

Adoption of Life-Cycle-Based Methods for Improving Product-Level Circularity: An Analysis from the Perspective of Stakeholders



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Abstract In recent years, many companies have incorporated environmental management practices aimed at reducing the environmental impact of their products throughout their life cycle. Considering the adoption of this perspective necessary, many companies have adopted various tools, techniques, or methodologies at the operational level and, even at the strategic level, with the support of even the public administrations, among other actors. Nevertheless, the process is not simple and the lack of practical knowledge of previous cases makes the process difficult and costly. Consistent with this point, the objective of the research focuses on the development of an exploratory analysis of the fundamental drivers, key aspects of the process, and the most relevant results of the adoption of life-cycle-based tools and methods for environmental management of manufacturers held in the Basque Country, a leading region in Spain in terms of GDP per capita with a strong and high-tech industrial base. Results show improving a company's image in the market seems to be a fundamental motivation, but there are other internal and external drivers, such as the possibility of increasing the value of products, environmental awareness, and increase competitiveness of companies themselves. The main difficulties were the acquisition of the necessary environmental information from suppliers, the need to adopt new working tools, techniques and methods for environmental impact assessment, and rethink operational and strategic processes to include environmental aspects, and the commitment of all the personnel involved. Overall, the results of the adoption process are

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positive and companies were satisfied. Stakeholders highlighted improvements in safety, quality, and innovation of products and the company image. Nonetheless, stakeholders claim a greater environmental commitment by public administrations is necessary, though they seem to be taking steps forward.

Keywords Product design · Environmental sustainability · Life-cycle thinking · Circular economy

1 Introduction

In the last decades, the behavior of our society with respect to the environment and how we approach the environmental problem has evolved. Since the ability of the planet Earth to meet the needs and ways of life of an ever-growing population is not sustainable, our awareness of this problem has grown.

In the industry, paradigms on sustainable development have been developed, such as “industrial ecology” or “cleaner production”, among others. Among the implications common to all of them, the need for therational exploitation of natural resources is highlighted, as well as a limitation of emissions at a level, at least, in line with the regeneration capacity of the Earth. To address this issue, many more or less specific and complex tools, techniques, and methods have been developed and designed to be integrated at different levels in the company, around concepts such as eco-design. Precisely, according to Papanek [1], design is the most powerful tool with which a human being shapes everything he employs and surrounds him, among other things to the environment (and, by extension, to society itself).

Design presents products as sources of environmental problems. It also implies that organizations are responsible not only for environmental damage due to their own physical activities, but also for a broader range of environmental interventions throughout the product chain. The adoption of the life-cycle perspective includes the indirect environmental impacts of an organization’s activities [2]. It also implies trying to take preventive measures, in order to reduce environmental impacts in all phases of its life cycle, from obtaining materials and components for processing to its disposal, reuse, or recycling. The main challenge for companies is related to the optimizations of the interactions among product design, manufacturing processes, and other life-cycle activities [3]. The environmental factor is considered as one more requirement as other factors like cost, safety, or quality, without compromising the sustainability of the company [4].

On the other hand, eco-design projects require that all the agents involved in the project collaborate. In order to achieve the objectives, changes are needed in the way of carrying out projects, but a series of guidelines and support tools are also necessary [5].

There are several methodologies and tools developed with the aim of successfully undertaking eco-design projects and, even, the integration of eco-design at an operational and strategic level [5, 6].

Despite the wide variety of tools, techniques, and methods, mostly theoretical examples are available, without the support of the practical application by companies [7, 8].

Considering these aspects, the research work has been focused on the analysis of the adoption of environmentally sustainable design and development methods of manufacturing companies from the Basque Country, Spain, a region that hosts one of the main eco-design hubs in Europe. Likewise, the impact of the adoption process on the company's management system, operational processes, and business results has been analyzed.

2 Literature Review

Companies interested in improving the environmental performance of the product and, therefore, of their activities must integrate specific support tools for operational management and, even, at a higher level, for strategic management in a dynamic process of continuous incremental improvement of environmental performance; otherwise, they will be specific improvements of limited scope [9].

The products offered in the market are so diverse that it is not possible to establish a series of specific eco-design actions applicable to all cases. Each product is conditioned by a series of limiting factors, which depend both on its type and the designer/manufacturer and the market where it will be put up for sale. Likewise, not all products generate the same environmental impact, neither at the same stages of their life cycle, nor for the same reasons [10].

In the process of implementing eco-design, the actions to be carried out in the company can be very diverse, depending on the objectives of the company, the characteristics of its products, the resources available, the level of integration of the eco-design to be achieved, etc. [11–13] (see Table 1).

Eco-design must be integrated into the design and management processes of the company, as it is a process. Therefore, it is necessary to consider management tools, strategy tools, communication tools as well as complementary tools for the design process, such as creativity tools and decision-making support tools [3, 15–19].

For these reasons, in recent years we have witnessed the development of numerous methodologies aimed at addressing the keys to the successful integration of eco-design into a single tool [3, 17].

Most of these eco-design tools and methodologies are mostly adaptations of the traditional methods and tools used in the product development process [20].

Among them are the environmental management standards, for example, ISO/TR 14062:2002 (ISO, 2002) or IEC 62430: 2009 (ISO, 2009), based on processes of continuous improvement of ecological and economic indicators of a product, and based on the systematic integration of the environmental variable in the strategies and practices of the company from the life-cycle perspective [3, 15].

The methodologies differ in the scope, the quality of the results, and the time required to apply them, but their application is scarce [15, 19]. Even when they are

Table 1 Techniques for the integration of environmental sustainability in product development

	Level 1	Level 2	Level 3
	Strategy	Tactics	Operations
<i>Implementation levels</i>	<ul style="list-style-type: none"> • Development and establishment of the environmental strategy • Focus: corporate level • Users: Top Management 	<ul style="list-style-type: none"> • Tactical decisions taking into account the product life cycle and interrelationships • Focus: development process • Users: Product Manager 	<ul style="list-style-type: none"> • Practical concepts to integrate the ESD in the process of developing traditional products • Focus: development process • Users: designers
<i>Features</i>	<ul style="list-style-type: none"> • Objectives of the company toward environmental sustainability • Manageable and simple to apply 	<ul style="list-style-type: none"> • Environmental performance taking into account the entire product life cycle • First stages of the product development process • Manageable and simple to apply 	
	Top-down approach $\Delta\downarrow$	Bottom-up approach $\Delta\uparrow$	
<i>Tools for Environmentally Sustainable Development (ESD)</i>	<ol style="list-style-type: none"> (1) Environmental benchmarking (2) Environmental strategies (3) Action plans and environmental champions (4) Integration into the structure of the organization (5) Environmental education programs (6) Environmental audit (7) Environmental management systems 	<ol style="list-style-type: none"> (1) ESD Process Statement (2) Communication systems (3) Advanced Environmental Systems (4) Life Cycle Assessment (5) Environmental accounting (6) Multicriteria evaluation criteria 	<ol style="list-style-type: none"> (7) Concept indicators (8) Deployment of the Environmental Quality Function (E-QFD) (9) Method of environmental failures and evaluation analysis (E-FMEA) (10) Concepts-matrix: MET, EPLC... (11) Checklists (12) Creativity techniques

Source Compiled from Kara et al. [14] and Bovea and Pérez-Belis [15]

applied, most of the times they are not systematically applied in companies due to their complexity, the time required for their application, and the lack of knowledge on environmental issues [15, 18].

3 Methods

In this exploratory research, a set of in-depth interviews were developed in three successive phases with 24 professionals from different fields related to the integration of the life-cycle-based environmentally sustainable product design practices in industrial companies. The election of this qualitative methodology was due to the possibility of comparing the different perspectives of the stakeholders about the adoption of eco-design and development practices with a life-cycle approach in the industry.

Before the study, semi-structured in-depth interviews with 11 professionals following guide notes based on several case studies of the literature were carried out [5]. The aim of this pre-test was to improve the guidelines verifying the information collected in the literature and the inclusion of new elements and life-cycle-based methods on sustainable product design highlighted by these professionals.

In the second step, the professionals selected were 9 leaders of eco-design projects belonging to companies of four industrial sectors (chemical, electrical–electronic, capital goods, and furniture), 5 auditing companies, 4 consulting firms, 2 academics, 3 public institutions, and one member of an industry eco-design cluster. We tried to draw up a group taking into account several aspects highlighted by Habidi [21], for example, the degree of affectation to the consequences of the research object, the degree of subjectivity, the degree of motivation, the level of knowledge about systematizing, measuring and acting on the constant improvement of the implementation, and management of environmentally sustainable product design practices in companies and other factors, such as the cost of displacement, proximity, and organizational considerations.

In the first round of interviews, it was tried to keep a flexible guide in order to be able to integrate new points into the study. In the second round with a shorter and less flexible guide, the participants assessed these new aspects.

To measure each item, different scales were created from 1 to 7 taking into account the pre-test and the responses of the interviewed professionals. In the following section, the median and range of each item are shown.

4 Results

In general, companies seek, above all, to improve their economic results, although they also understand that it is essential to comply with environmental legislation. In the study, it is highlighted that the final product manufacturer needs to communicate the environmental qualities of its product (added value of eco-design) to obtain a green image (see Table 2). The reinforcement of the marketing strategies is cited by the managers as one of the key aspects, for the integration of environmental criteria in the strategic plans with similar valuations among small, medium, and large companies.

Table 2 Main motivations of stakeholders to support the adoption of eco-design tools and methods

Stakeholders	Motivation	M ¹	R ²
Managers	Possibility of economic return	5,5	1
	Company image	6	0,25
Design and development dept	Possibility of increasing the added value of work	6	1,25
	Environmental awareness	5	1,5
Suppliers	Possibility of benefiting from the improvements	4	1,25
	New alternatives, new market niche	5	1,25
Dealers	Possibility of benefiting from the improvements	4	2
	Requirement of the main customers	4,5	1
Public administrations	Compliance with sustainability objectives	5	1,25
	Increase in the competitiveness of the local company	5,5	1,5
Customers	Reduction of costs in use	4	1,5
	Environmental awareness	4	1,25

¹M: Median. ²R: Range

Source Put together by the authors

Among the obstacles that hinder the adoption of eco-design tools and methodologies, the members of the group mention several (see Table 3). Among others are the requirement of implementing new tools and methodologies in the work routine, the external support needed, the lack of market incentives, and the added costs.

Companies also have difficulties in obtaining necessary environmental information about materials, components, and systems (see Table 4). For some of the managers, this problem represents one of the most important that companies face. However, this is not shared by suppliers.

Likewise, the belief that eco-design products increase internal costs seems to be a generalized problem. The members believe that sometimes there is a lack of

Table 3 Causes that imply the slowdown of the adoption of eco-design practices

Causes	M ¹	R ²
Bureaucratization of internal processes	4	2
Absence of market incentives	6	2
Need to reduce costs	6	1
Thought that there will be an increase in technical, economic, and human costs	5	0
The reduction or elimination of public supports (via subsidies)	5	1

¹M: Median. ²R: Range

Source Put together by the authors

Table 4 The most difficult obstacles to overcome during the process of adopting eco-design methodologies and tools

Obstacle	M ¹	R ²
Initial investment need: staff training, procedure development, certification, etc	4,5	1,25
Obtain the necessary environmental information about materials, components, and systems	5,5	1,5
Difficulty in applying a methodology for the identification and evaluation of aspects	4,5	1,5
Need to implement new tools and methodologies in the work routine	5	0,5
Need for external support to guide the adoption process	5	1
Get the commitment of all the personnel involved, from management to pawns	5	2

¹M: Median. ²R: Range

Source Put together by the authors

Table 5 Influence or impact in the different phases of the life cycle on the cost of eco-designed products

Phase	M ¹	R ²
Obtaining materials and components	4,5	1,5
Design and development	4	1
Manufacturing	4	0
Distribution	3,5	1,25
Use	2,5	1,25
End of life	3	0,5

¹M: Median. ²R: Range

Source Put together by the authors

knowledge about the implications of eco-design. For example, they do not agree on whether operating costs increase globally. They admit a probable increase, mainly in the phase of obtaining materials, substances and components, in the phase of design and development of the product, and in the manufacturing phase, that is, in the initial phases of the life cycle of the product (see Table 5).

Asked about the most used eco-design tools among companies, the members of the group do not agree on the preponderance of any of them over the rest (see Table 6). It is possible to think that companies demand tools to be able to assess the

Table 6 Level of use of the main eco-design tools

Tools	M ¹	R ²
Software LCA	3,5	3,25
Energy simulation software	1	0
Guidelines	2,5	3,25
Recommendations for product certification systems (eco-labels, Energy Star...)	4	3

¹M: Median. ²R: Range

Source Put together by the authors

Table 7 Influence of the adoption of methodologies and tools at the operational level

Aspect	M ¹	R ²
Introduction of new technologies	6	2
Work processes	6	2
Health/Safety at work	4	2
Stock rotation	3,5	1

¹M: Median.²R: Range
 Source Put together by the authors

environmental behavior of a product, but none of these tools predominates over the rest.

Other elements that facilitate the adoption of methodologies and tools at an operational and even strategic level are the support of associations, clusters, or public bodies.

The improvement of motivation among personnel in the area of design and product development is another of the most outstanding aspects (see Table 7). In addition, the companies know and control better the process of product design and development. Systematically, eco-design practices seem to be a factor with a positive influence on the introduction of new technologies in the activities of companies (see Table 7).

Regarding the product (Table 8), the experts assure that the adoption of eco-design tools allows the achievement of environmental improvements in various phases of the product’s life cycle and the improvement of the quality and safety of the products. For example, in the chemical sector, companies obtain more efficient and safe products for people, and also for the environment.

The systematic practice of eco-design has helped to improve the image of the company and, even, anticipate future environmental legislation (see Table 9). Nevertheless, sales of products do not grow especially, although the proportion of sales of eco-designed products does.

As can be seen in Table 10, the managers are particularly satisfied with the new life-cycle approach and the adoption of eco-design practices at the operational and strategic levels. In a way, it might be expected, since it is a process that depends on their decision and their leadership.

The public administrations are also satisfied with the adoption of eco-design practices, and they consider that it improves the competitiveness of companies and even

Table 8 Influence of the adoption of eco-design practices on the product

Aspect	M ¹	R ²
Quality and Safety	6	1
Innovation	6	1
Cost at factor prices	5	1
Sales margin	4	1

¹M: Median.²R: Range
 Source Put together by the authors

Table 9 Influence of the adoption of eco-design methodologies and tools on business results

Aspect	M ¹	R ²
Sales growth	4	0,5
Productivity	4	0,25
Economic profitability	4,5	1,25
Market share	4	1
Internationalization	5	0,5
Company image	6	0,5
Customer needs compliance	5	1,5
Environmental communication	6	2

¹M: Median.²R: Range

Source Put together by the authors

Table 10 Level of Satisfaction of the main stakeholders

Stakeholders	M ¹	R ²
Managers	6	0
Design and Development dept. Employees	6	1
Suppliers	3,5	1,75
Dealers	4	2
Public administrations	6	2
Customers	4	1

¹M: Median.²R: Range

Source Put together by the authors

contribute to the environmental strategy of the territory. Then, it seems possible to talk about the contribution to sustainable development, although it has obviated the social component in that statement. On the contrary, their attitude shown seems different, according to other members of the panel. They denounce a lack of government leadership in the development, implementation, and support of initiatives that promote green markets.

5 Conclusion

This research has addressed the study of the process of adoption by industrial companies of tools, techniques, and methods to improve the environmental performance of the product from a different perspective, from the stakeholders, with the aim of exploring other aspects of the process that could be key for success.

Companies have diverse internal and external drivers. Improving the company's image in the market is the most highlighted motivation, but it is linked with the possibility of achieving environmental recognition. The possibility of increasing the

value of the products and environmental awareness of the company, and increase of the competitiveness has been pointed out too.

The adoption process is not free of difficulties. Obtaining environmental data on materials, substances, or components has initially been one of the most difficult problems to overcome. Besides, the belief that eco-design practices increase the internal costs seems to be a generalized problem, but the interviewees considered that, in many cases, it is due to the lack of knowledge of the companies.

In general, they agree that, eco-design practices integrated at operational and strategic levels, contribute to improving key factors of the products or services such as quality, safety, and energy efficiency in the use phase or generation of less waste at the end of life. These improvements generate an innovative and green image of the companies. Managers seem to be satisfied with the adoption of eco-design practices, mainly due to achievements of improvements in safety, quality, and innovation of the products and the company image.

Nevertheless, to strengthen the motivation for adopting life-cycle-based eco-design methods, the implication of the public administrations is considered necessary. In this respect, the declaration of a climate emergency for a carbon-neutral Basque Country in July 2019 could be an important step.

Besides, recognition systems that, allow consumers to distinguish a product with better environmental performance from a worse one, should be promoted and current legislation should be improved and updated. Otherwise, the economic criteria will continue to be imposed on the environmental criteria.

The limitations of the study mainly are focused on the methodology used, which is eminently exploratory. As a result, the study serves to raise another series of questions that should be analyzed in depth. Among others, on methodologies aimed at facilitating the integration of eco-design practices in the daily management, the integration and internalization of life-cycle-based eco-design methods, and its influence on economic and environmental performance in companies, because they are key aspects to change in favor of a sustainable business model in companies.

Conflict of Interest The authors declare no conflict of interest.

Author Contributions All the authors contributed to the study conception and design. Naiara Uriarte-Gallastegi, Beñat Landeta-Manzano, Germán Arana-Landín, and Patxi Ruiz-de-Arbulo-López performed material preparation, data collection, and analysis. The first draft of the manuscript was written and commented on previous versions of the manuscript by all the authors. Likewise, all the authors read and approved the final manuscript.

Funding This paper is part of the work of the research group GIC IT1073–16 of the Research Group of the Basque University System funded by the Basque Government. There is no relationship whatsoever between the authors and the external participants (not belonging to the UPV/EHU) or the companies, associations, or public or private organizations to which they belong, apart from the contacts strictly necessary to carry out the research. Neither the research group nor University of the Basque Country, to which the authors belong, have received directly or indirectly funds from external participants or the companies, associations, or public or private organizations to which they belong. The study was conducted for purely academic purposes.

Statement on Compliance with Ethical Standards This manuscript has been prepared within the framework of research whose design, development, and dissemination plan of the results are in accordance with the “Regulations of the University of the Basque Country (UPV/EHU) for the Protection of Personal Data” (accessible at www.ehu.es/babestu) and in accordance with Regulation (EU) 2016/679 of the European Parliament and of the Council of April 27, 2016, on the protection of individuals with regard to the processing of personal data and the free movement of such data, as it has been certified by the Committee on Ethics in Research and Teaching of University of the Basque Country (CEID), with ref. no. TI0190.

All participants (internal and external to the UPV/EHU) and the companies, associations, or public or private bodies to which they belong were informed at the beginning of the study of the points included in article 13 of the RGPD, including the right to exercise the rights of access, rectification, suppression, opposition, portability, and limitation of processing in the UPV/EHU.

Likewise, the participants were duly informed with general information about the research project: objectives and scope of the research, duration of the project, methodology, funding organizations, security considerations and anonymity in the treatment and safeguarding of personal and company data, expected results of the study, and dissemination of results and publication policies. In this respect, research results and manuscripts prepared for dissemination contain only data processed in aggregate form, and were shared with participants on an individual basis for approval before publication. No personal data or opinions were shared at any time, or those of participating companies, associations, or public and private bodies.

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