slightly favor one over another
5	Essential or strong importance	Experience and judgment strongly favor one over another
7	Very strong importance	An activity is strongly favored, and its dominance is demonstrated in practice
9	Extreme importance	The evidence favoring one activity over another is of the highest possible order of affirmation
2, 4, 6, 8	Intermediate values between the two adjacent judgments	When compromise is needed

The matrix is considered consistent when all of the elements hold:

$$a_{ij} = a_{ik} \times a_{kj} \quad (1)$$

AHP uses the priority vector $\omega = (\omega_1, \omega_2, \omega_3 \ldots \omega_n)$, derived from the pairwise comparison matrix (PCM). There are several methods to derive this vector, one of which is the eigenvector:

$$A_w = \lambda_w \quad (2)$$

where $\omega \sum_{i=1}^{n} \omega_1 = 1$ where $\omega_i \geq 1$ and $i = 1, 2, 3, \ldots, n$.

Each expert judgment was considered consistent only when $\lambda_{max} = n$, but also $\lambda_{max} \geq n$. To determine the consistency, the consistency index (CI) was used:

$$\mu = \frac{(\lambda_{max} - n)}{(n-1)} \quad (3)$$

To determine the consistency of the entire PCM, the consistency ratio (CR), which is the ratio between CI and random index (RI) value, was used:

$$CR = \frac{CI}{RI} \quad (4)$$

The requirement for a PCM to be considered consistent is for the CR value to be no more than 0.1, or 10%. This requirement is set so that the results are not trivialized, but some inconsistency is allowed for: without it, new knowledge cannot be created, as experience shows that understanding must be regularly revised to move knowledge forward [42].

The last step is to normalize the matrix and obtain the relative importance of each element according to the experts by using pairwise comparisons. This can be performed manually by adding up the value of each column to normalize it and then summing up the lines to obtain the relative weights. Instead, this study used the Microsoft Excel template prepared by Goepel [43]. This template has the advantage of not only providing the convenient presentation of pairwise comparisons but also offering a mechanism to correct inconsistencies in the experts' judgments. Once comparisons are completed, the template automatically calculates and informs the user regarding the current CR, so the expert can adjust their responses as they proceed through the survey, rather than having it returned to them afterwards for correction. This not only saves time but also provides more consistent evaluations as little time elapses between initial decisions and corrections. Lastly, Goepel uses a consensus index to measure the level of agreement between experts. The online tool created by Goepel [44] was used to make this calculation and evaluate the consensus (see Table 3 on how to interpret the consensus index). Additionally, the online tool also provides the possibility to conduct a cluster analysis of experts and divide them into more homogenous clusters with similar responses to the survey. This will also be presented in the results section of this paper.

Table 3. Interpretation of the consensus index

Below 50%	Very low
50% - 62.5%	Low
62.5% - 75%	Moderate
75% - 87.5%	High
87.5% - 100%	Very High

The task was then to distill this environmental mix of criteria and subcriteria into a green development trajectory for the tobacco industry by establishing relative weights for each component of the mix and removing less significant components from the model.

The number of respondents in AHP can vary significantly, from 3 to dozens [45], depending on the complexity of the problems and the availability of respondents. The respondents (see Table 4), in this study, can be divided into two groups. First are tobacco industry 'insiders,' with working experience in the tobacco supply chain and occupying positions that are, to a certain degree, directly involved in the decision-making process concerning environmental questions. These are experts 1–4. The second group are tobacco industry 'outsiders,' but with direct experience of researching or working with environmental issues in their jobs. These are experts 5–8. The first group was chosen so that the industry's views on the green transition are represented in the research. The second group was chosen to provide a different perspective on the challenges facing the tobacco industry.

Table 4. Summary of experts

Respondent	Company/Institution type	Position
Expert 1	Tobacco industry supply chain	Head of Quality and R&D
Expert 2	Tobacco industry supply chain	Head of Procurement
Expert 3	Tobacco industry supply chain	Global Product Development Manager
Expert 4	Tobacco company	Head of Procurement
Expert 5	University	Researcher
Expert 6	University	Researcher
Expert 7	University	Researcher
Expert 8	Bank	Analyst

The hierarchical structure will include two levels: stages of the supply chain, and individual criteria in each of the stages. The stages of the supply chain were used and criteria for each stage were established by combining criteria and adapting them, if necessary, to the specifics of the tobacco industry from Table 1. The entire hierarchy is provided in Table 5.

Table 5. Hierarchy in the assessment of the green development of the tobacco industry

Criteria of a green business model	Sub-criteria
Climate change mitigation	Generating or using renewable energy
	Increasing energy efficiency
	Increasing clean or climate-neutral mobility
	Increasing use of carbon capture and carbon storage technologies
	Strengthening land carbon sinks
	Green building technologies
Sustainable use and protection of water and marine resources	Safeguarding against hazardous wastewater in the environment
	Reducing the hazardousness of wastewater
	Developing a water management strategy to increase efficiency and reduce water intensity
	Sustainable use and protection of marine environments
	Using alternative sources of water
Transition to a circular economy	Using natural resources more efficiently
	Increasing recyclability of products, especially of cigarette filters
	Reducing the content of hazardous materials used in products
	Preventing or reducing waste generation
	Re-using and recycling water
Criteria of a green business model	Avoiding or reducing litter
Pollution prevention and control	Preventing or reducing pollution other than GHG
	Improving air, land and water quality where the economic activity takes place
	Preventing adverse effects of the use or disposal of chemicals
	Cleaning up litter and other pollution
Protection and restoration of biodiversity and ecosystems	Nature and biodiversity conservation
	Sustainable land use management
	Sustainable agricultural practices
	Sustainable forest management
Green supply chain management	Eco-design, especially for efficient material use, biodegradability and recyclability
	Green purchasing, i.e. increasing the use of sustainably sourced services and renewable materials
	Collaboration with customers, through common projects and education campaigns
	Collaboration with suppliers
	Green human resource management

First, the experts were asked to make pair-wise comparisons of level 1 criteria, i.e., establishing the perceived importance of each of the stages of the supply chain when considering mitigating the impact of a business on the environment. Afterwards, the same was done with level 2 criteria to indicate which specific methods are seen as most important. In addition to this, an alternative model was devised by exchanging the weights achieved during the pairwise comparison of level 1 criteria with the weights derived from the actual current impact each of the stages has on the environment. This was achieved using figures calculated by Zafeiridou et al. [3], shown in Table 6. This comparison allowed for a more comprehensive and accurate model to be built.

Table 6. Total annual environmental impacts of the global tobacco supply chain, in millions

Impact category	Unit	Farming	Curing	Processing	Cigarette manufacturing	Distribution	Use and disposal	Total
Climate change	kg CO_2 equiv	20849	44674	1073	15720	386	870	83572
Terrestrial acidification	kg SO_2 equiv	119	240	11	78	2.4	2.9	453
Freshwater eutrophication	kg P equiv	6.8	0.6	0.3	8.3	0.03	0.3	16
Marine eutrophication	kg N equiv	11	3.7	0.4	4.3	0.2	1.0	21

The difference here from the traditional use of AHP is that this research did not compare different alternatives according to the weights achieved during the process. Instead, the weights were used to propose a green development trajectory by providing guidelines for decision-makers on where and how to invest in greening the tobacco industry. Figure 1 presents the steps of the methodology outlined above.

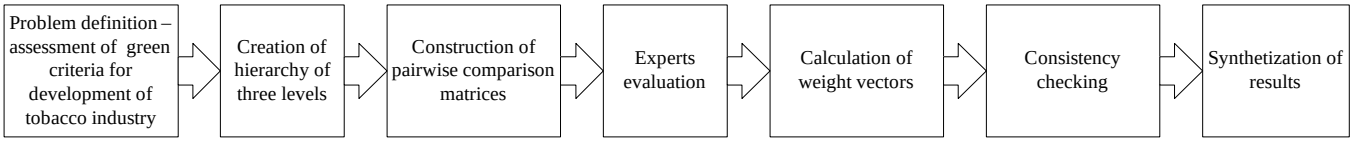

Figure 1. Steps of chosen methodology

4- Results and Discussion

The first level of the hierarchy, the goal, is the production of a significant environmental mix for the tobacco industry. The second level, as explained in the previous section, is composed of the five criteria from Article 9 of EU regulation 2020/852 and the additional GSCM criteria. The third and final level is composed of the sub-criteria presented in Table 5. The experts in the tobacco industry were asked to evaluate the sub-criteria of each cluster using pairwise comparisons and were then asked to perform the same comparisons on the main criteria. This sequence was chosen so that the experts would have a better understanding of each criterion and what constricts, or contributes to, it before making their decision.

The first cluster the experts were requested to conduct pairwise comparisons of was CCM. The experts judged that the most important subcriterion in this cluster was 'increasing energy efficiency,' marking its importance weight at 34.78%. This is to be expected considering the importance that most researchers place on energy efficiency, as it allows companies to make environmental gains without making substantial changes to their production processes or the types of materials used. The second most important criterion was judged to be 'generating or using renewable energy,' at 19.85%. This can be interpreted as a complementary component to energy efficiency, at least in the transitional phase until the economy fully switches to renewable energy. Finally, 'green building technologies' was judged to have an importance weight of 13.39%, 'increasing use of carbon capture and carbon storage technologies' 12.13%, 'increasing clean or climate-neutral mobility' 11.37%, and 'strengthening land carbon sinks' 8.48%.

Next was the WMR cluster. In this cluster, the experts decided that the most important factor was 'safeguarding against hazardous wastewater in the environment', with a weight of 31.50%. In the processing stage of the supply chain, 7.61 t of wastewater are emitted per 1 t of tobacco output, while during the manufacturing phase, the ratio is 1.5 t to 1 t of products [3], so the experts deemed this the most urgent topic to tackle. A connected issue regarding 'reducing hazardousness of wastewater' was seen as the third most important, with a weight of 21.01%. As a significant part of tobacco product waste eventually finds its way into marine waters, the 'sustainable use and protection of marine environments' component was given the second biggest weight in the WMR cluster of 22.78%. 'Developing a water management strategy to increase efficiency and reduce water intensity' was given a weight of 14.56%, and 'using alternative sources of water' 10.15%.

In the TCE cluster, 'reducing the content of hazardous materials used in products' was judged to be the most important component, with a weight of 28.20%. With many toxic and carcinogenic materials used in tobacco products, the need to reduce the amount of these materials used seems crucial. The second most important was 'preventing or reducing waste generation,' with a weight of 22.93%, reflecting the fact that the industry generates 25 million tons of solid waste every year [3]. 'Avoiding or reducing litter' came in third, with a weight of 14.48%; next was 're-using and recycling water,' with 12.46%; 'increasing recyclability of products, especially of cigarette filters,' with 12.33%; and 'using natural resources more efficiently,' with 9.61%.

The fourth cluster under consideration by the experts was PPC. The subcriterion 'improving air, land, and water quality where the economic activity takes place' was deemed to have the most positive impact on the environment in this cluster, with a weight of 35.58%. Second place was 'preventing adverse effects of use or disposal of chemicals,' which received a weight of 25.8%. 'Preventing or reducing pollution other than GHG' and 'cleaning up litter and other pollution' received weights of 21.26% and 17.38%, respectively.

In the next section, the experts were asked to perform pairwise comparisons of PRBE. By far the most importance was given to 'sustainable forest management,' with a weight of 47.41%. With around 5% of all deforestation attributed to tobacco growing (and even more if tobacco curing and other processes in the supply chain are included in this metric), its huge importance in this cluster is clear. The other two components that are tightly related—'sustainable land use management' and 'sustainable agricultural practices'—were' also considered to have similar importance, receiving weights of 21.57% and 20.95%, respectively. While still being important, 'nature and biodiversity conservation' was determined to be the least important factor of PRBE and was assigned a weight of 10.07%.

The last cluster in the third level of the hierarchy was GSCM. Two of the subcriteria in this cluster were considered more important than the others—'eco-design, especially for efficient material use, biodegradability, and recyclability' and 'collaboration with suppliers'—with' 34.89% and 29.49% of the importance weight, respectively. The weight given to the first component was due to the fact that all other stages of the value chain start with design, so designing from the start to ease environmental pressure at all stages is important. It is interesting that 'collaboration with suppliers' was judged to be much more important than 'collaboration with customers, through common projects and education

campaigns,' which received a weight of only 15.99%—almost half that of the former. This seems to hint at recognition of the pressure tobacco companies can apply to their suppliers as their clients and the difficulty of educating and engaging end consumers. 'Green purchasing, i.e., increasing use of sustainably sourced services and renewable materials' was judged to have a weight of 11.85%, while 'green human resource management' was assigned a weight of 7.77%.

Lastly, the experts were asked to perform pairwise comparisons on the second level of the hierarchy (see Figure 2). PRBE was judged to have the most importance over the effect of the entire tobacco industry on the environment, with a weight of 27.76%. Across almost all impact categories investigated in Zefeiridou et al.'s [3] study of the tobacco industry, the farming and curing stages—those with the most direct impact on ecosystems because of their intensive land and water use and deforestation—had the strongest negative effect on the global environment. CCM was judged to be only the third-most important criterion in the present study, with a weight of 17.34%. The second and fourth criteria in terms of relative weight were in a similar range to CCM: TCE with 19.28% and WMR with 16.52%. The criteria that received the lowest importance weight were PPC, with 11.06%, and GSCM, with 8.04%.

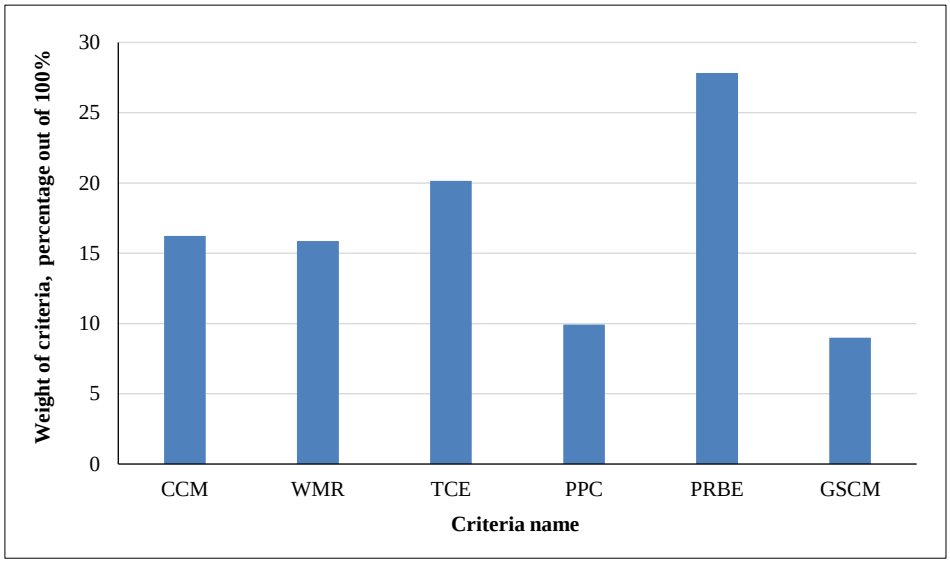

Figure 2. Weights of criteria

While the results of the survey are consistent—the aggregate consistency ratio (CR) is below 10% for every criterion and subcriterion—it seems the consensus between the experts was relatively low, averaging 58.7% (see Table 4). The most significant disagreements were on the subcriteria of TCE and PPC, followed by WMR and the second-level criteria. The issue in this case is not with consistency but with consensus, so any additional number of experts would not necessarily improve the level of consensus [43]. Because of this, the survey results can still be used as a 'consensus' result in the sense that they represent a compromise between differing points of view regarding green business development directions in the tobacco industry. Still, it is useful to consider whether there is a consensus between some of the experts. AHP group consensus cluster analysis shows that the experts can be divided into two groups (see Figures 3 to 5). Interestingly, three of the four industry insiders fall into one group, while the outsiders, along with one of the insiders, comprise the other. Those in the insider group seem to have put more emphasis on CCM and WRM, reflecting a view that the areas in which the tobacco industry can most improve are materials and energy efficiency. The outsider group, on the contrary, placed more importance on TCE and PRBE, thus on efforts to improve the circularity of products and their manufacturing processes and on sustainable land/forest management. This shows that there is an incongruity in the way that the industry sees its green transformation and how it is interpreted from the outside by researchers and those making investment decisions (Table 7).

Table 7. Breakdown of consistency ratios and consensus index

Cluster	CR	Consensus index
Criteria	1.6%	57.1% - low
CCM	1.1%	70.1% - moderate
WMR	0.2%	53.6% - low
TCE	0.4%	48.5% - very low
PPC	1.1%	42.5% - very low
PRBE	1.3%	72.5% - moderate
GSCM	0.9%	63.8% - moderate

0	2	8	6	5	7	4	3	1
2	100%	93%	89%	87%	87%	78%	78%	77%
8	93%	100%	85%	88%	83%	79%	77%	80%
6	89%	85%	100%	87%	81%	80%	82%	79%
5	87%	88%	87%	100%	86%	78%	74%	73%
7	87%	83%	81%	86%	100%	78%	75%	71%
4	78%	79%	80%	78%	78%	100%	94%	89%
3	78%	77%	82%	74%	75%	94%	100%	87%
1	77%	80%	79%	73%	71%	89%	87%	100%

Figure 3. Weights of criteria

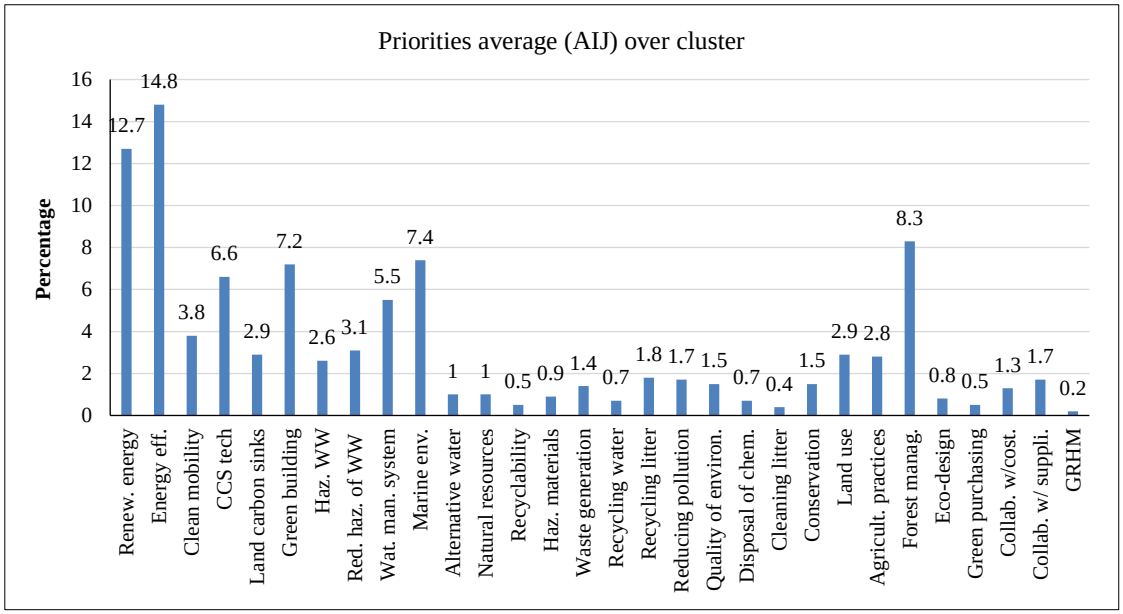

Figure 4. Priority averages of tobacco insiders (created using AHP-OS)

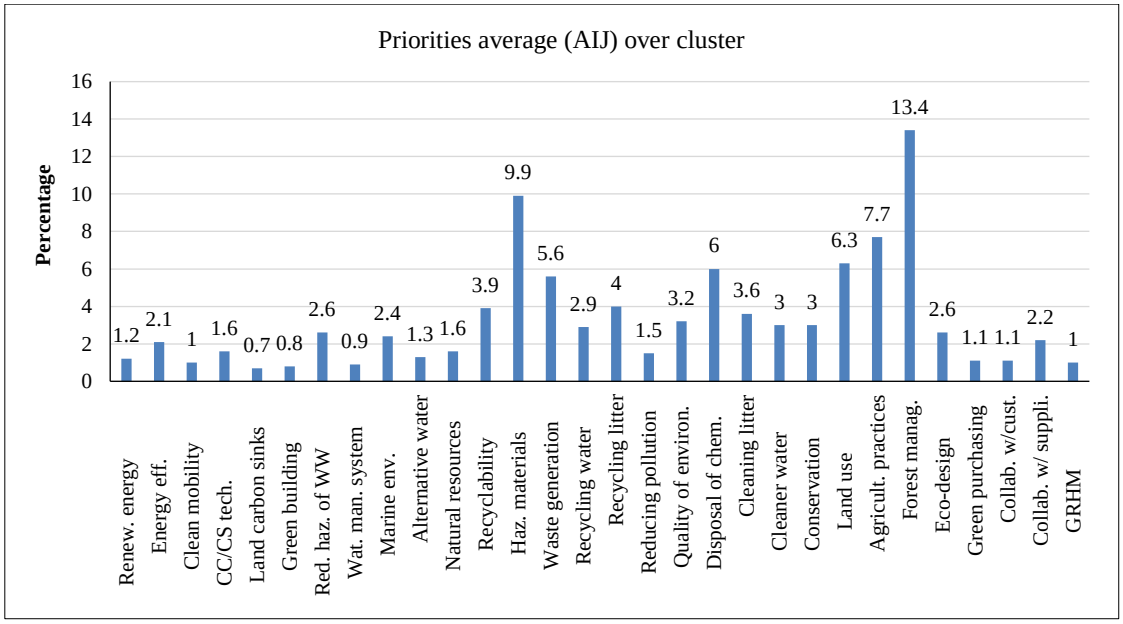

Figure 5. Priority averages of tobacco outsiders (created using AHP-OS)

Table 8 shows the same criteria and subcriteria. Here, the most important subcriteria are 'sustainable forest management', 'sustainable land use management', 'increasing energy efficiency', 'sustainable agriculture practices', and 'reducing the content of hazardous materials used in products'. The least important criteria are 'green human resource management', 'green purchasing', 'collaboration with customers', 'strengthening land carbon sinks', and 'using alternative sources of water'.

Table 8. Breakdown of consistency ratios and consensus index

Subcriteria	Global priority weight, %
Sustainable forest management	12.5
Sustainable land use management	6.5
Increasing energy efficiency	6.1
Sustainable agricultural practices	5.6
Reducing the content of hazardous materials used in products	5.4
Safeguarding against hazardous wastewater in the environment	5.2
Preventing or reducing waste generation	4.4
Improving air, land and water quality where the economic activity takes place	3.9
Sustainable use and protection of marine environments	3.7
Generating or using renewable energy	3.5
Reducing the hazardousness of wastewater	3.4
Nature and biodiversity conservation	3
Preventing adverse effects of the use or disposal of chemicals	2.9
Avoiding or reducing litter	2.8
Eco-design, especially for efficient material use, biodegradability and recyclability	2.8
Increasing recyclability of products, especially of cigarette filters	2.4
Re-using and recycling water	2.4
Preventing or reducing pollution other than GHG	2.4
Collaboration with suppliers	2.4
Green building technologies	2.3
Developing a water management strategy to increase efficiency and reduce water intensity	2.3
Increasing use of carbon capture and carbon storage technologies	2.1
Increasing clean or climate-neutral mobility	2
Using natural resources more efficiently	1.9
Cleaning up litter and other pollution	1.9
Using alternative sources of water	1.7
Strengthening land carbon sinks	1.5
Collaboration with customers, through common projects and education campaigns	1.3
Green purchasing, i.e. increasing the use of sustainably sourced services and renewable materials	1
Green human resource management	0.6

Although the data in Table 8 could be used as the final environmental mix for a green business model as all of the subcriteria are working towards the goal of improving the environmental performance of a tobacco firm, further streamlining is in order. To make the model more efficient, only significant activities should be included to lower the number of directions a firm focuses on. To do this, the least significant subcriteria were removed from the model. These criteria were determined by calculating the 1st quartile value of the data set, which in this case is 2.0. Anything below this value was considered not significant to the streamlined green business model. As such, the 5 least important subcriteria were removed. Additionally, 'cleaning up litter and pollution' and 'using natural resources more efficiently' also fell under this definition, so they were removed from the final model. All of the items removed are depicted with a grey background in Table 8. After normalization, the final set reduced the number of criteria in the least important group – GSCM – to only two: 'eco-design' (3.11%) and 'collaboration with suppliers' (2.67%). This meant that three subcriteria – 'green human resource management', 'green purchasing', and 'collaboration with suppliers' – were removed from this cluster, which was expected given its low importance in the overall model. On the other hand, the most important cluster retained all four of its subcriteria, with three of its subcriteria making it into the top four subcriteria overall – 'sustainable forest management' (13.89%), 'sustainable land use management' (7.22%), and 'sustainable agricultural practices' (6.22%). When looking towards the middle of the importance scale in the model, all four criteria groups lost one of their subcriteria: 'strengthening land carbon sinks' was removed from CCM, 'using alternative sources of water' from WMR, 'cleaning up litter and other pollution' from PPC, and 'using natural resources more efficiently' from TCE. In total, there were 30 subcriteria, of which 7 subcriteria were removed to streamline the scheme into a more efficient model featuring 23 significant subcriteria (Figure 6).

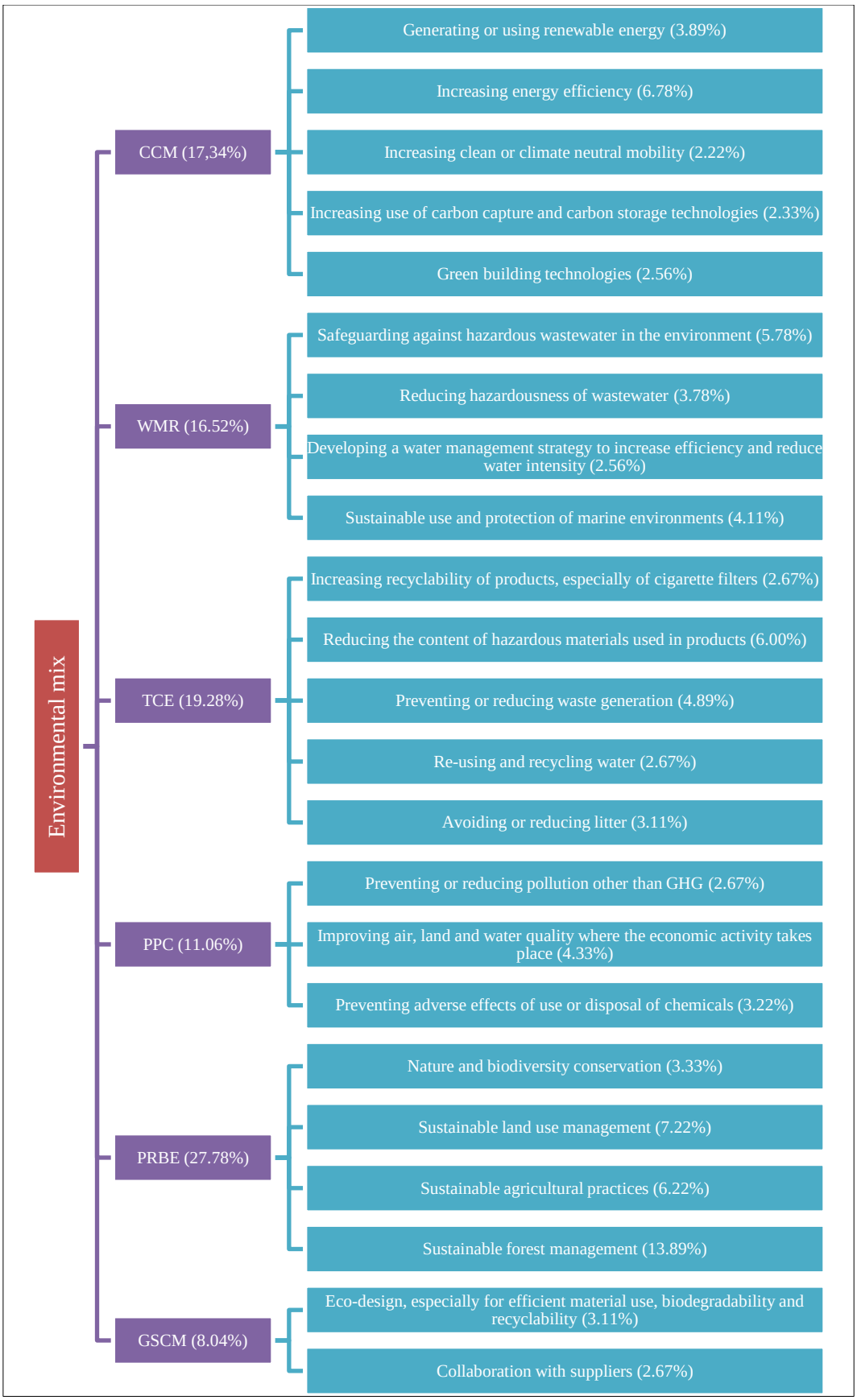

Figure 6. Final green business model for the tobacco industry

In this research, AHP serves as a robust decision-making framework for evaluating green criteria within the tobacco industry, facilitating a systematic approach to assessing green dimensions and guiding strategic decisions. The established hierarchy for green development in the tobacco industry is based on six groups of criteria, prioritized by selected experts in the following order of importance: protection and restoration of biodiversity and ecosystems,

transition to a circular economy, climate change mitigation, sustainable use and protection of water and marine resources, pollution prevention and control, and green supply chain management. According to our research results, this could be used to guide environmental investment directions for green development, as all of the subcriteria work towards the goal of improving the environmental performance of firms and their impact on the planet.

Negative perceptions of the tobacco industry in society will be hard to change. It is thus recommended that tobacco companies focus on where they can produce a positive impact: the environment. By selecting an appropriate environmental mix of policies and objectives, tobacco companies can get ahead of increasing pressures from consumers, investors, and regulators while maintaining their competitive edge.

The tobacco industry is globalized in more ways than one: almost three-quarters of the entire global market (excluding China) belongs to 4 big TTCs—BAT, PMI, JT, and IB. Because of this high level of concentration, much of the market belongs to companies whose operations span the entire planet. Moreover, the processes of the tobacco industry are global in terms of both their performance and impact. Most of the agricultural processes occur in developing countries such as Brazil, Zimbabwe, and Malawi, while manufacturing is widespread across all continents. Because of this, taking a global approach and tackling all stages of the entire industry is crucial in order to achieve a successful green transition.

5- Conclusions

The main group of tobacco industry processes consists of six stages: cultivation, curing, processing, manufacturing, distribution, and retail. The most environmentally harmful stage is curing, with 44,674 Mt of annual CO_2 equivalent emissions; second is cultivation, or farming, with 20,849 Mt of annual CO_2 equivalent emissions; third is manufacturing, with 15,720 Mt of annual CO_2 equivalent emissions. The environmental objectives set out by the EU are the basis for the criteria of green business development, as they provide a convenient general framework regarding what a business should strive for in order to be considered environmentally sustainable. The subcriteria for each of the criteria in this study were taken from the same source but were supplemented by industry-specific research and thus formed into clusters around the main criteria. Green supply chain management was added as an additional cluster to ensure that the model was comprehensive and included green managerial activities.

Using the AHP method, relative weights were distributed and green business directions were proposed. The experts deemed the protection of ecosystems and biodiversity to be the most important criteria in the environmental mix of green business development, with an importance weight of 27.78%. This demonstrates that experts recognize that the most harmful stages are related to agriculture and the curing of tobacco leaves. However, the relatively even distribution of the other criteria shows that one cannot discount any of them, and companies need to set aside resources for all criteria, albeit to varying degrees. Unsurprisingly, the most important of the subcriteria were identified in the PRBE cluster, with sustainable forest management (13.89% global weight), sustainable land use management (7.22%), and sustainable agricultural practices (6.22%) being in the top five most important subcriteria. These findings are fully consistent with the research of Zafeiridou et al. [3], who applied Material Flow Analysis to quantify the movement of natural resources and materials across the various stages of cigarette production and consumption, capturing both inputs and outputs. According to the authors, primary environmental impacts were associated with climate change, freshwater eutrophication, human toxicity, freshwater ecotoxicity, agricultural land occupation, natural land transformation, and metal depletion. It is no surprise that three of these indicators hold a prominent position in our study. Moreover, Falloon and Betts [18] also emphasized the importance of sustainable agricultural practices as critical factors.

Although GSCM was added as an additional criterion to ensure that the entire supply chain was taken into account in the model, the experts decided that it was the least important criterion and cluster of subcriteria. The prevailing view is that resources are better used in improving processes than engaging with suppliers (and customers especially, as this subcriteria was deemed insignificant). From a wider perspective, this approach might signal that companies should develop strategies by thinking not only about managerial tools and processes within the tobacco industry but also by considering their broader impact and taking a holistic view. This approach somewhat contrasts with studies that emphasize specific aspects such as green human resource management [5], the implementation of smart intelligence [8, 30], and various green management practices [22, 23].

The difference between how the industry is seen by industry insiders and outsiders was significant. Although both groups determined the protection of ecosystems and biodiversity to be important, the level of importance was much higher among outsiders. On the other hand, outsiders placed much less importance than insiders on climate change mitigation. One hypothesis that may arise from this is that insiders are unwilling to admit that the most significant damage the industry does is upstream of the supply chain or that they simply do not consider it their concern (especially given the low importance of GSCM). Another hypothesis is that insiders have more direct knowledge of the impacts of the industry's processes and can identify the best value per invested resource better than outsiders can, thus resulting in different priorities. Such conclusions align with basic economic logic: insiders also view sustainability as a means to enhance company profitability by focusing on material and energy efficiency, while outsiders adhere to stakeholder theory, which encourages companies to adopt a broader perspective and take greater responsibility for the well-being of the entire planet. This divergence needs to be studied in further research.

5-1- Limitation

The AHP method has its critics, especially regarding its accuracy when choosing the most suitable alternative with devised relative weights and corresponding ranks [46]. However, the method is suitable for this study. This is firstly because alternatives were not ranked in this study—only the right environmental mix for tobacco companies was established. Second, the immediacy of the adjustment of judgments allowed for the number of errors to be reduced. Lastly, AHP should not be considered the only and final tool to make decisions—it should be used in tandem with other methods or the judgments of final decision-makers, as was the case here.

6- Declarations

6-1- Author Contributions

Conceptualization, D.G. and G.L.; methodology, G.L.; formal analysis, N.S.; resources, G.L. and D.G.; data curation, M.B; writing—original draft preparation, D.G and G.L.; writing—review and editing, N.S.; visualization, M.B. All authors have read and agreed to the published version of the manuscript.

6-2- Data Availability Statement

The data presented in this study are available on request from the corresponding author.

6-3- Funding

The authors received no financial support for the research, authorship, and/or publication of this article.

6-4- Institutional Review Board Statement

Not applicable.

6-5- Informed Consent Statement

Not applicable.

6-6- Conflicts of Interest

The authors declare that there is no conflict of interest regarding the publication of this manuscript. In addition, the ethical issues, including plagiarism, informed consent, misconduct, data fabrication and/or falsification, double publication and/or submission, and redundancies have been completely observed by the authors.

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