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Competitiveness and sustainability in the paper industry: The valorisation of human resources as an enabling factor

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ABSTRACT

The concepts of green economy and circular economy are changing the strategies and operating practices of many companies, as the manufacturing sector must be able to strike a balance between technological challenges, sustainability demands, and digitization opportunities. This study focuses on the paper sector and aims to assess which actions could enable a company in the sector to be more competitive. The method used is multi-criteria decision analysis, and eight alternatives are compared (virgin fiber, recycled fiber, renewable energy, waste, wastewater, digitization, human resources, and customer relations) through a competitiveness indicator.

The results show that the criterion considered most relevant is health and safety, highlighting how the social sphere plays a fundamental role. Regarding competitiveness indicator, human resources management is seen as the most important parameter, showing how their valorization can be an enabling factor for a manufacturing company to be both sustainable and competitive. However, all the other combined alternatives can provide a winning mix. It emerges that only raw materials are of minor importance. Social changes affecting the paper industry both internally and externally reveal that underestimating this dimension of sustainability can be counterproductive. For this reason, eight different actions are proposed that can support green and competitive human resource management.

1. Introduction

A circular economy model aims to optimize the flow of material resources while minimizing waste. Conversely, a green economy approach extends the focus to include land, water, energy, and biodiversity management to ensure ecosystem resilience and human well-being (European Environment Agency, 2020). The Resource-Based View (RBV) theory, which holds that a firm's resources and capabilities can provide the basis for achieving sustainable competitive advantage (SCA), is the theoretical underpinning of the Natural RBV (Hart & Dowell, 2011). Green absorptive capacity and strategic environmental orientation facilitate eco-innovation, which can achieve SCA (Mady et al., 2023). Eco-innovation implies the integration of economic competitiveness with sustainable development and, thus, the rational and efficient use of natural resources (Dogaru, 2020; Ikram & Sayagh, 2023). Certain environmental practices, such as recycling, waste management, and sustainable innovation, can generate valuable, rare, inimitable, and irreplaceable advantages (Arsawan et al., 2022). In addition, stakeholder engagement is an order winner among sustainable strategies (D'Adamo, 2023). The circular supply chain is a key element in a systemic shift toward a decarbonization goal (Echefaj et al., 2024; Saccani et al., 2023), in a system where innovation plays a key role in green economy models (Ikram, 2022). Business performance management is a key topic in recent literature (Sassanelli & Terzi, 2023), and reshoring and nearshoring practices are gaining greater visibility (Fernández-Miguel et al., 2022).

The pulp and paper industry accounts for around 6 % of global industrial energy consumption and 2 % of direct industrial CO_2 emissions (Furszyfer Del Rio et al., 2022). In recent years, due to growing environmental concerns and the importance of sustainability, paper production has gradually reduced its use of virgin fiber, i.e., fiber from virgin pulp sources such as trees and plants (Danielewicz, 2023).

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Circularity in the paper industry represents a great opportunity to create a society based on a circular economy model, where materials are used efficiently, and waste is considered a valuable resource (Doddapaneni et al., 2022; González-González et al., 2022). The European Commission aims to achieve an 85 % recycling rate for waste paper by 2030. Paper is a material characterized by light weight, biodegradability, and mechanical stability, and it can be easily recycled (Rastogi & Samyn, 2015). Several research studies have shown that waste recycling significantly reduces greenhouse gas emissions (Deng et al., 2023; Qin et al., 2022). Recycled paper fibers from different sources show the potential for use in anaerobic digestion systems to produce energy (Hurst et al., 2023). A further advantage of circular models is the recovery of resources, such as energy, nutrients, and high-value chemicals, from wastewater (Han et al., 2021). Other analyses confirm that it is crucial to transform wastewater into a renewable and recoverable source of drinking water, energy, nutrients, and for other important applications (Angelakis et al., 2018). Creating synergies between the different stages of forest-wood value chains and developing solutions to improve customers' quality of life by offering durable and safe products with integrated service components is, therefore, strategic (Toppinen et al., 2017). In this regard, resource-efficiency benefits can come from the use of digital technologies (I. Costa et al., 2022) and the energy context (Lipiäinen et al., 2022). In addition, in this dynamic context, an aspect of increasing relevance concerns human skills and competencies (D. Costa et al., 2022; Mohammadi Nematabad et al., 2023; Shet et al., 2021). Skills are not simply limited to knowing how to do things but imply the development of capacities that enable one to achieve a competitive advantage, facilitating action in the social, economic, cultural, and personal spheres in an appropriate manner. This process transforms the individual into a professional who is able to adapt to environmental conditions and perform his/her work successfully (Amaris et al., 2022). Strategic decision-making is influenced by numerous human factors, such as the skills and capabilities of managers but also their daily routines (Wenger et al., 2022). Institutional and technological factors are considered the most critical for implementing multi-level supply chain sustainability to increase companies' competitiveness (Feng et al., 2023), and green quality is a competitive advantage that helps companies position themselves in the market. Factors driving the green paradigm are brand enhancement through the use of environmentally friendly materials and technologies, green product offerings and environmental protection (Nguyen, 2022). Producing paper recycling systems in a sustainable manner is strategic in order to reduce potential waste and meet customer needs (Yousefi et al., 2023).

Thus, a gap emerges in the literature where there is a need to update strategies to foster business competitiveness in the paper industry. Accordingly, the following research question (RQ) is identified:

- RQ - Identify different alternatives based on raw materials, energy, waste, water, digitization, human resources, and customer relations and calculate which one is the most effective to achieve the paper industry's competitiveness goals.

In fact, the competitiveness of the paper industry can be improved during the different stages of the life cycle, and this perspective implies adopting strategies and actions to reduce environmental impact, promote resource efficiency, contribute to responsible waste management, and evaluate the contribution of digital solutions and the role of human resources. In this regard, a multi-criteria decision analysis (MCDA) is applied, which, with the support of industrial experts, aims to assess the relevance of individual alternatives and provide managerial guidance to increase the competitiveness of paper companies.

The structure of the work is as follows. Section 2 proposes the methodological framework based on MCDA with the help of experts working in the paper industry. Section 3 describes the results from the AHP analysis and the identification of a competitiveness indicator comparing different alternatives. A discussion of the results allows us to elaborate on what emerges from this work (section 4). Section 5 shows the conclusions.

2. Materials and methods

MCDA is a decision support method for evaluating and comparing different alternatives when multiple criteria must be considered. This approach is widely used in the context of sustainability (Ahmad et al., 2023; Singh et al., 2022; Yalcin et al., 2022). The analytic hierarchy process (AHP) is a multi-criteria decision support technique and allows for prioritization based on expert preferences (Saaty, 2008). The objective of the work is to identify the alternative that most supports the competitiveness of a company in the paper industry. The product between a row vector (1, n) and a column vector (n, 1) will calculate this competitiveness indicator. The row vector represents the importance of the criteria, while the column vector reflects the value of the alternatives with respect to the individual criteria. The variable "n" indicates the number of criteria. The competitiveness indicator is described in this paper in accordance with the literature where several alternatives are considered in order to determine the one that performs best using an MCDA approach. In fact, there are several fields of application where this composite indicator can be calculated (Colasante et al., 2024; D'Adamo et al., 2023).

2.1. Description of alternatives

The business environment is characterized by increasingly intense competition, where companies are constantly seeking innovative ways to maintain or achieve competitiveness. In this context, strategic decisions play a crucial role in determining a company's long-term success. Particularly in the choice of alternatives, a special focus is assigned to the dimensions of sustainability, which is a driving force behind production models aiming at decarbonization within manufacturing sectors (Calabrese et al., 2021; Di Stefano et al., 2023; Vacchi et al., 2021). The choice of alternatives aims to cover the entire spectrum of business activities, from the procurement process to the delivery of the finished product to customers. Thus, this competitiveness can be enhanced whether in the pre-production, production, or post-production phase – Table 1. It is worth mentioning that both the alternatives and the criteria were validated by the head of the environmental department of a large and important company operating in the paper industry in Spain. This is a company that has achieved significant results in terms of sustainability, receiving awards. However, this choice is also a potential limitation given the subjectivity that could characterize this expert. Similarly, the choice of alternatives and criteria was made in accordance with the literature review but there is no work that provides a specific framework for this area. Consequently, an element of subjectivity also influences this choice.

Starting from the pre-production stage, competitiveness can be enhanced through the targeted use of specific raw materials. In the

Table 1
List of competitiveness alternatives.

Acronym	Alternative	Description
A1	Virgin fiber	Production with virgin fiber
A2	Recycled fiber	Production with recycled material
A3	Renewable energy	Energy efficiency/renewable energy production
A4	Waste management	Internal management of production waste
A5	Wastewater management	Internal process wastewater management
A6	Digitization	Automation and digitization of processes
A7	Human Resources management	Training and staff development
A8	Customer relations	Customer relationship management

context of this research, two types of raw materials were considered: the use of the traditional raw material, i.e., production with virgin fiber, derived from trees or plants, and the adoption of one of the alternative raw materials, namely, production with recycled fiber, from paper materials already used.

Three different options have been identified regarding strategies to improve competitiveness at the production stage. These include energy efficiency and renewable energy production, for example, through cogeneration (which simultaneously generates electricity and heat) or the installation of an energy enhancement plant to harness biomass through combustion or gasification processes. In addition, automation and digitization of processes with robots, sensors, and monitoring and control systems are considered, as well as automation for storage management and digitization of documents. Finally, investment in human resources is evaluated, which includes recruiting and retaining talent, developing skills through training courses, encouraging motivation and adherence to organizational culture, and managing change and adaptive flexibility.

Regarding the post-production phase, three other alternatives have been identified that can help increase business competitiveness. These include internal management of production waste through internal reduction and recycling practices, waste valorization, and collaboration with stakeholders to buy and sell recycled materials. In addition, the internal management of process wastewater was identified, through the implementation of efficient treatment systems that not only reduce and conserve water, but also enable the recovery of valuable by-products such as paper fibers that can be reused or sold or sludge from which, through anaerobic digestion, biogas is produced. Finally, customer relationship management through loyalty programs and active listening, clear and personalized communication, and pre- and post-sales support was considered.

Consequently, the choice of these alternatives enables us to take into account the entire product life cycle.

2.2. Description of the criteria

The choice of criteria is very important because it must be made in a way that best describes the alternatives. The number chosen was ten, as it was considered comprehensive and in accordance with what has been reported in the literature (D'Adamo et al., 2023) – Table 2. The criteria pay particular attention to the three dimensions of sustainability. Among the economic aspects, it is clear that a company must carefully consider the investment costs required to start a business and the costs incurred over time to maintain the business. In addition, opportunities to receive economic support from the government are a determining factor in choosing which initiative to undertake, as these result in significant savings for the company.

Table 2
List of criteria identified.

Acronym	Criterion	Description
C1	Subsidies	Government funding and aid in implementing the alternative
C2	Industrial ecosystem	Collaboration agreements with outside companies
C3	Social responsibility	Ethical and moral responsibility
C4	Health and Safety	Prevention of occupational hazards
C5	Environmental regulations	Compliance with environmental regulations
C6	Technological innovation	Technology improvement and optimization
C7	Product quality	Improvement of product quality
C8	Benefits from new market segments	Selling price of the product and additional economic benefits obtainable from the implementation of the initiative
C9	Operating costs	Costs of production, sales, advertising, maintenance, and administration
C10	Investment costs	Installation and implantation/ implementation costs of the initiative

In addition to economic aspects, social aspects also emerge. Social responsibility and the safety and health of employees are critically important elements to consider. It becomes clear that an initiative or project that generates negative social impacts, inconvenience to the community or endangers the health of workers will not achieve the desired success. Therefore, before starting any initiative, it is important to plan preventive measures, assess risks, and develop contingency plans and emergency management strategies. In addition to the economic and social aspects, environmental issues have become prominent in recent times. Increasing societal sensitivity to climate change is evident, and more and more customers are paying attention to the sustainability of the product they buy and the commitment of the manufacturing company. Complying with environmental regulations not only avoids potential penalties and fines, but can also improve corporate image and reputation in the eyes of customers, business partners, and the public.

However, other aspects of sustainability cover all dimensions and take other characteristics into consideration. The technical aspect of the product requires attention, and therefore technological innovation and product quality resulting from the adoption of the chosen initiative are included among the criteria considered. These aspects not only benefit the company by streamlining processes and increasing efficiency, but also have a positive impact on customers. New technologies enable customers to access better products with reduced wait times, thus helping to improve the overall experience. Increased opportunities to establish collaborative arrangements, facilitated by the identified initiative, is a vitally important aspect. In fact, such an increase means greater stability for the company by having appropriate partners in place when a decision is made to make an investment in a new project. Finally, it is necessary to assess the company's ability to strengthen its image within the current market segment but also the one into which it could move. Thus, it is necessary to evaluate both the direct benefits obtained from the activity itself, resulting from the determined selling price, and the indirect benefits, such as the sale of by-products or access to new markets.

Consequently, the choice of these criteria enables us to assess the main dimensions of competitiveness from a specific perspective aimed at the sustainable context.

2.3. Selection of experts and assignment of weights and values

The assignment of weights and values requires input from experts. In this regard, five distinct professional figures (electrical maintenance manager, process manager, utilities manager, production line manager, and laboratory manager) within the same Spanish company. The identification and selection of these five job profiles (Table S1) was proposed by the head of the environmental department, who considered them crucial to the objective of the research project and oversaw all the initial submission and communication stages. It is also interesting to note that two of these six profiles (if we include the head of the environmental department) are female. The results were aggregated while maintaining anonymity.

In the communication sent to the experts in May 2023, a detailed explanation of the methodology and objectives of the project was provided. Two distinct phases were identified. The first involved assigning weights to the criteria, where in the Excel sheet the value of the consistency index (CR) was calculated. The CR measures the strength of the judgments made by the experts. This assessment of importance (weighting) is done by assigning a number of points from a predefined scale (1–9) in accordance with (Saaty, 2008) – Table S2. It is worth noting that all completed questionnaires reported a suitable CR, as they did not exceed 0.10. The second step involved assigning values and the range 1 (worst) – 10 (best) was used (D'Adamo et al., 2023). For each alternative, the experts were asked to indicate how much that particular criterion could contribute to conferring an effective competitive advantage. Unlike in the previous step, there are no control steps on the

quantitative input from the experts.

3. Results

This section proposes the row vector (section 3.1) and column vector (section 3.2) in order to calculate the competitiveness value (section 3.3).

3.1. Row vector - aggregation of weights

The first step in this analysis of the results is to aggregate the different weights assigned by the experts (Tables S3–S7), and the AHP results are then obtained as an equally weighted average of the different contributions – Table 3.

The following acronyms are used: E1-E5 are the experts.

Analysis of the results reveals an almost unanimous consensus among the experts (four out of five) regarding the importance of criterion C4, i.e., employee safety and health, which reaches an average value of 0.242. The motivation concerning this aspect is relevant to Sustainable Development Goal (SDG) 3, as clearly, no company wants accidents or dangerous situations for its employees, yet not all companies place this aspect at the top of their pyramid. A social dimension that makes workers the beating heart of the company's sustainable process.

On the other hand, the other expert gave greater prominence to economic criterion C8, which has a mean value of 0.154 and is thus far from the first position. Once again, it is important to highlight the relationship with the SDGs. In fact, we can see how SDG 8, focused on decent work and economic growth, embraces both criteria at the top of the list. This happens because a company that wants to gain a significant competitive advantage needs to pay attention to its employees' safety and economic aspects, such as profitability and growth, which can contribute to the broader goal of business competitiveness and prosperity. This result is also explained by the fact that the experts refer to the same company, which has placed such criteria at the center of their work agenda. Indeed, it is no coincidence that it is a recipient of the "Corporate Commitment to Health and Safety Improvement" award within the Confederation of Paper Industries. This corporate philosophy is based on the principle that personal learning finds its greatest satisfaction in organizational learning. In third place in the ranking, we find an environmental criterion (C5) and in fourth comes another social one (C3), which combined with the previous two contribute about two-thirds of the total weight. It is also worth noting that there is homogeneity in the experts' opinions even with regard to the criterion of least importance (C1), which has an average value of 0.021. Thus, the range between the two extremes of the criteria appears to be consistent and equal to 0.221. This criterion refers to subsidies, i.e., government funding and aid for the implementation of alternatives. This motivation may be found in a different cultural approach in which more attention is given to the free market than to the choices that governments may offer markets by providing subsidies.

3.2. Column vector - aggregation of values

The second step of the analysis is to aggregate the different values that the experts gave to all alternatives according to the specific criterion considered (Tables S8–12). Table 4 proposes the average value of these values. It is also worth observing the distribution of values, from which it appears that about 66 % of the values are within the range 6–10 with the peak (21 %) recorded for value 8 – Fig. S1.

Analysis of the results shows a convergence of the experts in assigning alternative A1 (virgin fiber) the lowest value for all criteria except C7. This fact is not coincidental: the use of virgin fibers is of crucial importance in achieving paper bulkiness. Unlike recycled fibers, virgin fibers help create a thick and strong paper while maintaining a low bulk. This approach results in a high-quality paper with a superior opacity.

Another convergence emerges in the experts' responses. Alternatives A2, A3, A4 and A5 are characterized by the predominance of criterion C5, which indicates compliance with environmental regulations. This coincidence reflects the high degree of environmental sustainability that these practices embody, along with sensitivity to climate change. Consequently, any company undertaking the implementation of one of these options should direct its attention to environmental regulatory compliance and the resulting opportunities. Within the paper industry, benefits in terms of reputation and credibility are evident. This

Table 3
Vector row.

	Criteria	E1	E2	E3	E4	E5	Row vector
C1	Subsidies	0.017	0.015	0.030	0.017	0.025	0.021
C2	Industrial ecosystem	0.023	0.046	0.019	0.076	0.030	0.039
C3	Social responsibility	0.159	0.155	0.046	0.115	0.118	0.118
C4	Health and safety	0.294	0.299	0.115	0.293	0.207	0.242
C5	Environmental regulations	0.180	0.157	0.059	0.129	0.133	0.131
C6	Technological innovation	0.037	0.036	0.128	0.068	0.048	0.063
C7	Product quality	0.039	0.074	0.052	0.194	0.058	0.082
C8	Benefits from new market segments	0.106	0.115	0.282	0.025	0.241	0.154
C9	Operating costs	0.069	0.081	0.135	0.044	0.066	0.079
C10	Investment costs	0.078	0.023	0.135	0.039	0.074	0.070
			Min weight			Max weight	

Table 4
Vector column.

	A1	A2	A3	A4	A5	A6	A7	A8
C1	3.2	6.4	8.0	7.2	6.2	7.6	5.8	3.4
C2	2.4	4.0	6.0	5.0	4.2	6.8	5.8	8.0
C3	2.8	7.0	7.4	8.4	7.8	5.4	8.8	7.6
C4	4.4	6.0	6.0	7.2	6.2	6.2	9.6	6.8
C5	4.0	7.6	8.6	9.2	9.4	5.8	6.2	5.6
C6	4.4	5.4	7.4	5.8	6.2	9.2	7.4	5.6
C7	6.2	5.6	6.2	6.2	6.8	8.0	8.2	7.8
C8	4.6	6.0	7.4	6.2	6.2	8.0	6.2	7.2
C9	5.0	5.2	6.6	6.6	6.6	7.2	6.8	6.0
C10	4.6	5.4	6.0	5.6	6.0	6.6	7.8	7.6
		Min value			Max value			

The following acronyms are used: A1 = Virgin fiber; A2 = Recycled fiber; A3 = Renewable energy; A4 = Waste management; A5 = Wastewater management; A6 = Digitization; A7 = Human resources management; A8 = Customer relations.

translates into the enrichment of corporate reputation in the eyes of consumers, business partners and investors, resulting in increased trust and credibility of the company in the market. In line with this, we observe that for alternatives A2, A4, and A5, the second most relevant criterion is C3, which refers to social responsibility showing the strategic nature of ethical vision within paper companies (Pratoomsuwan & Chiaravutthi, 2023). Alternative A5, which relates to wastewater recovery, sees its highest score awarded precisely to criterion C5 since this showed good practices that enabled the transformation of this problem into a resource (Haq et al., 2020). Regarding criterion C1, on subsidies, alternative A3 stands out since the ecological transition associated with energy issues appears to still be tied to public intervention (Colasante et al., 2024).

On the other hand, with regard to alternative A6, which concerns digitization, a benefit in terms of technological innovation is suggested (C6). The introduction of new technologies, such as artificial intelligence, the Internet of Things or robotic automation can make it possible to automate previously manual processes. The adoption of digital solutions may be a natural progression as companies seek to take advantage of new technologies to improve efficiency, reduce human error, and optimize operations.

Another very relevant fact is that digitization can pave the way for access to new markets and customers. A company that aims for long-term growth ensuring the stability of natural resources and the supply of raw materials, cannot ignore the opportunities of automation for process efficiency. The experts reward alternative A6 by assigning it the highest value in three criteria, and this is repeated for alternative A7 in four criteria. Not surprisingly, under this alternative (staff training and development), criterion C4 gets the highest score related to employee well-being. With a score of 9.6, which is the absolute highest of all the scores obtained, this criterion emphasizes how employee training and development also include the technical and professional skills needed to effectively manage occupational safety and health. Employees must be able to understand and apply regulations, procedures, and practices aimed at minimizing the risks of accidents, injuries, and harm during work activities. This competency requires a thorough knowledge of laws, regulations, and preventive measures, as well as safety protocols. Often, such knowledge is provided through training provided by the company itself, as is the case in the company in which our experts are employed.

3.3. Competitiveness value

The final stage of the analysis involves the aggregation of the weights and values obtained in the previous stages. The main objective of this analysis was to identify the most suitable alternative for improving competitiveness within a paper industry company. From the product between the row column vector (Table 3) and the column vector (Table 4), the MCDA value for each of the alternatives was calculated – Fig. 1.

The results obtained, shown in Fig. 1, indicate that the first-ranked alternative, A7, is found to be the most beneficial, with an MCDA score of 7.71. Human resource management is gaining in importance as society and industry are experiencing a digital transition that has emphasized the risk of losing sight of the importance of human resources amid an overemphasis on technology. Indeed, the European Commission has stressed the need to pay more attention to the human dimension (Ammirato et al., 2023). This can help create a more inclusive, individual-oriented and sustainable world that will be able to meet future global challenges with resilience (Henderson, 2021). In addition, the fourth industrial revolution is redefining the way people work, learn, lead, manage, recruit, and interact with each other (da Silva et al., 2022). Some analyses show the correlation between adopting innovations in human resource management practices, innovativeness, and gaining competitive advantage in small and medium-sized enterprises (Wongsansukcharoen & Thaweepaiboonwong, 2023). Human resource management is recognized as a key element in improving business performance, attracting top talent, and developing a distinctive corporate culture, thereby creating a sustainable competitive advantage (Hoon et al., 2019).

It is worth pointing out that the competitiveness value of alternative A7 is strongly influenced by the fact that the value assigned to this alternative for the most relevant criterion (C4) is not only the highest value among all, but is also numerically much higher than all other

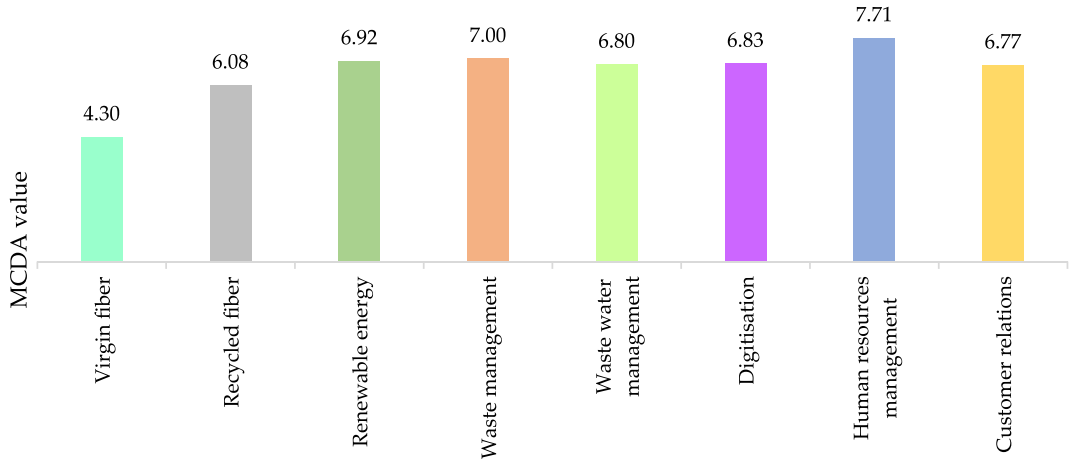

Fig. 1. Competitiveness value.

alternatives.

Returning to the analysis of the results obtained, we can see that in second place in the ranking of alternatives is "Internal Management of Production Waste" (A4), obtaining a score of 7.00. Interestingly, there is a significant gap of 0.71 between this alternative and the one in first place, whereas the gap between the second alternative and the sixth is only 0.23.

The paper industry generates large quantities of waste, including paper cuttings, dust, and other materials. Managing such quantities can require dedicated storage space and additional resources, while waste disposal can incur significant costs, especially if it requires specialized treatment processes. In addition, if not properly managed through recycling and reuse practices, waste can have a negative environmental impact. Paper companies must comply with strict environmental regulations regarding waste management, and noncompliance can lead to legal penalties and damage corporate reputation. A factory that aims to operate efficiently must turn waste management challenges into opportunities and strengths to gain a competitive advantage (Puyt et al., 2023). Reducing costs leads to greater company profitability, and this sustainable management enables access to specific markets and partnerships with other companies.

Finally, it is evident that all alternatives, with the exception of alternative A1, have achieved a sufficiency level. This significant gap (of 0.71) can be attributed to the ongoing change in the global landscape, with a growing concern for the environment and an increasing focus on sustainability. In this regard, the current context sees governments and industries engaged in reviewing production practices involving the use of natural resources. For example, in the Italian paper industry's latest environmental report of 2022, it appears that the use of recycled fiber has significantly surpassed the use of virgin fiber. Thus, experts point out that focusing on virgin fiber-based production clearly proves to be uncompetitive. Therefore, it is imperative to adopt more eco-friendly approaches to remain relevant and aligned with the needs of modern society.

The MCDA disaggregation analysis allows us to assess which criteria most affect the outcome – (Fig. S2 and Table S13). The first four criteria of the AHP (Table 1), namely C3, C4, C5 and C8, have a predominant impact on the result as they contribute to more than two-thirds of the total score obtained for alternative A7 (66.6 %). This relevance of these criteria also occurs for the other alternatives: 63.5 %, 59.6 %, 53.6 %, 59.8 %, 56.9 % and 54.5 % for alternatives A4, A3, A6, A5, A8 and A2. Criterion C4 ranks first in all alternatives. Furthermore, criterion C5 ranks second in alternatives A2, A4 and A5, while it ranks third behind criterion C8 in A3 and A6. On the other hand, it ranks fourth, with C3 and C8 as the second most relevant criteria in A7 and A8 respectively. Finally in order to give robustness to the results obtained, an alternative scenario was considered, in which the criteria were assigned equal importance – Table 5.

The results show that alternative A7 retains first place in both scenarios, although its value decreases (7.26 vs. 7.71). This figure is expected considering that its main contribution came from criterion C4. This determines that the difference between first and second place is less marked and equal to 0.18. The second place is occupied by alternative A6, which advances from fourth place, swapping its position with alternative A4. The other positions in the ranking, however, all remain unchanged. This confirms that, even in this scenario, alternative A1 remains significantly distant from being the winning choice for improving business competitiveness. However, alternative A2 also has a value below 6.

4. Discussion

Sun Tzu declared that "strategy without tactics is the slowest route to victory. Tactics without strategy is the noise that precedes defeat." Thus, strategy indicates the destination and the way in which one wants to reach a point, while tactics indicate the specific actions that need to be taken along this road. Adam Smith's concept of the invisible hand has been replaced by the sustainable hand, which shows that one must consider the interest of all categories of stakeholders and not just shareholders (D'Adamo, 2023). According to this model, the company envisages a system in which internal and external components interact continuously, and these flows can generate competitive advantage as well as destroy it. In this way creativity promotes sustainability (Saleh & Brem, 2023) and circular economy models play a strategic role (Sassanelli et al., 2023). Sustainability has entered the agenda of everyday life (Dubey et al., 2017; Martínez-Falcó et al., 2023); however it is not

Table 5
Ranking of alternatives with equal or different weights.

Ranking	MCDA value (Different weight)		MCDA value (Equal weight)	
1	A7	7.71	A7	7.26
2	A4	7.00	A6	7.08
3	A3	6.92	A3	6.96
4	A6	6.83	A4	6.70
5	A5	6.80	A5	6.56
6	A8	6.77	A8	6.56
7	A2	6.08	A2	5.86
8	A1	4.30	A1	4.16

The following acronyms are used: A1 = Virgin fiber; A2 = Recycled fiber; A3 = Renewable energy; A4 = Waste management; A5 = Wastewater management; A6 = Digitization; A7 = Human resources management; A8 = Customer relations.

always applied correctly and therefore, where the ideological aspect prevails over the pragmatic one, there is the risk of the spread of sustainability washing (Biancardi et al., 2023). The idea is that consumers are becoming increasingly mature about these issues and will therefore reward those companies that implement such choices. A limitation of this work is the chosen panel of experts belonging to an industry where sustainability was already applied. This aspect, however, is also a strength as it shows how companies that have implemented sustainability principles define their strategic goals.

Human resources are a focal point for the goals of competitiveness and sustainability. Organizations should promote green employee behavior and implement green human resource management practices (Farrukh et al., 2022). Benefits also emerge within technological and industrial development through strategic collaboration between multiple actors, knowledge sharing and change leadership (Mukhuty et al., 2022). Some authors pointed out that the social sphere was not well investigated in circular economy models (Mies & Gold, 2021); our study shows that training and staff development are basic. The manufacturing system moves toward innovative goals when it places emphasis on the green-circular premium and sustainable certification (Appolloni et al., 2022).

Several actions can support green and competitive human resources management:

- organization model;
- training courses based on the concept of continuous improvement;
- attracting new talent;
- internalization;
- involving university students in internships;
- risk prevention activities considered as core and not secondary;
- sharing values on environmental protection; and
- combining personal and organizational learning.

However, these actions need to be extremely pragmatic. Human resources, viewed as unique individuals, exhibit characteristics, expectations, and motivations that can vary significantly. The theoretical complexity arises precisely from this diversity and the challenge of foreseeing and managing the multiple facets of human nature. Human variability is clearly evident in team dynamics. People can react differently to the same stimuli, and a wide range of factors, including personal motivation, family situation, health status, and many other unpredictable variables, can influence their performance. Managing this diversity can be extremely complex, requiring a flexible and adaptable approach.

The difficulties in practical application stem as much from the inherent unpredictability of human resources as from the fact that the human contribution in companies is multifactorial and often escapes linear evaluation. Skills, creativity, leadership, problem-solving abilities, and other crucial attributes are challenging to translate into a precise monetary measure, complicating the process of attributing individual value in an organizational context. However, it is precisely this human variety and complexity that fosters innovation, creativity and resilience within organizations. The challenge of monetizing or quantifying the human contribution in companies calls for a balanced and adaptable approach. Developing metrics and indicators that reflect the complexity of human dynamics is essential for a conscious and sustainability-oriented business management.

The results of this work indicate that sustainability also requires other contributions, since the strategy of a manufacturing company is to be competitive and to ensure a balance with ecosystems, thus with an ethical perspective. The tactic to achieve this is to enhance resources and competencies by evaluating not only human resources, but also digital contributions and those coming from effective management of energy and material resources. Regarding this, one should not forget the role of technological development, which can be crucial in achieving certain goals (Lamperti et al., 2023; Rejeb et al., 2021), although green finance is also able to support this change (Kumar et al., 2023, 2022). This work has also highlighted the relevance of circular models with a view to recovering the waste produced and reusing it in order to reduce dependence on suppliers, creating and developing models of industrial symbiosis in which potential profits can be made from resources that seemed to have exhausted their value within their transformation in the production process. Green economy models, and the related use of renewable energy, make companies less dependent on the grid and thus favor decentralized models. The other three alternatives that follow in the ranking seem to be disconnected from each other, but in reality, from a business model perspective, they reveal a mature manufacturing model that, on the strength of its history, has been able to integrate with the changes coming from the outside world and has made them pillars of its corporate structure. Having implemented green and circular strategies has enabled them to be ahead of the times and ready to offer green value. This value results from initiatives coming from the digital and automatic world that make some processes faster and therefore cheaper; the recovery of wastewater that could represent a serious environmental problem, and the relationship with customers who are made protagonists of this change.

This work has some limitations. The experts interviewed belong only to the industrial side and the considerations made were modelled on a large enterprise. In fact, the results might change when considering small and medium-sized enterprises. Similarly, it would be interesting to assess the concept of sustainability within companies according to their background (recent or less recent) in order to observe whether divergences exist. In addition, it would be appropriate to investigate the correlations between different alternatives in order to provide a more dynamic picture of the strategies adopted.

5. Conclusions

Business competitiveness is one of the primary objectives for any company. In a dynamic economic context, it is essential for companies to be competitive to ensure their survival. Organizations that possess this characteristic are able to exploit more opportunities for expansion, conquer new markets and attract new customers.

The results of this work show that the criterion considered most relevant is health and safety, preceding the benefits from new market segments, environmental regulations, and social responsibility, which together with health and safety account for two thirds of the total weight. The value of competitiveness sees the emergence of the alternative of human resource management, which emphasizes how essential the human sphere is in the pursuit of business success through sustainable tactics. Similarly, corporate success occurs when other initiatives in terms of waste management, renewable energy, digitization, wastewater management and customer relations. The use of raw materials seems to play a less important role, but this may have been due to two circumstances: i) an industrial reality in which the use of alternative raw materials is now a given and not a goal to be achieved, and ii) the presence of two alternatives that both refer to the same topic depreciating its contribution.

Redesigning industrial systems to support systemic change toward a sustainable circular economy requires the contribution of multiple actions and managerial approaches based on quantitative analyses that consider the entire life cycle. In a framework in which interdisciplinarity plays a key role, the role of human resources seems to be essential to foster industrial ecosystems.

This study can be replicated in other manufacturing contexts. Social change is considered the order winner of any company that wants to pursue profits but also has an ethical vision. In this context, the human sphere is to be valued and various initiatives are proposed to promote green human resource management. The company can implement green and circular models, paying attention to effective resource management, ecosystem resilience and human well-being.

CRediT authorship contribution statement

Julieth Almanza Floyd: Writing – review & editing, Writing – original draft, Methodology, Data curation, Conceptualization. **Idiano D'Adamo:** Writing – review & editing, Writing – original draft, Supervision, Methodology, Data curation, Conceptualization. **Samuel Fosso Wamba:** Writing – review & editing, Writing – original draft, Methodology, Data curation, Conceptualization. **Massimo Gastaldi:** Writing – review & editing, Writing – original draft, Methodology, Data curation, Conceptualization.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

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Appendix A. Supplementary data

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