EXPLORING ECO-DESIGN STRATEGIES IN ITALIAN DESIGN-DRIVEN FIRMS

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Abstract

Given the growing emergence of environmental challenges, firms must reduce environmental impacts and achieve business performance. Hence, we investigate how environmental sustainability approaches relate to the design-driven innovation (DDI) connected to new product development, zooming in on active design-oriented firms in the industrial sector in Italy. This paper, in particular, addresses to what extent eco approaches to design are adopted and connected to new product development in these innovation-driven firms, and how such approaches relate to innovation, customer value creation, and business performance. These relationships are examined through an empirical investigation of the Italian manufacturing companies associated with the Industrial Design Association (ADI, Associazione del Design Industriale), from the entrepreneurial perspective. The study reveals three different clusters of companies with varying levels of adoption of eco-design approaches and a combination of such approaches. One cluster reveals the highest level of adoption of all the types of approaches, the second a high level of adoption of three types of approaches (durability, reduction, recycling), and a low level of adoption of the other three types (reparability, disassembling, regeneration) and a third cluster performs a medium level of adoption of all the types of approaches. Further, we discovered that from the entrepreneur's perspective, firms adopting design for durability and design for recycling approaches positively and significantly impact innovation, customer value and business performance. The study represents an additional revelatory contribution to the understanding of the relationship between innovation and environmental sustainability and the generic kinds of According to entrepreneurs, eco-design strategies are adopted by highly design-oriented firms in new product development.

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1. Introduction

This paper investigates environmental sustainability approaches in design innovation among small and medium-sized enterprises (SMEs). Innovations with reduced environmental impacts are a must in current competitive contexts for several industries in transition (Takalo et al., 202; Takacs et al., 2022). SMEs play a key role such as in Europe's industrial fabrics, "providing two out of three jobs, and are central to the success of this new industrial approach" (EU Commission, 2020a).

Design as a source of product innovation is becoming more and more important for competitiveness (Moultrie and Livesey, 2013; Dan et al., 2018), prosperity, and well-being (EU, 2013), and its importance is documented in several European nations, especially those with a strong tradition in design like Italy or Sweden (Verganti, 2003, 2017; Symbola, 2022, 2023). Yet, more action is called for towards sustainability in practice (European Commission, 2020b; Jevnaker and Olaisen, 2022a). Among the European countries, Italy has the highest number of design services (about 30,000) serving more than 60% of the domestic demand, especially furniture and automotive firms (Symbola 2023). This makes Italian industrial firms interesting and relevant to study from a design-intensive innovation perspective.

In addition to market-pull and technology-push strategies for product innovation, Verganti (2003) introduced a third kind of innovation guided by design which is characterized by the novelty of the message delivered to the users, and design language is significant and prevalent compared to the novelty of functionality and technology (Verganti, 2003, 2017).

Firms adopting design-driven innovation (DDI) approaches work closely together with designers to create breakthrough products that add new and unsolicited meaning that users love because they are so different from other products that dominate the market (Verganti, 2003, 2017). However, design is a relatively recent or revived topic in management studies and requires further deepening, especially empirical investigation (Conti et al., 2019; Verganti, 2003; 2017; Jevnaker et al., 2014).

Currently, being innovative is not enough as firms have to face new challenges: increasingly interested customers in environmental issues, legislation changes, environmental pollution, and a reduction of natural resources (Karimi Takalo et al., 2021). At the same time, firms increasingly see environmental factors as opportunities to stimulate innovation, drive business efficiency and improve brand positioning (Santolaria et al., 2011). Indeed, firms that integrate green product offerings are more likely to gain extended financial gains, thus leading them to improve their business performance (Pérez-Luño et al. 2019; Singh et al., 2020), and ecological performance (El-Kassar and Singh, 2019).

However, there is still limited research to understand the relationship between business, environment and innovation and even less between these variables and eco-design strategies (Santolaria et al., 2018; Takacs et al., 2022). In Europe, some studies show that Germany, Denmark, Netherlands, Austria and Sweeden are clear front-runners about method development, dissemination and education in eco-design (Tukker et al., 2000). Previous research on the perception of Spanish innovation-driven companies about

sustainability and eco-design revealed that process companies focus their eco-design strategies on improvement of activities in their factory subsystem (recycling and waste minimization, efficient use of technology) and product companies focus their eco-design strategies on the environmental improvement of materials (recyclable, recycled and low environmental impact materials) and less on other life cycle stages while service companies minimize resource and office automation recycling (Santolaria et al., 2018).

Hence, firms that seek to achieve eco-effectiveness as well as eco-efficiency and market share through continuous design innovation (Jevnaker, 2012) requires resources, capabilities, and investments (Conti et al., forthcoming; Jevnaker and Olaisen, 2022b) a certain degree of ethical responsibility and coherence with the society in which they operate (Oduro et al., 2022).

Management and knowledge-oriented practitioners, as well as researchers, are becoming aware of the increasing importance of sustainability (Jevnaker and Olaisen, 2022c; Tukker et al., 2001). For example, McKinsey & Company recognizes sustainability as a strategic priority that carries significant business opportunity and risk and suggests that success is more likely when executives enable sustainable organizations to actively and strategically engage, being responsible for creating measurable impact (De Smet et al., 2021).

The Ecodesign Directive 2009/125/EC has consistently delivered substantial benefits to businesses, consumers, and the environment over the years. In 2021, the directive's implementation across 31 product groups led to a significant reduction in energy costs, saving EU consumers approximately EUR 120 billion. Additionally, these measures facilitated a 10% decrease in annual energy consumption for the targeted products.

Recent reports of the Association of Industrial Design (ADI, Associazione del Design Industriale) stressed the increasing attention of designers to environmental sustainability in design-related projects for companies (Fondazione Symbola, 2022; 2023). However, little attention has been paid to understanding how to innovate in practice while being environmentally sustainable, and contributions investigating sustainability and DDI (Verganti, 2009) are even more underexplored (Conti et al., forthcoming; Jevnaker and Olaisen, 2022a).

Thus, our focus in this study is to empirically investigate which and to what extent eco approaches to design related to new product development are adopted by design-driven companies. Further, we investigate how these approaches relate to innovation, value creation for customers, and business performance from the entrepreneurial perspective.

To achieve these objectives, an exploratory study was conducted based on a survey addressing companies that are strongly design-oriented and belong to ADI. This study helped the authors to have a deeper understanding of the kinds of green strategies design-oriented firms adopt to develop new products and shed light on the relationship between design-driven innovation and environmental sustainability.

The subsequent sections of this article review the literature on green innovation and design-driven innovation by addressing the kinds of eco-design strategies followed in the industrial firms' design approaches, which is the gap the study aims to fill. The methodology section describes the explorative, quantitative approach implemented through the cluster analysis and regression analysis of the set of 86 design-oriented Italian firms. The findings section shows the underlying patterns of eco-design approaches emerging from the analysis of these firms. Finally, the discussion and conclusion explain the

importance of the evidence that emerged from data analysis with suggestions for future research.

2. Theoretical background

2.1 Green Innovation and Eco-design Strategies

In this article, we seek to understand the idea of green innovation from the perspective of "green innovation approaches" and the types of strategies connected to new product development. The literature on green innovation is wide and examines the phenomenon from different perspectives (Dangelico, 2016; Karimi Takalo et al., 2021; Oduro et al., 2022). Authors use various terms such as "green" "environmental" or "sustainable" innovation to indicate the reduced negative impact of innovations on the environment (Dasgupat, 2021). Eco-design is defined as "the systematic incorporation of life cycle considerations into the design of products, processes or services" (Tukker et al, 2001) and is regarded to play a strategic role in innovation-driven firms adding value to the firm's strategy (Santolaria et al., 2018). Previous research has analyzed mainly a few relations between business and the environment (Loorbach et al., 2009).

Furthermore, the emergent literature usually refers to sustainable development within business as green management (Singh et al., 2020; Song and Yu, 2018). Companies that implement green management make improvements to their goods, manufacturing processes, and organizations in the ecosystem. To put it in another way, to respond appropriately to the transformation of the environment and transform challenges into opportunities firms must adequate their strategies, organization, products, marketing, and finance (Zhang and Ma, 2021).

According to Dangelico and Pujani (2010), green innovation is defined as innovation in either software or hardware relating to green products or processes. This perspective includes innovation in technologies that aim to save energy, protect against pollution, enable waste recycling, and develop green products, or improve corporate environmental protection.

To face continuous changes in the competitive environment in the era of environmentalism, green innovation's potential to create a corporate competitive edge is strategic (Wang and Yu, 2021). Green innovation might begin with creating products and adopting manufacturing processes that protect the environment and promote product distinctiveness (Bin Hasanuddin, 2020; Kotler, 2020). Hence, it is fundamental to figure out how to get a distinct competitive edge by pursuing green innovation (Aron and Molina, 2020).

We follow Ottman et al. (2006) who argue that "although no consumer product has a zero impact on the environment, in business the terms 'green product' or environmental product' are commonly used to describe those that strive to protect or enhance the natural environment by conserving energy and/or resources and reducing or eliminating the use of toxic agents, pollution, and waste". The definition stresses that green products may focus on different environmental issues such as energy, material/resources, and pollution/toxic waste (Roy et al., 1996). Other literature has stressed that green products and green processes are positively correlated to competitive advantage (Chen et al. 2006). Further, companies that pay more attention to the environment are generally more innovative and entrepreneurial than their competitors (Etsy and Wilson, 2006; Santolaria et al., 2018). The

key environmental focus may impact the environment at different stages of the product's life cycle – manufacturing processes, product use, and disposal – (Dangelico, Pujari, 2010).

Overall, we recognized at least three key research gaps in the existing green innovation studies. First, the literature reveals that there is little knowledge of *how* companies integrate environmental sustainability into new products (Dangelico and Pujani, 2010; Santolaria et al., 2018). Secondly, research was done on single projects, rather than on programs or cycles of efforts (Rupasinghe et al., 2023). Thirdly, research is mostly conducted on large companies and technological sectors and is often quantitative studies (Passano et al., 2022). These research gaps motivated our research orientation, which we elaborate on next.

2.2 Green Innovation and Eco-design Strategies

Design innovation has attracted new strategic interest in our uncertain times with global/local, digital, and material transformations. In particular, design-driven innovation (DDI) regards design as a causal force that is oriented towards creating new or renewed configurations and their communicative meanings. Design-driven products when involving designerly competent contributions tend to integrate various attributes such as functionality, technology, aesthetics, and meanings (Bloch, 2011; Verganti, 2017) and can satisfy customers looking for high-quality products, as well as abundant hedonistic and semiotic benefits (D'Ippolito, 2014; Luchs & Swan, 2011).

However, firms seem to struggle with taking actionable steps towards sustainability (Jevnaker and Olaisen, 2022a; Tukker et al., 2001), and eco-design strategies in DDI in real-world firms seem hitherto sparsely researched and not well known (Conti et al., forthcoming).

A recent study has stressed that sustainability is considered by some entrepreneurs an important attribute of new design product development that creates value for customers (Conti et al., 2019). Other recent studies focused on how broader ecological considerations could become integrated in business enterprises, according to organization development, ecological effectiveness and other relevant perspectives (Jevnaker and Olaisen, 2022a, b). These eco-design considerations can contribute to innovation qualities that are becoming both necessary and important for firm competitiveness (Santolaria et al., 2018). However, DDI in practice is still understudied in management studies (Verganti, 2017) and contributions regarding uncovering its relationship with environmental sustainability are still scarce (Conti et al, forthcoming; Jevnaker and Olaisen, 2022a, b).

We will address DDI as a kind of innovation with a potential high relationship with the environment, generally, it refers to complex or even radical innovations and very original design work (Verganti, 2003). It is thus often characterized by the central role of designers or design teams (Jevnaker, 2000, 2005, 2012), as well as highly creative individuals immersed in a very creative network of actors (referred to as the design discourse) (Verganti, 2003, 2017).

Italian DDI companies belong to the Made in Italy sectors that are highly innovative and dynamic to face international competition.

In the context of design, recent studies promoted by the Italian Association of Industrial Design (ADI, Associazione del Design Industriale) stressed the key role of environmental sustainability in designer projects and six different eco-design approaches (Fondazione Symbola, 2022; 2023). Further, Compass d'Oro has dedicated a special

section to environmental sustainability projects, so the association has been promoting since many years the culture of environmental sustainability.

It would further be interesting to understand the perspective of entrepreneurs including their concurrent strategies and also gaps and further possibilities.

DDI companies are characterized as highly innovative through design, as designers and other collaborators help companies to make radical innovation. The designer and the network of actors seem to capture and anticipate the needs and desires of users, or even transform the users' problems and wants. It seems that some designers are aware of and experiment with selective environmental issues (Jevnaker, 2012), which helps understand user interest in green innovation (Jevnaker and Olaisen, 2022a,b).

However, the research on DDI lacks an understanding of how design-driven companies include environmental concerns in new products.

2.3 Framing Eco-design strategies in design-driven innovation

From the above paragraphs, it is clear that design-driven companies must integrate environmental considerations in new product development strategies to be competitive.

Hence, these companies have to face many challenges identified in the literature on green product innovation (Dangelico and Pujani, 2010) such as avoiding trade-offs between product quality and green attributes, selling at a competitive price (if green products may require high development and manufacturing cost) and the lack of customer awareness of green product benefits.

Together with conventional attributes such as functionality, technology, aesthetics, meanings (Bloch, 2011; Verganti, 2017), high quality, hedonistic and semiotic benefits D'Ippolito, 2014; M. Luchs & Swan, 2011) design products must include environmental sustainability considerations relating to consuming natural resources at a rate below the natural regeneration, or consuming a substitute, generating limited emissions, and not being engaged in activities that can degrade the ecosystem (Karimi Takalo et al., 2021; Kleindorfer et al., 2009). A recent study has stressed that sustainability is considered by some entrepreneurs an important attribute of new design product development which creates value for customers (Conti et al., 2019).

The previous literature underlines that designers must still develop skills and guidance to design for the new circular economy (Charnley et al., 2011) and that good design practice should consider sustainable issues connected to product design (e.g. the use of recyclable materials, low consumption of energy, user-friendly material, etc.) as key elements of competitiveness (Bumgardner & Nicholls, 2020). Recent practitioners report stress that industrial designers are developing green skills (Symbola, 2022, 2023) and the government is incentivizing sustainability together with ADI Associazione del Design Industriale which has created a dedicated award for sustainable design products. However, to our knowledge, there are no studies that identify the eco-design strategies of these companies.

Since there is no consensus regarding a single definition of eco-design, this study adopts the perspective that eco-design is a practice that consists of the systematic incorporation of life cycle considerations into the design of products, processes, or services (Tukker et al., 2001). More specifically, this practice is performed by the developers of a product and is aimed at reducing a product's negative environmental impact during its entire life cycle (Schäfer & Löwer, 2021).

Several effective strategies have been documented to enhance environmental sustainability in product design. For instance, Cerdan et al. (2009) describe the

implementation of straightforward indicators designed to enhance product recyclability. Furthermore, foundational principles and guidelines such as "reduce, reuse, recycle" (RRR) and "pollution prevention pays" (PPP) have been advocated by Boks and Stevels (2007) to minimize ecological impact. Additionally, the adoption of "eco-materials" which are more environmentally benign, has been explored by Cicconi (2020) as a means to further reduce the environmental footprint of products.

Hence, eco-design strategies play a fundamental role in innovative-driven companies, adding sustainable value to their strategy (Santolaria et al., 2011). For example, specific eco-design strategies toward the sustainability of Spanish companies have been identified (Santolaria et al., 2011) related to main company clusters: process, product, and service. In particular, process companies focus their eco-design strategies on the improvement of their activity in the factory subsystem (efficient use of technology, recycling, waste minimization), and product companies pay attention to the environmental improvement of materials (recyclable, recycled, and low environmental impact materials). Finally, service companies focus their design strategies on the minimization of resources and office automation recycling (selective waste connection, double-sided printing, e-mail billing, and advertising).

Given the challenging nature of green innovation, it is important to underline that especially SMEs lack the skills and resources (Kanda et al., 2018).

Many techniques have been proposed to adopt and apply eco-design in product development (Knight and Jenkins, 2009) but it seems that they are "tools for experts" and are quite generic.

A recent study of ADI (Fondazione Symbola, 2022) adopted a checklist to identify various approaches to environmental sustainability in designers' projects, which appears appropriate to our study. This list includes several types of eco-design strategies or approaches such as:

- "design for durability" (the product or its methods of use are designed in such a way as to improve its maintainability, physical and emotional duration);
- "design for reduction" (the products minimize the use of materials and energy and the production of waste);
- "design for recycling" (reduction of the quantity of materials used, use of mono-materials, use of easily recyclable materials and regenerated materials, ease in the separation of materials);
- "design for repairability" (replacement of components or updating of their functions is permitted);
- "design for disassembly" (the aim is to design products using reversible connection systems, functional to the separation of all the components of the different types of materials to facilitate the recovery and recycling process);
- "design for regeneration" (functional to the re-manufacture of products with the same or different function of use, or to the design of modular products to facilitate the reuse of parts of the product).

As this list of strategies was employed to determine which approaches are predominantly used by Italian designers who serve design-driven companies, we believe

that this measurement tool is also suitable for assessing the extent of strategy adoption by firms from the entrepreneurs' perspective.

In this study, we assume that entrepreneurs of design-driven companies make strategic decisions related to the eco approaches to design and may encourage and motivate employees and collaborators to innovate in this green direction. Leadership has been suggested to be an important factor affecting innovation (Gil et al., 2018) and several studies have shown that transformational leadership positively influences organizational innovation (Gumusluoğlu and Ilsev, 2009).

In this paper, a survey on Italian design-driven companies was carried out adopting the checklist proposed by ADI to investigate the types and the level of adoption of these approaches. Hence, we investigate the types and levels of adoption of eco-design strategies suggested by ADI from the subjective perspective of the entrepreneur. Furthermore, the paper aims to explore the relationship between specific eco-design approaches (and their combinations) and several key factors: the level of firm innovation, the impact of environmental sustainability of products and processes on customer value creation, and business performance, as perceived by entrepreneurs.

In particular, the research questions are the following:

RQ 1. *What types of sustainable design approaches characterize manufacturing design-driven companies?*

RQ 2. *How much do the identified clusters differ by type of product, company size, and revenue within manufacturing design-driven companies?*

RQ 3. *How much do the identified clusters of eco-design approaches relate to the level of innovation of the firm, the positive impact of environmental sustainability of products and processes on customer value creation, and business performance, from the entrepreneurial perspective?*

3. Methodology

We answered the research questions through an online survey conducted on a sample of Italian manufacturing design-driven companies which are members of the Association for Industrial Design (ADI – Associazione del Disegno Industriale).

Based on the literature on eco-design approaches, a questionnaire consisting of three sections was designed. The first section contains questions about the company profile (product types, company size, and revenue class) and the second investigates the level of adoption of the different types of eco-design approaches by the firms based on the checklist proposed by ADI explained in paragraph 2.2. (design for durability, reduction, recycling, reparability, disassembling, regeneration). The questions in the third section are designed to gauge entrepreneurs' perceptions of the firms' level of innovation, the positive impact of environmental sustainability of products and processes on customer value creation, and business performance.

To respond to multiple-choice questions, entrepreneurs were asked to indicate the relevance of the statements using a five-point Likert scale, where 1 represents "not at all" and 5 represents "very much".

A sample of 86 companies belonging to a total of 146 ADI companies was collected in the period July 2022-January 2023. Personalized emails were sent to each company.

The data were analyzed using both cluster analysis and regression analysis. Specifically, hierarchical cluster analysis was conducted using the R software to categorize sample companies into distinct groups. We implemented Topsis analysis (the Technique for Order of Preference by Similarity to Ideal Solution), a method that evaluates various criteria, choosing four criteria with the highest performance out of approximately forty. These criteria, detailed by Bernard Desgraupes (2017) in the "Clustering indices" section of the Clustercrit package in R, include Criterion 1 - C-Index Silhouette, Criterion 2 - Silhouette Index; Criterion 3 - Xie & Beni Index and Criterion 4 - Dunn Index. Additionally, the k-medoid method in R was utilized, employing a heuristic approach to identify initial medoid seeds for k-medoid clustering.

Additionally, regression analysis was conducted to explore the relationships between the cluster identified and three variables from the third section of the questionnaire. These variables include the firm's level of innovation, the positive impact of environmental sustainability of products and processes on customer value creation, and business performance. The coefficient values presented in the table of findings correspond to a significance level of 0.05.

4. Results

The characteristics of the sample are described in Table 1. In particular, the largest slice of the sample consists of small and medium-sized companies that manufacture mainly consumer products and with predominant revenue classes 10-49 and <5 million Euros.

Table 1 – Sample descriptive statistics

Product Type	n	%
Consumer product	55	63.95
Industrial product	16	18.60
Components	15	17.44
Company size		
Micro (<9 employees)	13	15.12
Small (10-49 employees)	25	29.07
Medium (50-249 employees)	31	36.05
Large (> 250 employees)	17	19.77
Revenue class (mil. Euros)		
< 5	20	23.26
5-9	9	10.47
10-49	32	37.21
50-99	12	13.95
100-199	5	5.81
200-400	4	4.65
>400	4	4.65

Note: N =86

Source: authors elaboration.

Table 2 offers descriptive statistics relating to the typology of eco-design approaches adopted, which entails design for durability, design for reduction, design for recycling, and so forth, that is, six respective categories in total. On average, a firm in the sample analyzed adopts a quite good level of eco-design approaches of 3.68, on a 1-5 Likert scale, especially about design for durability (4.49).

Table 2 - Descriptive statistics of eco-design approaches in the firms studied (N= 86).

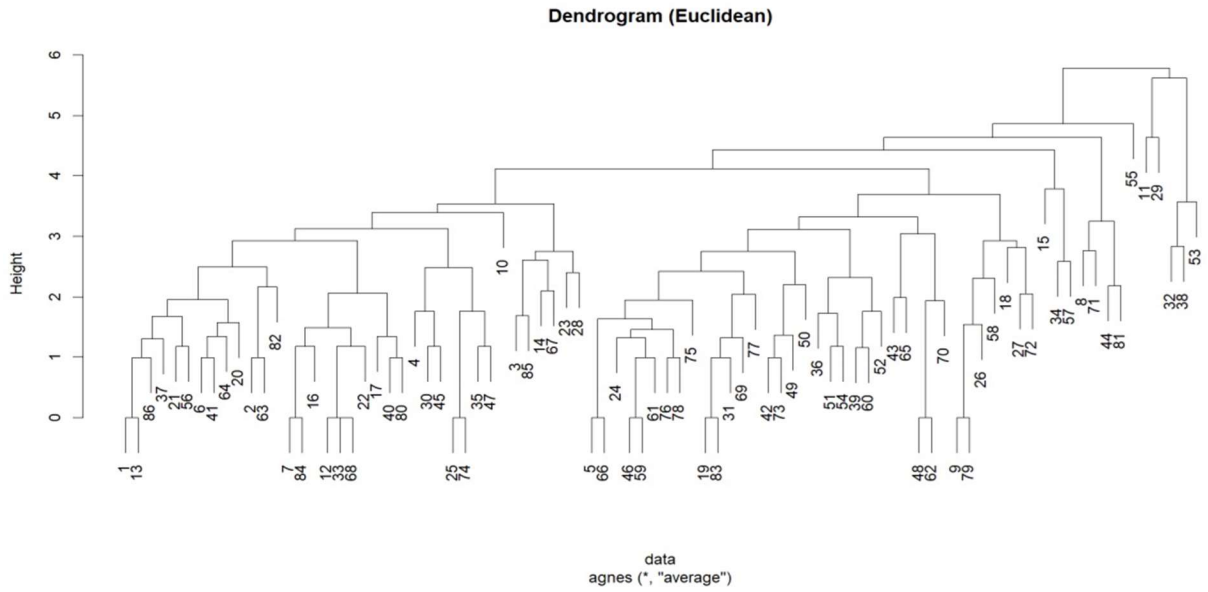
Eoc-design approach/ Descriptive statistics	Design for Durability	Design for Reduction	Design for Recycling	Design for Reparability	Design for Disassembling	Design for Regeneration
Minimum	3.000	1.000	1.000	1.000	1.000	1.000
1st Quantile	4.000	3.000	3.000	3.000	2.250	2.000
Median	5.000	4.000	4.000	4.000	3.000	3.000
Mean	4.488	3.744	3.965	3.442	3.326	3.116
3rd Quantile	5.000	5.000	5.000	4.000	4.000	4.000
Maximum	5.000	5.000	5.000	5.000	5.000	5.000
St. Dev.	0.650	1.030	0.890	1.000	1.190	1.090

Source: authors elaboration.

As introduced, we used cluster analysis to identify possible underlying patterns in the responses of the 86 firms. The cluster analysis results based on the Topsis analysis method indicate that a three-cluster solution appeared to be appropriate. Therefore, we identified three groups of design-driven companies with a different combination of eco-design approaches.

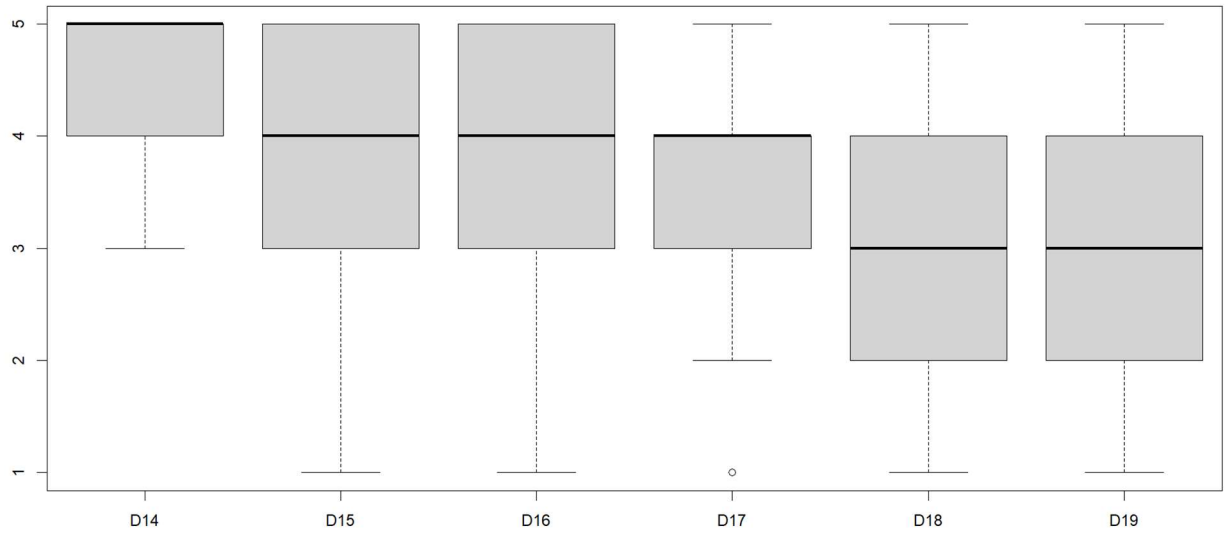
The graphic representations consisting of a dendrogram (Fig. 1), a plot box (Fig. 2), and a silhouette (Appendix 1), together with a brief description using the medoid values, and the most frequent answers over the threshold value of 65.16%, are presented. The graphic representations show that the data is divided into three groups of approximately equal size. All points in the three clusters have large silhouette values (approximately 0.6 or greater), indicating that the clusters are well separated. The cluster analysis thus identified three clusters of companies with a specific combination of eco-design approaches adopted. It consists of 40 companies in Cluster 1, 17 companies in Cluster 2, and 29 companies in Cluster 3.

Figure 1 - Dendrogram



Source: authors elaboration (N=86 firms).

Figure 2 – Box plot



Source: authors elaboration.

The semantics adopted to identify clusters are described below in Table 3. In particular, medoids were used. Medoids are representative objects of a cluster within a data set whose sum of dissimilarities to all the objects in the cluster is minimal.[1]

[1] Source: https://en.wikipedia.org/wiki/Medoid.

Table 3 – The semantics adopted to determine the clusters in the data set of 86 firms

Cluster	Durability	Reduction	Recycling	Reparability	Disassembling	Regeneration
1	5	4	4	4	4	4
2	5	4	4	2	2	2
3	4	3	3	4	3	3
1	13			12		
2	13			6		
3	10			10		
1	HIGH			HIGH		
2	HIGH			LOW		
3	MEDIUM			MEDIUM		

Note: Value from 3 to 6: LOW
Value from 7 to 11: MEDIUM
Value from 12 to 15: HIGH
Source: authors elaboration.

Therefore, Cluster 1 (40 firms) is characterized by a high presence of all eco-design approaches and for this reason these firms have been named "The highest eco-green design firms". Firms of Cluster 2 (17 firms) are highly sustainable because of the adoption of three approaches (durability, reduction, recycling) but low levels of more sophisticated approaches to design e.g. reparability, disassembling and regeneration. For this reason, we named this cluster "The traditional eco-green design firms".

Finally, the third cluster (29 firms) is characterized by medium adoption of all the six types of design approaches suggested by ADI. This cluster has been named "The medium eco-green design firms". Then, the characteristics (or illustrative variables) of each cluster (type of product, company size, revenue class) were provided (Table 4).

Table 4 – Descriptive characteristics of the clusters identified (N=86 firms)

Variables	All firms	Cluster 1	Cluster 2	Cluster 3
Types of Product				
Component	17.44%	17.50%	35.29%	6.90%
Consumer product	63.95%	62.50%	47.06%	75.86%
Industrial product	18.60%	20.00%	17.65%	17.24%
Company Size				
Micro	15.12%	15.00%	17.65%	13.79%
Small	29.07%	37.50%	17.65%	24.14%
Medium	36.05%	27.50%	47.06%	41.38%
Large	19.77%	20.00%	17.65%	20.69%
Revenue class (mil. euros)				
<5	23.26%	25.00%	23.53%	20.69%
5 - 10	10.47%	10.00%	11.76%	10.34%
11 - 50	37.21%	32.50%	47.06%	37.93%
51 - 100	13.95%	20.00%	5.88%	10.34%
101 - 200	5.81%	5.00%	5.88%	6.90%
201 - 400	4.65%	2.50%	0.00%	10.34%
>400	4.65%	5.00%	5.88%	3.45%

Source: authors elaboration.

Cluster 1 (40 firms) is made mainly of small (37.50%) and medium firms (27.50) and manufacturing consumer products (62.50%) followed by industrial products (20%). The prevalent revenue classes are 10-50 million euros (32.50%) and <5 million euros (25%).

Cluster 2 (17 firms) consists mainly of medium firms (47%) and firms manufacturing both consumer products (47 %) and components (35%).

Cluster 3 (29 firms) is represented by medium (41.28%) and small firms (24.24%). This is the cluster with the highest percentage of firms manufacturing consumer products (75.86%). Prevailing revenue classes are 10-50 and <5 million euros.

Finally, a regression analysis was performed (Table 5) to understand the entrepreneurs' opinions on how the adoption of the various eco-design strategies adopted by firms relates to the following variables: the level of innovation of the firm ("innovation"), the positive impact of sustainability of products and processes on value creation for customers ("value creation"), and the positive impact of sustainability of products and processes on business performance ("business performance").

Table 5 – Regression analysis results from the study of 86 firms in the Italian sample

Variable	Eco-design approach	All firms	Cluster 1	Cluster 2	Cluster 3
Innovation	Durability	0.518	0.394	0.626	
	Reduction				
	Recycling	0.356		0.659	0.365
	Reparability				
	Disassembling				
	Regeneration				0.288
Customer Value	Durability	0.398	0.029	0.681	0.421
	Reduction		0.040		0.395
	Recycling	0.318		1.023	
	Reparability	-0.186			0.722
	Disassembling	0.321			0.744
	Regeneration				0.359
Business Performance	Durability	0.296	0.384	0.664	
	Reduction	0.165	0.292		
	Recycling	0.266			
	Reparability				
	Disassembling	0.319	-0.189		0.574
	Regeneration		0.384		0.371

Source: authors elaboration

The regression analysis across all 86 firms investigated indicate that only the design for durability and the design for recycling approaches have a positive and significant impact on innovation, customer value, and business performance from the entrepreneur's perspective. The design for disassembling approaches significantly enhances both customer value and business performance. Conversely, the design for reduction approach

significantly benefits business performance alone, while the design for reparability negatively and significantly affects customer value.

Considering the three clusters we identified in this Italian sample of design-oriented firms, the regression reveals that the main differences among clusters concern the impact on value creation for customers. Firms in Cluster 3 demonstrate significance for five out of six eco-design approaches (except for recycling), whereas firms in Clusters 1 and 2 only show significance for two eco-design approaches. Specifically, Cluster 2 exhibits significance for durability and recycling, and Cluster 1 for durability and reduction, both with lower coefficients compared to the former cluster.

More specifically, concerning innovation, the regression across all companies shows significance only for design for durability and recycling, with different coefficients (0.518 for durability and for 0.356 recycling). Typically, an increase of one point in Durability increases innovation by about half a point, and a similar increase in Recycling enhances it by approximately a third of a point. In Cluster 2 (sum1 = High, sum2 = Low), both variables exert the same degree of influence, around 0.6. For Cluster 1, the design for recycling is no longer significant, and the design for durability reduces its influence on innovation. In Cluster 3 (sum1 = Medium, sum2 = Medium), the influence of the design for durability disappears, and the significance of regeneration emerges while maintaining the impact on recycling. This variation also indicates that the three clusters are different.

Regarding business performance, the regression analysis across all companies indicates that the design for durability and recycling both significantly impact business performance, with each having a similar degree of influence (approximately 0.26). In Cluster 1, reduction, recycling, and regeneration each show a positively significant impact. Meanwhile, in Cluster 2, only the design for durability is significant, and it has a higher coefficient (0.664). Finally, in Cluster 3, only the design for disassembling and regeneration approaches show a positive and significant influence.

5. Conclusions

The study's results enabled us to address the research questions, beginning with RQ1, which explored whether there are differences in the adoption of eco-design approaches within the design practices of design-oriented manufacturing companies and their product strategies.

Our study reveals a quite high level of adoption of eco-design approaches by these Italian firms. However, it also uncovers significant heterogeneity in sustainable design practices, as evidenced by the identification of three distinct clusters. The first and largest cluster classified as "The highest eco-green design firms" exhibits the highest level of adoption of eco-design strategies, the second cluster, named "The traditional eco-green design firms", demonstrates a level of adoption between high and medium and the third one, known as "The medium eco-green design firm", shows a medium level of green design. It is noteworthy that Cluster 1 adopts all eco-design approaches investigated, while Cluster 2 and 3 primarily use three specific strategies: design for durability, recycling and reduction.

Accordingly, these clusters highlight both similarities and differences in the composition of the eco-design approaches employed. In particular, our first result shows that the highly design-oriented companies in Italy have different strategies for product

design, but the majority of them adopt mainly design for durability, design for recycling and design for reduction.

This result suggests that the latter type of eco-design strategy is intuitively simpler to implement and less costly. The less adopted design approaches are design for disassembling, design for reparability and design for regeneration. For instance, designing products for disassembly typically demands more effort in the initial design stages and production phases of new product development compared to design for recycling, which may simply involve using recyclable raw materials.

Consequently, the landscape of the design world in Italy exhibits considerable diversity regarding green product innovation strategies. Hence, this somewhat less visible result in a set of Italian design-oriented firms suggests that sustainable design approaches are not uniformly adopted due to variations in firms' product or process designs, managerial cultural differences, and varying levels of environmental sensitivity. Furthermore, more comprehensive sustainability and green innovation approaches may entail perceptions of incurring higher costs and inherent risks and inherent risks (Takacs et al., 2022), although benefits surpassing the expectations may emerge over time (Jevnaker and Olaisen, 2022b).

The study also addressed RQ2 by investigating whether the identified clusters display subtle differences in firm characteristics. We found that firms within the three clusters exhibit slight variations in their company profile attributes, namely size, types of products, and revenue classes. While there are no pronounced differences among the clusters, Cluster 3, followed by Cluster 2, predominantly consists of firms that manufacture consumer products. Conversely, Cluster 2 has a significant number of firms that specialize in manufacturing components. Cluster 1 has the highest concentration of small firms. It is the cluster with the highest level of adoption of eco-design strategies. This finding indicates that the demographic characteristics of the design-oriented firms do not significantly influence eco-design strategy. Instead, factors such as the cultural orientation of the business, entrepreneurial mindset, and the competencies and culture of the personnel and design collaborators are likely more important.

Finally, RQ3 aimed to identify any potential differences among clusters and their relationship with the perceived level of innovation for Italian entrepreneurs, the perceived impact of environmental sustainability on customer value and business performance. We found that the most positive and significant impact for all clusters is innovation, followed by customer value and business performance. The analysis also reveals differences in the impact of adopted eco-design approaches on firm innovation, sustainability for customer value creation, and business performance. Specifically, firms of Cluster 1 predominantly view eco-design strategies as having a significantly positive impact on innovation and business performance. Firms of Cluster 3 consider sustainability strategy impacting all three variables, from innovation to customer value and business performance Finally, according to entrepreneurs of Cluster 3 showing the lowest level of green-strategies adoption, these strategies impact first customer value through three approaches: design for reparability, disassembling and durability followed by business performance.

6. Theoretical contribution

The analysis of the results suggests some theoretical and managerial implications. From the theoretical point of view, the study enriches the literature on design-driven innovation (among others Verganti 2003, 2017; D'Ippolito, 2014; Luchs and Swan, 2011) about the various eco-design strategies adopted in new product development. No previous studies have to our knowledge investigated the level of adoption and the combination of eco-design approaches practised in many contemporary design-oriented firms, in a data set with mainly SMEs and with responses from the company entrepreneurs' perspectives.

Thus, our study allows a possibly deeper understanding of the design-driven innovation processes in the current era (Verganti, 2017), where environmental sustainability is essential for competitiveness (Jevnaker and Olaisen, 2022a, b; Takacs et al., 2022).

Further, it sheds light on the relationship between innovation and environmental sustainability, providing a more nuanced portrayal of both similar and differentiated eco-design approaches, thus enriching the green innovation literature (among others Dangelico, 2016; Oduro et al., 2022; Wang and Yu, 2012).

Our empirical study also contributed to understanding the complex relationship among working towards realizing environmental sustainability, design product strategy, innovation, customer value, and business performance, areas of significant interest for practitioners (Symbola, 2022; 2023).

From the managerial point of view, this study shows the importance of enhancing eco-strategies to design in general that needs to include also the dynamic, collaborative designer and enterprise contexts (Jevnaker, 2012), thus suggesting entrepreneurs and their partners adopt new approaches to manage environmental issues, such as waste management and treatment, less use of virgin materials and hazardous chemicals, (re)use of eco-friendly materials, and use of environmental and statistical tools to measure and advance their improvements.

Further, design-oriented companies should improve meaningful marketing and communication practices to make consumers more aware of the eco-design-based products' value (Conti et al., 2019). The issue seems above all to be at a cultural level (for example, Verganti, 2003). In general SME entrepreneurs from all sectors in Italy pay less attention to marketing and consider it a cost rather than an investment (Conti et al., 2019). To this scope, eco-design-competent consultants, such as specifically design, creative marketing and strategic communication agencies should contribute to teaching these sustainability-enhancing skills and practices to entrepreneurs and their collaborators Pickett-Baker and Ozaki, 2008; Conti et al., forthcoming).

Finally, it is fundamental to develop enhanced sustainability-oriented collaborations with stakeholders at all levels, including trade associations such as ADI. Specifically, design firms are asked to enhance and communicate their environmental responsibility and green strategies by contributing to cultural change through communication that associates the relevant design attributes of products with their eco-friendly characteristics.

Entrepreneurs of Cluster 3 show the lowest level of green-strategies adoption, these strategies impact first customer value through three approaches: design for reparability, disassembling and durability followed by business performance.

7. Limitations and future research directions

This study reveals that the Italian design-oriented firms explored exhibit a relatively high level of eco-design strategies in new product development, according to entrepreneurs. Despite identifying three distinct clusters of firms ranging from high to medium levels of adoption, showcasing a certain level of heterogeneity, the most prevalent cluster demonstrates the highest level of adoption.

Additionally, we discovered numerous combinations of six eco-design approaches, yet all sampled firms primarily employ three: design for durability, design for reduction, and design for recycling. Rather than a comprehensive eco-designing, this result indicates even design-oriented industrial firms are following a fairly limited set of eco-design approaches. It could be hypothesized that these approaches are comparatively easier to adopt than the remaining three investigated; that is, design for reparability, disassembly, and regeneration.

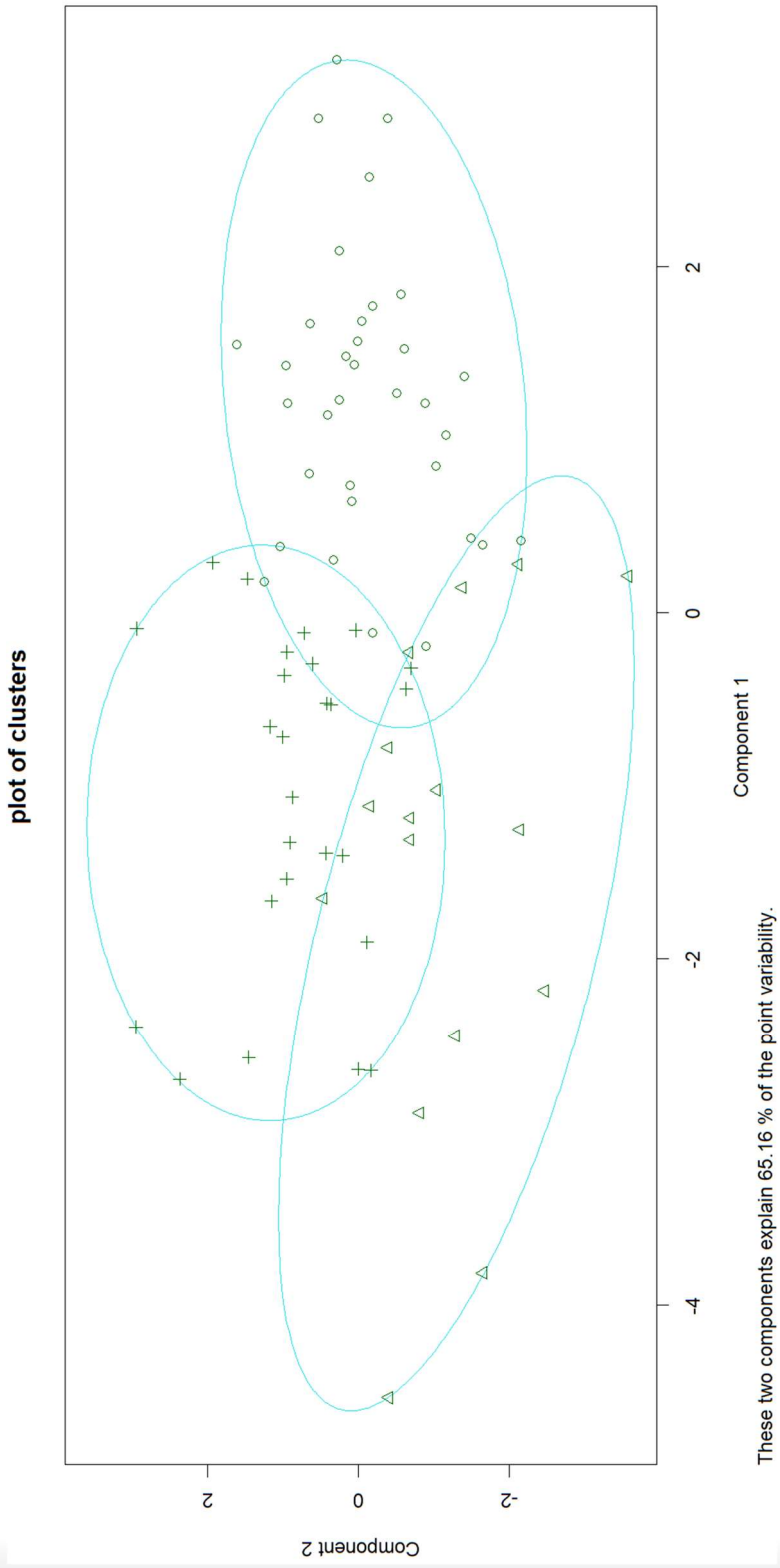
The novelty of this study lies in being among the first to investigate these aspects within design-oriented industrial firms thereby enriching the management literature, business innovation and sustainability literature on design-driven innovation (DDI) and green innovation. Grounded in the identified patterns of groups of design-oriented industrial firms not yet implementing several eco-design approaches, the study also draws some essential implications such as trying out as well as learning (Gil et al., 2018; Jevnaker et al., 2015) a fuller range of eco-designing in practice, which could also help overcome potential firm barriers (Takacs et al., 2022).

Accordingly, this survey study's Italian sample of design-oriented industrial firms (86 of 146 in total) as represented by ADI-member firms that were mainly SMEs with entrepreneurs' responses was both highly interesting and relevant to our study's exploratory aim.

However, there are limitations to the research. The most notable for the use of clustering and regression analytical methods is the limited sample size, and a broader sample would enhance the results and enable further analysis. Future research should also use qualitative methods, like case studies, to delve deeper into seminal (Jevnaker, 2012; Verganti, 2017) as well as the wider implementation of eco-design practices among the most environmentally-focused design-driven companies. That said, the most differentiated eco-design of companies typically needs to be tailor-made whereas not going towards a fuller range of ecodesign alone seems critical (Jevnaker and Olaisen, 2022a; Karimi Takalo et al., 2021) which is why we need deeper insights into real-world design innovation practices in and between groups of firms.

Appendix 1

Figure 1 - Graphic representations of the Cluster analysis “design approaches” from R software



Source: authors elaboration.

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