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Life cycle assessment as an enabler of an environmental sustainability strategy evolution amid institutional pressures: A best practice from the furniture industry

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ABSTRACT

Europe's furniture industry is facing burgeoning pressures that are reinforcing one another. With climate change undermining supplies, regulatory bodies imposing further constraints, and a steep increase in prices, the industry is being drawn into a vicious cycle. This study explores how masterfully embracing the Life Cycle Assessment (LCA) tool can help internalize Life Cycle Management (LCM) through receptive organizational learning (OL), ultimately facilitating companies in this industry to unravel this vicious cycle. The research demonstrates how, through a longitudinal single-case study of an Italian furniture company, employing mixed methods. Data span in-depth interviews with key personnel, including top managers and front-line workers, on-field observations, secondary data, and technical analyses related to products' LCA to the two company's flagship products (wood and laminated office desks). As a result, the company not only introduced solutions for raw material efficiency and packaging optimization but also amplified these effects by upgrading their entire production strategy. As a result, the company's strategic outlook has now been redesigned in accordance with LCM principles.

1. Introduction

Global challenges such as climate change, pollution, and biodiversity loss present companies with wicked problems, leading to internal and external tensions (Grewatsch et al., 2021; Burke and Wolf, 2021a). Climate change, for instance, has led to more unpredictable weather patterns, disrupting the supply of raw materials such as timber. This is particularly problematic in regions that depend on forests vulnerable to fires, pests, and droughts. Additionally, regulatory bodies like the European Environment Bureau (EEB) are imposing stricter environmental constraints, requiring companies to adopt sustainable practices and meet rigorous carbon reduction goals (EEB, 2022, 2017). For example, manufacturers now face tighter rules regarding waste management, the use of eco-friendly materials, and the reduction of emissions during production processes. Compounding these challenges is a steep increase in raw material and energy prices, largely driven by geopolitical factors and inflationary pressures. Indeed, furniture industry has been significantly impacted by rising costs since 2021, due to factors such as raw material shortages, supply chain disruptions, and increased post-pandemic demand (Statista, 2024).

As a result, many companies are caught in a vicious cycle where compliance costs rise, but margins shrink due to supply chain instability and higher production costs.

Companies strive to reduce environmental impact and increase efficiency through internal tools and practices (Miroshnychenko et al., 2017). Recent efforts focus on involving various actors in value chains to identify collaborative solutions for sustainable and circular products and services (Piila et al., 2022), since the linkage between green product strategy and financial performance has already been proved (Kim et al., 2022), as well as its overall competitive advantage (Lichtenthaler, 2021).

Among the number of ways through which companies can pursuit a sustainable business model redesign, digitalization stands at the forefront of the recent studies (Acciarini et al., 2022). However, such a transition towards a more sustainable business model has even been propelled by other technological tool like the Life Cycle Assessment (LCA).

LCA is pivotal in assessing environmental impacts of products and services (Araújo et al., 2019). As circularity increasingly becomes common ground for competition among companies, LCA serves as a benchmark for measuring circularity performance. Research highlights the strong link between LCA and circularity, particularly in construction

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(Incelli et al., 2023), while LCA-based indices effectively assess the impact of circularity strategies on environmental performance at meso- and macro-levels (Bastianoni et al., 2023). LCA also supports standards like ISO 59020 and UNI 11820:2022, providing clear criteria for evaluating resource efficiency and material circularity (Palomero et al., 2024). As a result, then, LCA plays key role in enhancing competitiveness through measurable progress toward sustainability.

No wonder, then, demands arise for LCA's adaptation to even more ambitious uses (Costa et al., 2020) igniting the spread of lifecycle-based managerial approaches, particularly Life Cycle Management (LCM) (Bianchi et al., 2022). LCM proves more effective, incorporating environmental, economic, and social aspects of products, processes, and organizations.

LCM is an integrated concept for managing the total life cycle of goods and services toward a more sustainable production and consumption. LCM is applicable for industrial and other organizations demanding a system-oriented platform for the implementation of a preventive and sustainability-driven management approach for a product service system.

Previous studies have recognized Organizational Learning (OL) as an essential factor influencing knowledge management processes, such as knowledge acquisition, creation, storage, transfer, and utilization, positively (Turulja and Bajgorić, 2018). Besides, based on the previous studies' results, these effective implementation processes positively affect sustainable organizational performance (Abbas, 2020).

However, since parameters in LCA may vary significantly across different product categories (Konradsen et al., 2024; Subramanian et al., 2012), the managerial effects on a broader scale can also vary considerably. Therefore, case-specific approaches are required through case studies (Cherubini et al., 2018).

The study, then, is designed to explore *how an organizational learning process can aid enterprises in embedding life cycle management practices by building on their experiences with life cycle assessment.* This investigation delves into the connection between learning processes and the adoption of sustainable management practices within organizations.

Starting from this concept, our research introduces the ECOFURNY case study, an Italian furniture company that, beginning with an LCA, adopted an LCM approach through OL. The company embarked on a pathway (from 2017 to 2022), following an "internalization" trajectory where LCA spread throughout the entire organization, reaching top-tier management. This led to the adoption of LCM, which encouraged managers and workers to shift towards a new life-cycle-oriented mindset and reshape the company's strategy accordingly. Through a four-phase framework described in the results section, the ECOFURNY case study offers a unique understanding of how OL played a functional role in embedding LCA insights across the organization, driving the adoption of LCM in the furniture industry. The applied method is the longitudinal single case study that allows to detect changes in the organisation during the process of life cycle concept internalization. ECOFURNY case study reveals drivers and barriers met in the LCM implementation process and the achieved outcomes. The research reveals the support that the OL provides in this process to fully sustainability internalization.

2. Literature review

2.1. LCA as a foundation for a more objective environmental sustainability

LCA has emerged as one of the most comprehensive tool for analysing the potential environmental impacts of products and services. The depth and objectivity of its informative power are indisputable, as much as the European Commission has heralded LCA as the "best tool currently available to assess products' environmental impacts," leading to its widespread adoption across various sectors for calculating environmental footprints and developing strategies for environmental sustainability (European Commission, 2023; Bianchi et al., 2021). Its undisputable benefits as a tool have led to its inclusion among the International Standards for Organizations (ISO 14044:2006).

Specifically, LCA is increasingly applied to circular economy, for example in combination with material circularity indicators to assess circular product strategies (Niero and Kalbar, 2019). Aling this line, research has started investigating the companies' path from LCA to circular economy (Zilset al., 2022). Indeed, recent study shows as the set of LCA-based indices of circularity are able to detect the effects of circularity/symbiosis strategies on the environmental performance of meso- and macro-systems (Bastianoni et al., 2023). And the same linkages between LCA and circularity are confirmed in further research on a sector as complex as building (Incelli et al., 2023).

Additionally, LCA can support the requirement of ISO 59020 standard or Italian UNI/TS 11820:2022, helping organizations identify how effectively they are minimizing resource use and optimizing the circular flow of materials. These standards provide the requirements to the circularity performance of an economic system that can be objectively, comprehensively and reliably measured by indicators and complementary methods as LCA (Palomero et al., 2024).

Companies, then, use LCA to compare different stages of supply chains, pinpoint the most impactful phases, and communicate their overall environmental performance to stakeholders (Chaves and Alipaz, 2007; Del Borghi, 2013). By integrating circularity and environmental impact indicators, LCA enables a holistic assessment of resource use and emissions across the lifecycle. Salvi et al. (2023) illustrate this through a case study on photovoltaic panel recycling, where coupling circularity (In-Use Occupation Ratio) and environmental (Global Warming Impact) indicators via Multi-Criteria Decision Analysis (MCDA) demonstrated how circular strategies reduce resource consumption and climate impacts. Similarly, Luthin et al. (2023) applied a Circular Life Cycle Sustainability Assessment (C-LCSA) framework to carbon-reinforced concrete (CRC), revealing both environmental benefits and trade-offs, such as increased human toxicity and higher costs during early development stages. These studies highlight LCA's critical role in driving circular economy innovations and balancing sustainability dimensions, while advocating for further robust, holistic assessments. However, there are certain pitfalls that, if not handled properly, could prevent LCA from realizing its full benefits.

Indeed, despite its widespread use, the LCA community faces challenges in expanding the tool's application to include societally relevant indicators such as biodiversity loss and ecosystem quality, which are often excluded or poorly integrated (Martin et al., 2018; Van der Giesen et al., 2020).

Furthermore, there is a pressing need for ongoing education to ensure the tool's proper application, underscoring the need for a strategic management approach that accounts for environmental impacts beyond organizational boundaries. On this point, recent research on furniture industry (Michelsen et al., 2023) has shown that LCA was used for product improvements based on hot spots detected through the analyses, and also to generate Environmental Performance Declarations (EPDs) for products. The implementation of these new procedures was integrated into the organisation's strategic work through certified Environmental Management System (EMS).

2.2. The benefits of a managerial approach drawn on LCA principles

LCM adopts a holistic strategy towards environmental sustainability, emphasizing the extension of corporate environmental management across the entire product lifecycle, or from "cradle to grave." This approach is grounded in the principles of supply chain management, which hold manufacturers responsible for the environmental, economic, and societal consequences of their products (Fava, 1997; Remmen et al., 2004; Jensen, 2009). LCM necessitates organizations to extend their environmental considerations beyond their immediate operations to mitigate environmental impacts throughout the product life cycle (Linnanen et al., 1995; Heiskanen, 2002; Hunkeler et al., 2003; Power,

2009). The LCM perspective has been described as moving beyond the traditional focus on individual production sites and manufacturing processes to encompass the environmental, social and economic impact of a product over its entire life cycle, i.e. from the extraction of the raw materials to the end of the product's life (Remmen et al., 2004; Bey, 2018).

Specifically, LCM integrates circularity metrics with LCA to measure sustainability and guide transitions to circular business models. Recent literature review highlights the value of combining LCA with indicators like material efficiency and social considerations to evaluate trade-offs and foster eco-innovation, ensuring both environmental and economic sustainability (Basile et al., 2024).

Therefore, LCM is implemented not just to achieve short-term business success but to guide companies toward long-term results, and sustainable value creation across for itself, along its value chain and eventually across its industry. This is demonstrated, for example, in extensive research on the bakery industry (da Rocha et al., 2023). It is no wonder that this approach requires a holistic view and a full understanding of the interdependence between companies in order to support relevant decisions and actions to improve environmental performance, so as to enhance both the environmental sustainability component and the social and economic component (Tessitore et al., 2024). The three main criteria related to LCM (Klaver and Jonker, 2000) are:

1) the principle of responsibility, not only from a legal point of view, but in an ethical and social sense;
2) the principle of the circularity of the economy, which should inspire the re-insertion into production and consumption cycles of everything that is removed from them, as waste;
3) the principle of cooperation between the actors of the value chain and between them and the other stakeholders.

Transitioning from LCA to LCM requires more than the mere adoption of LCA; it demands the integration of a life cycle perspective into all business facets, a process that is supported by both quantitative and qualitative research into how LCA can support decision-making and facilitate the adoption of LCM (Freidberg, 2014b; i Palmer et al., 2011; Bey, 2018). Nonetheless, LCA provides LCM with a structured, standardized starting point for such a transition. By integrating methodologies such as Waste Flow Mapping (WFM), recent research reveals that LCA supports decision-making by quantifying resource consumption, emissions, and waste generation in fashion industry while identifying sustainability hotspots (Rehman et al., 2024).

The path to sustainability integration starting from LCA, however, requires substantial changes as other research demonstrated (Lu et al. , 2022). Supporting this, cross-sector research involving furniture have investigated the linkages between LCA and LCM, concluding that the use of LCA can lead to reconceptualization of product systems and renovated priorities for improvement options (Basile et al., 2024; Coelho and McLaren, 2013). Although the connection between LCA and LCM is widely acknowledged at the management level, a blind spot still exists regarding the organizational factors bridging the two.

2.3. Translating LCA principles into holistic managerial approach: the role of OL

The role of OL in transitioning from LCA to LCM is critical for internalizing environmental sustainability practices within an organization. OL "is a process through which experience performing a task is converted into knowledge, which, in turn, changes the organization and affects its future performance." (Argote et al., 2021). Several studies have explored the connections between OL with either LCA or LCM, demonstrating how OL can aid in spreading life cycle perspectives within organizations (Gond et al., 2012; Siebenhüner and Arnold, 2007; Wijethilake et al., 2018).

More specifically, recent research has inquired at the crossroad of LCA and organizational dynamics. Gofferetti and colleagues (2020), for instance, shed light on the linkage between LCA and OL by presenting a framework that describes the engagement process inside and outside the organization while LCA has been carried out. Further scholars have brought to life what is knowns as the "Organizational LCA (O-LCA)", which is a methodology that allows compilation of the inputs, outputs, and environmental impacts of the activities associated with an organization according to a life cycle approach (Martínez-Blanco et al., 2020). By elaborating on that, others have embraced the Social Organizational Life Cycle Assessment (SO-LCA), breaking it down into its main parts while focusing on wine production in Italy, for instance (D'Eusanio et al., 2020).

On the other hand, literature connecting OL and LCM is prolific as well. Bianchi et al. (2022) meticulously address the role of OL in spreading the awareness of institutional pressure across the organizations and, eventually, to bolster LCM. Specifically, shreds of evidence from Bianchi and colleagues (2022) a pointed at a "system thinking mindset" as a main driver to embed LCM practices in their strategy and operations regarding SMEs. Firms that successfully institutionalized LCM in their strategy and operations incorporate their business partners in their activities, new product design or developing new logistics options (Bianchi et al., 2022; Ny et al., 2006). Moreover, the LCM supports the knowledge development through innovative and collaborative activities (Nilsson-Lindén et al., 2019). Testa et al. (2022) detect the environmental improvements and the organizational awareness raising on sustainability emerging in some Italian companies where LCM is internalized. They even identified the barriers, internal and external, setting this process back. For instance, lack of information and data (Testa et al., 2016), lack of resources (Bey et al., 2013; Sánchez et al., 2004), technical difficulties and lack of internal management support (Sánchez et al., 2004).

At this point, since OL is crucial for transforming experiences gathered from ad-hoc product environmental assessment projects — specifically, LCA — into innovative organizational dynamics, it seems reasonable to incorporate OL within the LCA-LCM dyad. So far, none of the studies have outlined the trajectory of the organizational learning process that spans from LCA to LCM. Therefore, to the best of our knowledge, understanding how OL leads the organization to translate LCA principles into LCM, specifically in relation to the peculiarities of the furniture industry, remains an area that deserves exploration. This is encapsulated in the following research question:

RQ: How does an OL process support the enterprise in the internalization of LCM by drawing on LCA experience?

3. Method

To investigate our research question, we conducted a longitudinal single case study using engaged scholarship. The choice of a longitudinal single case study method was made to analyze how and why our case successfully implemented a new approach to sustainability management, contributing to the theory as a result (Eisenhardt, 1989). In this analysis researchers repeatedly examine the same individuals, events, activities, and choices to detect changes over time (Yin, 2003). Engaged scholarship was employed to best serve the purpose of the analysis, allowing for the collection of information at the broadest and finest-grain levels possible, spanning key informants within the company as well as internal documentation. Such a participative form of manager-researcher collaboration allowed us to study the complex issue at hand in the most effective way (Van de Ven, 2007). This methodology was suitable for our research project focused on the adoption of LCM, a long and slow process. Such methods are best suited for our inquiry as they allow us to follow the learning process (Eckstein, 1975) and draw logical deductions regarding organizational changes aimed at adopting a holistic approach like LCM (Flyvbjerg, 2006).

3.1. Case study selection

The case study selection followed a stepwise process, made out of two stages. In the first stage, three context criteria were employed to identify the industry. In the second stage, four additional criteria related to the LCM process were used to select the sample of companies. The three criteria for the field selection included: (i) context, (ii) transferability, and (iii) the learning process (Yin, 2003): (i) the furniture industry covers a main role in the European industry. Italy is the second Member State in the furniture export in EU market. Furniture supply chain includes 73.000 companies where 311.000 people work and it is an one of main sector for national economy (data source Federazione Legno Arredo, 2019); (ii) the Italian furniture sector, through its trade sectoral association (Federazione Legno Arredo – FLA), plays an active role in the European Federation (EFIC) by promoting the transferability and scalability of Italian initiatives in Europe mainly concerning the sustainability management. (iii) Furniture sectoris strongly committed in sustainability and circular economy issues (Susanty et al., 2020) and the learning process of the Italian furniture sector conducted during the LIFE EFFIGE project was very much participated by companies and workers, with a much more significant involvement than in the other sectors involved.

In the second stage aimed to case study selection, four criteria related to the LCM were applied: (a) continuity in performing LCA studies, (b) introduction of eco-design principles, (c) adoption of new technologies, and (d) implementation of marketing strategies (Bianchi et al., 2022). By following along the rationale of the stage prior to this, we applied these further four selection criteria on the context of the furniture industry. Its attention to reducing environmental impacts and implementing LCA-based tools as demonstrated in research and reports has increased sharply lately (EESC, 2022; Furn, 2018; Hoxha and Jusselme, 2017; Bianchi et al., 2021). Moreover, the scarcity of evidence regarding the internalization of life cycle principles in the furniture organizational model and the prominence of Italian firms in the European furniture industry's turnover has definitely made us focus on such industry (Bianchi et al., 2022; Testa et al., 2022; Cherubini et al., 2018; Statista, 2021).

The choice of an individual case study was the result of a funnel selection process using purposive sampling (Campbell et al., 2020), which unfolded as follows. Italian firms in the furniture industry were deemed the most suitable for this study, considering factors such as convenience, accessibility, and the support provided by the sectoral trade association. The trade association played a key role in the case study selection process. We started from a sample of about 2000 Italian furniture companies affiliated with the trade association, identified as experienced in sustainability management practices (e.g., Environmental Product Declarations (EPD), Life Cycle Assessment (LCA), ISO 14001, and EMAS). Among the 2000 companies, 42 had implemented EPD and/or LCA, in addition to having an environmental management system registered under EMAS Regulation 1221/2009 or the ISO 14001 Standard. Of these, 12 companies expressed their willingness to participate in the European-funded project LIFE EFFIGE (Environmental Footprint for Improving and Growing Eco-efficiency) following the request of the trade sectoral association, FLA. The authors of this study aimed to support all these companies in adopting the Product Environmental Footprint (PEF) methodology based on LCA. However, among expressing willingness to participate in LIFE EFFIGE, only four were willing to measure their environmental footprint, while the others focused solely on training initiatives. And ultimately, among them, only 1 company was selected as the case study —the organization that demonstrated the highest level of commitment and participation. To maintain anonymity, the selected company was assigned the fictitious name ECOFURNY.

By checking these further four stages, a case study company stood out to us, demonstrating ideal characteristics for in-depth analysis on nurturing LCA principles to foster LCM. The company showcased a longstanding commitment to environmental sustainability, engaging in certification schemes and implementing innovative tools.

3.2. ECOFURNY and the main features of the products involved in the research

ECOFURNY is a small business (54 employees, revenue 22 mln in 2018) based in Milan, Italy, specializing in the production of office furniture for international brands. ECOFURNY is an Italian interior design company founded in the 1969. Company involves around 180 workers and is primarily concerned with large orders in office furniture, which it exports to Europe and many other countries around the world. Its sustainability journey began in 2015 with LCA and commenced the implementation of PEF in 2017, setting in motion an internalization process of LCM.

The ECOFURNY office desks (laminate or wood) are its main products. They are equipped single desks with a very simple and accurate structure. The details are few and light. The metal structure consists of under-top rails and shaped aluminium legs and is equipped with a special fastening system that allows the various elements to be positioned according to different requirements. Office desk is realized in wood or laminate.

The functional unit for the PEF study is a product unit corresponding to a single-seat office desk. The product is identified in the NACE/CPA Rev.2 classification under code 31.01 Manufacture of office furniture and, more specifically, 31.01.11 Metal furniture of a kind used in offices. So summarizing the functional unit is:

- A Provides a work surface in an office environment.
- 1 office desk
- Desk life 15 years
- The office desk satisfies the requirements of EN 527-1 and EN 527-2.

The reference flow is an office table supplied with its packaging. The system boundaries considered in the study include all phases of the desk life cycle, from cradle to grave.

Empirical evidence was supported by technical and quantitative data, including product environmental footprint based on LCA and performed using the PEF Method (Rec. CE 179/2013).

3.3. Data collection

The case is built upon close collaboration between the authors with key managers within case study company and Italian sectoral trade association and was built via mixed sources of data, qualitative and quantitative. We collected multiple in-depth interviews, conducted on-site visits and observational research, and got access to public and private company documents. We used different types of sources to triangulate our findings using cross-checks (Eisenhardt, 1989; Yin, 2003). The main sources of data collection were:

1) through researchers' direct observation during in site visit or meetings. From 2017 to 2021, ECOFURNY gathered in 14 meetings (in person or online). To collect observational data, researchers enacted diverse observer roles throughout the project. Observational data were collected in the following settings and involved all research team included as authors: (i) during technical project meetings, training initiatives with company and/or trade association; (ii) during so-called "coordination meetings" between researchers, ECOFURNY and the other project partners; (iii) during sectoral events, where the research team and ECOFURNY were invited to participate.
2) Materials produced within the LIFE EFFIGE project (e.g. research reports, PowerPoint slides, project deliverables etc.), materials collected from company (e.g. internal documents, report, excel data etc.). We collected information through desk research based on

various sources, either directly – related to the organization – or indirectly – related when they had to do with their industrial field or macro-economic setting.

3) Data for the PEF implementation was collected through a checklist that for each product phase required the main inputs for the functional unit office desk. ECOFURNY completed the checklist in the 2018 for the first PEF and in 2021 for the comparative assessment.
4) Interviews with managers and researchers. Five rounds of in-depth interviews were conducted across the five rounds, involving nine interviewees of which six managers of ECOFURNY (environmental manager, CEO, quality manager, one manager from R&D and the supply chain manager) and three researchers. Following a structured interview protocol, three researchers conducted interviews. All interviews were held by web in Italian from 2017 to 2021. Each interview followed a different protocol whose goals were detecting the changes for the LCM adoption and contribution of OL to this process. Interviews were audiotape recorded and transcribed verbatim. In total, we performed five interviews (average duration 1 h and 12 min), ranging from 15 to 35 min, and obtained approximately 20 pages of transcripts. Each researcher sent a case study report for transparency purposes (Bansal and Corle, 2011; Gioia et al., 2013). We then compiled all the reports to make a new, exhaustive one, following a predefined format, which we sent to the firm to be checked for transparency purposes (Bansal and Corle, 2011; Gioia et al., 2013). Finally, we included data from environmental assessment analyses, for which we applied the PEF method and processed by SimaPro® software in 2018 and 2021, respectively.

3.4. Data analysis

Phase 1: Data organisation and the exploration of the ECOFURNY development linked to LCA. The first phase of data analysis was to develop a narrative of the project over the 3-year experience through desk work (Jarzabkowski et al., 2019). By researching data such as meeting minutes, power point slides, company reports, project deliverables, online meeting recordings, emails, and cell phone messages, the authors directly involved in the project reconstructed a detailed chronology of project activities applied with company and the research activities carried out. This phase allowed tracking changes by ECOFURNY to integrate the life cycle (LC) concept and improve their own products. This phase includes the PEF data analysis. PEF quantitative results consolidate the qualitative evidences emerged from the interviews and the observations.

The software used for LCA is Simapro 8.5.2.0 (employing calculation method ILCD, 2011 Midpoint+ 1.10.) This software allowed to compare the environmental footprint of two office desks and identify the main significant impact categories throughout their entire lifecycle. By comparing this with the concomitant organization changes has allowed us to find connections between environmental improvements and the internalization process of the LCM.

As a methodological reference for PEF is the May 2018 version 6.3 of the European Commission's PEFCR Guidance on the drafting of category rules for assessing the environmental footprint of products (PEFCR Guidance) was used, excluding all those parts applicable only on products already covered by sectoral PEFCR. All deviations to PEFCR Guidance 6.3 were made based on previous versions of the PEFCR Guidance and the judgement of technical experts.

Phase 2: Identifying the key OL stages through which LCM internalization unfolded.

In the second phase, we coded five rounds of interviews with ECOFURNY managers and the researcher, along with other sources of information. Qualitative text analysis was conducted using a thematic approach (Schulz, 2012; Kuckartz, 2014). The transcripts of interviews were systematically evaluated through axial coding, resulting in 1st order codes, 2nd order themes, and overarching aggregate dimensions (Strauss and Corbin, 1998; Gioia et al., 2013). Through axial coding, we identified codes from open coding and refining them to the status of categories derived from the relationships between the codes. After the axial coding process, we have a handful of categories, supported by subcategories, carried out from the codes analysis. The coding process involved assigning codes to relevant data sections related to key research questions. Around 48 1st-order codes emerged, which were further condensed into 13 2nd-order subcategories and finally 4 aggregate categories (Appendix A1 and A2). Figure n.1 represents the axial code results. The four aggregate dimensions summarizing the process development by ECOFURNY to apply the LCM: a) The aggregate dimension *"Drawing on LCA"* summarises how starting from LCA study the sustainability and the life cycle concept direct the company's commitment for the environmental improvements. Qualitative data from the interviews and the results the PEF studies were combined to describe the ECOFURNY process to LCM; b) The dimension "*Trigger a process of identity change"*, includes the drivers and the pressure that encourage ECOFURNY in the LCM adoption". Here again, the PEF results confirm the company's commitment and conviction, which emerged from the interviews, to implement a strategy based on life-cycle logic and sustainability; c) The aggregate *dimension "Reshuffling organizational tasks"* summarises the changes achieved in the organization through the LCM adoption; d) The aggregate dimension *"Reconfiguring business strategy"* dimension summarises the role of OL in the adoption of LCM and its support to merge LCM with the safety and health needs.

Figure n. 1 shows the adopted research process.

4. Results

4.1. Context overview: GPP and customers' request for life-cycle-backed certifications

ECOFURNY embarked on the adoption of LCM driven by LCA insights. The company's focus on sustainability and the need for environmental performance information prompted the application of LCM, particularly in response to customer preferences and LEED or EPD certification requirements and following the new knowledge on the positive opportunities related to life-cycle logic. The company's managers expected improved reputation, marketing opportunities, and economic value as LCM adoption would consolidate trust with customers, satisfy data requests and improve the supply chain approach. The transition from LCA to LCM proved effective, with ECOFURNY implementing practices reducing raw material usage, increasing company effectiveness and streamlining manufacturing processes. This integration led to organizational changes, enhanced communication and knowledge transfer with stakeholders increased employee awareness of sustainability and mainly changing the internal decision-making processes introducing a more participative and shared model.

Identity change was even prompted by both external and internal drivers. Initially, ECOFURNY business strategy aimed to reduce the natural resources input and increase the company's environmental efficiency. At the same time the company's managers have emphasized the need to affirm ECOFURNY as sustainability leader in office desk furniture sector demonstrating its environmental commitment. So, the efficiency needs to be combined with the external pressures for better information on product environmental performance from suppliers and customers has encouraged the company to apply an LCM approach. Additionally, the mindset changes and the increasing of LC' knowledge among the ECOFURNY managers allows to start the LCM adoption process.

ECOFURNY mainly operates in business-to-business areas and with interior designers. From these stakeholders emerged the main external pressures concerning the need of environmental data on office furniture. Recently, large buyers (companies and public institutions) and retails introduced requirements on the environmental performance for furniture products; the customers, mainly from the USA (12,5%), select furniture products with the LEED certification that encourage the use of

products and materials for which life-cycle information is available. So, for ECOFURNY, requests for technical data on the product environmental performance of are increasingly frequent.

Additionally, public institutions through the Green Public Procurement (GPP) have represented another driver to ECOFURNY environmental commitment. The product's compliant to GPP criteria has represented a significant business opportunity. By starting from these external pressures (blues square in Fig. 2), the internalization process through which ECOFURNY has consolidated its LCM is depicted as a pathway divided into four phases (dark grey rounded-corners rectangles in Fig. 2); each of them was detailed in the following sub paragraphs. Fig. 1 explains the adopted methodology in the longitudinal case study research.

4.1. Drawing on LCA

ECOFURNY's strategic realignment toward environmental sustainability, anchored in the insights drawn from a LCA conducted in 2018, has led to transformative changes across the organization. The LCA results, identifying key impact categories and process stages with the highest environmental impacts for office desks made of wood and laminate, have informed significant shifts in operations, design, and supply chain management. Notably, the PEF study highlighted that the most relevant life cycle stages cumulatively contribute more than 80% to each impact category for both products. Climate change emerged as a significant impact category, with the "components" phase (mainly Aluminum-machining components) and the "use and maintain" phase for the laminate version contributing most to this result.

In response, ECOFURNY has undertaken strategic product ecodesign, optimizing company efficiency through operations optimization, and improved environmental criteria in supplier selection. These measures include adopting sustainable components and packaging, reducing raw materials, replacing energy-consuming machinery, and streamlining assembly processes. Moreover, ECOFURNY has focused on packaging reduction for the laminate version of the office desk and integrated environmental criteria into the choice of suppliers, highlighting an organization-wide commitment to sustainability.

Drawing on LCA, indeed, has become a cornerstone for ECOFURNY in embedding sustainability into its operational ethos, guiding the company through three significant areas: selection criteria for providers based on sustainability, integration of environmental sustainability in the design stage, and strengthening the eco-innovation process.

The foundation of ECOFURNY's approach lies in the principle that: "The choices are based on data from the LCA study" as cited by CEO. This philosophy not only prioritizes sustainability as a selection criterion but also ensures that operational decisions, from the ground up, are informed by environmental impact assessments. Such a data-driven strategy underscores the importance of LCA in identifying and implementing changes that align with sustainability goals.

In the realm of design and construction, ECOFURNY has placed a premium on collaborations that prioritize environmental consciousness. The company asserts, "Working with environmentally aware architects and workers is a priority for our company and the adoption of LCA has supported ECOFURNY in this process" as confirmed by R&D manager. This approach emphasizes the integration of environmental sustainability at the design stage, ensuring that projects are conceived with ecological considerations at their core.

Lastly, the company's environmental ethos extends to its supply chain management. The supply chain manager: "We have environmental criteria when choosing suppliers, where we go for water-based paints, etc. For the company, environmental impact is now criterion in the choice of partners (suppliers, distributors, customers, etc.) that guides us in our selections and purchases" declared supply chain manager. This statement underlines the comprehensive impact of LCA in fostering a sustainability-driven culture within ECOFURNY, influencing decisions across the spectrum of its operations, from design to supply chain management.

4.2. Trigger a process of identity change

Triggering a process of identity change within a company, particularly in the context of environmental sustainability, involves a multifaceted approach centred around consolidating corporate environmental image, developing a collaborative approach to sustainability, and changing the company's relations with its stakeholders. ECOFURNY's journey exemplifies how these concepts are not just theoretical ideals but actionable strategies that lead to tangible outcomes.

Firstly, consolidating the corporate environmental image is crucial in a market that increasingly values green features and high environmental performance. ECOFURNY recognizes this shift, as reflected in the statement by CEO, "The international market is increasingly interested in office furniture with high environmental performance and green features. Customers ask us for scientific data and reports on product environmental performances before purchases and we must be able to give it. So, our LCA has this goal" explained the environmental manager. This approach not only responds to customer demands but also enhances the company's image and competitiveness by aligning with ethics and social responsibility, which are "essential to its long-term profitability", as cited by environmental manager.

Developing a collaborative approach to sustainability is the second pillar, emphasizing the importance of engaging with various stakeholders. ECOFURNY's engagement with its trade association and suppliers illustrates this principle: "We frequently held meetings with our trade association on sustainability and our process on environmental sustainability started with the association involving us in various initiatives and interesting projects. Our suppliers are now familiar with LCA and have experienced this methodology, which they see as a tool to improve trust and collaboration among stakeholders" (as cited by CEO). These actions foster a culture of cooperation and shared goals towards

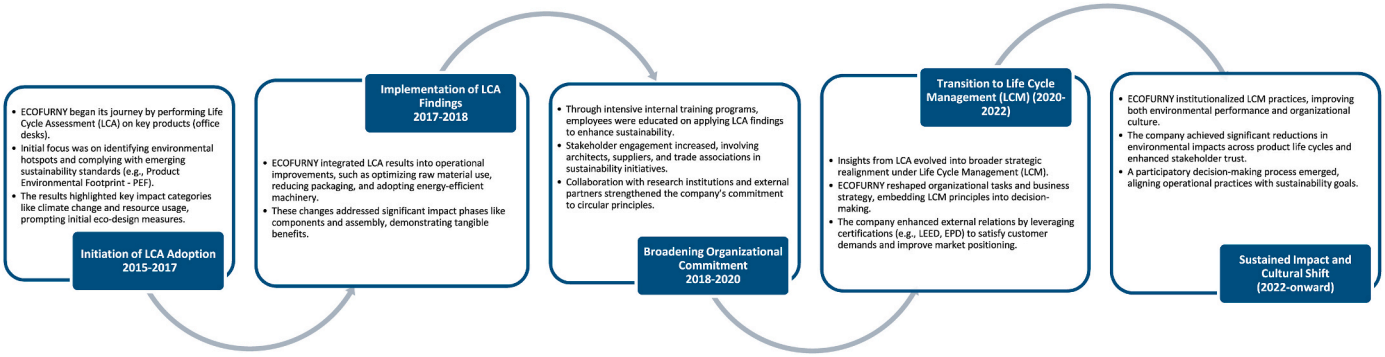

Fig. 1. Longitudinal case study methodology process adopted for ECOFURNY.

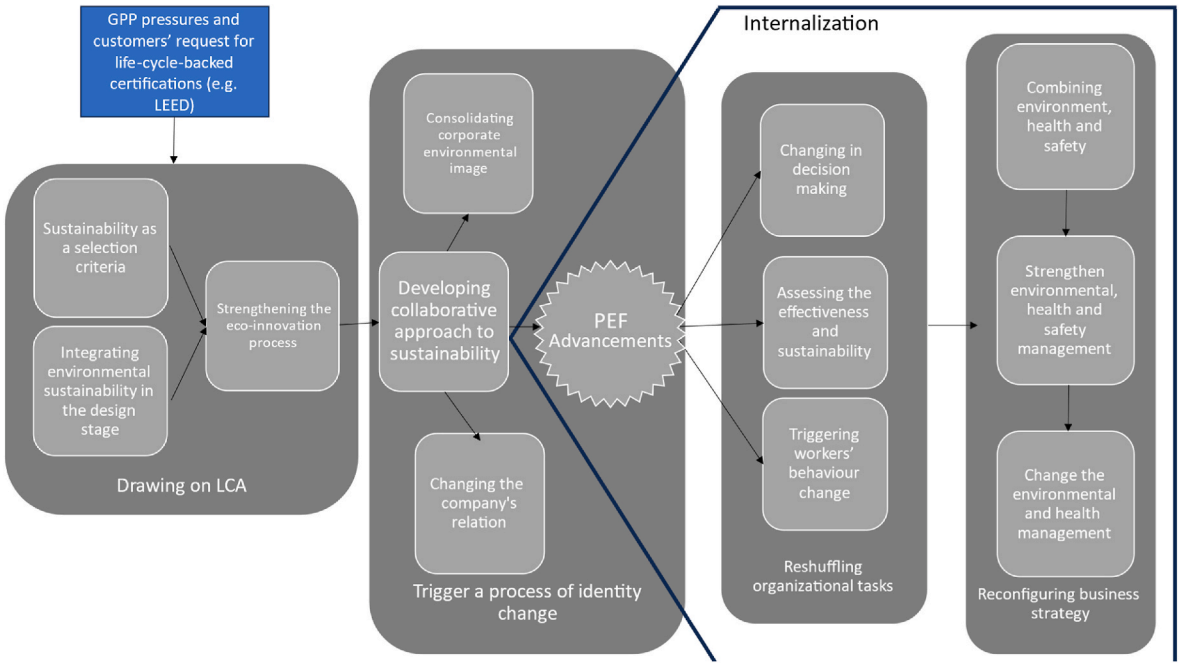

Fig. 2. The OL pathway starting from the LCA to LCM. Axial coding results.

sustainability.

Lastly, changing the company's relations underscores the transformative impact of LCA on stakeholder trust and collaboration. The certification of an LCA study, as noted by environmental manager, "consolidates trust with customers and suppliers and increase the business opportunities. PEF also includes institutional value as well as role at European level" confirm the supply chain manager. Moreover, "LCA has helped us improve our corporate image and communication with our international customers, demonstrating the vital role of transparent, science-based communication in enhancing relationships" (from CEO interview).

4.2.1. Spotlight on PEF advancements: the ignited lit of internalizing life-cycle principles

Circling back to PEF, ECOFURNY has devoted its effort to reducing component and packaging, increasing energy efficiency through the implementation of new technology and changing internal and external relations such as stakeholder engagement and increased employees' involvement in decision-making processes. By drawing on these research results, we can assert that ECOFURNY LCM approach does not consist of a mere product update according to LCA results (Nilsson-Lindén et al., 2019). In fact, PEF study represents the ignited lit that spreads lifecycle principles.

ECOFURNY defined the improvements actions based on the results of the first PEF studies in 2018. From this assessment emerged the environmental performance of the office desks to identify the main issues to improve. Climate change was as the main significant issue in the two desks. Contributing most to this result is "components" phase (mainly Aluminum-machining components) for both products and "use and maintain" for the laminate version. Resource use, mineral and metals and resource use, energy carriers were two other relevant impact categories for the laminate office desk. Finally, the packaging contributed enough to environmental footprint of the ECOFURNY desks.

So, the improvements of the office desks interested the most significant issues emerged from the first PEF that can be summarized in the following results:

1. Reducing the amount of metal parts (−25%) used to produce the structures and identifying finishes that require less processing and raw materials. These actions aim at improving the "components" phase of life cycle assessment.
2. Wood dust removal is a major source of energy consumption. These machines have been replaced with more efficient and less energy-consuming ones. So productive stages as "use and maintenance" can improve.
3. Reducing the energy consumption. This measure aims at improving the climate change impact category in all productive stages.
4. Reducing processing stages concerning assembling of the components and machining the desktop and substitution of virgin raw materials with recycled to reduce the environmental footprint in "assembly" stage.
5. Reducing packaging amount (−20%) in the laminate office desk to improve the relative life cycle phase.

The results highlight the emerged changes as showed in Tables I and II on the wood and laminate office desk. Generally, with the LCM adoption, the environmental performance of ECOFURNY office desks improve. The wood product achieves a result of −25% compared with the first PEF. For this product the "Resource use, mineral and metals" impact category obtains a reduction around by 27% linked to minimization of metal components. Climate change and acidification improve by 25% in the life cycle and in the "Component" product stage. Concerning the wood desk the improvements are linked to the adopted measures in the "component" phase as the reduction of metal component and the energy efficiency solutions (see Table 3).

The comparative PEF (2021) analysis of laminate desk, in the table n. III, shows improvements by 11% in the life cycle compared to the PEF in 2018. The study, completed in the 2021, summarises the evolution of products to greater environmental sustainability. Indeed, eutrophication freshwater impact category reduces by 13% and many others included the climate change improve by 12%. Contributing to this result were not only measures on metal components and energy efficiency changes but also the packaging's replacement. Three productive stages (component, packaging and end of life) obtained significant reductions in all impact categories. "Thanks to the PEF results, we have been able to understand the effectiveness of our production choices and will be able to rely on a scientific information base in our decision-making processes" confirmed CEO.

Table 1
Data collection and data sources.

Interviews	Meeting with company managers	Training sessions	documents	Other sources
October 9, 2018/ environmental manager, CEO, quality manager	June 20, 2018 9 attendees	6/2018 8 attendees 4 h	76 pages improvement plan report	Web site
September 11, 2019 environmental manager, CEO, quality manager, one manager from R&D and the supply chain manager		September 10, 2018 9 attendees 5 h	4 pages hot spots report	Company sustainability report
January 25, 2020 environmental manager, CEO	September 12, 2018 11 attendees	September 12, 2018 8 attendees 5 h	4 PEF reports (around 80 pages)	
August 18, 2020 environmental manager, CEO, quality manager, one manager from R&D and the supply chain manager	January 23, 2019 8 attendees	January 2019 16 attendees 5 h	150 pages of meeting minutes	
March 22, 2021 environmental manager, CEO, quality manager, one manager from R&D and the supply chain manager	July 14, 2020 4 attendees	February 2019 10 attendees 4 h		
June 10, 2021 environmental manager, CEO, quality manager	March 30, 2021 5 attendees			

Other result consolidated in ECOFURNY concerns the mindset. ECOFURNY conducted an intensive internal training programme for workers in each department. Two events in 2017 on the life cycle concept and PEF and three more events in 2018 involved around 100 of the 180 employees and specific initiatives for managers. The aim of this process was to make workers aware of how to apply the LCA information to produce better furniture products.

Additionally, to environmental results, ECOFURNY declared improvements in the external relations. The ECOFURNY managers detected most customer satisfaction, improving company's image and new business opportunities during the LCM adoption process, "Our customers and suppliers have shown a significant interest in the research and the achieved environmental improvements. The data produced was provided to confirm our path by providing scientific data and guarantees" declared supply chain manager. Stakeholder engagement improves through the involvement of architects, suppliers, consultants and other organizations in the PEF and then LCM implementation process.

Cooperation with universities, trade associations and suppliers gave the company access to a set of knowledge and experience that was valorised in the internalization process of the LCM, "Several barriers faced in the implementation of the LCM were overcome by the support and sharing of knowledge with the research team" explained the environmental manager.The OL supported the company in making choices based on the LCM, problem solving and staff involvement promoting the cooperation and the knowledge transfer among organizational level and departments. Cooperation about LCM made ECOFURNY' managers more available towards dialogue and meeting customer needs.

4.3. Reshuffling organizational tasks

ECOFURNY's strategic realignment towards environmental sustainability illustrates the transformative power of integrating LCA into organizational processes. The company's journey highlights three main pillars that have been pivotal in reshaping its organizational tasks, each underscored by insights drawn from LCA studies.

Firstly, "The choices are based on data from the LCA study, in operations, the LCA established changes, modifications to installations" cites environmental manager demonstrates the foundational role of LCA in informing operational decisions. This approach not only anchors strategic choices in robust environmental data but also directs tangible alterations in operational practices, ensuring that sustainability is woven into the fabric of ECOFURNY's daily activities.

Secondly, the challenge of distilling critical insights from complex data is acknowledged, as noted by environmental manager: "According to the LCA study, there are few relevant impacts and precisely those require our commitment… My colleagues find it difficult to understand which things are most important" explains environmental manager. This statement reflects the organization's proactive efforts in demystifying LCA findings through internal collaboration. By translating the LCA data into accessible formats, such as graphs, ECOFURNY enhances its

Table 2
Improvements in the wood office desk after the PEF adoption (percentage emerged comparing weighted results).

Impact category	Unit	Total	Component	Packaging	Assembly	Distribution	Use and maintaining	End of Life
Total	mPt	**−25,0%**	−25,0%	0,0%	0,0%	0,0%	0,0%	0,0%
Climate change	mPt	**−25,4%**	−25,4%	0,0%	0,0%	0,0%	0,0%	0,0%
Ozone depletion	mPt	**−21,8%**	−21,8%	0,0%	0,0%	0,0%	0,0%	0,0%
Ionising radiation, HH	mPt	**−23,7%**	−23,7%	0,0%	0,0%	0,0%	0,0%	0,0%
Photochemical ozone formation, HH	mPt	**−24,3%**	−24,3%	0,0%	0,0%	0,0%	0,0%	0,0%
Respiratory inorganics	mPt	**−25,1%**	−25,1%	0,0%	0,0%	0,0%	0,0%	0,0%
Non-cancer human health effects	mPt	0	0	0	0	0	0	0
Cancer human health effects	mPt	0	0	0	0	0	0	0
Acidification terrestrial and freshwater	mPt	**−25,9%**	−25,9%	0,0%	0,0%	0,0%	0,0%	0,0%
Eutrophication freshwater	mPt	**−24,7%**	−24,7%	0,0%	0,0%	0,0%	0,0%	0,0%
Eutrophication marine	mPt	**−24,1%**	−24,1%	0,0%	0,0%	0,0%	0,0%	0,0%
Eutrophication terrestrial	mPt	**−23,6%**	−23,6%	0,0%	0,0%	0,0%	0,0%	0,0%
Ecotoxicity freshwater	mPt		0	0	0	0	0	0
Land use	mPt	**−8,0%**	−8,0%	0,0%	0,0%	0,0%	0,0%	0,0%
Water scarcity	mPt	**−18,3%**	−18,3%	0,0%	0,0%	0,0%	0,0%	0,0%
Resource use, energy carriers	mPt	**−23,4%**	−23,4%	0,0%	0,0%	0,0%	0,0%	0,0%
Resource use, mineral and metals	mPt	**−26,9%**	−26,9%	0,0%	0,0%	0,0%	0,0%	0,0%

Table 3
Improvements in the laminate office desk after the PEF adoption (percentage emerged comparing weighted results).

Impact category	Unit	Total	Component	Packaging	Assembly	Distribution	Use and maintaining	End of Life
Total	mPt	**−11,1%**	−8,5%	−2,5%	0,0%	0,0%	0,0%	−0,2%
Climate change	mPt	**−12,3%**	−9,5%	−2,5%	0,0%	0,0%	0,0%	−0,3%
Ozone depletion	mPt	**−8,6%**	−5,1%	−3,3%	0,0%	0,0%	0,0%	−0,3%
Ionising radiation, HH	mPt	**−9,2%**	−4,0%	−5,1%	0,0%	0,0%	0,0%	−0,1%
Photochemical ozone formation, HH	mPt	**−11,8%**	−8,8%	−2,7%	0,0%	0,0%	0,0%	−0,4%
Respiratory inorganics	mPt	**−11,2%**	−9,4%	−1,6%	0,0%	0,0%	0,0%	−0,2%
Non-cancer human health effects	mPt	0	0	0	0	0	0	0
Cancer human health effects	mPt	0	0	0	0	0	0	0
Acidification terrestrial and freshwater	mPt	**−11,9%**	−10,0%	−1,8%	0,0%	0,0%	0,0%	−0,1%
Eutrophication freshwater	mPt	**−13,4%**	−10,5%	−2,9%	0,0%	0,0%	0,0%	−0,1%
Eutrophication marine	mPt	**−12,7%**	−8,7%	−3,5%	0,0%	0,0%	0,0%	−0,6%
Eutrophication terrestrial	mPt	**−12,8%**	−10,0%	−2,4%	0,0%	0,0%	0,0%	−0,4%
Ecotoxicity freshwater	mPt	0	0	0	0	0	0	0
Land use	mPt	**−12,3%**	−1,9%	−10,3%	0,0%	0,0%	0,0%	0,0%
Water scarcity	mPt	**−8,7%**	−5,3%	−3,3%	0,0%	0,0%	0,0%	−0,1%
Resource use, energy carriers	mPt	**−12,2%**	−7,9%	−4,1%	0,0%	0,0%	0,0%	−0,1%
Resource use, mineral and metals	mPt	**−7,8%**	−6,5%	−1,4%	0,0%	0,0%	0,0%	0,0%

collective understanding of key environmental issues, facilitating targeted improvements.

Lastly, the quote “Despite the difficulties in understanding the results, there has been enthusiasm among the company’s various departments in sharing the LCA studies and the work done, also because it is linked to a certification we are trying to obtain” (as explained by CEO) highlights the motivational impact of LCA studies across the organization. This enthusiasm for shared environmental goals, spurred by the pursuit of certification, signifies a cultural shift within ECOFURNY. It underscores the importance of LCA as not only a tool for environmental assessment but also a catalyst for organizational unity and commitment to sustainability.

In summary, ECOFURNY’s strategic refocusing around LCA findings exemplifies how data-driven insights, collaborative understanding, and organizational enthusiasm are crucial in transitioning towards more sustainable operations. These pillars underscore the importance of embedding a lifecycle perspective into every layer of the organization, ultimately guiding ECOFURNY towards achieving its sustainability objectives and consolidating a new organisational culture based on the acquisition of new knowledge and awareness.

4.4. Reconfiguring business strategy

In the wake of COVID-19, businesses are compelled to rethink their operational models, particularly in terms of integrating environmental sustainability with health and safety measures (Lukito-Budi et al., 2023). This revaluation has led to a strategic reconfiguration of business units within organizations, focusing on a holistic approach that blends environmental considerations with health and safety requirements. This evolution is underpinned by three interconnected concepts that become the core of business environmental strategy (Khalifa, 2021): combining environment, health, and safety; strengthening environmental, health, and safety management; and changing the environmental and safety management framework to better meet contemporary challenges and customer expectations. So, the reconfiguration process follows an integrated strategy combining environmental, health and safety management.

The pandemic has notably shifted risk perceptions, prompting companies to apply a longer time horizon to their planning and operations. This shift acknowledges that “Since COVID, risk perception has changed and a longer time horizon is applied,” declared CEO illustrating the newfound emphasis on comprehensive risk management strategies that encompass not just immediate concerns but also future sustainability. This approach necessitates a nuanced balancing act, as "The environment is taking a bit of a back seat to health and safety issues", declared the company CEO. Organizations are navigating the complexities of meeting customer demands while ensuring that procedures account for both environmental sustainability and health safety. The innovative development of sound-absorbing panels from recycled fabric exemplifies this dual focus. However, the challenge of sanitising these environmentally friendly options compared to laminate counterparts underscores the operational complexities introduced by health considerations, as noted: "For example, one of our sound-absorbing panels is made of recycled fabric and has been very popular in the market but the difficulty of sanitising it favours the laminate one."

This period of transformation signifies a critical juncture for businesses, compelling them to integrate environmental, health, and safety considerations more cohesively into their operations and strategies. By doing so, companies not only respond to the immediate challenges posed by the pandemic but also pave the way for more resilient and sustainable business practices that can weather future uncertainties. The reconfiguration of business units along these lines represents a forward-thinking approach to corporate sustainability, emphasizing the need for an adaptable, integrated management system that aligns with evolving global standards and stakeholder expectations.

5. Discussion and conclusion

ECOFURNY’s strategic realignment towards environmental sustainability, driven by a Life Cycle Assessment (LCA) conducted in 2018, highlights the impactful integration of LCA insights across its operations, design, and supply chain management. This research contributes to the scientific literature by exploring the pathway from LCA to Life Cycle Management (LCM) and its consolidation into the organization’s decision-making processes.

First, our findings confirm the effectiveness of LCA (Sonnemann and Margni, 2015). Continuous product modification, supported by advanced methodologies, is essential for improving environmental performance (Bianchi et al., 2021; European Commission, 2013). ECOFURNY utilized the Product Environmental Footprint (PEF) process to identify opportunities for improvement, emphasizing collaboration between R&D and production to reduce raw material usage. Product design, exemplified by eco-designed office desks, plays a pivotal role in this process. Managers should adopt PEF-based LCA changes to enhance manufacturing efficiency and reduce the environmental footprint. Beyond individual operational improvements, LCA offers scalable insights that could be effectively applied across diverse industries, including construction, textiles, and electronics, to address environmental challenges while enhancing economic and operational efficiency.

However, in today’s context, where institutional and market pressures are prevalent, these efforts alone are insufficient. Companies must

embrace a holistic approach to sustainability (Bianchi et al., 2022). ECOFURNY's commitment to LCM demonstrates how organizations can meet emerging demands from customers, suppliers, and competitors. Addressing increasingly complex environmental challenges requires businesses to extend their efforts beyond organizational boundaries and adopt a life cycle perspective (Greenwood et al., 2011). This transition necessitates collaboration across stakeholders and industries, leveraging LCA insights to guide decision-making processes and foster circular economy practices. For instance, digitalization and tools like Waste Flow Mapping (WFM) have been shown to enhance the application of LCA, facilitating its integration into broader LCM frameworks across manufacturing sectors.

ECOFURNY's organizational learning (OL) journey from LCA to LCM exemplifies this transformative shift, showcasing the pivotal role of LCA in fostering a deeper organizational commitment to sustainability and life cycle management (Nilsson-Lindén et al., 2018). OL enabled ECOFURNY to engage stakeholders, reconfigure business strategies, and adopt eco-innovative solutions, offering a replicable model for other industries. Additionally, rigorous scientific methodologies like LCA play a critical role in enabling organizations to adapt, learn, and thrive in a rapidly changing industrial landscape.

This research also contributes to the academic discourse on the role of stakeholders in LCM adoption. As highlighted by Testa et al. (2022), LCM is inherently collaborative, requiring engagement with multiple stakeholders throughout its implementation. Scholars have emphasized the complexity of embedding LCM in practice, noting that diverse phases and actors across the product life cycle play a crucial role (Nilsson-Lindén et al., 2021; Sonnemann and Margni, 2015; Vermeulen and Seuring, 2009). Collaboration with both internal and external stakeholders is consistently identified as a key success factor for effective business strategies (Linnanen, 1995; Remmen, 2007; Strothmann et al., 2015). The OL pathway identified in this case study provides concrete evidence of these arguments, demonstrating how collaboration among managers, workers, associations, suppliers, and other stakeholders consolidates LCM adoption.

From a global perspective, LCA's scalability enables its adoption in industries with varying levels of complexity. For example, its application in the furniture sector offers a replicable framework for industries such as automotive and electronics, which face similar regulatory and market pressures. Insights from this case highlight the importance of aligning national and international policy frameworks, like Green Public Procurement (GPP) in Italy and ISO standards globally, to support LCM adoption.

For practitioners, our findings outline a process and collaborative approach to adopting LCM and implementing sustainability in a holistic manner. Collaboration and organizational learning emerge as crucial factors, enabling managers to better anticipate and manage the change process. This includes understanding the stages, enablers, and barriers associated with embedding sustainability into operations. LCM requires collaboration across the product life cycle with stakeholders both inside and outside the organization, fostering stronger relationships and improving operational outcomes.

The research also has substantial managerial implications. Implementing LCM requires companies to undergo significant organizational and managerial changes, which may introduce new structures, skills, and working methods. These changes establish systems of knowledge that enable managers and workers to manage and monitor sustainability-related transformations. By internalizing efficiency-driven logic promoted by LCM, organizations can improve production processes, enhance competitiveness, and boost both environmental and economic performance. Managers may face new organizational scenarios, as demonstrated in the ECOFURNY case study.

From a policy perspective, the research identifies actions institutions can take to facilitate LCM adoption. Financial incentives, technical and technological support, and training programs are among the key areas where institutional interventions could drive broader adoption of LCM.

Finally, this study acknowledges certain limitations, which, if addressed, could enhance its validity. First, the research focuses exclusively on the furniture industry, a sector under particular scrutiny from the European Environmental Bureau as it transitions towards a circular economy. However, replicating this study in other industries facing similar social, environmental, and regulatory pressures—and in diverse geographical contexts—could provide valuable insights and broaden the applicability of the findings.

CRediT authorship contribution statement

Sara Tessitore: Writing – original draft, Methodology, Investigation, Data curation, Conceptualization. **Francesco Testa:** Validation, Supervision, Methodology. **Vinicio Di Iorio:** Writing – review & editing, Investigation, Data curation. **Fabio Iraldo:** Supervision.

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.

Appendix A1. Codes emerged from first round

1. Changes in communication strategies
2. Changes in costs and prices of supplied products
3. Changes in Italian and European legislation have pushed towards sustainability
4. Climate change and optimization of resource use
5. Combining environment, health and safety
6. Commitment to sustainability already for some years
7. Customer interest in recycled products
8. Data from LCA valorised in R&D activities
9. Design of furniture products integrates LCA results
10. Difficulties in interpreting data and applying LCA results for internal decision-making processes
11. Improve communication strategy
12. Improved traceability of the supply chain
13. Increase the stakeholder engagement
14. Increased workers environmental awareness
15. Increasing raw material price and needs to substitutions
16. Interest in EPDs and product certifications spread to other countries
17. Larger suppliers are more environmentally aware and familiar with LCA

18. LCA as input for decision making process
19. LCA as input to improve product's environmental performances
20. LCA to improve the company's image and raise customer awareness
21. LCA valorised in the trading dynamics
22. LCA as a tool to aware architects and office furniture designers
23. LCA identifies company main hot spots in the productive cycle
24. LCA increase the trust between company, costumers and providers
25. Managing emergency situations and work and production stoppages
26. Market increasingly interest on sustainability issues
27. Measure the environmental improvements and the effectiveness of adopted solutions
28. Need for tools to understand LCA results by workers
29. Need to certify LCA studies
30. New environment and safety procedures
31. New plant organisation
32. New safety protocols
33. New software for environmental, safety and quality data management
34. New work organisation following the pandemic
35. Organisational changes
36. Rethinking the organisation of office space in line with environmental sustainability
37. Scientific data to share with costumer
38. Sharing of data and information through technological innovations
39. Sharing the LCA results with workers
40. Smaller suppliers know little about LCA and are less knowledgeable about the environment
41. Strengthening the role of certification as an assurance tool during the pandemic
42. Suppliers are also evaluated with regard to environmental performance
43. The company asks suppliers to obtain environmental certifications
44. The covid subordinated the environment to health and safety requirements also in offices
45. The technical round table on sustainability set up by the trade association was strategic
46. Trade association involved companies in training and awareness-raising initiatives
47. Trade association involves companies in sustainability projects
48. Updating work plans for environmental sustainability

Appendix A2. Axial coding of the interviews

Quotations	Key 1st Order concepts	2nd Order themes	Aggregate dimensions
The international market is increasingly interested in office furniture with high environmental performance and green features	Market increasingly interest on sustainability issues	Changing the company's relation with customers and suppliers	**Trigger a process of identity change**
Customers ask us for scientific data and reports on product environmental performances before purchases and we must be able to give it. So our LCA has this goal	Scientific data needs to share with costumer	Developing collaborative approach to sustainability	
We frequently held meetings with our trade association on sustainability and our process on environmental sustainability started with the association involving us in various initiatives and interesting projects	Trade association involves companies in sustainability projects		
A company's ethics and social responsibility are essential to its long-term profitability and allow to improve our imagine and competitivenes	Sustainability as driver to competitiveness		
Our suppliers are now familiar with LCA and have experienced this methodology, which they see as a tool to improve trust and collaboration among stakeholders	Larger suppliers are more environmentally aware and familiar with LCA		
	LCA increases the trust between company, costumers and providers	Consolidating corporate environmental image	
Certification of an LCA study consolidates trust with customers and suppliers and increase the business opportunities. PEF also includes institutional value as well as role at European level.	Need to certify LCA studies	Modelling behaviours	
	LCA valorised in the trading dynamics		
LCA has helped us improve our corporate image and communication with our international customers	LCA to improve the company's image and raise customer awareness		
	Improve company communication strategy		
Working with environmentally aware architects and workers is a priority for our company and the adoption of LCA has supported ECOFURNY in this process	LCA as a tool to aware architects and office furniture designers	Integrating environmental sustainability in the design stage	**Drawing on LCA**
Ecodesign is important because it allows us to grasp even small changes and increasing company efficiency that can bring environmental benefits and is very popular	Rethinking the organisation of office space in line with environmental sustainability	Strengthening the eco-innovation process	
	LCA for product eco innovation	sustainability as a selection criteria	
We have environmental criteria when choosing suppliers, where we go for water-based paints, etc. For the company, environmental impact is now criterion in the choice of partners (suppliers, distributors, customers, etc.) that guides us in our selections and purchases	Suppliers are also evaluated with regard to environmental performance		

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(*continued*)

Quotations	Key 1st Order concepts	2nd Order themes	Aggregate dimensions
The choices are based on data from the LCA study, In operations, the LCA established changes, modifications to installations.	LCA provides input for decision making process LCA as input to improve product's environmental performances	Changing in decision making Assessing the effectiveness Triggering workers' behaviour change	**Reshuffling organizational tasks**
According to the LCA study, there are few relevant impacts and precisely those require our commitment. There is a lot of information in the PEF document, which can be difficult to interpret and understand which ones are relevant. My colleagues find it difficult to understand which things are most important. We had meetings, represented the most important data in graphs, data. So, we can identified the main environmental topics to improve and the better solutions to apply.	Difficulties in interpreting LCA data LCA identifies company main hot spots in the productive cycle		
Despite the difficulties in understanding the results, there has been enthusiasm among the company's various departments in sharing the LCA studies and the work done, also because it is linked to a certification we are trying to obtain.	Increased awareness of implemented changes Increased workers environmental awareness Sharing the LCA results with workers		
LCA allows us to compare the performance of our products over time and against our input choices as well as finalise improvement plans	Measure the environmental improvements and the effectiveness of adopted solutions		
	Updating work plans for environmental sustainability and LCA	Strengthen environmental, health and safety management	**Reconfiguring business' strategy**
Since COVID, risk perception has changed and a longer time horizon is applied	Risk analyses considering long time	Change the environmental and health management	
The environment is taking a bit of a back seat to health and safety issues. We are adopting procedures that take both aspects into account, but meeting customer demands is complex. For example, one of our sound-absorbing panels is made of recycled fabric and has been very popular in the market but the difficulty of sanitising it favours the laminate one	New environment and safety procedures Environmental sustainability becomes secondary to health and safety Organisational changes New software for environmental, safety and quality data management	Combining environment, health and safety	

Data availability

Data cannot be made available for confidentiality reasons requested by company.

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