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Towards a greater integration of environmental sustainability into product innovation: Action research and proposition of an Ecodesign Transition Framework

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Thesis submitted at the Polytechnic School of University of São Paulo (USP) for the degree of Doctor of Philosophy in Production Engineering

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Em direção a uma maior integração da sustentabilidade ambiental na inovação de produto: pesquisa-ação e proposição de um Modelo de Transição em *Ecodesign*

Tese apresentada à Escola Politécnica da Universidade de São Paulo para obtenção do título de Doutor em Engenharia

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RESUMO

Desde os anos 1990, a evolução em direção de operações mais ambientalmente sustentáveis ganhou maior reconhecimento em empresas e na Academia, com a sustentabilidade se tornando uma prioridade competitiva. Apesar de uma grande quantidade de pesquisas sobre *ecodesign*, ou a integração dos aspectos ambientais no desenvolvimento de produtos, estudos recentes indicam que uma implementação completa do *ecodesign* ainda é um desafio para a maioria das empresas. Para superar as lacunas encontradas em estudos anteriores (como a distância entre teoria e prática, e recomendações excessivamente técnicas e fragmentadas), esta pesquisa teve como objetivo identificar como incorporar a sustentabilidade ambiental de forma mais efetiva na inovação de produtos de uma empresa, e propor um modelo que sintetiza os resultados. Esta tese, baseada em cinco artigos, aplicou uma abordagem multimétodos. O modelo foi construído combinando revisões sistemáticas de literatura e uma pesquisa-ação de cinco anos. Dentro de uma empresa brasileira líder do setor cosmético, dois ciclos de implementação foram conduzidos, incluindo customização de ferramentas de ecodesign e sua aplicação em oito projetos de desenvolvimento de produtos, com ampla capacitação de diferentes partes interessadas. A pesquisa levou a três contribuições. Como primeira contribuição metodológica, diretrizes de aplicação da pesquisa-ação promovem um modo de colaboração efetivo entre a Academia e as empresas, especialmente adaptado para a inovação aberta e sustentável. Em segundo lugar, o presente estudo desenvolveu uma visão larga das atividades relacionadas ao *ecodesign*, ampliando a abordagem tradicional centrada em projetos individuais, e validando o conceito de inserção formal de ferramentas de *ecodesign* customizadas no Processo de Desenvolvimento de Produtos. Além desse princípio, outros aspectos gerenciais, tais como gestão de projetos e de portfolio foram considerados, ligando-os com o planejamento estratégico. Adicionalmente, novas abordagens de gestão de mudanças foram experimentadas, com base na teoria de Gestão de Transição. A terceira e maior contribuição, decorrente de uma síntese de mais de cinquenta modelos encontrados na literatura, associada à pesquisa-

ação, é a proposição do "*Ecodesign Transition Framework*". O chamado "15Ps ETF" compreende um "Padrão" com oito construtos (Propósito, Portfolio, Processo, Plataforma, *Pipeline*, Práticas e ferramentas, Procedimentos e Projetos) para um *ecodesign* maduro, e um componente chamado "Percurso", com cinco construtos (Planeta, Público, Programa, Piloto, e Pessoas), para a realização da necessária transição endereçando aspectos não técnicos. A parte central do modelo, com formato de "pirâmide azteca", representa uma estrutura sistêmica com três níveis - estratégico, tático e operacional - combinando os processos e atividades ligados à inovação de produto. O modelo ETF almeja apoiar uma abordagem ampliada para planejar, implementar e monitorar a integração das considerações ambientais em todaa inovação de produto de uma empresa, através de uma dinâmica de aprendizagem sistêmica. O aumento global da maturidade em *ecodesig*n observado na empresa mostrou congruência com o modelo, com desafios significativos também observados. Para maior validação, o ETF poderia ser aplicado em diferentes contextos, e aprofundado através de estudos qualitativos e quantitativos de fatores de sucesso associados, a fim de considerar as especificidades das empresas e complexidade associada (como: cultura, resistência a mudanças, entropia organizacional, etc.).

Palavras-chaves: Ecodesign. Integração. Inovação de Produto. Sustentabilidade. Gestão de mudanças. Pesquisa-Ação.

ABSTRACT

Since the 1990s, the evolution to more environmentally sustainable business operations has gained increased recognition incorporations and the Academia, with sustainability becoming a key competitive priority for companies. In spite of a large amount of research on ecodesign,or the integration of environmental aspects into product design and development, recent surveys state that thorough ecodesign implementation is still a challenge for most firms.To overcome gaps found in prior studies (such as a distance between theory and practice, and over-technical and fragmented recommendations), this research aimed to identify and experiment how to incorporate environmental sustainability more effectively into product innovation and related activities of a company, and to propose a framework summarising the associated learning. This thesis is based on a set of five articles, applying a multi-methods approach. The framework was built with a methodology combining systematic reviews of previous literature and action research through a five-year long experiment. Inside a leading Brazilian cosmetics company, two implementation cycles were conducted, including customisation of ecodesign tools and their application in eight product development projects, and wide capacity building involving different stakeholders. The research led to three contributions. As a first methodological contribution, action research methodology and application guidelines were developed, for an effective collaboration mode between the Academia and companies, especially adapted to sustainable open innovation. Secondly, this study has deepened and experimented in real company context a broad view of ecodesign related activities, expanding the recognised approach centred on individual projects and validating the concept of formal insertion of customised ecodesign tools into of the Product Development Process. Such principle was further extended to include other managerial aspects, such as project and portfolio management, and linking them with strategic planning. To complement such technical and process related aspects, new “soft” side approaches were also experienced, building on the Transition Management theory. The third and major contribution, deriving from a synthesis of more than fifty models found in the literature and the action research, is the proposition of an “Ecodesign Transition Framework”. The so-called “15Ps

ETF”comprehends a “pattern” with eight main constructs (Purpose, Portfolio, Process, Platform, Pipeline, Practices & tools, Procedures and Project management) for a mature ecodesign and a “pathway” component, with five constructs (Planet, Public, Programme, Pilot, and People), for conducting the necessary transition addressing soft issues. The central “Aztec pyramid” shape of the framework represents the systemic three-level structure, combining the strategic, tactical and operational product related processes and activities. The ETF intends to support a far-reaching approach to better plan, implement and monitor the integration of environmental considerations in the whole innovation process of a company, through a systemic action learning process. The overall increased ecodesign maturity observed in the company showed congruence with the framework, with substantial challenges also observed. For further validation, the ETF could be applied in different contexts, and explored through qualitative and quantitative studies of associated limiting or success factors, to better address corporate specificities and complexity (e.g., culture, resistance to change, organisational entropy, etc.).

Keywords: Ecodesign. Integration. Product innovation. Sustainability. Change Management. Action Research.

LIST OF FIGURES AND TABLES

LIST OF ABBREVIATIONS

AR	Action Research
CEW	Creative Ecodesign Workshop
COP	Conference of Parties
CP	Cleaner Production
DfE	Design for Environment
EcoM2	Ecodesign Maturity Model
ETF	Ecodesign Transition Framework
IAR	Insider Action Research
KJ	Kawakita Jiro
NPD	New Products Development
OM	Operations Management
PDP	Product Development Process
PF	Portfolio
PM	Project Management
SCP	Sustainable Consumption and Production
SLR	Systematic Literature Review
TM	Transition Management

TABLE OF CONTENTS

1 INTRODUCTION

This chapter introduces the general context of the research, starting with the background and implications, knowledge gaps and main concepts that underpin ecodesign (section 1.1 and 1.2). Then the research objectives will be presented (section 1.3) as well as the structure of the thesis (1.4).

1.1 A GROWING MOMENTUM FOR SUSTAINABILITY & INNOVATION

1.1.1 Sustainability Imperative, from society to businesses

A growing number of scientists argue that planet Earth has entered a new era, called the Anthropocene, where humans constitute the dominant driver of change to the planetary system (EHLERS et al., 2006). As anthropogenic pressures on the Earth System have reached a scale where abrupt global environmental change can no longer be excluded, such new challenges require new thinking on global sustainability (ROCKSTRÖM et al., 2009; STEFFEN et al., 2015).

This worldwide context invites all actors of society to the debate – as will occur at next Conference of Parties, COP21, in Paris, on December 2015.To face such scenario, Ryan (2004) proposed the idea of sustainable development through innovation as an emerging new paradigm capable to shape government, business and community approaches to a sustainable future.

Countless publications dealing with sustainability start and refer to the outbreak of the sustainable development concept on the international and political scenery through the United Nations in 1987 with the report from the Brundtland Commission: “sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs” (WCED, 1987).

In fact sustainability derived from the Latin sustenere (tenere, to hold; sus, up), and used to mean “maintain", "support", or "endure”. Then the word progressively acquired this new sense of human development and continuity on planet Earth instead of steady growth in earnings in business vocabulary (BASCOUL; MOUTOT, 2009).

Discussing how to achieve “Sustainability by design”, Erhenfeld (2008), stated that Business is indirectly the agent of much of the damage to environment, and should be a key target for institutional change regarding sustainability, acknowledging the incomparable capacity of companies to promote both innovation and change.

Sterman (2012) argued that “after decades of false starts, “sustainability” is becoming mainstream”. Indeed, pioneers like Gladwin et al. (1995) in the USA had announced the emergence of Sustainability as an “hypernorm”, while in Europe the concept of “Ecological modernisation” was introduced as a way for capitalism to achieve its version of sustainable development (Pepper, 1998).

A radical evolution has occurred in business management. Once blamed for promoting companies obsessive and myopic commitment to short-term profits (AKTOUF, 1992; HOLFORD et al., 2008), management theories have progressively established that firms may be both green and competitive (KING; LENOX, 2001; ORSATO, 2006; PORTER; VAN DER LINDE, 1995; PUJARI et al., 2003).

For Kiron et al. (2015), corporate sustainability has evolved from expressing good intentions and looking for internal operational efficiencies to become more global and central to the success of most companies. Such, “megatrend” means that sustainability is growingly recognised as an imperative by businesses and will require companies to update traditional business tools to encompass the specialised requirements of environmental sustainability (LUBIN; ESTY, 2010).

According to Unruh (2014), this new sustainability “revolution” implies to alter the way business is done in every function and unit of the company.

1.1.2 Sustainability in operations and innovation

From the Operations Management (OM) perspective, environmental and social sustainability are becoming key competitive priorities for companies, but the way in which they are integrated in operations strategies remains an open issue (LONGONI; CAGLIANO, 2015).

Lubin and Esty (2010) warned that such megatrend requires businesses to adapt and innovate to survive. Sustainability will force companies to change the way they think about products, technologies, processes, and business models, becoming the key driver of innovation (NIDUMOLU et al., 2009).

This recommendation is consistent with the fact that of all the core functions of most companies, innovation has the most competitive value – and is often managed with the least discipline (JARUZELSKI et al., 2005, NAGJI; TUF, 2012).

However, Goffin and Mitchell´s (2010) comprehensive guidebook on innovation management did not consider sustainability as a topic. More recently, Goffin recognised this concern: “There is a growing consensus that `there´s no alternative to sustainable development and corporations must develop products and services that are both environmentally and socially acceptable” (GOFFIN, 2012, p.105).

Hence, operations and innovation management increasingly acknowledge the need for Sustainable OM, which may have an important role to play in contributing to solutions for global sustainability challenge (DRAKE; SPINLER, 2013).

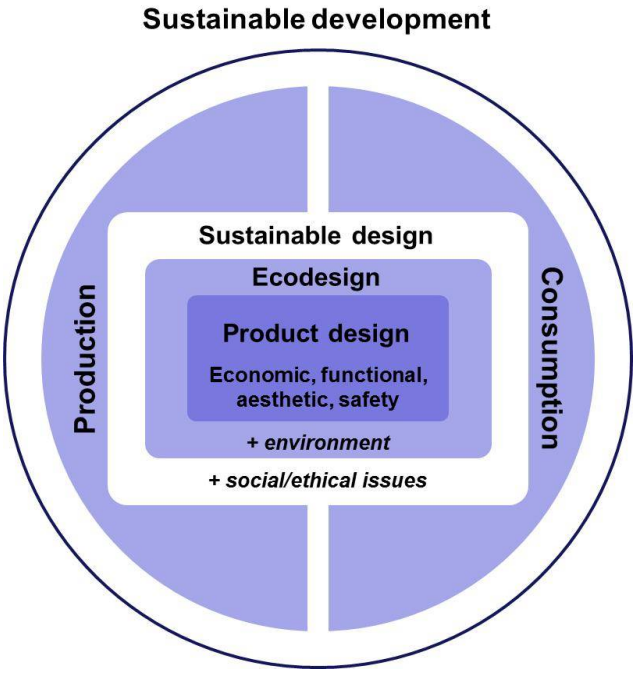
1.1.3 Ecodesign, linking sustainable production and consumption

Such concern for sustainability, innovation and firms’ competitiveness has called research efforts for several decades. For Seager (2008) the sustainable decision making in management, policy and design is a necessity, but remains in mere nascent stages of development and requires further progress.

Since the United Nations Conference on Environment and Development, held in Rio de Janeiro in 1992, sustainable consumption and production (SCP) has been recognised as an overarching theme to link environmental and development challenges (TUKKER et al., 2008; UNEP, 2010).

Dobers and Strannegard (2005) stated that the interplay between production and consumption is a point of departure for understanding the critical quest for sustainable development. With a similar view, Charter and Tischner (2001) participated in the development of ecodesign and sustainable design, echoing at company level the sustainability challenges as defined at society level (SPANGENBERG, 2001), as represented in Fig. 1. Indeed, the theme of ecodesign had emerged in the 1990s, as a promising approach to sustainable production and consumption (BREZET; VAN HEMEL, 1997).

Fig. 1 -Ecodesign and sustainable production and consumption



Source: Charter and Tischner, 2001, p.120.

1.2 ECODESIGN IMPLEMENTATION CHALLENGES

Ecodesign or Design for Environment – defined as the integration of environmental aspects into product design and development with the aim of reducing adverse environmental impacts throughout product´s life cycle (INTERNATIONAL STANDARD, 2011) - has evolved to a more mature and normalised knowledge area, after the publication of ISO standards TR 14062 and ISO 14006 (INTERNATIONAL STANDARD, 2002, 2011). Product oriented life cycle thinking is seen as an increasingly relevant question for sustainability and innovation strategies and policies. However, the application of ecodesign principles does not simply require the inclusion of a few environmental considerations. Goffin (2012) declared that organisations will need to make significant modifications to New Product Development (NPD) processes to achieve sustainable innovation.

1.2.1 Low integration

Since the 1990s, numerous authors have deplored that the uptake of ecodesign in companies, after initial experimentations and projects, was still modest in different parts of the world (BAUMANN et al., 2002; CHARTER; TISCHNER, 2001; DEUTZ et al. 2013; GUELERE, 2009; PIGOSSO 2012; VERHULST; BOKS, 2012).

Northern Europe was generally recognised as the most advanced region in the world for the topic.However, recent surveys stated that the vast majority of companies in UK and Sweden, though agreeing that Design for Sustainability should be part of the product development process, did not practice ecodesign at all (SHORT et al., 2012).

In another survey in the UK, Deutz et al. (2013) observed that ecodesign engagement is generally low. In an Italian study, May et al. (2012) concluded that most ecodesign projects fail, reflecting that companies were incapable to implement sustainability in product development process.

According to recent PhD studies on the subject of implementing sustainable design, ecodesign application is not consolidated in businesses around the world, although theory and methods are available, mainly due to the difficulties in management challenges (PIGOSSO, 2012; VERHULST, 2012).

1.2.2 Disconnect between thought and action

A first obstacle for implementation is a significant gap between the theory and practice of ecodesign (DEUTZ et al. 2013; HANDFIELD et al., 2001; MAY et al., 2012, VERHULST; BOKS, 2012). This concern is not only found for the product innovation side, but also more broadly for sustainability topics, as stated in a recent survey of large companies (KIRON et al., 2013).

Such question had already been raised in previous studies. According to Lenox and Ehrenfeld (1997), Design for Environment work is usually carried out by specialist functions and the results are not fed back efficiently to the rest of the product development process inside the company - a separation also observed by Lindahl et al. (2003). Margolin (2007) argued that the majority of the design community had not adopted sustainability in their core values and practices, a disconnection between design and sustainability also deplored by Spangenberg et al. (2010).

This situation is still acknowledged by Goffin (2012), pointing out a gap in many organisations between the proponents of sustainability and those who develop the products, which Boks (2008) called a gap between the proponents and executors.

1.2.3 Sustainability thinking in Product Innovation: technicist and fragmented

Scholars have recognised that ecodesign research and literature has mainly focussed on tools (ARANA-LANDIN; HERAS-SAIZARBITORIA, 2012; BAUMANN et al. 2002; ORSATO, 2006; STEVELS, 2007), and this trend is still increasing (RIO et al., 2013). Baumann et al. (2002), in an extensive review, concluded that there has been an excess of tool development, but little connection between strategic intent and content, and too little attention about the broader context of product development. Stevels (2007) has named these technical aspects the ecodesign technicalities: Environmental impact data, technological improvements, material substitution, ecodesign tool development. More recently Petala et al. (2010) observed a similar gap between the development of sustainability tools and their actual usage and implementation.

Technically centred approaches often led to little change in practice (BOKS, 2006). Hence a substantial challenge has been pointed out in the literature on how to deal with non-technical aspects, which gave rise to the “soft side of ecodesign”, as coined by Boks (2006). Such duality between “hard” and “soft” aspects is increasingly considered in operations and management research (GUSTAVSSON; HALLIN, 2014).

Besides this “over-technicist” tendency, another challenge for ecodesign research and integration is a fragmentation issue. Boks (2008) identified a lack of connection of environmental activities with business considerations as an obstacle for successful ecodesign or environmental management implementation.

Goffin (2012) warned that, in order to integrate sustainability in NPD, some researchers have ignored the very comprehensive body of NPD knowledge that has been developed from practice and research over several decades; on the

contrary, existing tools and techniques should be adapted to consider sustainability issues.

Pujari et al. (2003) also argued that the effective integration of these two paradigms – conventional and environmental NPD - was a challenge for academics and practitioners, if companies want to be more sustainable and competitive.

According to Verhulst and Boks (2012), to overcome this fragmentation of sustainable design “a holistic view on the complete implementation process is lacking, both from a theoretical and from an empirical perspective”.

A comparable statement, recommending more recognition of systemic perspectives, was previously proposed by Baumann et al. (2002). Orsato (2006) similarly argued on lack of clarity on how to prioritise environmental investments, and how these investments can be aligned with the general strategy of a company.

Finally, Verhulst and Boks (2012) observed that the main challenge lies with moving from successful pilot projects to recurring initiatives and long-term sustainability. The lack of in-depth and long-standing studies in business conditions was previously raised, including by Ritzén (2000) who recommended more case studies and action research for future research.

1.2.4 A need for a new approach to ecodesign

In order to bring new contributions to the general challenge of sustainability integration, this research was built in accordance with the pioneering positions from Gladwin (1993) who made a plea for greater theory development and application on environmental practices and innovation, and recommended “green” action research. Turning sustainability into action is still a main challenge (SCHRETTLE et al., 2014).

1.3 RESEARCH OBJECTIVES

This research, considering the relevant research topic and gaps previously discussed, intended to approach the question of ecodesign integration and implementation building on extensive existing knowledge in ecodesign management and associated knowledge areas (Innovation Management, Sustainability, etc.). At the same time, a strong link should be maintained with the reality of innovation in company context, in other word to generate actionable knowledge, defined by Coghlan (2007) as knowledge that is useful to both the academic and practitioner communities.

1.3.1 Main objective

The principal objective of the research is to build a conceptual model for the integration of environmental sustainability into the product innovation process at company level.

1.3.2 Specific objective

A more specific associated objective is to identify the key dimensions or variables to be considered for the incorporation of environmental sustainability into the product innovation process. Such scope included the (more classical) technical/hard aspects, but also organisational and human oriented issues, as well as the implementations conditions and obstacles. Hence the work dealt with both “hard” and “soft” aspects increasingly considered in research.

The purpose of the model is to bring light and consistency to the main aspects necessary for ecodesign integration. Beyond a theoretical steadiness, the model should permit to support a company face the technical and organisational challenges commonly recognised for sustainability integration.

1.4 THESIS STRUCTURE

This PhD thesis, following the article based format recently accepted at the Production Engineering Department of USP, is composed of two main parts, as shown in Fig.2.

The first or integrating part presents the main knowledge provided by the whole research projects, and is divided in four chapters.

The present chapter has provided an introduction to the research including the motivation for the study, knowledge gaps and challenges, and research objectives.

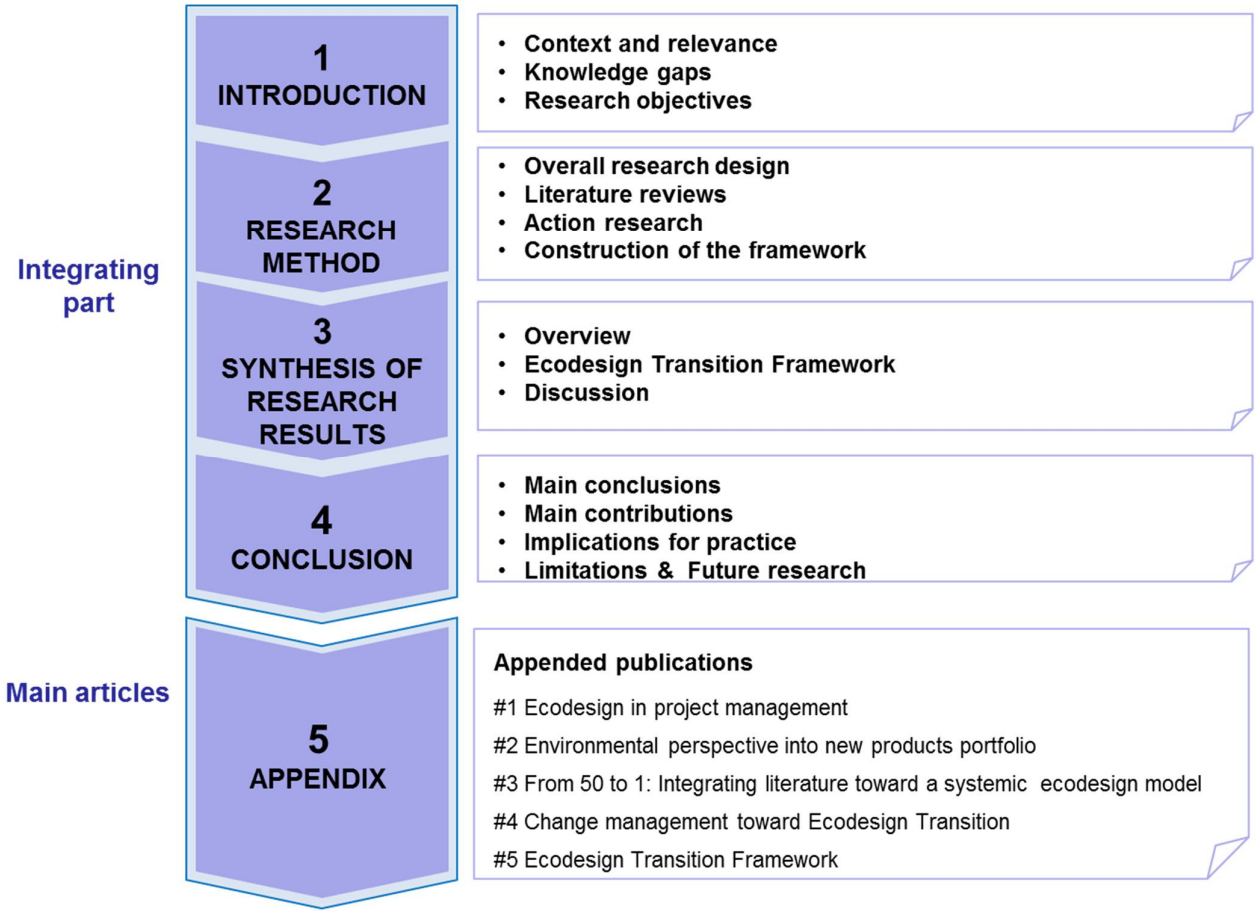
Chapter 2 covers the overall research approach and the main methods used in the PhD - namely systematic literature review and action research.

Chapter 3 summarises the main results of the PhD research, centred on the Ecodesign Transition Framework developed along the PhD.

Chapter 4 proposes the main conclusions of the research.

Finally, section 5 comprehends the second part of the thesis, composed of five selected articles produced during the PhD, which content is being discussed in the synthesis covered in the four previous chapters.

Fig.2 -Thesis structure



1.5 HOW TO READ THIS THESIS?

This PhD thesis can be read in different ways, and three of them are proposed below.

A simply linear reading, going through all the four chapters of the integration part before reading the articles, will give a coherent view of the rational and main results of the research. However, some important detailed results are not repeated in the Integrating part. This is the reason why the reading of the appended publications is also needed to perceive the completeness of the results and arguments, described in the articles in details.

A second way for reading the thesis is to consult parts of the articles along the integrating chapters. For this purpose, the most important results and arguments present in the articles are mentioned along the four initial chapters, and their exact location indicated (article, section and page).
A third way is to follow a combined flow for reading the integration part and the articles, in order to capture the detailed results and arguments produced along the PhD study, as described below:

1/ Integration part: Research method (p.26)
Overview of the results (p.48)

2/ Articles # 1 (p.79): Ecodesign in project management: A missing link for the integration of sustainability in product development?

2 (p.112): Environmental perspective into new products portfolio: a challenge for the effectiveness of Ecodesign

3 (p.126): From 50 to 1: Integrating literature toward a systemic ecodesign model

4 (p.159): Reviews, action and learning on change management for ecodesign transition

5 (p.194): Ecodesign Transition Framework toward companywide sustainable product innovation

3/ Integration part: Discussion (p. 52)
Conclusion

2 RESEARCH APPROACH AND METHODS

The purpose of this section is to expose the overall research strategy and the main methodologies used along the PhD – systematic literature reviews and action research.

2.1 OVERALL RESEARCH APPROACH

The chosen PhD approach implies that the research results are progressively constructed, and characterised through the production of quality articles published or submitted.

The PhD research as a whole was organised following guidelines for building a quality research in Operations Management, consistently linking theory, research and contributions (FLEURY, 2010; GHAURI, 2005; MARTINS, 2010; WHETTEN, 2003). Starting with steady conceptual definitions related to the topic to be studied (see in Table 1 the main definitions used in the thesis), a clear scientific and/or operation problem was identified, and characterised as actual and relevant, as introduced in the previous chapter.

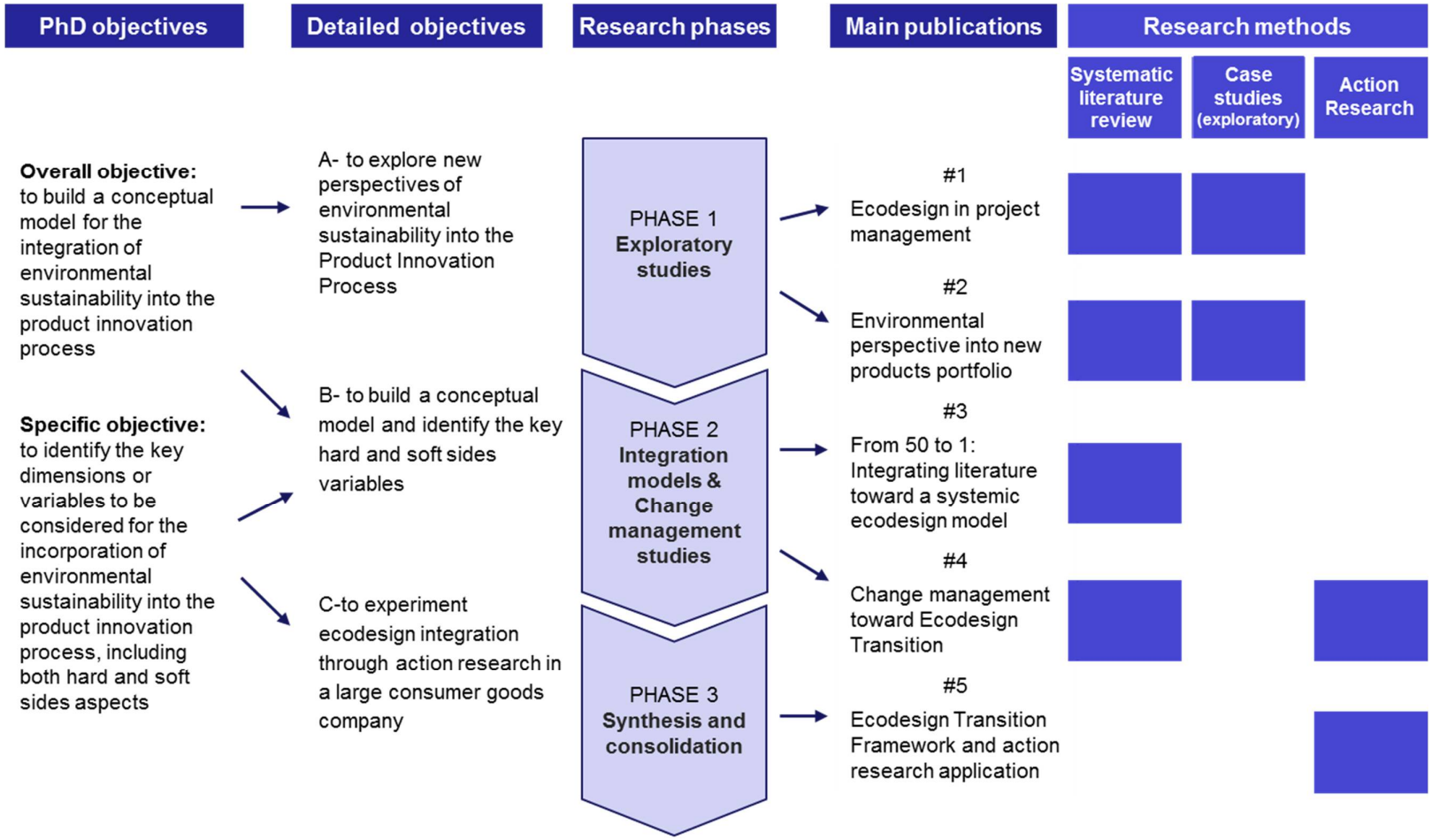
Then, adapted scientific methods were chosen, planned, executed and the results presented to the community in different formats (scientific conferences and articles, and through this final thesis). The final objective of this research process is to produce original contributions to the state of the art in OM, which are expected to be real, valid and well established, relevant and new (WHETTEN, 2003), as will be proposed in chapter 4.

The global design and main steps of the research are visualised on Fig. 3, linking the overall and specific research objectives, the detailed research objectives, and the research phases. The main articles produced along each phase are represented on the right side of the figure, as well as the main methodologies used for each phase and article, showing their alignment and participation to answer the research objectives.

Table 1 - Main terms and their definitions adopted in the thesis

TERMS	DEFINITION	SOURCE
Design and Development	Set of processes that transforms requirements into specified characteristics or into the specification of aproduct, process or system. Note: The terms “design” and “development” are sometimes used synonymously and sometimes used to definedifferent stages of the overall process of turning an idea into a product.	International Standard, 2011, ISO 14006-2011
Ecodesign	Integration of environmental aspects into product design and development with the aim of reducing adverse environmental impacts throughout product´s life cycle. Note: Other terminology used worldwide includes Environmentally Conscious Design (ECD), Design For Environment (DFE) , green design and environmentally sustainable design	International Standard, 2011, ISO 14006-2011
Hard side(of ecodesign)	Design and engineering aspects. Note:Also referred as “technicalities”, or technical aspects	Boks, 2006
Innovation Process	All set of activities related to product innovation within an organisation, including the PDP, but also “Front End” activities, etc.	Adapted from Larsson, 2007
Integration	The action or process of integrating - combining (one thing) with another to form a whole. Note: Used in the thesis for environmental sustainability into innovation practices	http://www.oxforddictionaries.com
Portfolio (of new products projects)	Whole set of projects within an organisation	Cooper et al., 1997
Portfolio management	A dynamic decision process, whereby a business´s list of active new products (and R & D) projects is constantly updated and revised. In this process, new projects are evaluated, selected and prioritised; existing projects may be accelerated, killed, or de-prioritised; and resources are allocated and reallocated to active projects	Cooper et al., 1997
Process	Set of interrelated or interacting activities which transforms inputs into outputs	International Standard, 2011. ISO-TR 14062
Product	Any goods or service	International Standard, 2011, ISO 14006-2011
Product Development	Transformation of a market opportunity and a set of assumptions about product technology into a product available for sale.	Krishnan and Ulrich, 2001
Product Development Process	A disciplined and defi ned set of tasks, steps, and phases that describe the normal means by which a companyrepetitively converts embryonic ideas into salable products or services.	Kahn, 2013
Project	A temporary endeavour undertaken to create a unique product, service or result.	PMI, 2013
Project Management	The application of knowledge, skills, tools, and techniques to project activities to meet the project requirements	PMI, 2013
Soft side(of ecodesign)	Sociological, psychological, emotional and perhaps intangible factors	Boks, 2006

Fig. 3 - Research design and connection with the appended publicationsand methods



Hence, the research comprehended three major phases. Initial exploratory studies (Phase 1) allowed confirming the research gap and potential contributions, especially by bringing knowledge from Innovation Management to the field of ecodesign. Produced during this phase, article #1 discussed the potential consideration of ecodesign in project management, and article #2 explored the emerging environmental perspective into new products portfolio.

Then, researches were conducted to deepen the understanding of key issues associated with ecodesign integration (Phase 2), which led to two additional publications. Article #3 systematically analysed more than fifty previous publications on the topic, toward the foundation of a systemic ecodesign model.During this phase, change management issues, as approached in the “soft side” of ecodesign, were also studied, in order to bring new insights to answer the research questions.The findings of reviews, action and learning on change management for ecodesign transition were exposed in article #4.

Finally, phase 3 of the research consisted in the synthesis and consolidation of previous results into the elaboration of a framework that was also operationalized within a longitudinal action research. Article #5 concretised the whole research and presents the proposed Ecodesign Transition Framework (ETF) toward companywide sustainable product innovation.

Along the research, multi-methods approaches were applied, as introduced in Fig. 3. For the development of the ETF, comprehensive literature reviews and action research methods were used, as presented in next sections.

2.2 SYSTEMATIC LITERATURE REVIEW METHOD

According to Eisenhardt and Graebner (2007), sound empirical research begins with strong grounding in related literature, but literature search can also take place at different stages of the research (FLEURY, 2010).

However, not all scholars consider literature review as a research method. In a sample of fourteen PhD thesis on ecodesign or sustainable innovation from different countries (Belgium, Brazil, Denmark, France, Netherlands, Sweden and UK) that were consulted along the PhD, four of them considered literature review in the research methods briefly and qualitatively (BUCCI, 2010;

GUELERE, 2009; TAN, 2010, VLADIMIROVA, 2012) and only one in a more detailed and systematic form (PIGOSSO, 2012). The remaining did not mention literature review in the research methods (CRUL, 2003; JANIN, 2000; LINDAHL, 2005; O´HARE, 2010; ÖLUNDH, 2006; REYES, 2007; RITZÉN, 2000; TINGSTROM, 2005; VERHULST, 2012).

Nonetheless, systematic literature review as a research method seems to have received growing scientific interest, with the multiplication of scientific articles using this approach, as well as multi-methodological research increasingly recommended in OM (SINGHAL; SINGHAL 2012 a, b). Webster and Watson, (2002) advocate such approachin order to propose a conceptual model that synthesises and extends existing research for mature topics, and for theory building,where an effective review creates a firm foundation for advancing knowledge (EISENHARDT; GRAEBNER, 2007), consolidating results to turn them more useful for the community (SHLONSKY et al., 2011).

Articles based on literature reviews have become more common and appreciated, and some of them refer to the concept of “systematic review”, reflecting what Littell (2005) calls“the science of research synthesis”.Asearch conducted on the methods used by different authors (BIOLCHINI et al., 2005; BRERETON, et al., 2007; COMFORTO et al. 2011; LEVY; ELLIS, 2006; LITTELL, 2005), revealed that the concept of Systematic Literature Reviews (SLR) is not new and spreads with multiple methodological references and applications in various fields. SLR are characterised by the use of an explicit, transparent and reproducible procedure (CROSSAN; APAYDIN, 2010, TRANFIELD et al., 2003), to improve the quality of the review process and outcome.

However, a precise definition for SLR was not found, neither a standardised process, because the implementation depends on the context and the author's personal interpretation. Generally, the review process consists of three parts: Data collection, data analysis, and synthesis, each step conducted with scientific rigueur (CROSSAN; APAYDIN, 2010).

The article by Webster and Watson (2002) appeared as the most cited reference, which led to consider the methodological guidelines of this article as a reference for conducting consistent literature reviews in the PhD, as presented in the first column of Table 2.

Table 2 - Guidelines for literature reviews followed in the PhD
Adapted from Webster and Watson (2002)

CRITERIA FOR QUALITY REVIEWS (Webster and Watson, 2002)	**APPLICATION IN ARTICLES # 1,2,3, and 4**
1/ Motivates the research topic and explains the review's contributions	Relevance and contemporaneity of the subject presented with recent references of relevant research. Reviewing process to identify gaps or dispersed results from previous studies.
2/ Describes the key concepts	Basic concepts explained in the different articles (sustainability, ecodesign, PDP, PM, Portfolio management etc.)
3/ Delineates the boundaries of the research, seeking completeness and variety (methodologies, geographies, publications); main journals; searches back and forward	Analyses showed that distribution of the set of 52 articles has good range and coverage in geography, types of publications, magazines. The two major journals of the theme are present. Classification and representation of publications in subgroups facilitates the understanding of the scope and limits of the study. Searches were carried back to include models based on primary sources ("snowball sampling").
4/ Reviews relevant prior literature in the central and related areas	Quick comments, especially with specific thematic focus: PDP type and systemic approach.
5/ Develops a model to guide future research	Article #3 develops five conclusions of the analysis and builds the foundations a conceptual model summarising the findings. Article #4 completes the reviews on the soft side.
6/ Justifies propositions by presenting theoretical explanations, past empirical findings, and practical examples	Knowledge and practice gaps identified, for example the low level of consideration of innovation management principles. Proposition discussed in the different articles, based on wide literature and in the light of the field action research.
7/ Presents concluding implications for researchers and managers	Focus on a more comprehensive model of integration with important implication for researchers and managers, as discussed in article #4 and #5 and the conclusion of this thesis.
8/ Is explanatory and creative	Original systemic approach, bringing new insights on the topic. Large scope of search and analysis, as well as form of representation and analysis are differentiated characteristics of the work. Consolidation of previous knowledge may explain challenges to face and low integration levels observed.

Criteria 3 of Table 2 emphasises the need for organised, transparent and replicable procedures at each step of the process (CARVALHO et al., 2013), explicit inclusion and exclusion criteria, and systematic search strategy specifying the keyword strings and sources (LITTELL, 2005).

Several systematic literature reviews were conducted within the PhD research. Beside specific searches on exploratory subjects at the frontier of ecodesign and project management (article #1), and ecodesign and portfolio management (article #2), the more complete review was led on the central subject of the thesis, i.e. ecodesign integration models. Main processes and results of this systematic review are presented in articles #3 (sections 2 and 3, p.128-139) and #4 (sections 2 and 3, p.162-173).

After diverse tests, the searches were conducted in ISI Web of Science and particularly Scopus database, which appeared to be the database offering the best coverage of articles in ecodesign literature. Multiple key words were used due to the varying vocabulary used in this theme in different parts of the world, with more than fifteen expressions with meanings similar to “ecodesign”.

As a complement to the rigorous general design and conduction of the review, the methods used in the analysis phase are determinant for the quality of a SLR, such as the bibliometric approach, content analysis, and meta-analysis (CARVALHO et al., 2013).

Hence, once the relevant pools of documents were identified, detailed content analysis and synthesis were conducted, as exposed in articles # 1, 2, 3 and 4.

Content analysis included encoding, specific analysis of content (frequency counts and cross-tabulations) and interpretation of the results (DURIAU ET AL., 2007; BARDIN, 2010).

Among bibliometric technics (MACIAS-CHAPULA, 1998; ARAÚJO, 2006), simple statistical treatment and graphics were used to represent and analyse the distribution and evolution within the corpus of documents identified and selected in the reviews, after conducting an encoding of external information (such as: type of publication, country of origin, etc.) or internal information (WHITE; MCCAIN, 1998; PRASAD; TATA, 2005; CARNEVALLI; MIGUEL, 2008; CARVALHO et al, 2013). Content analysis and bibliometrics were closely associated in search of a thorough understanding of the associated knowledge

(recommendation #6 of Table 2), and directed the experimental side of the PhD research.

2.3 ACTION RESEARCH

As introduced above, the research was designed by exploring Gladwin´s (1993) early recommendations to combine knowledge building and action, but following recent business and operations methods (BURNS, 2014; HOLIAN; COGHLAN, 2013).The PhD study, besides the wide reviews of existing literature and previous experiences, involved a long term experimentation, in order to build and test new approaches in the real company context of applied research and product development, as presented in the following sections.

2.3.1 Justifying action research choice

The PhD field research was built and conducted through action research – a methodology used in social sciences since the 1940´s as a way of learning about organisations through trying to change them (LEWIN,1946). The choice and application of the methodology have been carefully analysed.

AR was considered as the method most adapted to the objectives and context of the research. Firstly, because such methodology permits to attend complementary practical and theoretical objectives: To solve a problem and to contribute to theory building (LEWIN, 1946). In the case of the PhD, both interests were shared by the author, with a dual position as a researcher at USP and within a large company. Such situation characterises a variant of AR developed in the last decade, Insider Action Research (IAR), when a member of an organisation undertakes an explicit AR role in addition to the normal function in an organisation (HOLIAN; COGHLAN, 2013), with potential superior value for the AR (WILLIANDER; STYHRE, 2006).

Secondly, the research subject and objective conducted to investigate product innovation activities of a company, trying to tackle the often-mentioned gap between theory and practice. Certain previous ecodesign researches have

studied such process as a “Trojan horse” - an external observer and influencer inside the company (REYES; MILLET, 2013). However, such metaphor can call attention on the complex relationship that should be considered between researchers and practitioners within the research process (MCDERMOTT et al., 2008). Insider action research offers a unique perspective on organisational systems, precisely because it is led from the inside (COGHLAN, 2007).

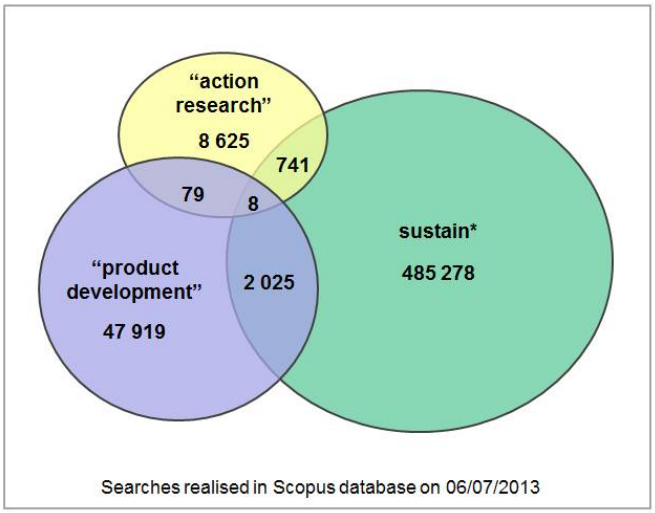
AR, if well designed and executed, could permit to conciliate both objectives and points of view in a more transparent way. In addition, Zuber-Skerritt and Perry (2002) advocated that “traditional research” is applicable for clearly defined hard systems, while action research is appropriate for the soft systems of management and organisational learning. Erhenfeld (2008) similarly argued that the modernist model of rationality and standard positive scientific epistemology is of little use in explaining and managing complex systems involved in sustainability issues.

In spite of such arguments, AR was sometimes presented as a variant of case research or as a real new paradigm for research in production and operations management (WESTBROOK, 1995). O´Hare (2010) stated that the engineering design research community did not commonly use AR.

In order to verify such assumption, a search of previous studies using AR in the context of ecodesign or sustainable design was conducted in Scopus database (strings present in the titles, key words and abstracts). Fig. 4 summarises the results of this search, showing that although AR is relatively well-represented (8625 papers), only 79 articles related AR to “product development”, and hardly eight papers containing simultaneously “product development” and “sustainability” or “sustainable” expressions.

This search was repeated with ecodesign and synonym expressions and led to a reduced number of articles (publications using the word “sustainable” in the meaning of time duration were excluded). Only four articles were found with “action research” AND ecodesign, however different from the previous search. These articles were considered as potential methodological inspirations, but brought limited information about the detailed research protocols.

Fig. 4 - Articles related to Action Research, Product Development and Sustainability



2.3.2 Overall action research orientation and guidelines

Though rarely reported in the ecodesign field, action research and insider action research have become more accepted as 'real' and credible forms of research in business and organisations, over the past twenty years (HOLIAN; COGHLAN, 2013).

In accordance with the overall context of the research, two associated but distinct views about research "projects" or perspectives have been explored in the thesis and related articles – the applied action research project and the generalising or thesis research project, as recommended by Thompson and Perry (2004). Both perspectives are represented in Fig. 5, including the separate (but synergetic) objectives on the left side of the figure. Such view explores Zuber-Skerritt and Perry´s (2002) model that illustrates the distinction and relationship between thesis research, core research and thesis writing.

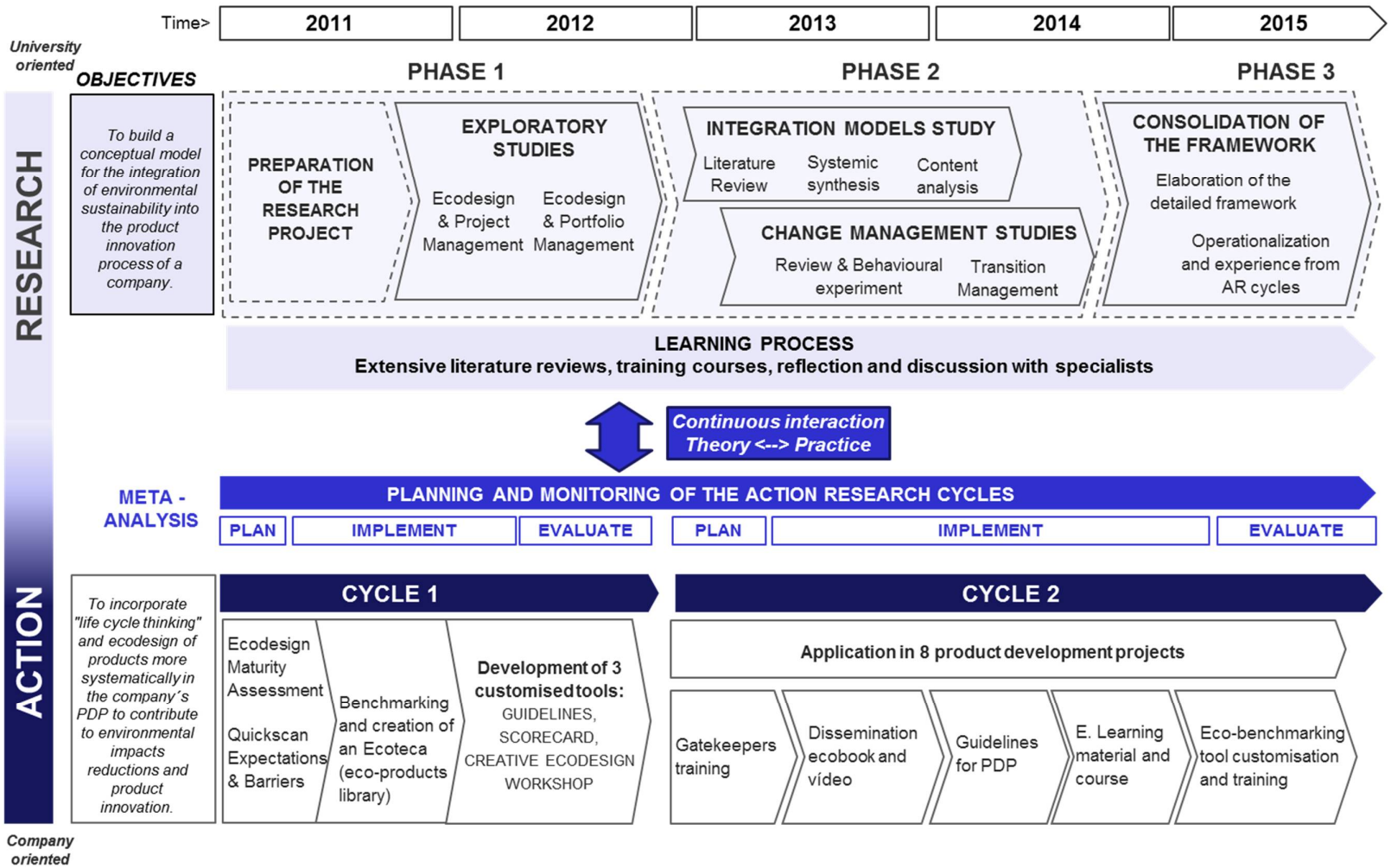
Hence, as a representation of the whole action research developed during the PhD, Fig. 5 summarises the main activities realised along the five–year-period. This figure was developed and explored within article #5, where section 2.3 and table 2 give additional details (p.203-205).

This figure should be read considering three parallel perspectives featuring in different layers of activities. In the upper layer, the research activities were developed in three phases to address the research sub-objectives, as presented previously in Fig. 3, and each of the five appended article carries a piece of this sequence of research activities. A complementary continuous personal learning process was also fundamental all along the research, complementing the specific research activities of the three phases with additional reviews, courses, conferences, publications, etc.

In the lower layer of the figure, the action oriented activities are represented, within two cycles of ecodesign application and implementation activities conducted in the company (presented in section 2.3.3.). This layer is more developped in articles #4 and #5, exploring the transition process and the results of the implementations activities. However, other intermediate publications also reported and explored such applied related activities, including the preparatory activities and ecodesign tool developments (BRONES et al., 2012, 2013; BRONES; CARVALHO, 2014). A synthesis of these activIties is given in articles #5 (p.202-207), including the initial creation of an eco- products library (Ecoteca) for exemplification and inspiration, and the conduction of an Ecodesign Maturity Assessment, in collaboration with USP from São Carlos site (PIGOSSO et al., 2013).

An intermediate layer represented at the center of Fig. 5 connects the two layers described above. Such stratum symbolizes the “meta-analysis” activities, for planning and monitoring of the action research cycles, following a plan-do-check-act approach (COUGLAN; COGLAN, 2002). This perspective also contributed to a continuous interaction between the research and applied activities, in search of a fertile relationship between theory and practice: Bringing best practices and recommendations for the field application on one side; and delivering field observation and learning for theory building on the other side.

Fig. 5 - Representation of the overall research design through multi-methods followed during the PhD



Even with such clarification of the complementary views, AR, sometimes seen in opposition with positivist science, may generate scepticism or resistance mainly related to the potential lack of impartiality on the part of the researcher (COUGHLAN; COGHLAN, 2002).

To surpass the researcher´s subjectivity, Coghlan (2007) recommended a critical realist approach. Feldman (2007), in search of validity and quality in action research, described an ontology “somewhere between the extreme views of naïve realism and radical constructivism”: To recognise the social construction associated with our perceptions of the social reality, while at the same time seeking some level of correspondence to a reality that is separate from us. Thompson and Perry (2004) proposed a slightly different view, associating a critical theory paradigm for the applied action research project within an organisation, and the realism paradigm for the generalisation from those findings to other situations.

Besides these general principles, specialists like Wilson (2004) have proposed different solutions to methodological problems in search of more "rigour in action research”. Action research data should be analysed in a rigorous way,and attention should be paid at to minimise the biases that can arise from the action researcher's dual role as participant and observer.

In order to respond to quality requirements, numerous references were considered, and a research protocol was elaborated, described in article #5 (based on more than 30 references in AR and IAR, plus 15 in other qualitative methods, as presented in Article 5, section 2.1, p.196).

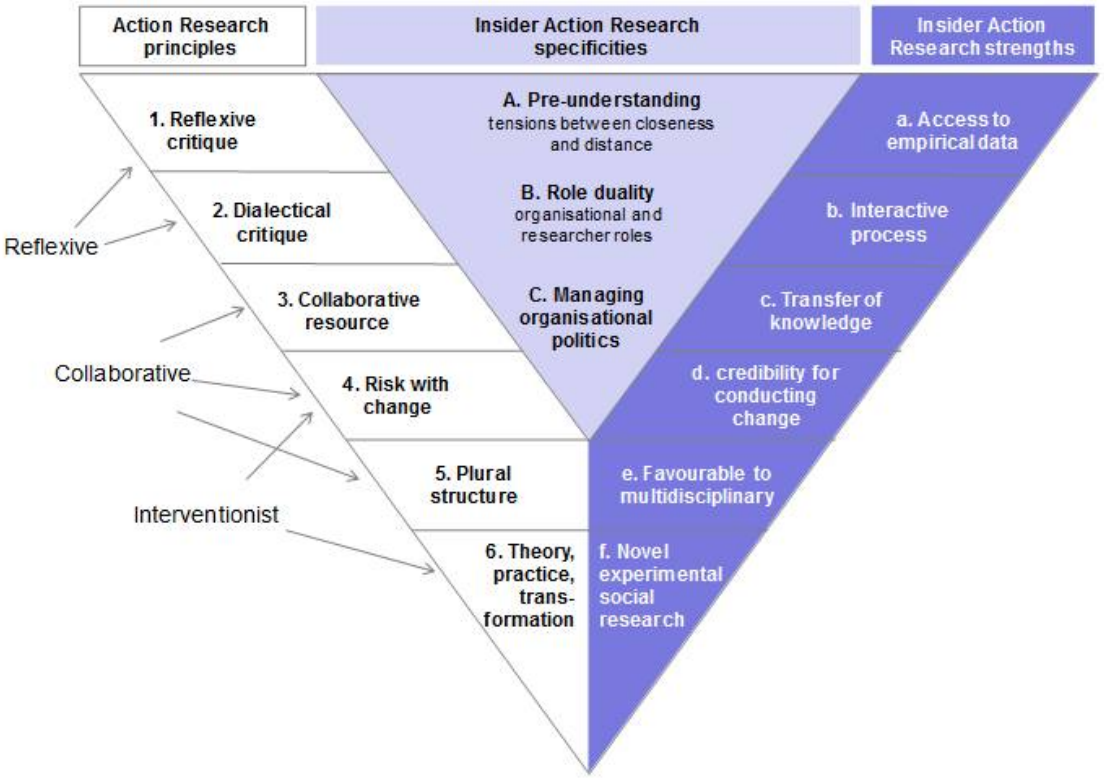
From this methodological review, AR methodology arouse as characterised by a reflexive, collaborative (or participative) and interventionist nature, and consciously cyclical process (COGHLAN, 2007, MCDERMOTT et al., 2008; WILLIANDER; STYHRE, 2006). In addition, AR often takes the format of a single case longitudinal field research (KARLSSON, 2002).

Building on such basic features, Fig. 6 represents a combination of AR and IAR in a triangular shape, associating main features of AR (left side of the triangle) organised within the six key principles recommended by O´Brien (2001) as a synthesis of AR guidelines, with three IAR specificities (upper central part), and stressing the main strengths and benefits that can be expected from good IAR (right side of the triangle).

Critical reflection, described by Coughlan and Coghlan (2002) as “the process of stepping back from experience to process what the experience means, with a view to planning further action” (p.235), plays a central role in the methodology. Moreover, the shape of Fig. 6 evokes a key concern in search of stronger internal validity through triangulation (CASSELL; JOHNSON, 2006).

The concept of triangulation originates from a metaphor of navigation and military strategies that use multiple reference points to locate an object's exact position (JICK, 1979). Similarly, organisational researchers intend to improve the accuracy of their judgments by collecting different kinds of data, to produce a more complete picture through the integration of different perspectives (KELLE, 2001). Nonetheless, the value of triangulation depends more on the critical interpretation than the number of qualitative data (DENZIN, 2012).

Fig. 6 - Relating action research principles with insider action research specificities and strengths



In the context of AR and OM, triangulation translates into a series of principles. Attention upon transparency on the objectives and methodology, use of data of multiple nature, reports from diverse actors, within and outside the organisation, are important concerns, as well as higlighting the complexity or contradictions that may occur in the organisation (TURRIONI; PEREIRA MELO, 2010). Triangulation builds on stories and results, where self-reflection and learning of the action researcher are confronted with experience and the theory (COUGHLAN; COGHLAN, 2002).

The application of these methodological guidelines involves two additional principles. The cyclical approach recalls Lewin´s original view: “a spiral of steps, each of which is composed of a circle of planning, action, and fact-finding about the result of the action” (LEWIN, 1946, p.38). Additionally, Couglan and Coglan (2002) described a meta-step of overall organisation and analysis, which plays an important role for the theoretical interpretation and dissertation.

2.3.3 Action research application

Thus, a full AR plan was elaborated and progressively deployed.Fig. 5 presents the macro design and planning of the research, with the more theoretical perspective in the upper part and in-company application in the lower part. This figure highlights that the entire initiative was a collaborative study, with parallel and synergetic research and application objectives, as represented on the left.

As a whole, the study associated University of São Paulo and the company - a leading Brazilian cosmetics firm - with complementary theoretical and practical intentions, and allowing a five-year long change management experiment in real field conditions.

At a second level, the study was conducted in two implementation cycles of planning, action, interpretation of the result of the actions, conducted from 2011 to 2015.

Then, in a more operational and detailed perspective, the main activities led within cycles 1 and 2 followed a process of planning and monitoring, for selection, customisation and implementation of ecodesign practices considering both hard and soft sides, developed in article #4 (section 4, p.177-178) and article #5 (section 3, p. 203-207).

An important Ecodesign Maturity Assessment diagnosis was conducted in 2011 (PIGOSSO et al., 2013), including more than 15 individual interviews of the main audiences involved in product innovation and sustainability, document analysis, and careful reviews and discussions of the results for triangulation.

2.3.4 Company´s context and profile

Several criteria were considered for chosing the company and considering it as relevant for such long term study. Besides the possibility to access data, experiment and monitor initiatives from the inside, the company and situation also offered facilitated access to different stakeholders involded in the innovation and corporate sustainability processes, and was characterised by well structured product development activities coherent with classical Innovation Management literature (ROZENFELD et al., 2006; GOFFIN; MITCHELL, 2010). Additionally, the consistent interest in ecodesign activities was also a fundamental enabling condition for conducting such study.

The company involved in the research is one of the leaders in the personal care, perfumery and cosmetics sector in Brazil. The firm is generally recognised by different types of stakeholders for several features including business performance, innovation and a leading role in sustainability, as embedded in the company´s ethics and identity formalised in the vision, reason for being and values.

Founded in the late 1960s, the firm has shown substantial expansion over four decades by organic growth and a net revenue superior to 3 billion dollars in 2013 with around 7,000 employees. The company uses innovation as a main source of value creation within the entire activities and value chain. The business model drives the company to a high level of product innovation and a fast product portfolio turnover (around 30% of the products substituted every year). The company had already implemented many corporate and product initiatives towards the reduction of associated environmental impacts since the 1980´s, but had not considered ecodesign in a systematic wayyet. In 2011, an ecodesign programme was created by the Science and Technology group, to bring new practices into the Product Development Process.

The company´s PDP, internally called the “product funnel”, was inspired by the stage–gate model, and was divided in six phases (Pre-Briefing, Briefing,

Prototype, Validation, Availability and Evaluation). The ecodesign programme was conducted within a separate “technology funnel”, as a part of the Sustainable Technologies portfolio, which is one of the three main research strands of the company. More detailed research application conditions were described in article #5 (section 2.4, p. 202).

2.4 CONTRUCTION OF THE FRAMEWORK

2.4.1 General approach for theory building

As indicated earlier, a theoretical research perspective was developed in parallel with the company application, in accordance with the action research method, aiming at building and testing a new integration model. Such framework attends the view of a “mental construction aiding action” (MARTINS, 2010), and passing from disorder (dispersed and contradictory information) to order (articulated concepts or constructs, with logical relationships).

The construction also followed a cyclical evolution, as suggested by Fleury (2010), similarly to Eisenhardt and Graebner´s (2007) proposition that the theory-building process occurs via recursive cycling among the field data, emerging theory, and previous literature. According to Meredith (1998), case studies and field research are recommended for building new operations management theories, and bringing the advantages of high relevance, understanding and exploratory depth.

The framework was progressively designed from a systems perspective integrating a wide range of information, grouped in four main sources: Three sets of conclusions derived from literature reviews (on ecodesign literature and integration models; change management; and innovation management) and a fourth source of complementary insights resulting from the field AR study.

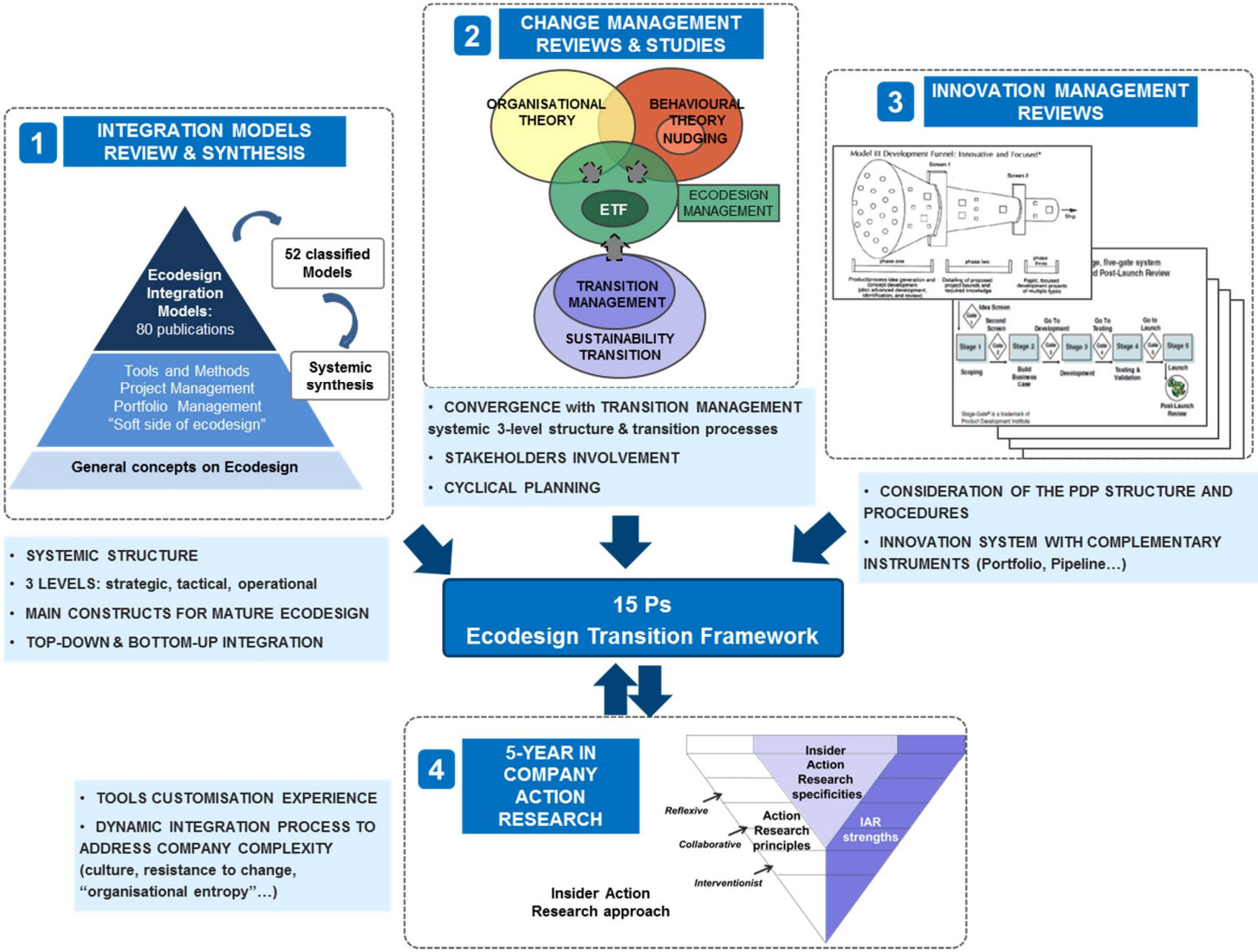
For such construction,the research sought similarities across different domains to increase the completeness and abstraction level, following Wacker´s (1998) orientations for theory building. This method,with gradual refinement and development building on the strengths and limitations of previous models associated with the learning from the application, is recommended for research

in applied disciplines for developing a more integrated and complete model (CHENHALL; CHERMACK, 2010).

Within the different sources, the data sets collected (from content analysis and field observations) were classified in Excel tables, analysed and organised using affinity diagram or Kawakita Jiro (KJ) method (CARNEVALLI; CAUCHICK, 2008; MOHAMEDALLY; ZAPHIRIS, 2009), suitable for dispersed data. Such qualitative technique proceeds through abottom-up sorting procedure with five steps: (1) determine the theme; (2) gather the data; (3) sort the data into clusters; (4) choose the heading, and (5) draw the finished diagram with blocks of information (CHENG, 2014).

The initial systematic literature review (article # 3) revealed three gaps pointed out from previous studies, as exposed in section 1: Need to develop the soft side and change management aspects; necessity to consider the whole innovation process; and need to better relate the general recommendations to business field reality. Fig. 7 presents how the four sources were explored in order to fill these gaps and build the framework, as described in next section.

Fig. 7- Representation of the four main sources for building the Ecodesign Transition Framework



2.4.2 The four building blocks for the construction of the ETF

First, a SLR of previous ecodesign integration models, from 1993 to 2013, brought the foundations for the framework (BRONES; CARVALHO, 2015, article # 3, section 5, p.141; the preliminary version of the framework is shown in Fig. 6, p. 143). More recent publications subsequently found present convergent conclusions and propositions (such as the navigation system from Zhang et al., 2013), but with a more limited scope. From this source, as a synthesis of the content analysis of more than 50 integration models found in previous studies, emerged the three levels of the ETF (strategic, tactical and operational) and some of the main constructs of the framework were identified.

Secondly, this structure was completed by new insights from a multistep literature review on the soft side of ecodesign management and change management theories, as developed in article # 4 (section 3.5, p.173-176). A notable convergence and complementarity was found between the previous conclusions on ecodesign integration models (article # 3) and the emerging Transition Management (TM) approach designed for sustainability issues facing different types of organisations (p. 174, and Fig. 4, p. 175).
This source conducted to discriminate two main elements in the ETF: A central “pattern” that will represent a mature ecodesign structure; and a “pathway” component for conducting the necessary transition addressing soft side requirements. The constructs of the transition process were also developed with the findings of this part of the research, including the cyclical planning and stakeholders management, and detailing the complementary bottom-up and top-down integration processes. With this source, the systems approach of the framework was reinforced, with a particular emphasis on soft aspects and the change management perspective lacking from previous ecodesign models.

As a third source, additional detailed considerations of product innovation management principles were brought from qualitative reviews and exploratory searchesin order to fill a knowledge gap with sustainability management (GOFFIN, 2012) (as developed in articles #1 and #2, analysing the potential gaps between ecodesign publications and project and portfolio management principles),.

Product innovation, described as a complex business process at the interface between the company and its market (ROZENFELD et al., 2006), is a challenge to effectively manage because of the wide range of hard and soft factors influencing its success or failure. Formal NPD procedures are necessary to enhance innovation and business performance (GOFFIN; MITCHELL, 2010).

Similarities have been observed between several PDP models (KATZ, 2011;LARSSON, 2007) with a consensus on general recommendations associated with the stage-gate models (COOPER, 2008), or complementary Product Development Funnel (CLARK; WHEELWRIGHT, 1992), as developed in more recent publications and reference models (ROZENFELD et al., 2006). Katz (2011) proposed a new version of funnel, giving greater definition and emphasis to NPD's initial stage, the "Fuzzy Front End".

NPD process defines the responsibilities of different functions, and provides descriptive and prescriptive models and procedures for the management of the process (GOFFIN; MITCHELL, 2010; LARSSON, 2007). Further PDP best practices and associated instruments, such as portfolio and pipeline management, and their links to strategy and project concerns completed the construction process (GOFFIN; MITCHELL, 2010; LARSSON, 2007; ULRICH; EPPINGER, 2004).

The organisation of product development activities on strategic, tactical and operational level – with the portfolio management process linking strategy and product development actions across the company (LARSSON, 2007) - was fully consistent with the observations from both previous sources.

Such considerations led to the insertion of the PDP (stage-gate based) at the centre of the ETF, with its articulation with other complementary management instruments (Strategic Planning, Portfolio, Pipeline, Technological Platform) and linking with the operational activities at the bottom of the "pattern".

Complementing the three previous theoretical foundations, a fourth source of inspiration came from the in-company observations. The empirical action research brought insightful relationships with previous findings to form the conceptual interpretation (WACKER, 1998) and finalised the construction of the framework.

In addition, this part of the research included the operationalization of the framework, connecting the conceptual development phase and practice observations (as symbolised by the bi-directional arrows, linking the framework and the field experiment, in Fig. 7). Indeed, as described by Chenhall and Chermack (2010), during such application phase, the theory is tested through experience and learning from the real-world application and the practice gets to judge and inform the usefulness and relevance of the theory for improved action and problem solving.

In real company conditions, the ecodesign tool customisation approach was applied (as presented in #5, p. 206, with the main activities and results of cycles 1 & 2, and the application of ecodesign in 8 product development projects represented p. 207). A dynamic integration process was experienced to address organisational complexity, and considering internal factors such as culture, resistance to change, cultural or organisational entropy (MASH et al., 2013), as discussed in #4, p.217 and 2018, with selected comments from some participants of the company.

As exposed in articles #4 (section 4, p.176) and #5 (section 3.3, p. 213), the field experience served as a kind of laboratory for ecodesign integration and change management issues, and was a useful lens to select the relevant constructs and their concrete expression as far as environmental considerations are concerned, in addition to classical innovation requirements (quality, cost, time to market).

3 SYNTHESIS OF THE MAIN RESULTS

This chapter summarises the main results of the PhD research, from the scientific production to the Ecodesign Transition Framework developed as a central outcome of the PhD.

3.1OVERVIEW OF THE SCIENTIFIC PRODUCTION

As introduced above and in Fig. 3, during the PhD several articles were produced, exposing pieces of research realised within the general scope of the PhD as a whole. The five principal publications are summarised in Table 3, representing the main scientific production progressively elaborated.

Though #5 can be considered as the most accomplished article, synthetizing and exploring the whole research process and experience, the first (exploratory) and third articles were already accepted and published in the Journal of Cleaner Production, chosen as the main publication for ecodesign research, by far (as shown in the systematic literature review –article #3).

A preliminary version of article #4 on change management aspects of ecodesign integration was presented at the 5th International Workshop, Advances in Cleaner Production, in May 2015, and was recognised with a Special Mention. This positive reception encouraged the preparation of a full article, which was submitted for the special issue associated with the same event.

Following a similar process, the main results of the research were introduced at the Global Cleaner Production and Sustainable Consumption Conference, in November 2015 (Sitges, Spain), and developed in a full article (#5) ready for submission to this publication as planned for early 2016.

Table 3 - Overview of the appended publications

#	Title	Journal	Purpose	Research method	Status
1	Ecodesign and project management: A missing link for the integration of sustainability in product development?	Journal of Cleaner Production	To explore the points of intersection between ecodesign and project management.	Systematic literature review + single case study	**Published** v. 80, p. 106-118, 2014.
2	Environmental perspective into new products portfolio: a challenge for the effectiveness of Ecodesign	Proceedings 20th EurOMA Conference,	To explore how new product portfolio managementconsidersthe environmental perspective.	Systematic literature review + multiplecase study	Presented at EurOMA, June 2013, Ireland
3	From 50 to 1: Integrating literature toward a systemic ecodesign model	Journal of Cleaner Production	To build a systemic framework for a more complete integration of ecodesign at company level.	Systematic literature review+ bibliometry + systemic synthesis	**Published** Special Volume: CP Strategies, v.96, p. 44-57, 2015
4	Reviews, action and learning on change management for ecodesign transition	Journal of Cleaner Production	To explore the “soft side” of ecodesign integration, and change management issues concerned in the transition toward sustainable product innovation.	Multistep literature review + Longitudinal Action Research	Presented at 5th International Workshop Advances in Cleaner Production, May 2015. **Submitted**
5	Ecodesign Transition Framework toward companywide sustainable product innovation	Journal of Cleaner Production	To propose an analytical and application oriented framework for broader and deeper ecodesign integration, combining technical and “soft side” approaches.	Longitudinal Action Research	Presented at Global Cleaner Production and Sustainable Consumption Conference, Nov. 2015. **Full paper ready for submission**

3.2 MAIN RESULT: ECODESIGN TRANSITION FRAMEWORK

Article #5 covers the five-year longitudinal AR study, approaching in real field conditions the complex process for integrating ecodesign in company product innovation. Simultaneously, a systemic Ecodesign Transition Framework (ETF) was developed, proposed as a synthesis of a wide range of previous works and knowledge from different fields (engineering and environmental sciences, innovation management, and social sciences), combing a theoretical foundation elaborated on systematic reviews and experimental studies. The frameworkresults from a construction process described earlier and represented on Fig. 7.

This framework was named “15Ps ETF” to facilitate memorisation of the content. As a consolidated result from previous research, described and discussed in article #3, three main components were identified: A systemic three-level structure (Strategic, Tactical and Operational levels), deployed in two complementary perspectives, called Pattern and Pathway.

The central three-level construction can be remembered as an “Aztec pyramid” shape symbolising the strategic, tactical and operational product related activities, inspired from Larsson (2007). This pyramid represents a companywide mature ecodesign process, translating Business Process Management principles to the question of ecodesign integration, where ‘‘to-be’’ processes should be based on best practices (ROZENFELD et al., 2009). Hence, the Pattern is composed of eight constructs: Purpose, Portfolio, Process, Platform, Pipeline, Practices & tools, Procedures and Project management.

A complementary Pathway brings a change management perspective adapted from Transition Management theories. This module comprehends five key constructs (Planet, Public, Programme, Pilot, and People) for conducting the necessary transition, engaging stakeholders, and synergising bottom-up innovation and top-down planning.

The fifteen words starting with P chosen to name the constructs have equivalent words in Portuguese to provide multicultural applicability of the framework: *Padrão, Propósito, Portfolio, Processo, Plataforma, Práticas, Procedimentos, Projetos;Percurso, Planeta, Público, Programa, Piloto* and *Pessoas*.

These constructs are briefly described in Table 8, to complement the more visual representation of Fig. 8.

Fig. 8 - Proposed “15Ps Ecodesign Transition Framework”

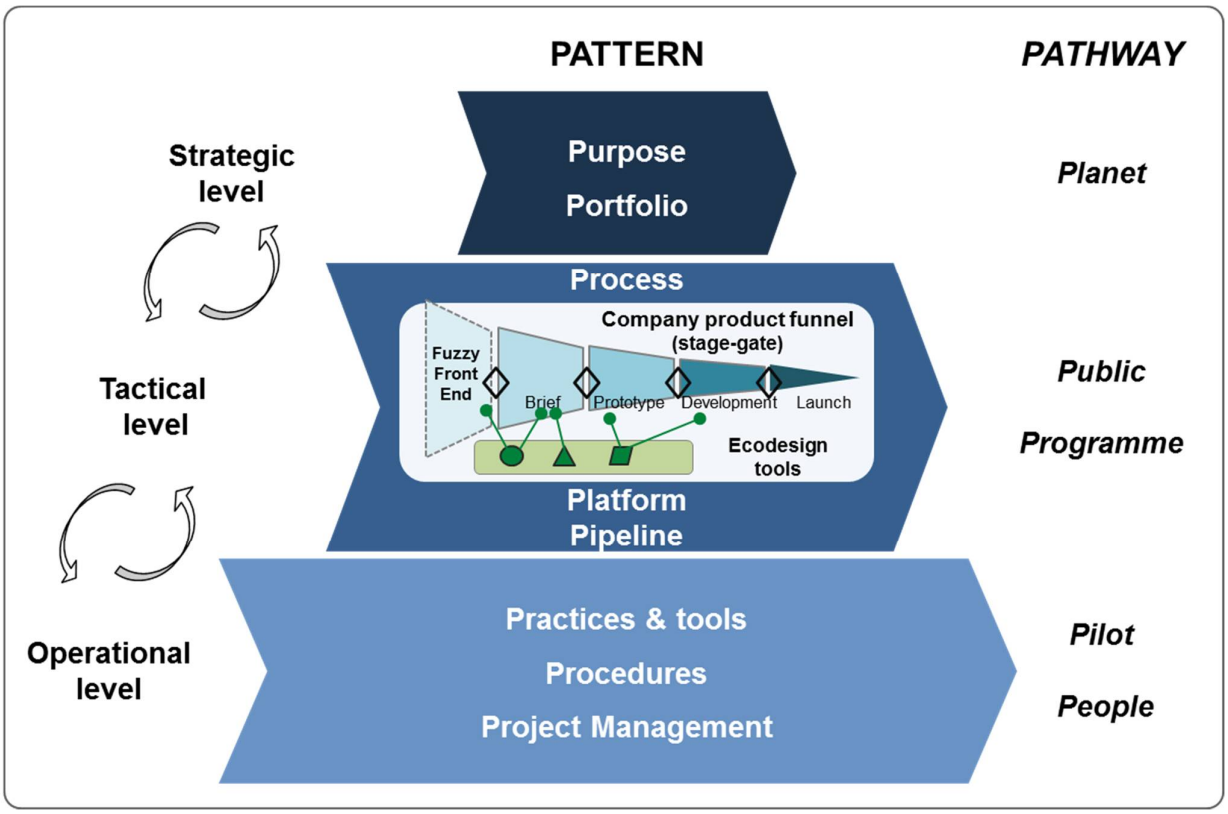


Table 4 - 15Ps Ecodesign Transition Framework / constructs description

Level	PATTERN: –capabilities for a mature ecodesign integration		PATHWAY: applying transition principles		
Strategic Defining corporate and long term objectives in innovation and environmental sustainability, based on life cycle thinking principles	**Purpose**	Define and promote company environmental sustainability ambition and direction, including global and deployed goals with clear targets and preferably a set of indicators.	***Planet***	• *Define or update the long-term ambition of the organisation in environmental sustainability.* • *Align Product innovation strategy with the environmental ambition.* • *Monitor the long and midterm plan, and coherence between corporate vision and business processes*	*Problem structuring, envisioning, long term goals*
	Portfolio	New products projects portfolio aligns sustainability strategy together with business goals. Quantitative environmental life cycle indicators integrated to allow effective product planning: opportunity identification, project prioritisation; resource allocation and planning.			
Tactical Deploying and piloting the environmental strategy into the innovation processes and instruments	**Process (PDP)**	Environmental requirements incorporated throughout the principles and elements of the PDP for decision making, from the early and particularly decisive stages. Integration of ecodesign in portfolio management, including decision/trade-offs criteria associated with the environmental dimension;	***Public***	• *Engage/influence the different groups involved in the deployment of environmental goals and procedures (middle management)*	*Agenda-building, negotiation, networking*
	Platform	Technological/applied research programmes bring solutions applicable at product level (internal or external, depending on organisation size and sector); internal recommendations for applying/deploying such solutions.			
	Pipeline	Qualitative and quantitative environmental indicators integrated in Pipeline Management, with other business and technology factors to deliver results within the company dynamics. Operational reviews and decision-making (GO/Kill decisions and resource allocation) consider sustainability goals.	***Programme***	• *Formalise a plan for progressing toward a higher integration of environmental sustainability within Product innovation processes* • *Monitor and evaluate results, progresses and gap.*	
Operational Applying ecodesign principles into all related activities for decision making and product performance	**Practices & tools**	Customised ecodesign tools covering different needs along the PDP, including orientation (guidelines, checklists…), solution generation (creativity tools), and productenvironmental performance assessment (quantitative or semi-qualitative).	***Pilot***	• *Adapt and experiment ecodesign tools and practices to company culture*	*Experiments, implementation, mobilising actors*
	Procedures	Guidelines and capacity building on how to use the tools within the PDP for different kinds of projects. Stage-gate reviews consider the environmental aspects and indicators.	***People***	• *Engage the different groups involved in product development to understand and apply ecodesign principles and tools (internally and externally/ supply chain and innovation partners)* • *Capacity building and associated monitoring*	
	Project Management	Environmental sustainability integrated with other dimensions (quality, cost, time); multifunctional teamwork, covering the life cycle perspectives of products and the various stakeholders of the value chain.			

The five-year long company experience conducted in parallel to the construction of the framework showed congruence with the elements and principles of the 15Ps ETF, as presented and discussed in the articles:

- Article #4, showing the how the transition management principles were applied for ecodesign integration (p.174), and the results of these integration initiatives during cycle 1 and 2 (p.176).
- Article #5, presenting how the ETF was applied, at the Strategic, Tactical and Operational levels, based on the initial diagnosis realised in 2011, considering the initial observed strengths and challenges (p. 214 and p.215).

Hence, the evolution of practices within the three levels was described following the central Pattern part, and the change management initiatives conducted were coherent with the recommended Pathway guidance.

Such framework is proposed as a facilitator to better plan and monitor collective efforts necessary at company level to leverage a more effective and advanced incorporation of sustainability concerns into the diverse activities involved in the product innovation process.

3.3 DISCUSSION: SYSTEMIC ACTION LEARNING FOR SUSTAINABLE CHANGE

To complement the discussion of the results and propositions presented in more details in the different articles, this section highlights a few transversal observations for their importance in the PhD research as a whole.

This research has tried to approach the different dimensions involved in ecodesign integration, schematically called the technical aspects and soft issues. The intention has been to explore and build on diverse perspectives and to complement more fundamentally analytical approaches found in previous studies, particularly on ecodesign tools and practices (BOVEA; PEREZ-BELIS, 2012; BUCCI et al., 2012; PIGOSSO, 2012).

Thus,the research deliberately explored a more systemic line on the subject. The systematic review and synthesis brought the foundations for the framework (article #3, p.142, and Fig. 6, p.143, showing the preliminary version of the

framework), and confirmed the emerging but not consolidated view of systemic principles for sustainable design. Other recent publications contain convergent propositions (i.e. the 3-level system from Zhang et al., 2013), but in a more limited scope than developed in the PhD.

In fact the “systemic” concept has been found in several articles, since almost the origins of ecodesign literature. Fiksel (1993) already argued that "a primary failing of the current approach to environmental management in the U.S. is the failure to treat environmental issues and impacts in a systemic, comprehensive manner, as opposed to piecemeal" (p.131). However, in most ecodesign related publications mentioninga system or systemic perspective, the concept refers either to management system or to system modelling, as part of Life Cycle Assessment. Even the reference paper from Bauman´s (2002), urging for more systemic approach to ecodesign, did not explicit what a real systemic perspective might be.

This PhD approached the systemic concept not in the general meaning of a mere allusion to any system, but in direct reference to the systemic thinking related to complex systems theory (LASZLO, 1986). Some authors have presented systemic thinking as a real paradigm shift in science (CAPRA, 1989), characterised by three key aspects: Shift from the parts to the whole; Shift from structure to process; Shift from building to network as metaphor of knowledge.

Such approach,explored only initially in previous ecodesign publications, turned into a constant inspiration for elaborating the Ecodesign Transition Framework.

This leitmotiv permitted to connect other converging recommendations along the research. For example, Sterman (2012) advocated the necessity of systems science for sustainability, since such complex problems require the development of systems thinking.

Also, during the research Transition Management has emerged as the most adapted approach for dealing with the change management challenges, and brought novel principles successfully adapted to the soft side questions raised in previous publications and also met in the field experience (as developed in article #4, showing how Transition Management Principles were adapted to ecodesign integration, p.176).

In a very coherent way, TM concept was rooted in the complex systems approach, along with new forms of governance and social theory (LOORBACH, 2007; MARKARD et al., 2012).

An additionalperspective that appeared as an essential feature for the research and model was the learning dimension. The longitudinal AR illustrated the complexity for integrating ecodesign in company product innovation, as mainly a progressive capacity building experience, with key success factors linked to engaging NPD actors in such process.

The Fifth Discipline theory, which uses the practice of systems thinking toward a transformational process and promotes organisational learning, and building on collaborative action research (SENGE; STERMAN, 1992), presents similarities with TM. This mature approach is still contemporary, as confirmed by evolving management practices (GROYSBERG; SLIND, 2012), to be explored both in company and academic research, particularly through action learning (CHENHALL; CHERMACK, 2010; ZUBER-SKERRITT, 2002). Recently, Burns (2014) argued in favour of systemic action research as a meta-learning architecture, to support dynamics change, connecting the inquiries horizontally and at different levels of scale.

Such view coincides with the line developed in this research, and Erhenfeld´s (2008) recommendations toward his “flourishing” definition of Sustainability, “coupling complexity with management and engineering, taken to represent all fields of applied science” and promoting experiential knowledge produced in action.

4 CONCLUSIONS

This final section of the integrating part summarises the research findings and conclusions, then sets out the contributions to knowledge and the implications for practice, and recognises a few limitations of the research. Finally, some opportunities for future research are proposed.

4.1 CONCLUSIONS OF THE THESIS

In accordance with the principal objective of this thesis, an Ecodesign Transition Framework is proposed, for integrating the environmental sustainability into the product innovation process. The main results related to this model are the following:

• 15Ps Ecodesign Transition Framework construction and application

a) A systemic Ecodesign Transition Framework was proposed, as a synthesis of previous works and knowledge from different fields (engineering and environmental sciences, innovation management, and social sciences), and building on the lessons from the parallel longitudinal field action research.

b) The “15Ps ETF” combines within a systemic three-level structure (Strategic, Tactical and Operational), two complementary perspectives: A pyramidal Pattern for a companywide mature ecodesign, composed of eight constructs (Purpose, Portfolio, Process, Platform, Pipeline Practices & tools, Procedures and Project management); and a complementary Pathway module based on five key constructs (Planet, Public, Programme, Pilot, People) for conducting the necessary transition, engaging stakeholders, and synergising bottom-up innovation and top-down planning.

c) Tools customisation and integration in the PDP was confirmed as a corner stone for ecodesign implementation and deployment, though this process is not sufficient in itself to ensure the effective use and diffusion of ecodesign practices.

d) The necessity to find the adequate governance and monitoring processes of sustainability transition was a critical issue, for the fundamental balance of bottom-up innovation and top-down integration support.

e) The slow observed transition was also associated with some “invisible barriers” perceived by the team in charge of the field initiative, complementing the main obstacles previously identified by Boks (2006). Resistance to change could possibly be related to second order barriers, such as prioritisation issues, divergent individual and collective interests and concerns, or “organisational entropy”.

f) The increase of maturity in ecodesign can be seen as collective learning process, which needs progressive capacity building, including formal tools and practice but also the diffusion of tacit knowledge.

g) From a methodological perspective, Action Research was confirmed as fruitful methodology, which can be increasingly recommended to bring a strong interaction between academic and applied works in OM, aiming at faster learning loops in the field of sustainable innovation management.

Complementing the principal objective, specific objectives were also achieved by the identification of different dimensions.involved in ecodesign integration, as listed below:

• Exploration of ecodesign and project management and portfolio

h) The points of intersection between ecodesign and project management and portfolio have been explored combining systematic literature reviews with qualitative case studies in two consumer goods manufacturers. Several gaps have been observed between ecodesign practices and literature, on one side, and consolidated innovation management practices and principles, such as project management and portfolio management, on the other side.

i) As new propositions, the integration of the environmental dimension into the project management of new products, and similarly into portfolio management, could increase the effectiveness of ecodesign applied in companies.

j) The inclusion of environmental sustainability in project and portfolio management brings a high increase in complexity, and new guidelines would be required to better consider environmental sustainability issues within project and portfolio management.

• Integration models & change management studies

k) 52 integration models from the ecodesign literature (1993-2013) were identified and analysed in depth. These models feature a wide variety of approaches and representations, but rarely refer directly to the most accepted models of innovation management.

l) Based on a synthesis of these analyses, several principles emerged for the construction of the framework: Three systemic levels (macro, meso and micro); the combination of top-down and bottom-up flows that promote vertical integration; and a transversal integration axis for change and people management.

m) A novel change management method for ecodesign integration was identified and adapted from the Transition Management theory, as a useful instrument to organise, deploy and monitor soft aspects of ecodesign integration, both organisational and behavioural. Such approach could answer the necessity for “softer” change management in organisations, as opposed to command-and-control principles – as a growing tendency in society.

4.2 MAIN CONTRIBUTIONS

To summarise the main contributions of the PhD research, Fig. 9 links the initial research problem and research objective to build a conceptual integration model, with five proposed contributions, and the appended articles where they were developed. In addition, a table at the centre of Fig. 9 proposes the justifications for these five contributions, as far as three criteria are concerned: Validity, relevance and newness (WHETTEN, 2003). These propositions are founded on the whole research results and analysis, and based on multiple

evidences, from the field observations confronted with broad previous literature, and triangulated and discussed along the thesis.

The contributions as summarised in Fig. 9 are discussed in depth in each appended article, as represented in the right side of the figure. Articles #4 and #5 were critical for achieving the research objectives and presented the main contributions as visualised in Fig.9, which shows that article #4 links with four of the five contributions, and article #5 participates directly to all five contributions.

First, this research proposes a methodological contribution, through the development of Action Research methodology and application guidelines, contributing synergistically to Academia and field purposes. As argued in article #5, AR approach can bring a strong interaction between academic and applied works, aiming at faster learning loops in sustainable innovation management. Action research proposed principles, also intimately incorporated in Transition Management, stimulate transformative change through a collective learning process (CHENHALL; CHERMACK, 2010; LOORBACH; WIJSMAN, 2013), which can be constructive both for practice and theory. Such approach has been increasingly recognised as an effective collaboration mode between the Academia and companies with mutual benefits in innovation and science (OPRESNIK; DOLINSEK, 2012), which is aligned with OM goals.

As a second line of contributions, this study has permitted to deepen ecodesign integration in three directions identified in previous publications: Consolidating tool customisation, extending ecodesign from PDP´s frontiers, and linking hard to soft aspects.

The research consolidated tool customisation approach in real company context, which can be applied to tools and practices from different levels of complexity and directed to the whole PDP, since the very early stages. The concept of formal insertion of customised ecodesign tool was discussed in article #5 (section 4.1, p.217).

Also, a broad view of ecodesign related activities was explored, stretching the most common view centred on individual projects or the PDP itself, from operational project issues to pipeline and portfolio management, and linking with strategic planning (see particularly article #2 p. 122, article #5 p. 216) .

Fig. 9 -Summarising the main contributions of the research

RESEARCH PROBLEM & OBJECTIVE

Low integration of ecodesign into product innovation; gap between technical recommendations and reality of innovation practices.

Research Objective
to build a conceptual model for the integration of environmental sustainability into the product innovation process of a company.

RESEARCH CONTRIBUTIONS

	Validity	Relevance	Newness	Association with articles				
				#1	#2	#3	#4	#5
❶ ***Methodological contribution*** • Development of Action Research methodology and application guidelines, contributing synergistically to Academia and company interests.	Positive results on both perspectives, to be confirmed and consolidated	AR increasingly recommended form OM; synergy with Open Innovation trend	Very few articles found on AR and ecodesign				■	■
❷ ***Deepening ecodesign integration*** • Consolidation of the concept of tool customisation in real company context.	Concept recognised as valid by previous research, as an answer to companies diversity	Tools at the centre of technical ecodesign principles and learning processes	Derived from previous research, but lacking application and insertion in the PDP					■
• Development of a broader view of ecodesign related activities, from operational project management issues to pipeline, portfolio and strategic planning.	Interrelation of different aspects within the whole Innovation process seen in theory and field experience	Broader deployment of environmental practices necessary for higher maturity in ecodesign	Few publications found in the systematic literature reviews	■	■	■	■	■
• Expanding soft side aspects, linking with the systemic Transition Management theory adapted to company context and scale.	Strong similarities shown between different approaches, and underlying systemic principles	Change management issues recognised as essential for sustainability transitions	Soft side still limited in ecodesign research; TM emerging at company level				■	■
❸ ***Novel Integration model*** • Proposition of an Ecodesign Transition Framework, for the integration of environmental considerations in the whole innovation process of a company.	Coherence with literature corpus and company experience and observations	Ecodesign integration confirmed as a complex process requiring wide views and tools	Model different from all previous found in SRL, with broader scope			■	■	■

Then, complementing technical and process related aspects, the concept and principles of soft side integration were developed, linking with the systemic Transition Management theory adapted to company context and scale.

Finally, as a fiftht and main contribution, a novel integration model was proposed, the 15Ps ETF. This framework presents a novel perspective for a broad integration of environmental considerations in the product innovation process and activities of a company, and organises the soft issues to be considered for the necessary transition toward such a comprehensive integration, consolidating and advancing previous theoretical views of ecodesign, and bringing a new perspective for practical implications.

4.3 IMPLICATIONS FOR PRACTICE

Several implications can derive from the results of this study, as potential applications suggested for practitioners, in the context of applied product innovation in companies: Researchers participating in applied projects, company innovation or sustainability managers and product developers or designers.

The whole study brings insights that can be used by practitioners interested in sustainable innovation, from the procedures selected, challenges faced, lessons learnt and conclusions. Particularly, the 15Ps ETF could serve as a reference model, with both a descriptive and managerial function.

The framework can helpbetter envision the implementation challenges and see the integration process a progressive evolution. Moreover, this qualitative model promotes a broad systemic view of environmental related activities, which can permit to plan, implement and monitor more effectively the integration of environmental considerations in the whole innovation process of a company.

With a didactic structure and visual representation, the 15Ps ETF can be used as guidance at managerial level with the purpose of initiating more systematic sustainable innovation, and as an internal communication tool within the whole implementation process.

Managers and the employees in charge of the implementation process of sustainable design could adapt the implementation approach to the culture and

specific needs of the different departments involved, as permitted by the modular structure of the ETF.

Executives and managersin charge of the Innovation process in large companies might use this research as a benchmark, analyse similarities with their own situation with a diagnosis of their particular situation, and make decisions for the future direction.

4.4 LIMITATIONS OF THE THESIS

Two principal limitations can be acknowledged for this research.

First, the study mainly relied on qualitative observations of the company processes, activities and people´s perceptions. More tangible and concrete results linked to products and development projects were not shared for confidentiality reasons, as required during the development period of new products. In addition, even after almost five years of related activities, direct applications have not come to the market yet. More quantitatively measurable results will be expected in the following years, through potential business benefits and associated reduction of environmental impacts, as followed for all products inside the company. Thus, these propositions are to be seen within the methodological approach and paradign of action research (critical theory and constructivism), and are not supposed to be demonstrated as in a positivist perpective.

Secondly, this study is also limited by the single company context (large national scale company, of the cosmetics sector), which is an obstacle for generalisation. However, AR and IAR practitioners recognise that this situation is the condition to access a business organisation from inside and to have the possibility to really experiment new solutions in a long period of time (KARLSSON, 2002). To counterbalance this main threat, the theoretical perspective associated with the field research has considered a large diversity of information sources, for inspirations and comparison with the empirical findings. For example the proposed reference model for PDP, as represented in the 15Ps ETF, combining Product Funnel and Stage-Gate, is recognised by different authors as the most common and adapted process, at least for

medium and large companies. Noticeably, the relevance and applicability of the findings and framework may be lower for more distant contexts, such as micro or small companies, or larger multinational organisations, or highly complex products.

Also, if the application sector (cosmetics, part of Fast Moving Consumer Goods) can be seen as specific, the knowledge considered in the reviews as a foundation for the construction of the ETF came from different contexts, with field observations mainly from the electronic sector (BOKS, 2006; STEVELS 2007), but also textile industry (MILLET et al.., 2006; ZHANG et al., 2013) or even multi-sectorial (for example: Verhulst, 2012), though 67% of the 52 analysed model did not specify the application context.

4.4 FUTURE RESEARCH

To terminate this dissertation and research journey, a few research challenges are proposed as possible continuations of this study, classified in three horizons: Consolidation of the findings; deepening of the results and interpretations; And extension to other related perspectives.

4.4.1 Consolidation of the findings

Besides the future confirmation of the results of the present experience in the company, expected in the next years, such study could be reproduced in other conditions.

For further validation, similar experience could be replicated in differentcontextsand levels of complexity of innovation (GOFFIN; MITCHELL, 2010). Several contingencies should be considered, such as company size and sector, geographic location and associated culture, organisation format, and different types of innovation processes, as observed by Ulrich and Eppinger (2004). The overall approach and particularly the 15Ps ETF could be applied to other firms in similar longitudinal studies, considering that a significant period is

necessary to obtain the recommended transformation of processes and practices, as imbedded in the Ecodesign Transition Framework.

Possibly, multi-case study could be used, spanning from the introduction of tools through all the transition process. Ideally, qualitative and quantitative results should be combined to confirm the validity of the observations.

4.4.2 Deepening of the results and interpretations

Beside such consolidation, additional research could permit to identify company-specific factors, including human factors, as imagined by Boks and McAloone (2009) as a future transition in the field of sustainable product innovation management.

In addition, future research could address and deepen the additional soft factors raised along the study, such as the governance of sustainability transition adapted to company culture, a better understanding of resistance to change processes, and the tacit side of ecodesign knowledge diffusion, as discussed in article # 5 (section 4, p.216).

Such research could lead to refine the 15 Ps ETF, and possibly to approach what Boks (2008) called a “customisation of ecodesign strategies”, and relating them to different clusters of companies profiles, trajectories and associated success factors, as suggested by Verhulst (2012) for future research.

4.4.3 Extension to other related perspectives

Another route for extending the present research could be to deepen theecodesign perspective toward more radical product innovation, using a combination of products and services, as initiated by Ölundh (2006) in order to “modernise ecodesign”.

The question whether more radical ecodesign innovation requires a different process or not could be addressed, as debated for innovation management as a whole. Ney´s (2008) view, of ecodesign practices displaying features of both exploration and exploitation activities could be studied more profoundly, building on the findings of this research.

Additionaly, the potential role of ecodesign-integrated innovation toward the emerging “circular economy” model - a production and consumption system that relies on the continuous reuse, recycling and recovery of natural resources - could be further studied. Recent papers have already pointed ecodesign as one of the key enablers for system innovation, and suggested to connect eco-innovation with the transition to a new circular economy model that will require a radical change (EUROPEAN COMMISSION, 2014).

The perspectives of global innovation and changes in the value chains underpinning current production and consumption patterns will certainly entail and motivate profound research in the field. The participation to expand such knowledge in Sustainable Operations and Innovation would be a proactive contribution to broader transitions toward a sustainable society.

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5 APPENDED PUBLICATIONS

PUBLICATION # 1: Ecodesign in project management: A missing link for the integration of sustainability in product development?
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ABSTRACT

Although ecodesign is a well-defined concept in the literature, the potential exists to increase its use and effectiveness in practice and in the company context. By searching for new approaches that could foster ecodesign application, this article explores the points of intersection between ecodesign and project management. The research approach combines a systematic literature review with a case study conducted at a consumer goods manufacturer that is recognised as a relevant benchmark in sustainability commitment and practices. The analysis of the literature reveals that project management principles are addressed in a limited manner in specialised articles on ecodesign, and no specific articles on project management were found that address issues of environmental product development and environmental sustainability. The case study indicates that environmental requirements interfere with project management, thus creating new challenges for the project teams. This study reveals that the gap identified between the two areas of knowledge can be considered as a missing link that, if filled, could enhance the effectiveness of ecodesign in the product development process. This new link would complement the current ecodesign approaches that focus on technical tools and organisational aspects by introducing original and useful guidelines for sustainable project management.

Keywords: Ecodesign; project management; product development.

1. Introduction

Ecodesign, which involves the application of life-cycle thinking in the product development process (PDP), should favour the development of more sustainable products (ISO, 2002). However, although this concept is already relatively mature, it has yet to be applied more widely in the corporate environment (Guelere, 2009; Pigosso and Rozenfeld, 2012).

Much of the research on this subject has focused on the tools and methods aimed at environmental issues, albeit with limited success in terms of practical application in product development (Guelere, 2009). Other issues addressed extensively are the challenges and strategies for integrating the environmental dimension into the PDP as a whole (Stevels, 2007).

In product development, which is defined as “the process of taking a product idea from planning to market launch and review of the product, in which business strategies, marketing considerations, research methods and design aspects are used to take a product to a point of practical use” (ISO/ TR 14062, 2002), activities are conducted at the project level with consideration that a project is “a temporary group activity designed to produce a unique product, service or result” (PMI, 2013).

Project management, another recognised area of knowledge that originated from the management discipline, has undergone significant scientific advances in the last decade (Carvalho and Rabechini, 2011). According to a broad survey and review of 200 papers conducted by Krishnan and Ulrich (2001) in the academic fields of marketing, operations management, and engineering design, project management is one of the three areas of decision determinants in product development (the other two areas are product strategy and planning and product development organisation).

Goffin (2010) insisted on the importance of project management for implementing innovations: “Turning an idea for innovation into reality is bound to be something of unique experience that must be treated as a *project*: a finite activity with its own objectives and resources, and above all its own leadership. Successful implementation of an innovation starts with good *Project Management*, nowadays properly regarded as a professional discipline in its own right” (p.227).

Similarly, in their consolidated reference model for product development management, Rozenfeld et al. (2006) included project management explanations and recommendations for professionals and academics based on the internationally recognised Project Management Institute (PMI) principles and guidelines (p. 151).

Project management is defined as the application of knowledge, skills and techniques to execute projects effectively and efficiently (PMI, 2013). Specialists in this area view it as a strategic competency for organisations that could enable them to improve project results and institute values aligned with business goals. One of the most recognised frameworks, the Project Management Body of Knowledge or PMBOK (PMI, 2013), defines ten knowledge areas typical of almost all projects: Project Integration Management, Scope, Time, Cost, Quality, Human Resource, Communications, Risk, Procurement Management and Stakeholder Management. The ISO 21500:2012, a guide for project management, emphasises project competences and proposes similar categories (known as subject groups). The ISO 21500 standard is also comparable to other methods, i.e., ICB - The International Project Management Association Competence Baseline (IPMA, 2006) and Prince 2, developed by British organisations (OCG, 2009).

However, sustainability and environmental issues are not considered specifically or systematically in these existing frameworks.

Carvalho and Rabechini (2011) proposed an original initial approach to connect sustainability to both project management processes and project context, but the overall concepts do not provide guidance and solutions that are directly applicable to product development projects using ecodesign.

Building on the insight into a potential knowledge gap between ecodesign and project management, the aim of this paper is to identify the points at which these two fields of knowledge (ecodesign and project management) intersect. Based on a research approach that combines a literature review and a case study, this work attempts to determine whether the concepts and advanced practices of project management have been (or can be) applied to contribute to the effective integration of ecodesign into business processes. The case study involves a Brazilian consumer goods manufacturer whose product development activities have included an environmental dimension for several years. This

research is a component of a larger research endeavour towards a more systematic and effective ecodesign integration and management framework that is applicable by companies.

This paper is divided into six sections. Section 2 describes the research methodology and details the protocol of the research strategy that combines a literature review and a case study. Sections 3 and 4 describe the research results. Sections 5 and 6 present a discussion and the conclusions, respectively, focusing on the implications of the intersection of the two concepts in the academic and corporate contexts as well as the challenges posed by effectively including the environmental dimension in project management for product development.

2. Research methods

This study explores the points of intersection between ecodesign- and project management-related knowledge via a multi-method combination of literature review and field research. According to Singhal and Singhal (2012a, b), there is an increasing interest in applying multi-methodological research in operations management.

In this study, several data collection methods were combined to achieve triangulation (Flynn et al., 1990; Voss et al., 2002). Such an approach aids in mitigating method weaknesses by combining complementary research methods.

Both research approaches, i.e., literature review and case study, were performed in an integrated manner (Bryman and Bell, 2011, Saunders et al., 2007). First, the conceptual framework was developed as a starting point for case research (Voss et al., 2002, Carvalho, 2014) via a systematic literature review. This phase demonstrated the exploratory stage of this research field.

The literature review was performed to better explain the general constructs of ecodesign and project management and their relationships by merging bibliometrics and content analysis. Both methods are complementary (Carvalho et al., 2013). Whereas bibliometrics aid in understanding the publication patterns in the main databases, content analysis focuses in depth on the surveyed references.

Duriau et al. (2007) suggested that the value of content analysis lies in the recognition of the importance of language in human cognition. Content analysis allows analytical flexibility, but in general, it is conducted at two levels: the manifest content of the text that can be captured and revealed in a number of text statistics and the latent content and deeper meaning embodied in the text, which require additional interpretation.

Table 1 summarises the research plan, which consists of seven steps. The first stage of the research involved a systematic literature review to build the conceptual framework, and a case studywas carried out in the second stage.

Table 1 – Research plan for ecodesign and project management

PHASES	LITERATURE REVIEW				COMPANY CASE STUDY		
Main Steps	1. Preliminary analysis of ISO standards	2. Search in publication databases	3. Content analysis	4. Content summary	5. Documentary analysis of PDP	6. Preparation of a questionnaire	7. Field research and interpretation
Approaches and main activities	Word search in the ISO/TR 14062 and ISO 14006 standards	ISI Web of Science and Science Direct + article filtering	Encoding of articles. Identification of the main articles.	Detailed analysis of the most relevant articles.	Survey and analysis of documents and procedures	Relevant themes and questions/relevant audience. Test and adjustments.	Application of the questionnaire to various actors in PDP. Analysis and synthesis.
Nature of the sought-after results	Occurrences of the expression “project management”	Number of papers on the two themes and at the intersection between project management and ecodesign. Identification of articles and extraction of information.	Graphics for interpretation; Identification of the most relevant articles.	State of research on the theme. Indication of the main project management and ecodesign constructs.	Description of PDP and project management practices involving issues of the environmental impacts of products.	Semi-quantitative questionnaire aimed at evaluating the effectiveness of current approaches, difficulties and improvement potential.	Relevance of the theme in PDP. Strong points and gaps. Clues for improvement.

2.1 Literature review

The literature review consisted of four steps. First, a preliminary survey was carried out of the regulatory framework of ecodesign, which includes two

documents recognised as technical references, i.e., ISO/TR 14062, (2002), and ISO 14006 (2011), to identify the presence of the project management concept in the introductory guidelines of ecodesign (step 1).

Step 2 consisted of a systematic review of the literature (Littell et al., 2008), involving a search for scientific papers published in two leading scientific databases: ISI Web of Science (http://www.apps. webofknowledge.com) and Science Direct (http://www.sciencedirect.com). The ISI Web of Science database was selected because it includes all of the journals that are considered for calculation of the impact factor by the Journal Citation Reports (JCR). Additionally, this database provides a detailed set of meta-data, which is essential for bibliometric analysis (i.e., abstracts, cited references, number of citations, authors, institutions, countries, and the journal impact factor) and is not readily available in other databases. Other databases were introduced to expand the article sample; however, the intersections among the search processes have become more extensive in each interaction (~68%), and thus, we decided to stop after the second database, i.e., Science Direct, a database highly recommended for the field of ecodesign.

The search aimed to identify articles at the intersection of the two fields of knowledge of project management and ecodesign, as indicated in the introduction. The term “project management” was used in the streaming search, and multiple keywords pertaining to ecodesign were used due to the widely diverse vocabulary on this topic used in various parts of the world, namely: *eco-design, ecodesign, design for environment, sustainable product development, sustainable product design, life-cycle design, life cycle design, green design, sustainable design, sustainable product development, life cycle engineering, design for sustainability,* and *environmentally conscious design* (ISO 14006, 2011; Pigosso and Rozenfeld, 2012).

A filter was applied to the two databases specifically to retain scientific articles, aiming to analyse the most homogeneous set of publications previously approved by a peer review system.

In step 3, based on the group of articles identified, content analysis was used to ensure that the articles addressed the central topic of the research. The topics covered in the articles were encoded to analyse their distribution and evolution

(White and McCain, 1998, Prasad and Tata, 2005; Carnevalli and Miguel, 2008, Carvalho et al, 2013).

According to Duriau et al. (2007), content analysis encompasses coding, analysis of content (frequency counts and cross-tabulations) and interpretation of results (theoretical framework). Once the reliability of the content analysis was addressed, particular care was devoted to the coding process, primarily through the use of multiple coders.

The initial content analysis (step 3) considered the general information on the articles (journal, year, authors, keywords and abstract). From this analysis, the most relevant articles were chosen according to their alignment with the research topic, i.e., consistently addressing the two issues of ecodesign (methods and integration) and project management.

This set of the most relevant articles was studied in depth in step 4. The content analysis and summary of this group of articles considered the articles' entire argumentation and examples to systematise and summarise the contributions to the two topics covered in the research, i.e., ecodesign approaches, project management approaches and points of intersection.

2.2 Case Study

The purpose of the exploratory case study was to understand how these two topics of ecodesign and project management for product development are integrated in the company context. Therefore, the second phase of the study aimed to analyse how the environmental dimension and ecodesign are integrated into the project management practices of product development in a company as well as to identify the challenges of this integration.

This qualitative study can be defined as exploratory and inductive, seeking to identify premises that could be further developed in subsequent research. It follows recommendations for the use of case studies for the identification of constructs on the path of theory building (Eisenhardt, 1989; Voss et al., 2002). The selection of the company under study was based on the criterion of the relevance of ecodesign issues in the PDP and the access of researchers to various types of evidence and to the stakeholders involved, given that access to the organisation is a key aspect (Bryman and Bell, 2011).

The case study was conducted at a large Brazilian consumer goods company that is considered as a benchmark in environmental policies and practices, in line with its strong commitment in sustainability as recognised by different types of stakeholders and international rankings and prises. The company's main line of business is focused on personal care. This case study was based on two types of evidence: documentary analysis (step 5) followed by interviews (steps 6 and 7).

To understand the degree of implementation of the guidelines by the product development public as well as its implications, i.e., the difficulties and potential improvement in project management practices associated with ecodesign, the interviews were based on the questionnaire presented in Appendix 1.

In the process of designing the research instrument, the potential advantages and disadvantages were explored of both self-administered and interviewer-administered questionnaires as well as structured, semi-structured and conversational approaches (Saunders et al. 2007, Bryman and Bell, 2011). The research protocol selected was the interviewer-administered questionnaire in a semi-structured approach that mixes open-ended and closed-ended questions.

As a classical research tool applicable to the areas of operations management, particularly for studying organisational and administrative processes (Voss et al., 2002; Eisenhardt, 1989), this questionnaire addresses several aspects of project management and ecodesign (i.e., knowledge areas, success criteria and consideration of environmental issues) using a set of 16 open-ended questions. To answer these questions, the interviewees were asked to choose a completed project or one that was underway.

Finally, as suggested by several authors, a pilot test of the questionnaire was carried out (Saunders et al. 2007, a Bryman and Bell, 2011). An assessment of the face and content validity of the research instrument was conducted with scholars and practitioners. After a pilot test of the instrument, nine quantitative questions were included in the questionnaire to aid in objective interpretation of the number of PDP phases in which environmental issues are considered and the degree of interference of environmental issues with various aspects of project management. These questions are closed and use a Likert-type scale (0 = not considered; 5 = considered extensively).

This exploratory questionnaire was administered to a sample of ten representatives of the target audience via face-to-face interviews, with the aim of reaching the main functions involved in PDP: marketing (two people), product development (two people), packaging development (two people), other areas of the project teams (two people) and process management support area (two people).

The interpretation of the case study combined quantitative data from the questionnaires (as described above) with qualitative information and selected verbatim evidence from interviews and other observations from the field, following the classical recommendations for qualitative research methods (Eisenhardt, 1989). Data were analysed using descriptive statistics for closed-ended questions.

As several authors indicate (Eisenhardt, 1989; Voss et al., 2002, Saunders et al. 2007, Bryman and Bell, 2011), certain aspects of the case study approach could limit generalisation of the findings because the focus is on a specific organisation and its characteristics and contextual conditions.

3. Results of the literature review

Step 1: Preliminary analysis of ISO standards

A preliminary textual analysis was conducted on the technical standard ISO/TR 14062 (ISO, 2002), which is one of the reference documents for the definition of ecodesign as the “integration of environmental aspects into product design and development”. The document extensively addresses the management question (the word is used 60 times). Although the guide “is written for those directly involved in the process of product design and development” (p. v), it uses the word “project” only four times. Therefore, it appears that the document scarcely addresses questions related to (product development) projects themselves. Additionally, the expression “project management” is not used in this document.

This gap is confirmed in the standard ISO 14006, “Environmental management systems - Guidelines for incorporating ecodesign” (ISO, 2011), as illustrated in Figure 1. As shown, the concept of project management is not addressed formally in these two normative documents

Figure 1 – Number of citations in the ISO standards related to ecodesign
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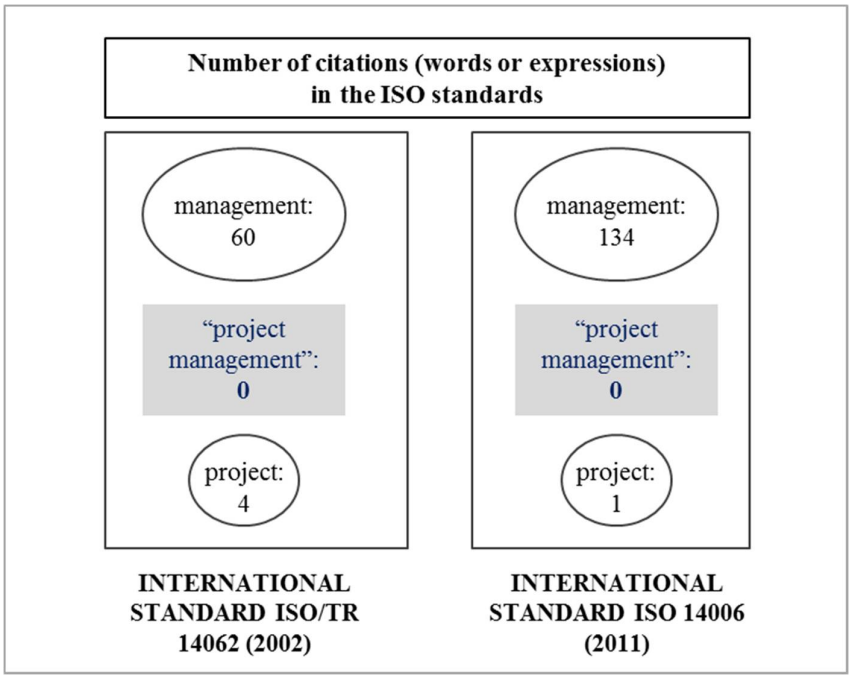


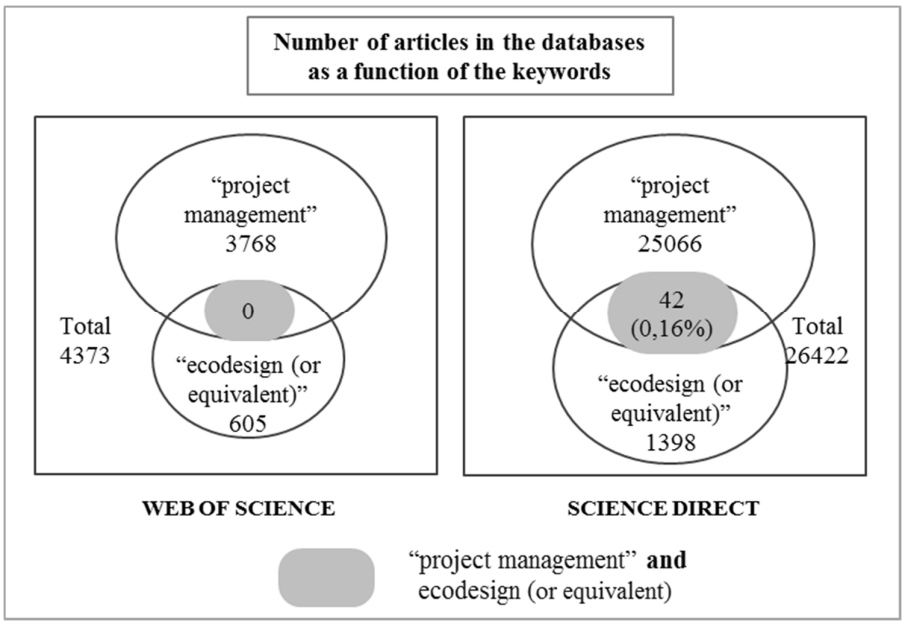
Step 2: Search of publication databases

The exploratory search was extended to the academic literature. Figure 2 presents the quantitative results of the numbers of items found in the two consulted databases.

The search in ISI Web of Science did not produce any article that simultaneously mentions the two expressions "project management" and "ecodesign" or any other equivalent designation, as indicated in the section research method. However, the search in the Science Direct database reported 42 articles that mention the two expressions, which represents a rather small fraction of less than 0.2% of the intersection of the two topics.

Therefore, the result of this quantitative survey of articles in the two databases indicates a certain gap between the two topics and the fields of knowledge with which they are associated.

Figure 2 – Search of articles in databases
(Searches carried out on 12 April 2012)



Step 3: Content analysis

Selected results of the content analysis of the set of identified articles are described below.

A reading of the abstracts revealed that although the articles were identified based on these two expressions (project management and ecodesign), a large number of the 42 articles were not directly connected with the two topics. It should be kept in mind that the search in the Science Direct database considered the presence of search words in the titles and keywords of the articles as well as in the abstracts, but this did not ensure that the topics were central to the articles.

The selective search based on the abstracts of the articles in this content assessment step resulted in the identification of seven articles that actually address the research topic. The graphs below illustrate how the articles are distributed as well as the limited group of articles with the highest relevance.

Figure 3 shows the temporal distribution of the articles, which reveals a higher incidence of publications in 2006. Among the observers of the topic sustainability, a frequent comment is that the year 2006 (which was marked by

the global release of the documentary “An Inconvenient Truth” by Al Gore, former vice president of the United States) coincided with a significant increase in media coverage of the topic of climate change in world public opinion. In this series of articles, there is an apparent drop in publications in subsequent years, particularly after 2009. Similarly, in the limited group of the most relevant articles, five of the seven articles were published in 2006, and two thereafter.

Figure 3 – Distribution of publications per year

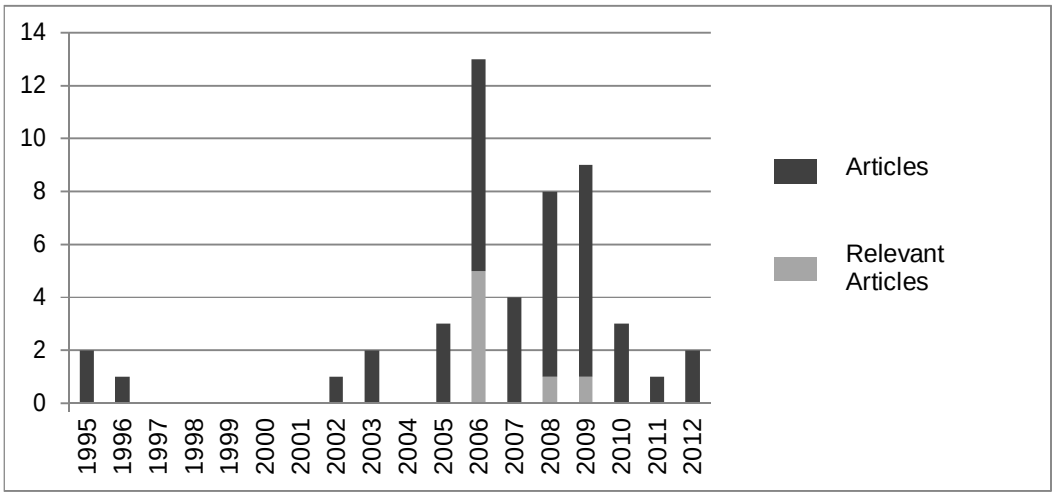
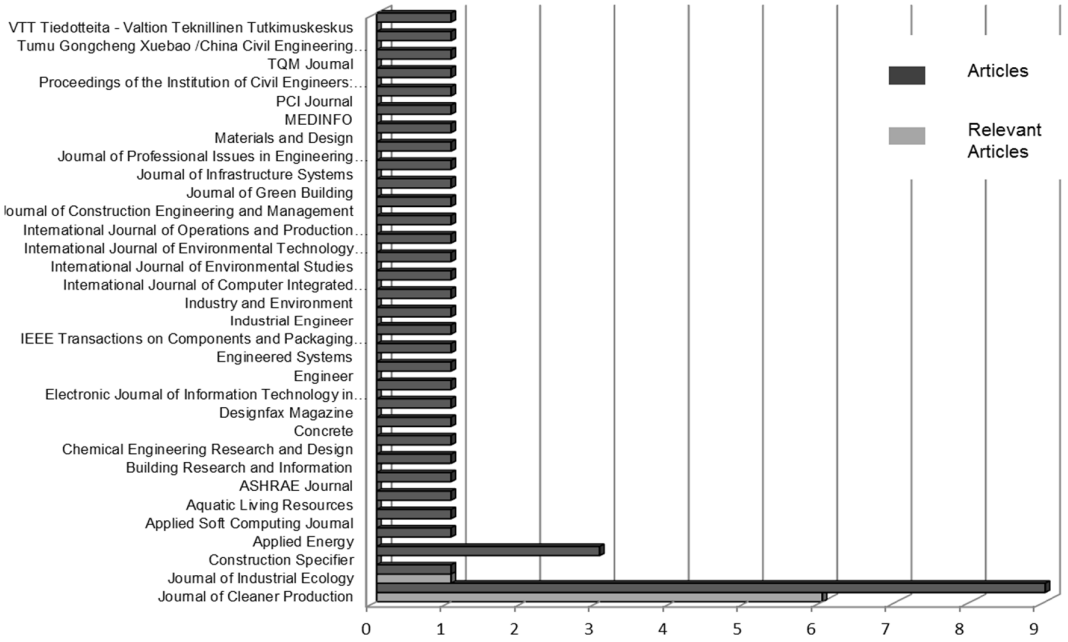


Figure 4, which classifies the publications according to the source of the articles, shows a clear distribution. Most of the articles come from 30 different journals with only one publication each from various sectors and specialties (note that none of them specialises in project management). In addition to these, only two journals include more than two occurrences, namely, *Construction Specifier*, with three publications, and the *Journal of Cleaner Production*, which contains nine publications. It is this latter journal, known as the main channel of dissemination of scientific articles on the subject of ecodesign, that is the source of six of the seven articles selected for detailed content analysis (although this criterion was not considered in the choice).

Figure 4 – Distribution of publications by journal



Step 4: Content summary

For the content analysis, Table 2 summarises the main approaches and conclusions of the seven most representative articles.

The information was organised in three columns according to the topics *ecodesign approaches*, *project management approaches* and points of intersection between *ecodesign* and *project management*.

It should be noted that all of the articles contain case studies on a single company that illustrate the arguments of their authors.

In terms of ecodesign approaches, all of the articles refer to similar definitions and cite the technical standard ISO 14062 or reference publications on the subject. Moreover, the articles address the question of ecodesign tools as an important concern, which is viewed as the priority solution of needs. This finding is consistent with specific publications on the topic (Guelere, 2009; Pigosso and Rozenfeld, 2012). The tools mentioned are guidelines and checklists, Life Cycle Assessment and other qualitative methods (Tingström et al., 2006; Vezzoli and Sciama, 2006; Tingström and Karlsson, 2006; Knight and Jenkins, 2009).

With respect to the above-mentioned project management approaches, it was noted that the authors address the topic in a limited manner, with few references to knowledge, key concepts and international standards. The Stage-Gate product development model is cited formally in two articles (Knight and Jenkins, 2009; Tingström et al., 2006) and indirectly in two others (Ny et al., 2008; Tingström and Karlsson, 2006). Only rare mention is made of such knowledge areas in project management as Scope, Cost, Communication, Time and Human resources. Topics such as Acquisitions, Quality and Risk are completely absent.

Finally, in analysing the approaches of the two topics, the proposals of the articles are quite restricted, generally remaining in line with the recommendations of ISO/TR 14062. This standard, as discussed at the beginning of our paper, presents only an introduction to ecodesign at a global level of the development process and does not specifically address project management issues.

In general, the articles reflect the literature on ecodesign, focus primarily on technical issues, and display little proximity to and familiarity with issues related to project management.

For the four cases reported as successful in integrating ecodesign with product development processes, the following comments are relevant:

• The most advanced and complete case of ecodesign integration (Tingström and Karlsson, 2006) does not provide concrete evidence of this situation, particularly with respect to project management practices.

• Three cases correspond more closely to pilot projects conducted by external experts (Knight and Jenkins, 2009; Vezzoli and Sciama, 2006; Tingström and Karlsson, 2006) but do not report true integration replicated by development teams and their practices.

The case reported by Ny et al. (2008) primarily addresses a strategic approach aimed at pre-development with a method for senior management sensitisation and mobilisation and possible implications for portfolio management, which are not described. The same gap has been noted in the Technology Roadmapping (TRM) literature (Carvalho et al., 2013).

This synthesis shows that few aspects of project management were addressed in these articles, although these were the only articles found in the literature

search that mentioned the topic of project management together with ecodesign (or equivalent) in the abstract.

The results of this systematic literature search in and review of article databases can be compared with the general recommendations and best practices found in reference publications on ecodesign. Such classical documents generally insist on ecodesign tools and PDP management as a whole (ISO, 2002; ISO 2011; Brezet and Van Hemel, 1997; Charter and Tischner, 2001; Fiksel, 2001; Stevels 2007).

These books and standards address the integration of environmental considerations in product development and often refer to recognised best practices of innovation management, i.e., the Stage-Gate process (Cooper, 2008). However, these materials do not approach the specific question of project management, as also verified in the exploratory textual search described in step 1.

Furthermore, in parallel to this research on ecodesign and project management, a wider review was carried out in our laboratory on the scope of Sustainability and project management (Martens et al., 2013). We found that the subject of Environmental sustainability is infrequently addressed in the literature on project management. Few reviewed articles and examples of applications were found, primarily in the specific sector of civil construction projects (Robichaud and Anantatmula, 2011). The convergences and differences will be further commented in the discussion section.

In this context, a case study exploring the relationship between ecodesign and project management can be considered as a new approach to the area of ecodesign management.

Table 2 – Cross-reference analysis of articles on ecodesign and project management

Article	Case presented	Ecodesign approach	Project management approach	Ecodesign and project management
Knight and Jenkins, 2009.	Manufacturer of gas and vapour detection equipment	Barriers: Lack of tools and pressures in PDP. Techniques: **Checklists**, **guidelines**, and **MET matrix** (material, energy and toxicity). Adoption of ecodesign depends on **identifying the right tools** (usable and useful).	**Stage-Gate PDP.** Internal public **skeptical** of **change** in PDP. Pressures occur during the PDP, so the staff must make efficient use of available **time**.	Ecodesign "thinking and analysis" requires several **suitable methods** and their application **to each of the different PDP phases**. **Pilot project and creation of customised tools**. Full integration represents a future challenge.
Ny et al., 2008.	Matsushita Group, Japanese multinational manufacturers of electronic products	General method for sustainable product development (MSPD) of the NGO The Natural Step: • Provides basic knowledge on sustainability/ systemic perspectives and life cycle and product development methodology; • Provides a strategic approach for the development of sustainable products; • Helps prioritise in the short and medium term. Associated **qualitative tables** (TSPD).	The TSPD can be used in the **initial phases** of the PDP to create a vision of the current situation and future options to shift product categories toward sustainability. General conclusions applicable to more detailed phases of the **concurrent engineering process** cannot be reached because they involve rather **specific** aspects for each development project.	Main **challenges** of sustainability and **opportunities** for **a product category in the early stages of development**. Facilitated **communication** and **commitment of top management** to support sustainability efforts in product development.
Tingström et al., 2006.	ABB, a large Swedish company in energy and automation technology (B to B).	Developers require information, support by specialists, and checklists to integrate environmental issues throughout the process. The **"Sustainability Tool Site" on the intranet: Lists of restricted materials, LCA, and Environmental product Declarations (EPD)** to assist in product development and management processes.	Product development as an **interdisciplinary** activity; **Stage-Gate** model with a clear focus on evaluation of the project as it passes through its phases. Top management is involved in decision-making in these Gates.	Interviews revealed a common understanding of the meaning and content of this methodology. *A sample result is shown in a project but without evidence of integration and use.*
Vezzoli and Sciama, 2006.	Necta Vending Solutions, Europe's leading manufacturer of food and beverage machines	**Guidelines and checklists,** essential and effective tools for development processes. Guidelines should inspire and indicate solutions that have the highest potential for environmental sustainability. The guidelines must be evaluated on a **case-by-case** basis.	Guidelines are procedures to guide the **decision-making process** according to the objectives considered. In ecodesign, the decision-making process is related to design activities, from briefing to conceptualisation and development. *PDP is not described; the term "project management" is not used.*	Checklist created as an operational tool to integrate the guidelines as a **mandatory step of the PDP**. Quite positive feedback on the method used by the company, but it is rarely adhered to by those responsible at Necta. After the **initial project,** a second project with another typology was hired for consulting.
Tingström and Karlsson, 2006.	International Swedish company Volvo Wheel Loaders AB / automotive equipment	Methods: **LCA and EEA** (environmental effect analysis/ qualitative method) in three **combinations**. Explanation of **difficulties** encountered: Environmental assessment tools are **analytical**, while **development is synthetic and multidimensional**.	To incorporate environmental considerations into PDP, **specify the relevant environmental information** in the form of documents and other forms of project information. *Discusses little and mentions "project management" only once.*	A key to real transformations of design practices is to bring up environmental issues for **discussion by product development teams**.
Zwolinski et al., 2006.		REPRO2 tool for remanufacturing restrictions in development; *A highly technical and specific approach*.	*Does not address aspects of project management. The expression "project management" is not used.*	*Not addressed.*
Johansson and Magnusson, 2006.	B To B Commu-nications product development, with environ-mental require-ments.	Despite the **large number of tools**, environmental considerations are not a component of the product development practice. Ecodesign research should **expand** its technical and regulatory guidelines to include **managerial and organisational aspects**.	Limited knowledge of **organisational aspects** related to environmental issues in product development. Originality: Approach **at theproject level**. Focus on **how the project was organised**, with the **introduction of a specific "Green" sub-project**. *Project management only of organisational issues.*	**Mobilising** effect and channels of communication. Risk of **confusion** as to who is **responsible** for compliance with environmental requirements. A platform that fosters **networking among environmental experts** and the organisation of product development.

4. Results of the case study

The case study involved a Brazilian manufacturer of consumer products that is one of the leaders in its area of action in the Brazilian market. This company is known for its leading role in sustainability issues in Brazil and for considering environmental issues in its product development activities for several years. Founded in the late 1960s, the company has shown significant growth over four decades. In recent years, the company has sought to shift to a more process-oriented management style, which it formally adopted in 2008. As a result, the company analysed and formalised its core business processes, including the product development process.

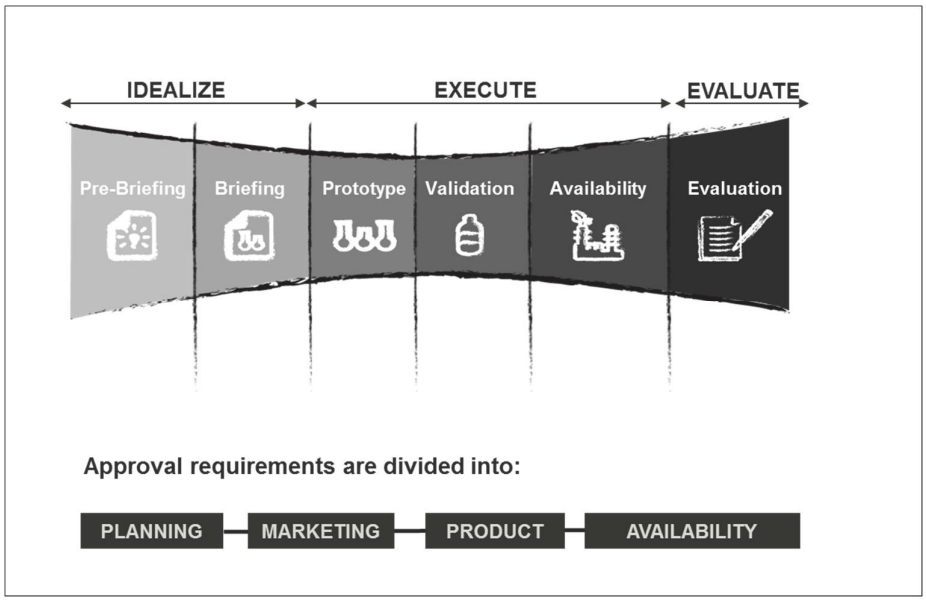
This process, which the company revised in 2010 and which it refers to as a "product funnel", is briefly described based on the available documents that outline the internal guidelines. More specifically, an analysis is carried out of how the company considers the dimension of environmental sustainability and its connections with the guidelines for project management.

4.1 Environmental dimension in the product development process (PDP)

The case study begins with the investigation of the company documents related to the PDP (step 5).

The company's PDP structure, known internally as the "product funnel," is illustrated in Figure 5. The structure consists of three macro-phases (Idealize, Execute and Evaluate), which in turn are subdivided into six phases (Pre-Briefing, Briefing, Prototype, Validation, Availability and Evaluation), similar to the divisions and classical terminology in the context of consumer products (Rozenfeld et al., 2006). There are certain similarities between Figure 5 and the processes of ISO 9004:2009, although the precise origin of this figure was not informed by the company.

Figure 5 – The “product funnel” representation of the company’s PDP



The main company supporting documents for this process consists of responsibility matrices and lists of requirements per phase.

The responsibility matrices describe the main duties of the various participants of the project (or project team) throughout the phases of the funnel. Within the company, the project teams are led by members of the marketing teams, who assume a dual role in most projects. Only a few strategic projects have a dedicated project manager allocated to them who is separate from the marketing manager.

The lists of requirements per phase describe the activities to be performed and the deliverables required for approval in the gates or phase passages.

According to the representative of the area of process management, this PDP was inspired by the creation and revision of knowledge on project management from the Project Management Institute (PMI), in order to incorporate best practices of project management. However, these best practices are not described explicitly in the PDP documents (during the period when the interviews were being held, the company began to improve its organisation via creation of a Project Management Office to support the development projects, formalise its project management practices, and provide user training).

The company's funnel and project guidelines contain orientations that primarily focus on the classical dimensions of project management: scope and product specification and performance, cost and financial performance, and timing.

The guidelines also formally include a topic that relates to the product's environmental impact, beginning in the briefing phase. The area responsible for analysing this topic is marketing, with representatives from the areas of product development and packaging development playing a "supporting role."

A specific company document known as "guidelines for product launches" establishes "guidelines for approval of stages in the product funnel based on equivalent carbon emissions." This indicator is obtained by means of an internal tool, i.e., the environmental calculator, which was developed via LCA (Life Cycle Assessment) methodologies and is used by employees in the areas of product and packaging development. These guidelines imply the need for a new product to have a carbon footprint that is smaller than or equal to a reference product, and the definition of this reference is highly important for comparisons. The document precisely defines the references for each type of project (product improvement, product line extension, new category or brand).

4.2 Analysis of the questionnaires

The last two steps (6 and 7) of the research plan involve an analysis of the interviews and tabulation of the questionnaires.

The answers to the initial questions indicated that the interviewees have a good understanding of the environmental impacts of the products and project management.

Thus, most of the interviewees linked environmental impacts to the concept of product life-cycle and spontaneously mentioned their considerations of the various stages of the production chain. However, the interviewees admitted that in the company context, the main focus is on the carbon footprint, which is used as the main indicator of the environmental performance of the company's projects.

Similarly, the concept of ecodesign is relatively well understood, although the term is rarely employed in the company's day-to-day operations:

"Product design aimed at reducing environmental impacts, with the same value proposition." (Marketing coordinator)

All of the interviewees showed a correct and full understanding of project management issues because they are members of the development teams or project leaders. Moreover, four of the ten interviewees reported that they obtained training in project management, citing the guidebook Project Management Body of Knowledge – PMBOK (PMI, 2013).

The projects chosen by interviewees for comment (eight different projects in all) were of various archetypes or categories used in the company, but this parameter seems little related to variations in the responses. However, the attributes of the sub-brands of the products seem to have a certain amount of influence on the teams' involvement in environmental issues:

"Some sub-brands raise this [environmental] concern more strongly." (PDP management coordinator)

The main results are summarised in Table 3, which describes the quantitative data and lists interpretive comments. In addition to the average of the results of the ten interviewees, the average results of projects linked to sub-brands with or without environmental appeal were also calculated.

Table 3 – Summary of the findings obtained from the questionnaire at the company

QUESTIONS	Mean SB+	Mean SB-	Mean	Standard Deviation	COMMENTS
Years of experience in the company	5.7	4.0	5.4	3.7	
In how many **phases of the product funnel** do you consider environmental issues?	5.7	4.5	5.5	1.0	There is near consensus on the consideration of environmental issues in all the phases
Are environmental criteria considered in the project's **scope and success criteria**?	4.3	4.0	4.2	0.6	This aspect of project management is more closely related to the environmental dimension
Are environmental issues considered in decisions pertaining to the product's supply chain?	2.4	0.0	1.9	1.4	This aspect of project management is less related to the environ-mental dimension and is not considered in incremental projects
Are environmental issues considered in the decisions concerning the **technologies** chosen or developed for the product?	3.6	3.5	3.6	0.5	There is a strong relationship
Do environmental issues affect **quality** issues throughout the project?	3.4	0.0	2.7	1.9	An intermediate relationship; strong in projects with environmental appeal
Do environmental issues affect **cost** issues throughout the project?	3.7	1.0	3.2	1.4	An intermediate relationship; strong in projects with environmental appeal
Do environmental issues affect **deadlines** throughout the project?	2.4	0.5	2.1	1.6	An intermediate to low relationship; stronger in projects with environmental appeal
Do environmental issues affect **risk** issues throughout the project?	2.9	1.0	2.4	1.4	An intermediate to low relationship; stronger in projects with environmental appeal
Do environmental issues affect aspects of **communication and human resources** throughout the project?	3.4	0.0	2.7	1.5	An intermediate relationship; strong in projects with environmental appeal

Caption: SB+: sub-brand project with environmental appeal; SB- : sub-brand project without environmental appeal; Likert scales 0-5, except for the first 2 questions.

Table 3 indicates that environmental issues are considered in virtually all of the phases of sub-brand projects with environmental appeal, either due to the need to meet the requirements in the funnel or to internal interest in the project:

[Consideration of the] *"Environmental Impact is a requirement; we seek solutions to meet the requisite of not increasing the environmental impact, per product family, per year."* (Marketing coordinator)

"The motivation came from the sponsor, starting in the pre-briefing phase; the project was created with the need for sustainability; it sought lower environmental impact, which was a success criterion." (Engineering manager)

This finding is consistent with the documents of the PDP requirements in which environmental standards are still optional in the pre-briefing phase. Thus, for the projects related to a sub-brand with higher sustainability concerns, the project teams consider environmental issues starting at the beginning of projects, i.e., in the pre-briefing phase.

Additionally, the dimension of "project scope/success criteria" consistently appears as the one most connected to environmental issues.

"[The project's sub-brand] *has a sustainability flag, so it incorporated environmental deliverables, seeking to be at the forefront in aspects of design with less environmental impact."* (O&L coordinator)

Next, the dimension "technology" is the topic that implies a stronger consideration of environmental issues:

"The main challenge of the project is to render feasible the technology of the use of recycled (material) at the industrial level." (Packaging development researcher)

However, environmental issues were also strongly related with the other dimensions of project management in the case of projects with environmental appeal, particularly with Cost, Human Resources, Quality, Deadlines and Risks:

"Environmental issues have created differences; nobody wanted to take responsibility. It required much more work time, efforts and perseverance, and new competencies; we had to carry out additional environmental impact studies with a consultant. There is insufficient knowledge and training even in the R&D area that participates in the team." (Packaging development researcher)

"The schedule was set up to address multiple challenges considering environmental issues, which entailed a longer duration." (Packaging development researcher)

"Recycled material technology entails a risk, and solutions were sought to mitigate the risk." (Packaging development researcher)

"With high environmental goals, there is a risk they will not be met; this was discussed by the team." (Packaging development researcher)

Various difficulties in and suggestions to improve the way in which environmental issues are addressed in project management were also expressed. These comments reflected not only awareness that the supply chain as a whole is insufficiently considered but also the need for greater integration of the various knowledge areas:

"There are several challenges for a more complete vision expanded to the various dimensions; to establish the supply chain more firmly, and the issue of trade-off among the various dimensions, and to integrate everything." (PDP management coordinator)

"The teams have too little understanding about environmental impacts to have any greater concern." (Formula development researcher)

"The teams engage in extensive but inconclusive discussions. They would need to be able to make more holistic decisions." (Engineering manager)

5. Discussion of the results

A systematic literature review revealed that the publications found in two of the main databases of scientific articles are notably limited in the number of papers on the topic of ecodesign and project management (42 articles, only seven of which are more consistently linked to both topics). These papers originate from a restricted group of research on ecodesign, published primarily in a specialised journal, the *Journal of Cleaner Production*, in 2006 and subsequent years.

The set of seven articles analysed in detail primarily covers "classical" topics in ecodesign literature, i.e., the choice and adaptation of tools aimed at issues of the environmental impacts of products (guidelines, environmental assessment methods such as LCA, and qualitative methods), and more generally, the introduction of environmental considerations in the development process. The approaches reported in these papers are quite consistent with the general recommendations and best practices found in other reference publications on ecodesign, (ISO, 2002; ISO 2011; Brezet and Van Hemel, 1997; Charter and Tischner 2001).

In the few articles we identified, project management issues and knowledge with a focus on the feasibility and effectiveness of ecodesign were reported only quite

superficially; in fact, even if the expression is used, the principles or issues of project management (i.e., project Integration management, Scope, Time, Cost, Quality, Human Resource, Communications, Risk and Procurement management) were not specifically addressed. Furthermore, the environmental and technical aspects that are classically considered in ecodesign tools and practices refer only to the Scope dimension of project management, but more detailed organisational considerations and practices at the project level were not found in these publications on ecodesign.

However, more advanced knowledge of project management has not resulted in scientific articles on the topic of environmental sustainability in product development projects, thus characterising a potential knowledge and application gap (Martens et al., 2013).

Although the literature review revealed little material on the topic of project management insofar as it pertains to ecodesign, the case study conducted in this work sought to explore the relevance of the intersection of the two fields of knowledge because the absence of previous studies or publications on a new area does not mean that the topic would be meaningful and pertinent.

In the context of a company that shows a fairly high maturity relative to considerations of environmental criteria in its PDP, this study indicates that environmental issues may affect not only technical issues but also the main dimensions or knowledge areas of project management as they pertain to the Project Management Body of Knowledge (PMI, 2013).

The interviewees showed a good understanding of the two topics and the ability to answer general and specific questions.

The company's efforts to integrate environmental sustainability in its PDP over recent years are reflected not only in the process via environmental requirements that are known and applied in almost all phases of the funnel but also in the various dimensions of the projects and their management, particularly in projects in which this environmental dimension provides a differential advantage in marketing (linked to the most involved sub-brands).

However, this integration continues to pose a challenge for the teams, for project management and for the process as a whole:

"We are still little prepared to incorporate ecodesign in our day-to-day routines; there is a gap between strategy and implementation / execution, where the deadlines are too short." (Marketing coordinator)

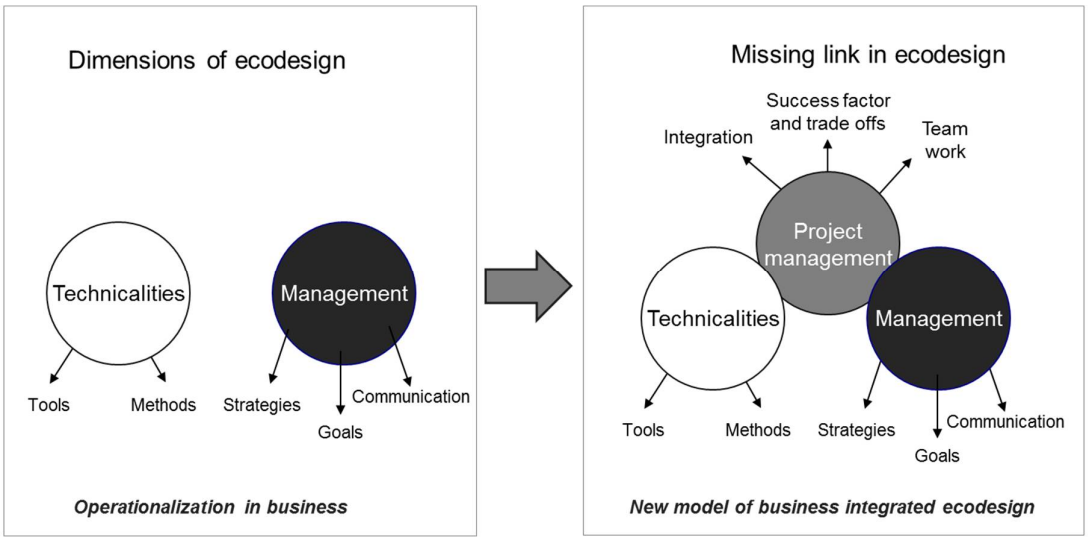
Several relevant suggestions for improvement were identified that can be addressed by the company in the future with the support of the teams involved in Sustainable Technologies and PDP management.

The most critical aspects for integrating environmental issues into the discipline of project management (where the company showed the largest gap) appear to involve decisions concerning the product supply chain, the quality throughout the project, timing issues and risk-related issues throughout the project.

However, this exploratory research does not allow for conjectures as to whether these dimensions of project management (i.e., term, risks, and supply chain) can potentially incorporate or interfere with the environmental dimension. The fact that this relationship was not observed in the context of this company does not rule out its potential relevance in another context.

At the same time, the findings of this study led us to propose that an intermediate approach systematised at the project management level could strongly complement classical ecodesign guidelines and practices and significantly strengthen their effectiveness, as illustrated in Figure 6.

Figure 6 – The potential role of project management in ecodesign



(Figure on the left is from Stevels, 2012)

This proposition is aligned with and goes beyond the best practices of ecodesign management exposed in the reference book from Charter and Tischner (2001, p. 229):

“There will be various stages to the product development process, and the environmental considerations should be integrated at each stage or ´gate´. The difficulty is balancing and prioritising the importance of environmental considerations against other factors, such as cost, quality and performance.”

Similarly, in the same edition, Fiksel (2001, p. 185) exposes the same type of statement:

“An ecodesign organisation must incorporate sustainability awareness systematically into the daily work of development teams. This is a logical extension of the modern practice of integrated product development (IPD) whereby cross-functional teams begin at the conceptual design stage to consider life cycle issues, including quality, manufacturability, reliability, maintainability, environment and safety. For example, many companies use a ´stage-gate´ process, requiring that a product satisfy a variety of performance criteria before passing on to the next stage of development.”

This material, as reflected in the literature review and Stevels´ views (2007, 2012), also details the technical and tool issues as well as global PDP integration issues but does not mention the possible necessity of stretching ecodesign into the scope of project management.

Our finding and proposition is quite consistent with other general recommendations for “good innovation management”, as stated by Goffin and Mitchell (2010, p. 26): “Innovation management often requires managers to match ‘technical’ expertise, in areas such as technology, project management and finance, with ‘soft’ skills in managing people and creativity”. However, when Goffin (2012) recently discussed sustainability in product development, although he recognised that “organisations need to make significant modifications to NPD processes to achieve sustainable innovation”, he still focused on recommendations at the PDP level based on a Stage-Gate model and did not mention project management implications.

In addition, it should be noted that project management issues extend beyond the direct framework of projects to the dimensions of portfolio management and innovation strategy and are directly linked to the effectiveness of sustainable innovation, as commented by an interviewee in the company:

“Portfolio and sales mix strongly influence the requirements; our vision is slightly nearsighted; more innovation is needed to reduce environmental impacts.” (marketing coordinator)

In Figure 6, initial dimensions of project management are proposed that could foster ecodesign application, i.e., Integration (in the meaning used in the PMBOK), Success factor and tradeoffs, and Teamwork, which reflect certain important aspects of project management for which environmental considerations could be systematically included in concert with comments collected in the interviews.

In other words, it can be observed that the management of projects aimed at more sustainable products or services should include new principles that are not embedded in current project management best practices that traditionally ignore environmental sustainability. This new practice would generalise what certain authors have already proposed in the more advanced green building development sector, the existence of barriers in current project management principle that prevent “the ability to deliver a green project within acceptable cost constraints” (Robichaud and Anantatmula, 2011). New project management principles should be brought in, e.g., the participation of a wider range of stakeholders in the early stage of the development projects may bring new practices that remodel the projects as a whole, such as the so-called “Charette Procedure” (collaborative multi-stakeholder session) found in the construction sector.

Thus, this proposition of considering project management adaptation as a necessary link in the effectiveness of ecodesign offers a promising opportunity and a challenge for future research in sustainability management in the continuation of the investigations presented here.

We propose that this “knowledge gap” can be transformed into a real “link” between the “Technicalities” level and the “Management” or PDP level of ecodesign that generally follows a Stage-Gate model in companies (Goffin and Mitchell, 2010; Katz, 2008), as described briefly in the case study in Section 4 and Figure 5. This observation is in good agreement with the principles of innovation management as exposed by Cooper (2008, p.217): “Stage-Gate is a macroprocess—an overarching process. By contrast, project management is a microprocess. Stage-Gate is not a substitute for sound project management methods. Rather, Stage-Gate and project management are used together. Specifically, project management methods are applied within the stages of the Stage-Gate process”.

6. Conclusions

Reinforcing the argumentation drawn in Section 3, our analysis of the literature indicated that project management concepts and practices applied to the context of considering environmental sustainability in product development (ecodesign) have been reported only incipiently in scientific papers.

Because the reference documents on project management (i.e., those of the PMI) have yet to address sustainability issues in detail, it can be concluded that a gap exists between the two areas of knowledge discussed in this work, i.e., project management and ecodesign.

However, the case study presented in Section 4 showed that a deepening of the relationships between the environmental dimension and project management provides relevant indications of the challenges faced by innovation project teams.

Considering that one of the main objectives of ecodesign research is to identify solutions to increase the effectiveness of the integration of ecodesign in PDP and that this is also the expectation of companies involved in the topic, this knowledge gap may open up promising perspectives for the construction of knowledge and practical recommendations and guidelines for ecodesign management at the project level.

This view arose from a different route than the main research and practices observed in ecodesign, which have focused primarily on technical aspects and tools and secondarily on certain issues related to company strategy and management, e.g., as described in the ISO standards.

This study therefore puts forward a new proposition that the integration of the environmental dimension into the project management of new products could increase the effectiveness of ecodesign applied in companies. Such a view can be treated as quite new in the field of ecodesign literature, although it is completely coherent with good innovation management practices and was confirmed by the exploratory case study.

Thus, the inclusion of the original project management guidelines that consider environmental sustainability issues could aid in increasing the effectiveness of ecodesign integration and implementation for project managers and team members. The lack of such specific guidelines can be presumed as a limiting factor for projects and companies that attempt to consider environmental aspects as a performance factor expected for their activities.

However, the limitation of this study is its solely exploratory and qualitative nature. Although it applied a systematic search in large databases, the literature review led to a notably small sample of papers. Additionally, the case study was conducted in a point-wise manner and involved a single company, which limits its generalisability as recognised by experts, and the qualitative interpretations of the content analyses of the articles and the questionnaires involve a certain degree of subjectivity.

For a more in-depth consolidation, this preliminary study may be extended to several applications by replication in various companies in future. Such additional research would be helpful to explore and define the relevant variables for ecodesign-oriented project management and to attempt to visualise how such an extended project management approach could improve the environmental performance of product development.

Nonetheless, the knowledge gap and the associated new insight presented in this article can be acknowledged as a relevant though modest contribution to the construction of a broader framework for the full integration of ecodesign in new product development. Investigation into this topic will be continued and integrated in a wider diagnosis and review of ecodesign implementation challenges and models and will be associated with an Action Research programme in the search for greater effectiveness of such all-inclusive integration and a better understanding of associated success factors.

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PUBLICATION # 2: Environmental perspective into new products portfolio: a challenge for the effectiveness of Ecodesign

BRONES, F.A.; CARVALHO, M.M.; SALERNO, M. S. Environmental perspective into new products portfolio: a challenge for the effectiveness of Ecodesign, 20th EurOMA Conference, Dublin, 2013.

Abstract

This study explores how the environmental perspective is being considered in new product Portfolio Management. A systematic literature search was conducted at the intersection of Ecodesign and Portfolio Management, followed by a case study in two companies. A gap was observed at the junction of both areas of knowledge. Then, management of environmental indicators in the project Portfolio was seen as hardly an emerging practice and evaluated by managers as having the greatest potential of improvement. Four challenges are presented as propositions to enhance the integration of Ecodesign in strategic planning, tactical deployment and operational monitoring of sustainable innovation.

Keywords: Ecodesign, portfolio management, new product development

Introduction

Understood as the application of life cycle thinking into the Product Development Process (PDP), Ecodesign should favor the development of products with lower environmental impacts and therefore more sustainable (ABNT, 2004). This concept has been structured since the 1990s (Kurk, 2006), but is still in search of greater expressiveness through effective applications in the business world (Guelere, 2009; Pigosso, 2012).

Several authors reported that most research and publications on Ecodesign have dealt with practices and tools (Guelere, 2009). According to Stevels (2007), these "*Technicalities*" represent over 60% of the publications, the second most treated question being related to strategy and global management aspects.

On the other hand, in the academic world of Innovation Management, understanding and managing PDP have evolved within the last decades. Concepts and models created in the 1990s have been widely disseminated and adopted by organizations,

mainly large or medium sized, towards a more efficient product development management.

Two models are well known: the "development funnel" (Clark and Wheelwright, 1993), and the Stage-Gates model from Cooper, Edgett and Kleinschmidt (1997, 2002), emphasizing the decision points between phases along the PDP.

In this conceptual and methodological framework, one of the relevant issues relates to the management of, not individual projects, but the whole set of projects within an organization, usually called a "Portfolio" of new products projects (Cooper et al., 1997).

Portfolio management can be defined as "*a dynamic decision process, whereby a business´s list of active new products (and R & D) projects is constantly updated and revised. In this process, new projects are evaluated, selected and prioritized; existing projects may be accelerated, killed, or de-prioritized; and resources are allocated and reallocated to active projects*" (Cooper et al., 1997, p. 16). Such management aims at three objectives: to maximize the value of the portfolio; to ensure a good balance of projects and to achieve strategic alignment with the business.

For Goffin and Mitchell (2010, p.222) "*selecting and managing the portfolio of innovation projects are difficult but vital parts of managing innovation*", so this is still a challenging task for most organizations.

Moreover, sustainability issues and environmental performance of products are not mentioned in Portfolio Management principles and methods, in the reference texts cited above.

On the other hand, in an article published in 2010 in the Harvard Business Review, with "The Sustainability Imperative" as a provocative title, Lubin and Esty state: "*most executives know that how they respond to the challenge of sustainability will profoundly affect the competitiveness- and perhaps even the survival of their organizations*"; *"the sustainability megatrend will require companies to update traditional business tools (...) to encompass the specialized requirements of environmental sustainability*" (Lubin and Esty, 2010, p 48).

These statements are in line with what the recent ISO 14006 standards "Environmental management systems - Guidelines for Incorporating ecodesign", advocate:

"*In order to be of benefit to the organization and to ensure that the organization achieves its environmental objectives, it is intended that ecodesign be carried out as*

an integral part of the business operations of the organization. Ecodesign might have implications for all functions of an organization." (International Standard, 2011, p. v).

Nevertheless, in a textual analysis of the two main normative documents related to Ecodesign, ISO 14006 as just cited, and TR 14062, "Environmental management - Integrating environmental aspects into product design and development" (International Standard, 2011; ABNT, 2004), "portfolio" as a word or concept is totally absent.

Also, in these documents, Ecodesign integration focuses individual projects and some practices in the design process.

In this context, this article explores the meeting points of both fields of knowledge- Ecodesign and Portfolio Management, in a theoretical and practical perspective. It seeks to identify best practices in the intersection of both subjects in order to assist and direct an efficient new product Portfolio Management including the environmental sustainability dimension.

As an exploratory research, the presented study associates a literature review and case studies carried out in organizations using both Portfolio Management and Ecodesign.

This paper is divided into 5 parts. Section 2 describes the methodology used. Section 3 presents a summary of the systematic literature review, followed by case studies in Section 4. Finally, discussion and conclusion are presented (5).

Research design

This exploratory work initially faced several challenges at the interface of two complex subjects, Ecodesign and Portfolio Management.

Ecodesign Management literature is still sparse and can be considered at a low stage of maturity. As for innovation Portfolio Management, scientific literature is much more extensive and profound, but it reveals more challenges than certainties.

For example, Cooper et al. (1998) point out that "*Portfolio management is a critical topic because it integrates a number of key decisions areas, all of which are problematic*".

Considering the research objectives and complexity challenges, an approach that combines systematic literature review and a case study was used, with three phases described here below.

Phase 1: Literature review

After examining some of the major publications in Portfolio Management, as an initial orientation of the study, a systematic literature review was conducted on Ecodesign and Portfolio Management, in a period of twenty years.

The search for publications was conducted in two major scientific databases: ISI Web of Science - or http://www.apps.webofknowledge.com and Science Direct or Scopus - http://www.sciencedirect.com

The terms "portfolio" OR "pipeline" AND "management" were used as search stream in publications abstracts, associated with multiple key words used in reference to Ecodesign, due to the diverse vocabulary used in this theme in various parts of the world, with similar or proximate meanings: eco-design; ecodesign; “design for environment”; “sustainable product development”; “sustainable product design”; “life-cycle design”; “life cycle design”; “green design”; “sustainable design”; “sustainable product development”; “life cycle engineering”; ”design for sustainability”; “environmentally conscious design” (International Standard, 2011; Pigosso and Rozenfeld, 2011), and also “sustainable innovation”, “sustainable R&D”, “eco-innovation”.

Phase 2: Summary of key concepts and challenges for case study preparation

Since the reference publications from Cooper et al. (1997, 1998), the issue of strategic alignment points to the necessity of Portfolio Management be associated with other processes such as strategic planning and management of the business as a whole.

Also, within the Stage-Gate model, the approval of any project at a gate depends on criteria related to the own project and also of the Portfolio; i.e. the management of individual projects is directly linked to the Portfolio Management (Cooper et al, 1997).

Larsson (2007, p. 42) reinforces this complexity:

“*Thus the overall portfolio management process spans strategic and operational levels in the company, and this emphasizes the pervasive nature of the phenomenon. In order to accomplish this linkage the overall portfolio management process may be seen ascomprised by multiple processes, which are closely integrated. A strategy process, portfolio review process and the development process are the typical processes considered by different authors*.”

Along with the results of the literature review (Phase 1), these issues have been considered for the preparation of the case study and in particular the questionnaire.

Phase 3: Case Studies

Advancing into the exploratory and inductive study towards premises that may be further developed in subsequent research, two case studies were developed, following the main recommendations from the literature (Eisenhardt, 1989; Voss et al., 2002), to identify constructs and build theory.

The criteria for selection of cases were: the existence of a structured new products Portfolio and the consideration of environmental criteria in the R & D and / or sustainability management. Based on these criteria, two large Brazilian companies from the consumer sector were selected. This sector is characterized by a large number of products that leads companies to develop a high number of projects and therefore is a context where issues of Portfolio Management and projects choices or prioritization are particularly relevant.

The case studies were initiated by preliminary contacts aimed at collecting and analyzing documents and aligning vocabulary, followed by interviews. It was observed that the issues were relatively new and therefore there were limited documents in companies exploitable for the research.

For this reason, the main focus was given to interviews, to explore and understand the alignment of Portfolio Management and Ecodesign in the context of these companies.

To that end, a semi-structured questionnaire was created, instrument particularly relevant for studying organizational and administrative processes (Voss et al., 2002; Eisenhardt, 1989).

Through a set of twenty open-ended questions, this questionnaire explores several aspects of Portfolio Management and Ecodesign, such as the description of the process and main practices and tools involved; environmental sustainability measurement/ indicators and targets; organizational aspects, macro processes involved, accountability / governance.

Taking into account the challenges of managing Portfolio exposed here above, the questionnaire was split into three sets of questions, directed to three possible roles of respondents *vis-à-vis* the Portfolio Management and environmental issues, or subthemes: Management and Monitoring new products Project Portfolio; Business

Strategy and new products Strategy (company or business unit); Sustainability Strategy and environmental goals Management.

Respondents were identified to meet three roles listed in Portfolio Management and / or environmental issues: R & D and Sustainability managers; area responsible for Portfolio Management; Business Units manager, if relevant.

The questionnaire was conducted in three stages, starting with initial questions to verify the role of the interviewee and choose the appropriate script of questions, then continuing with questions specific to the role and finally with questions common to all respondents.

This third part included five quantitative questions in order to better assess the perceived performance of the Portfolio Management process and specifically its environmental dimension, according to the various actors. These questions used a six level Likert scale: Bad, Poor, Fair, Good, Very Good, Excellent, for various dimensions of Portfolio Management process.

After collecting information in the companies, the results were analyzed, synthesized and compared with the literature review results.

Environmental perspective into new products portfolio: systematic literature review

The searches performed on two of the main publications bases with more than 15 expressions of Ecodesign or synonymous and Portfolio or Pipeline, brought a very small number of publications, less than twenty elements in total.

An initial analysis of the abstracts of this set of publications associated with the two studied subjects, showed a limited content, both in number of publications and in depth, with a majority of publications presented at conferences.

Several publications were excluded since the term "portfolio" referred to all of an organization's products, not new products development Portfolio.

Resulting from this process, no more than six publications were identified as directly or indirectly mentioning Portfolio Management and Ecodesign, as summarized in Table 1, indicating the constructs as well as the limitations of these articles.

This reduced set of six articles published between 1999 and 2012 indicates that the issues related to the introduction of environmental sustainability into the more strategic product innovation management processes are hardly present in the scientific literature.

While indicating the interest of researchers for questions directed to more strategic management of Ecodesign, even the latest articles just point to the need to study these issues further, as suggested avenues for future research (McAloone and Boks, 2009). Also, according Decouttere and Vandaele (2012, p.1), "*Research and development portfolio is traditionally technologically and financially dominated, with little or no attention to the sustainable focus*".

Among these publications, the article from Ölundh and Ritzen (2004) is the most focused on the research topic. Published in a congress of the "Institute of Electrical and Electronics Engineers", it addresses the Portfolio Management focusing only on the selection of projects in the early, pre-funnel, stages, which can be regarded as oversimplified to address the challenges of Portfolio Management and Ecodesign as a whole, in view of the recommendations of Cooper´s work (1997, 1998, 2001).

Table 1: Summary of literature on Ecodesign and Portfolio Management

Articles and constructs related to research topics	Comments and opportunities
Bhamra et al (1999) One of the key success factors is the introduction of Ecodesign at pre-specification stages of the project, however this stage rarely involves designers and also lacks tools to support the process of decision making.	Does not address the portfolio and management related issues. Gap and opportunity to develop tools for this phase.
Simon et al (2000) Successful Ecodesign requires activity on two levels: strategic, to set the matter within the entire organization, and operational study to put the good intentions into practice in product development. Prioritization stage is key	Does not address directly the portfolio issues and its management.
Ölundh and Ritzén (2004) Proposition based on a case study to include structurally environmental aspects in the evaluation process and preparation for different project ideas The portfolio selection ensures that environmental aspects are considered at a strategic level. Recommends including environmental targets in the idea selection process and guidelines for new projects.	Despite referring to the classical concepts of Cooper for Portfolio Management, focuses only on the project selection process. Does not describe the form or method for integrating environmental aspects in Portfolio Management.
Donnelly et al. (2006) Describes a product oriented environmental management system that allows incorporating sustainability principles during product development, in the context of a large company (Lucent Technologies). Includes "Front End" process, a mechanism by which suggestions for new features or additional functionality are considered for inclusion in the portfolio. The integration of Ecodesign as early as possible in the product realization process offers the flexibility to make changes and improvements to products.	How to consider the environmental dimension in the Front end is not explained. Does not address Portfolio Management procedure
Boks and McAloone (2009). The fourth transition in Ecodesign research addresses the connection and integration with other scientific disciplines started only recently. Suggests extending the classical methodology of Ecodesign in portfolio management for green products, proposing to use current tools to identify options for more sustainable products	Initial suggestion for future research.
Vandaele and Decouttere (2012). R & D Portfolio management is dominated technologically and financially. Sustainability seems to be difficult to integrate into the formal decision-making process; it is either presented as a strategic and few strategic projects materialize, or is at the end of the development process where mostly incremental improvements can be expected.	Mainly deals with mathematical multicriteria methods of modeling and optimization, without indicating how a central issue of lack of quantified and reliable data (on the dimension of sustainability) can be treated.

However, this article points out that, despite Portfolio Management being "*a strategically crucial activity for companies in order to gain success with their product development*", there is a double gap: "*Several companies lack a planned evaluation process for selecting development projects, and there is also a lack of methods for integrating environmental considerations in the selection process*." (Ölundh and Ritzen, 2004, p. 913).

Case studies

The case studies were conducted in two Brazilian consumer products companies, referred to as Company A and Company B. Both are leaders in their operation area in the Brazilian market. They are also characterized by their protagonist role in product innovation and sustainability issues in Brazil and for considering environmental issues in their product development activities for several years.

From an organizational standpoint, Company A is the Brazilian subsidiary of an international worldwide group, while Company B has its core business in Brazil, with growing activities in other Latin American countries.

Despite many differences (markets, distribution channel, international organization) both companies have several points in common in their organizations and development process: they have a "stage-gate" type PDP with formalized phases and decision criteria for the gates with multifunctional committees, a structured project Portfolio that is managed in a formal way.

Interviewed managers are characterized by a relatively senior profile (nine years average company experience), which may be related to the fact that Portfolio Management is recognized as a complex process. Through their answers to open questions, they showed a good knowledge of the Portfolio Management concepts, in line with the classic Cooper guidelines as previously mentioned, which facilitated the communication during the interviews.

Also, both companies consider carbon footprint criterion as a relevant environmental indicator in the PDP, related to their corporate sustainability strategy and associated reduction target publicly disclosed in their annual reports.

Both companies have computerized tools for Portfolio Management and Company B has recently implemented a specialised software (that will be referred to as PMS). These tools allow to track a variety of indicators and information (project, objectives, financial data, Portfolio consolidation by brand or Business Units (BU), by type), and

use of various information and graphics for management purpose as described in the literature (Cooper et al. 1997, 1998).

However, the form of considering the Carbon indicator in both companies showed some specificity: control indicator for the Company A, it is a qualitative trend indicator for Company B, not followed as a quantitative indicator similarly to financial indicators.

Cross case Analysis

In both companies, managers seem relatively satisfied with the performance of the Portfolio Management processes as a whole, as well as the dimensions of strategic alignment and maximization of the portfolio value, generally rated at "Good" level, as indicated in Table 2.

The Portfolio balance was better evaluated in Company A than in Company B, which scored this item below the other dimensions.

As for the “performance of Portfolio Management for environmental improvement of products and achievement of environmental goals”, this dimension was assessed at a relatively low level (weak to fair), tending to be lower than the other dimensions of Portfolio Management.

This observation was further explored through the analysis of qualitative comments from open questions, and discussed within the improvement opportunities for current processes suggested by the interviewed managers.

Table 2: Summary of results for quantitative questions

	Company A	Company B	Global
Number of managers interviewed	2	4	6
Years of experience in the company	13	7,3	9,2
Perceived performance of the new products Portfolio Management process:			
Overall process performance	3,5	3	3,1
Alignment with corporate strategy	3	3	3,0
Maximizing the financial value of the Portfolio	3	3,7	3,5
Portfolio balance (types of projects, time, risks)	4	1,7	2,3
Environmental improvement of the company's products and achievement of environmental goals	1,8	2,0	1,9

Note: 0-5 Likert Scale, except for the first two questions

For Company A, two main axes of process improvement were mentioned.

Firstly, the current process management is regarded as giving a major focus to the short-term (ongoing year), seeking financial results with flexibility and responsiveness

to market signals: *"it might be more challenging and less opportunistic, with a more long-term vision.*" (Director, head of R & D and Sustainability in Company A)

On the integration of environmental concerns, it was recognized that "*the Portfolio Management could include more of the environmental perspective than today (in its rules etc.), besides considering other environmental aspects than carbon*" (Sustainability Manager).

According to this Sustainability Manager "*Portfolio Management would be a very relevant place to discuss and evolve the products sustainability*"; he also states that "*there is still much room for improvement: more concrete indicators; more concern about the products life cycle,considering the whole value chain*; *we would need a greater awareness among the teams and achieve greater proactivity to environmental improvement*". However, "*this is not due to tools limitation or Portfolio Management system, but of how relevant or important this aspect is viewed by the organization, our CEO and the Group"*, pronounced the Director.

Within Company B, respondents insisted on the newness of the process and software: "*We are still in the acculturation process, the tool is super powerful; we need to empower teams and managers, which is not easy and it all takes time; it is a difficult task with multiple parameters.* " (Portfolio Manager).

Another reflection of this novelty, major challenges in better managing this process were flagged: "*a real culture of Portfolio Management is still to be built, today we only have a strategic planning; the PMS is not being used well, we need more discipline in the BUs*"(Portfolio Manager)."*The data in the system are poorly reliable; they must be completed and updated, we are uncertain about as much as 50% of the projects, particularly because information is not provided at time*." (BU, Sustainability and Development Manager). For this reason, a BU Manager admits he continues to follow up manually his project Portfolio on a separate Excel file.

Additionally, in a similar way to Company A, another issue is pointed: "*our focus is still on the short term: we have up to 75% tactical projects*." (BU, Sustainability and Development Manager). As for the environmental management in the Portfolio, the belief is that the PMS does not allow managing carbon data in the best way: "*weneed to evolve; systems are limiting factors, and also indicators that should be better informed. Besides the PMS, we need an integrated tool to incorporate various*

systems, to be able to track environmental indicators more effectively"(Corporate Sustainability Manager).

Discussion

This article makes a contribution by providing a systematic review of the literature on Portfolio Management and Ecodesign, which identified gaps in the literature on these two issues in an integrated manner. From the perspective of organizational practices, the scenario also shows emerging approaches to deal with environmental criteria into new products Portfolio, even in companies considered as leaders in innovation and sustainability in the Brazilian context of consumer products.

The literature search and analysis, by identifying a reduced number of publications of limited depth, showed that the two areas of knowledge considered - Portfolio Management and Ecodesign – did not generate yet sufficient insights at their interface to produce consistent theories and application processes.

Thus, on the side of environmental research, the main focus has concentrated on tools and technical aspects of Ecodesign and, as a secondary concern, overall strategy and management consideration, but left a gap to address the new products Portfolio Management, despite this being recognized as an essential tool for effective PDP (Cooper et al., 1998; Goffin and Mitchell, 2010).

Several collected evidence - records of literature, case study in two pioneering companies in these topics, information about one of the most advanced computerized Portfolio Management software available in the market, used by Company B - tend to indicate that the environmental dimension is present only limitedly and emergently in companies Portfolio Management. In our cases, it was considered by managers as the most perfectible performance dimension of that process.

By introducing new complex indicators associated with new concepts (multicriteria environmental impacts indicators, related to products´ life cycle), but also for being at the confluence of several processes, the inclusion of environmental sustainability in Portfolio Management potentially brings a high increase in complexity for the strategic and operating management of project Portfolio.

Therefore, the leap in the management processes evolution announced by Lubin and Esty (2010) is more of a challenge than a consolidated reality.

The main observations can be clustered into four types of challenges facing the integration of environmental sustainability in Portfolio Management: Quantitative modeling environment, that requires new life cycle indicators and systems; solutions to environmental and financial tradeoffs; more effective articulation of processes management of product innovation, strategic planning and sustainability management; deployment and consolidation of goals and Portfolio in large companies composed of several entities.

This study has limitations related to its qualitative and exploratory character. The literature review led to a reduced sample. Also, the case study is limited to only two companies from close sectors (consumer products), which limits the generalizability (Voss et al., 2002).

The content analysis, of the publications and questionnaires, contain a part of subjectivity, particularly in the evaluations of individual testimonies and qualitative interpretations.

This is hardly an initial investigation that calls for future deeper studies, as part of a larger research framework focused on a more systematic Ecodesign integration and management in companies´ PDP, and understanding of the associated success factors for such changes.

Nevertheless, the knowledge gap and explored research route presented in this paper open up a promising perspective for the advance of knowledge oriented to innovation, business management and sustainability, where solutions for a sustainable Portfolio Management will represent a significant progress.

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PUBLICATION # 3: From 50 to 1: Integrating literature toward a systemic ecodesign model

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Integrating Cleaner Production into Sustainability Strategies

From 50 to 1: integrating literature toward a systemic ecodesign model

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Highlights

- Integration concept is key in ecodesign at project and process level.
- A comprehensive model in accordance with innovation management is still lacking.
- 52 models since 1993 were analysed with focus on process types and systemic levels.
- Proposed framework combines vertical systemic integration with change management.
- 3 levels system (macro, meso, micro) connects top-down and bottom-up initiatives.

From 50 to 1: Integrating literature toward a systemic ecodesign model

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Abstract

Integration plays a key role in ecodesign, with its concept defined as incorporating environmental aspects into projects and product development process of businesses with a life cycle perspective. Assuming the lack of a comprehensive integration framework in accordance with the principles of innovation management, this study aims to fill this research gap. The research method, based on a review of the worldwide literature, used two databases and other sources, classifying and prioritising publications from primary sources. The result was a set of 52 models which was then analysed by encoding the information content according to key variables. Accordingly, a conceptual framework that combines scientific constructs and best practices with five integration principles was created. 1: a three level systemic approach (macro, meso and micro scales), integrating “top-down” and “bottom up” initiatives. 2: at macro level, strategy and goals for innovation and environmental sustainability. 3: at “meso” level, formal incorporation of environmental requirements in the product development process and portfolio management. 4: at “micro” level, implementation of customised ecodesign tools and integration of environmental aspects into project management. 5: in addition to the three levels, a transversal approach focused on change management and the “soft side” of ecodesign, emphasising the company's culture and human factors in a multifunctional vision. The conceptual model is proposed as a synthesis of main theoretical contributions found in the surveyed literature, in a systemic perspective. It is a path towards more effective ecodesign integration, building on fundamental principles of innovation management coupled with environmental sustainability knowledge.

Keywords:Ecodesign; integration; model; product development process; systemic.

1. Introduction

Interest in environmental sustainability and its relationship with product innovation is not new, however this concern has grown and is increasingly acknowledged as essential for organisations, as stated in an article in the Harvard Business Review (Nidumolu, 2009), which explains "Why sustainability is now the key driver of innovation". According to Hart and Dowell (2010) "15 years after the publication of "A Natural-Resource-Based View of the Firm" (Hart, 1995), the argument contained in that original piece has only become stronger and more relevant." However, "leading researchers have lamented that the 'revolution' has taken decades" (Goffin, 2012, p. 105). This evolution refers to ecodesign, which emerged in the 1990s as a promising approach to sustainable production and consumption (Brezet and Van Hemel, 1997).

The concept of "integration" (from the Latin "integrare", to make whole) plays a key role in the literature of ecodesign. The term appears with two perspectives: as the definition of what ecodesign is and as organisational challenges. Thus, the recent ISO 14006 standard (International Standard, 2011) determines ecodesign as "The integration of environmental aspects in product design and development, aiming to reduce adverse environmental impacts throughout the product's life cycle", whose document title is: "Environmental management systems - Guidelines for incorporating ecodesign", where the words "integrate" and "incorporate" are synonymously used. This dual use can be viewed as a consistency/alignment advantage, or as a possible confusion. Nevertheless, it explains the substantial use of the term in the literature.

However two decades after the publication of the first ISO 14000 standards, notwithstanding that environmental dimension in product innovation of companies is seen as an increasingly relevant guideline for sustainability strategies and policies, most publications still report modest results in terms of application effectiveness and scope, and also in terms of the limited effective integration of ecodesign and product innovation (Baumann et al., 2002; Deutz et al. 2013, Guelere, 2009, Hart and Dowell, 2010, Pigosso et al., 2013, Verhulst and Boks, 2012, etc.)

A key issue with regards to ecodesign research, whether academic or applied, remains "how to make it happen?", according to a widely cited article by Karlsson and Luttropp (2006), in the introduction of a special edition of the Journal of Cleaner Production, which included 15 articles on ecodesign.

Deutz et al. (2013) pointed to the "significant implementation gap between the theory and practice of eco-design". Since the beginning the literature has focused on ecodesign tools (Arana-Landin and Heras-Saizarbitoria, 2011; Baumann et al. 2002; Stevels, 2007), and such publications continue to increase (Rio et al., 2013). Although the theory and methods are available, in practice it appears that implementing sustainable design is not an easy task, possibly due to the lack of a holistic approach to the implementation process, from a theoretical and empirical point of view (Verhulst and Boks, 2012). Other studies corroborate this perspective, declaring that the reason ecodesign has not been consolidated in businesses around the world is mainly due to difficulties in the ecodesign management (Pigosso, 2012, Pigosso et al., 2013).

Part of the integration problem may be related to the gap between the abundant literature on new product development (NPD) and the literature on ecodesign. Goffin (2012, p. 106) warned that "Organisations need to make significant modifications to NPD processes to achieve sustainable innovation". "So adding a sustainability perspective to NPD complicates

an already complex process"; and further: "Research has shown that there is a gap in many organisations between the proponents of sustainability and those who develop the products and so are responsible for implementation" (p. 110). Spangenberg et al. (2010) also highlighted the gap between sustainability and design, and regreted that "sustainability plays a minor role in design education and practice, and design is not recognised as a relevant factor in the sustainability discourse." (p. 1485).

Consequently, there is still little recognition of systemic perspectives in ecodesign research (Baumann et al. 2002). Also, insufficient attention was paid to change processes and management, which could take into account the different dimensions of the company's Product Development Process (PDP) (Goffin and Mitchell, 2010, Rozenfeld et al., 2006).

As a starting point this article assumes there are still gaps in ecodesign literature about implementing a systemic change management approach, which considers the interaction of environmental issues with the various dimensions of the PDP. To deal with this research gap this article tried to address the following questions:

Q1: What is the scientific state of the art for the integration of ecodesign and PDP in companies?

Q2: Are there available and complete models to direct such integration? How are these models characterised? What are their main variables and relationships?

Q3: How do the existing models converse with the most accepted PDP models in companies?

Q4: What requirements and propositions can be prepared in terms of scientific concepts (Questions 1 to 3) to guide the development of a conceptual model in order to leverage the integration of ecodesign in companies?

These issues were addressed using the methodological approach of a systematic literature review.

This article is structured in five sections. Section 2 presents the methodology that was followed, detailing the protocol for the literature review. Section 3 contains the results of the bibliographic review. The following sections show the discussion of the models found (4) and propositions for building a more complete model (5) and the conclusions and limitations (6) of this broad study on best practices in the literature directed to the business context.

2. Research Methods

The chosen methodological approach is a systematic literature review, striving for an overview of the state of the scientific art of ecodesign integration, focusing on previously published models.

The systematic review followed the three steps of the process suggested by Tranfield et al. (2003): data collection, data analysis and synthesis. Synthesis is the step that most adds value to a review as it generates new knowledge based on complete data collection and meticulous analysis (Crossan and Apaydin, 2010, p. 4). Several qualitative and quantitative methods can be used to help review the literature, such as the bibliometric approach, meta-analysis and content analysis (Carvalho et al., 2013); the latter was chosen for this work.

This work focuses on analysing the literature on the subject of ecodesign integration. Due to the scope of the subject, such review entails several challenges, which were categorised into three topics: aligning the vocabulary, dispersed literature and organisational aspects and macro processes taken into account. These challenges, which are discussed at the beginning of this section, justify our methodological choices.

- Aligning the vocabulary

In the sphere of environmental sustainability, though the term ecodesign is widespread and substantiated by ISO 14006-2011 (International Standard, 2011), similar terms are still used. For example, in the United States the term “design for environment” (DFE) is preferred and ecodesign is less used as it has a restrictive connotation associated with aesthetic design. The multiplicity of terms used for the concept and its expansion create search difficulties in the databases and compromises the quantitative research assessments. However within a comprehensive interpretation, several expressions have equivalent meanings, with the possibility of being interpreted differently depending on the authors.

- Dispersed literature

There are still few publications on ecodesign specifically targeting innovation management (Stevels, 2007). Yet, there is a scientific work on ecodesign that addresses “Environmental Management”, as for instance through the concept of POEMS: Product Oriented Management System (Donnelly et al., 2006). There is also a series of publications dedicated to eco-innovation, a term which can lead to multiple interpretations.

- Organisational aspects and macro processes

According to the introduction, this work follows a proposal directed to a systemic approach to sustainable innovation, with the life cycle perspective (extended supply chain). This outlook leads to strongly consider other business processes interacting with PDP, such as sustainability management and supply chain management. Therefore, the search for information and publications should exceed the boundaries of the product innovation management area (search scope, keywords, etc.), aimed at careful consideration to elaborate an ecodesign integration model in the future.

2.1. Literature review approach

Due to the research scope focused on a concept intrinsically linked to ecodesign definition, a complete literature review might require a review of all literature on ecodesign. Unfortunately such a task would hardly be feasible today, in light of the multiplication of scientific productions observed. For example, Baumann et al., in a classic article in 2002, mapped 650 publications on ecodesign and environmental product development, showing a rapid growth in the number of publications. This trend was confirmed by Rio et al. (2013) with regards to the growing number of papers published on ecodesign methods (437 publications).

Considering this quantitative challenge, the methodology prepared for this study included three complementary assessment approaches of the publications (Fig.1), to combine the scope of the subject and the depth and completeness sought in the main theme.

Sub themes related to ecodesign	**Search and exploration method of the literature**
Approach 1: **General concepts**	- Normative and related documents - In-depth study of some key materials in the literature, identification of reference publications - Identification of relevant sub-topics
Approach 2: **Models and frameworks for the integration of ecodesign** = main research theme	1. Systematic search conducted in ISI Web of Science and Scopus database, publications since 2002 2. Selection by relevance from abstracts 3. Systematic content analysis 4. In-depth study of other key publications cited in recent articles 5. Identification and selection of models
Approach 3: **Specific or emerging sub-topics**	Directed qualitative or quantitative search: basis for content analysis and relevance of articles and propositions
Methods and tools	The most classic theme in ecodesign. Search of reference or recent articles, with a focus on literature synthesis or survey on the topic.
Project management	Systematic search in ISI Web of Science and Scopus database conducted in previous research, personal summary available
Portfolio management	Systematic search in ISI Web of Science and Scopus database, conducted in previous research, personal summary available
"Soft side of ecodesign" (socio-psychological factors)	Related theme identified as relevant in the analysis of general literature; Expression created by Boks (2006) and addressed by Stevels (2007). Additional search in databases and qualitative analysis.

Fig. 1: Ecodesign literature review approaches

Approach 1: Analysis of basic concepts and identification of relevant subtopics associated with classic or emerging ecodesign.

With the in-depth essential normative documents and some key material from the literature, we sought to identify a set of reference publications, as well as relevant subtopics that favoured a literature analysis of ecodesign integration.

Besides the topic "integration models", the main subject of the search and of the research, four subthemes were regarded as useful to complement the assessment: "Methods and tools", "Project management", "Portfolio management" and "Soft side" (relating to socio psychological or organisational practice and ecodesign integration).

Approach 2: Models and frameworks for the integration of ecodesign, key theme of the research.

At the forefront of the main work, a literature review was conducted in the scientific literature (especially focusing on publications in the English language), for a period of twenty years. To search for articles in the databases ISI Web of Science, Scopus, multiple key words were used due to the varying vocabulary used in this theme in different parts of the world: *eco-design*, *ecodesign*; "*design for environment*"; "*sustainable product development*"; "*sustainable product design*"; "*life-cycle design*"; "*life cycle design*"; "*green design*"; "*sustainabledesign*"; "*life cycle engineering*"; "*design for sustainability*"; "*environmentally conscious design*" (Baumann et al., 2002; International Standard, 2011; Pigosso, 2012). As this research focuses on the product development business process, life cycle design and life cycle engineering were considered, more than wider life cycle management principles, which apply to other business processes as stated by Jensen and Remmen (2006): "Life cycle management has been defined as the application of life cycle thinking in modern business practice".

This step confirmed the increasing publication trend. Table 1 shows the updated results until May 2013.

Table 1
Main search strings and results (March/2013).

Search strings	ISI/Web of Science	Scopus
eco-design; ecodesign; "design for environment"; "sustainable product development"; "sustainable product design"; "life-cycle design"; "life cycle design"; "green design"; "sustainable design"; "life cycle engineering"; "design for sustainability"; "environmentally conscious design"	1,206	2054

Moreover, as seen in the initial searches carried out, additional keywords were included in order to identify publications focusing on the more strategic dimension of ecodesign and innovation management, such as "*sustainable innovation*", "*sustainable* R&D", as well as "*ecoinnovation*".

As the literature review focused on identifying integrative models and frameworks in the NPD and PDP literature, complementary keywords aimed at "models" were used as, namely: "*model*", "*framework*", "*development process*", "*new product development*".

The abstracts were used to analyse and select the publications according to their relevance. Next, a content analysis was performed, with which other key and older publications cited in the previous ten years were identified. This iterative process sought to identify the models published under various perspectives in the ecodesign literature. The selection criterion was articles' alignment with the research topic, i.e., consistently including ecodesign (or equivalent concept) models or framework.

Approach 3: Directed qualitative searches on specific or emerging subtopics.

Complementing previous studies, searches, analyses and additional classifications of publications related to four ecodesign themes were performed. Moreover, the snowball sampling method was applied (Fink, 1995), thus, the sample was expanded by incorporating other publications that had been cited in the initial sample. In this activity, additional publications with different functions were identified, helping to interpret the main set and as a basis for analysing the content relevance of articles and propositions. The arrows in Fig. 1 show the dynamic interconnections between the three approaches and the sets of publications analysed.

2.2. Content Analysis

Next, focusing on the set of publications identified comprehending integration models, a content analysis of publications and models was carried out. The characteristics of publications and models were encoded in order to analyse their distribution and evolution (Carnevalli and Cauchick, 2008; Prasad and Tata, 2005). This set of models, considered relevant, was studied in depth taking into consideration the full contents of the articles, in order to systematise and synthesise the contributions to the research topic and to enable discussing the key constructs found.

The coding included two blocks of parameters in order to facilitate the representation and analysis. The first block comprised the following characterisation parameters: year of publication, authors, geographical origin (first author's country) and type of publication (J= scientific journals; C= conference proceedings; B= books or brochures; T= doctoral thesis and S= standards). The content analysis block displays the following information about the main contents of the integration models: summary of the models' main focus; systemic levels addressed in the models (micro, meso and macro), and type of PDP considered in the models (see Appendix 1).

As pointed out in the introduction, the work is developed in a systemic approach in order to analyse the innovation processes, in particular PDP, NPD and ecodesign as integrated systems with multiple levels of analysis. This assumption was also proposed in previous studies on portfolio management as an intermediate level system ("meso") between the corporate or strategic level (here termed as "macro") and the operational level to run projects and associated decision making ("micro" level). Such classification is consistent with business experience in innovation and also with recognised publications on the subject (Goffin and Mitchell, 2010; Larsson, 2007). Similar systemic approaches were found as the main or underlying propositions in several publications of the set.

The encoding of the models' type of PDP, according to the information in the publications, was based on several reference models in the field of innovation management. In the literature of innovation management, two classical models are particularly found, the "development funnel" (Clark and Wheelwright, 1993) and the "stage-sates" model of Cooper et al. (2002), emphasising the decision points between phases along the design of new products. In summary, the concepts and types of PDP found in the publications were classified as: Stage-gate, Multiphase, Multiphase Funnel, Specific, PDCA (common cyclic process in quality management, Plan, Do, Check, Act), or ND if undefined.

3. Results

The search results of publications in the literature were recorded in Table 2, which shows the main articles or theses found and considered in the subsequent analyses. The main assessment focus is highlighted in the last line that shows the publications found and selection flow performed to identify the associated integration models. This set was obtained by an iterative process that included “recycling” of publications from or to other topics, and search for primary sources of the models cited in the selected publications. From this analysis, the most relevant articles were chosen according to the selection criterion. 35 articles were selected from the search in the databases, checking that they really addressed the studied subject and contained ecodesign integration models. Another 45 publications were identified indirectly, through the snowball sampling from the references cited in the initial set of 35 articles or appearing in the other publications identified on the other topics related to ecodesign (general concepts, methods and tools, project management, portfolio management and “soft side”), resulting in 80 publications. From this pool a final sample of 52 publications and models was constituted by selecting the relevant publications and eliminating duplicated models, representing 65% of the initial sample of 80 publications.

Although several literature reviews on ecodesign methods and tools were performed and reported in the literature (Baumann et al., 2002; Bovea and Perez-Belis, 2012; Guelere et al., 2007; Guelere, 2009; Pigosso et al., 2013), no previous review on integration models was found.

Table 2
Overview of the inquiry results in the literature on ecodesign

Related topics	Publications considered and main concepts	Key References	# Ref.
General concepts of ecodesign	Two main normative documents	ISO/TR 14062: ABNT, 2004 ISO 14006: International Standard, 2011	2
	Focus in 10 publications between recent and classic works on the subject in the literature	Baumann et al., 2002, Bhamra and Lofthouse, 2007, Brezet and Van Hemel., 1997, Deutz et al, 2013, Hübner, 2012, Johansson, 2002, Karlsson and Luttropp, 2006, Kurk and Eagan, 2008, Luttropp and Lagerstedt, 2006, Stevels, 2007	10
Main sub-themes related to Ecodesign			
Methods & tools (M&T)	Among the subtopics, the highest concentration of publications in ecodesign was in M&F	Baumann et al., 2002, Bovea and Perez-Belis, 2012, Byggeth and Hochschorner, 2006, Guelere, 2009, Guelere et al., 2007, Lofthouse, 2006, Lofthouse and Bhamra, 2001, Luttropp and Lagerstedt, 2006, O´Hare, 2010, Pigosso and Rozenfeld, 2013, Ritzen and Lindahl, 2001	11
Project management	Incipient theme approached in specialised ecodesign articles	Brones et al, 2014, Johansson and Magnusson, 2006, Knight and Jenkins, 2009, Ny et al., 2008, Tingström and Karlsson, 2006, Tingström et al., 2006, Vezzoli and Sciama, 2006	6
Portfolio management	Theme rarely addressed in ecodesign: only in Ölundh and Ritzén (2004) with initial propositions, focusing on project selection.	Arnold and Hockert, 2011, Bhamra et al., 1999,Boks and McAloone, 2009, De Caluwe, 2004, Donnelly et al., 2006, Ölundh, 2006, Ölundh and Ritzén, 2004, Simon et al., 2000, Stevels, 2007, Vandaele and Decouttere, 2013	10
"*Soft side*" of ecodesign	Theme under development	Boks, 2006, Hassi et al., 2009, Lofthouse 2003, Lofthouse 2004, Petala et al. 2010, Stevels, 2007, Verhulst and Boks 2012, Verhulst et al., 2007	8
Models and frameworks for ecodesign integration	80 publications found in databases (mostly at conferences) ➔ 35 articles deemed relevant ➔ + 45 other publications identified by citations (theses, books or articles) ➔ Content analysis and selection of articles with relevant models (priority of primary sources)	Creation of a body of **52 classified publications:** Excel file with models and comments to content analysis	

3.1. Set of publications obtained

The collection of 52 selected publications that show integration models contains a rich set of scientific and historical information about the evolution of the subject in the last twenty years worldwide. It was organised in a complete Excel file which was used for all the encoding tasks and content analysis. To answer the research questions outlined above a synthetic representation was organised and is available in Appendix 1a-c (the full Excel file contains more than a hundred A4 pages). The appendix summarises the content analysis by model presented in chronological order and coded by geographic origin, type of publication, type of PDP, and systemic level of analysis. Moreover, each model is accompanied by a brief description of the goals.

3.2. Distribution of publications: type, journals, time and geography

Fig. 2 shows the distribution of the 52 publications analysed by type of document, highlighting the articles published in scientific journals (48%), accounting for almost half of the sample, followed by conference proceedings (29%), books or brochures (10%), doctoral dissertations (10%) and standards (4%), in decreasing order of participation.

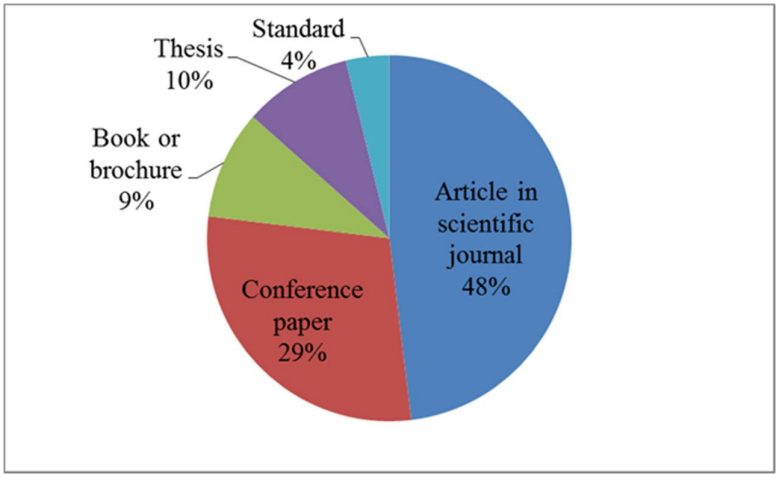

Fig.2: Distribution in types of publications

Table 3 shows the distribution of the 25 articles (48%) regarded according to the journals. This calculation clearly indicates the predominance of the Journal of Cleaner Production as the main knowledge dissemination platform for the subject of ecodesign management. But it also indicates that, occasionally, the topic was addressed in several journals of other areas such as engineering, business and design.

Table 3
Distribution of articles in periodicals

Journal	#	%
Journal of Cleaner Production	14	56%
Business Strategy and the Environment	2	8%
Computers & Chemical Engineering	1	4%
International Journal of Production Economics	1	4%
Journal of Achievements in Materials and Manufacturing Engineering	1	4%
Journal of Mechanical Design	1	4%
Journal of Systems Science and Systems Engineering	1	4%
Materials and Design	1	4%
The International Journal of Life Cycle Assessment	1	4%
The Journal of Design Research	1	4%
The Journal of Sustainable Product Design	1	4%
Total	**25**	100%

Fig. 3 shows the evolution of publications over the sample period analysed. A higher rate of publications is observed since 2001; however, there is no logical explanation for the absence of publication in 2003.

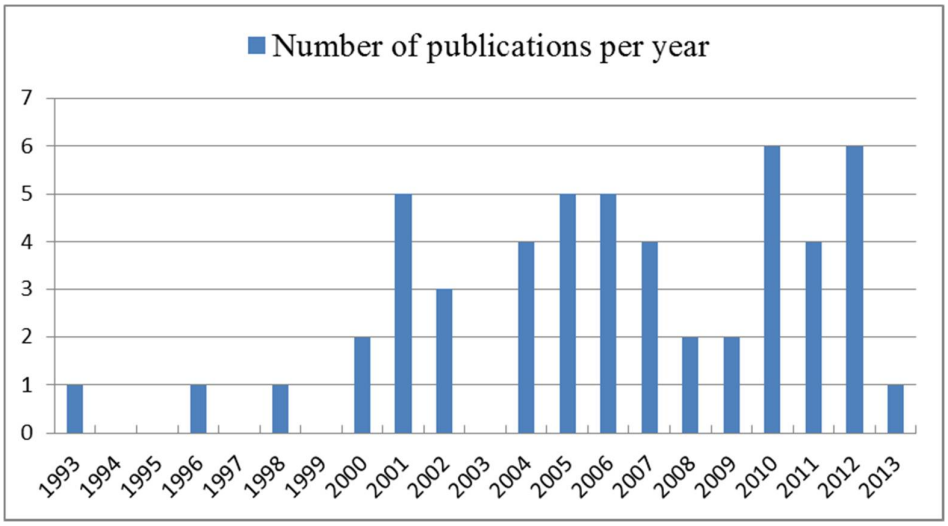

Fig. 3: Distribution of publications per year.

According to Fig. 4 the geographical origin of publications shows a wide range of distribution worldwide. The classification by continent points to a greater representation of Europe (73% in 11 countries), followed by North America (12%), Asia (8%), South America (6%) and Oceania (2%). Three European countries stand out for their longer tradition in publishing this subject: UK, Sweden and the Netherlands, known for their universities which are active in ecodesign research. Surprisingly, there is no publication coming from Japan in this set – a country recognised for its activity in ecodesign particularly through the technical conferences held on the subject since the late 1990s. This gap just means that no Japanese publication on the research subject was found in the searches in the database or in the models cited in other studied references.

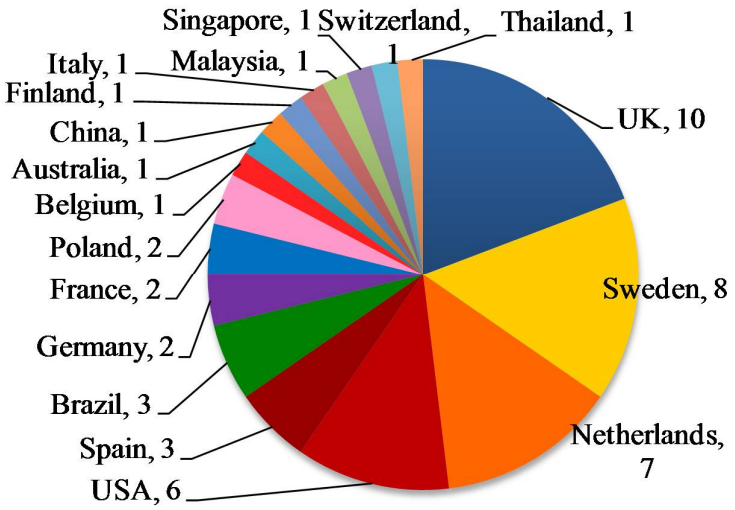

Fig. 4: Distribution of publications by country (first author's affiliation)

3.3. Systemic levels and types of PDP

Table 4 outlines the distribution of the systemic levels regarded in the models. The micro or operational level predominance (73% of the models) is observed, however there is a significant presence, over 50%, of other levels in the set. The distribution of the number of levels in the model shows a higher occurrence of one or two levels (around 40% for each modality), with only 20% of the sample addressing the three levels.

Table 4
Distribution of models in the systemic levels

Level	# Models	%	References
Micro level	39	75%	ABNT, 2004, Ammenberg and Sundinb, 2005, Baumann et al., 2002, Bhamra, 2004, Bovea and Perez-Belis, 2012, Crul et al., 2009, Dewulf and Duflou, 2004, Donnelly et al., 2006, Ferrer et al., 2012 , Fiksel, 1993, Ghazilla et al., 2008, Goffin, 2012, Hallstedt et al., 2010, Handfield et al., 2001, Hassi et al., 2009, Howarth and Hadfield, 2006, International standard, 2011, Jeganova, 2005, Jones et al., 2001, Kara et al., 2005, Kengpol and Boonkanit, 2011,Le Pochat et al., 2007, Lewandowska and Kurczew, 2010, Lofthouse, 2006, Neal and Heintz, 2001, Nowosielski et al., 2007, Pigosso, 2012, Poyner and Simon, 1996, Ramani et al., 2010 , Ritzén, 2000, Robert et al., 2002, Simon et al., 2000, Stevels, 2001, Trappey et al., 2011, Van Hemel, 1998, Vezzoli and Manzini, 2008, Waage, 2007, Yang and Song, 2006, Zwicker et al., 2012
Meso level	29	56%	ABNT, 2004, Alakeson and Sherwin, 2004, Ammenberg and Sundinb, 2005, Arana-Landin and Heras-Saizarbit, 2011, Baumann et al., 2002, Berchicci and Bodewes, 2005, Bhamra, 2004, Bucci et al., 2012, Dewulf and Duflou, 2004, Donnelly et al., 2006, Fiksel, 1993, Goffin, 2012, Handfield et al., 2001, Hermenau et al., 2005, International standard, 2011, Jeganova, 2005, Kara et al., 2005, Keskin et al., 2013, Le Pochat et al., 2007, Ölundh, 2006, Pigosso, 2012, Poyner and Simon, 1996, Ritzén, 2000, Robert et al., 2002, Sherwin and Bhamra, 2001, Stevels, 2001, Tingström, 2007, Van Hemel, 1998, Vezzoli and Manzini, 2008
Macro level	27	52%	Alakeson and Sherwin, 2004, Baumann et al., 2002, Carrillo-Hermosilla et al., 2010, Crul et al., 2009, Dewulf and Duflou, 2004, Donnelly et al., 2006, Dusch et al., 2010, Hallstedt et al., 2010, Handfield et al., 2001, Hassi et al., 2009, Hermenau et al., 2005, Howarth and Hadfield, 2006, International standard, 2011, Kara et al., 2005, Ölundh, 2006, Pigosso, 2012, Ramani et al., 2010, Ritzén, 2000, Robert et al., 2002,Simon et al., 2000, Spangenberg et al., 2010, Stevels, 2001, Tingström, 2007, Van Hemel, 1998, Van Hemel and Cramer, 2002, Verhulst and Boks, 2012, Waage, 2007
Models with 1 level	20	38%	Arana-Landin and Heras-Saizarbit, 2011, Berchicci and Bodewes, 2005, Bovea and Perez-Belis, 2012, Carrillo-Hermosilla et al., 2010, Ferrer et al., 2012 , Ghazilla et al., 2008, Jones et al., 2001, Kengpol and Boonkanit, 2011, Keskin et al., 2013, Lewandowska and Kurczew, 2010, Lofthouse, 2006, Neal and Heintz, 2001, Nowosielski et al., 2007, Sherwin and Bhamra, 2001, Spangenberg et al., 2010, Trappey et al., 2011, Dusch et al., 2010, Van Hemel and Cramer, 2002, Verhulst and Boks, 2012, Yang and Song, 2006,
Models with 2 levels	21	40%	ABNT, 2004, Alakeson and Sherwin, 2004, Ammenberg and Sundinb, 2005, Bhamra, 2004, Bucci et al., 2012, Crul et al., 2009, Fiksel, 1993, Goffin, 2012, Hallstedt et al., 2010, Hassi et al., 2009, Hermenau et al., 2005, Howarth and Hadfield, 2006, Jeganova, 2005, Le Pochat et al., 2007, Ölundh, 2006, Poyner and Simon, 1996, Ramani et al., 2010 , Simon et al., 2000, Tingström, 2007, Vezzoli and Manzini, 2008, Waage, 2007,
Models with 3 levels	11	21%	Baumann et al., 2002, Dewulf and Duflou, 2004, Donnelly et al., 2006, Handfield et al., 2001, International standard, 2011, Kara et al., 2005, Pigosso, 2012, Ritzén, 2000, Robert et al., 2002, Stevels, 2001, Van Hemel, 1998

Fig. 5 shows the evolution of the number of levels regarded in the 52 models of the sample over time (classification used in 3 levels).This distribution of levels suggests that there was no clear evolution over time, as there was no growth of multilevel systemic approaches, particularly with the three levels.

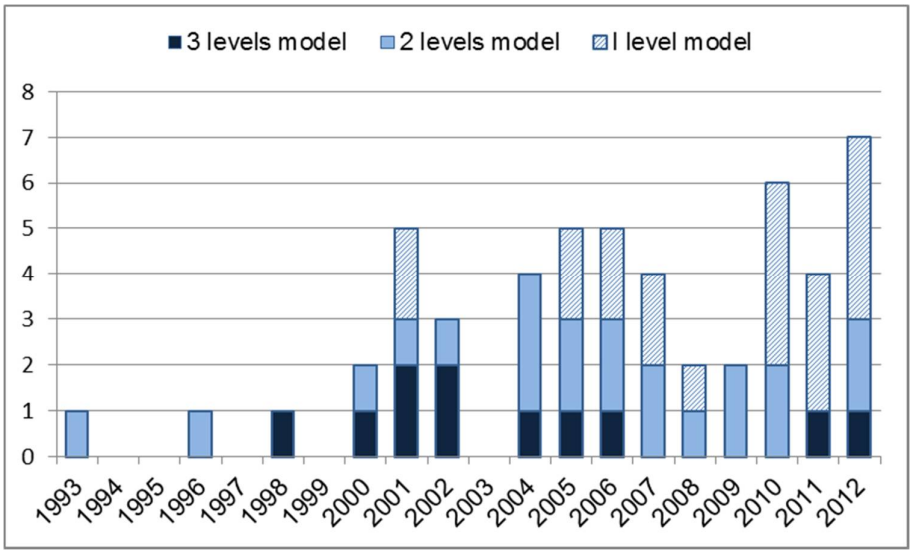

Fig. 5: Number of levels in the models by year of publication.

With regards to the types of PDP in the 52 models, Table 5 shows that 50% of the publications do not determine a specific type of PDP reference model. The multiphase type models are considered in one fourth of the publications, followed by stage-gate type models.

Table 5
Types of PDP in the models

Type of PDP	#	%	References
Not defined	26	50%	Alakeson and Sherwin, 2004, Ammenberg and Sundinb, 2005, Arana-Landin and Heras-Saizarbit, 2011, Berchicci and Bodewes, 2005, Bovea and Perez-Belis, 2012, Carrillo-Hermosilla et al., 2010,Dusch et al., 2010, Ferrer et al., 2012 , Fiksel, 1993, Hallstedt et al., 2010, Hermenau et al., 2005, Howarth and Hadfield, 2006, Kara et al., 2005, Kengpo and Boonkanit, 2011, Lofthouse, 2006, Neal and Heintz, 2001, Ramani et al., 2010 , Robert et al., 2002, Simon et al., 2000, Spangenberg et al., 2010, Stevels, 2001, Trappey et al., 2011, Van Hemel and Cramer, 2002, Van Hemel, 1998, Verhulst and Boks, 2012, Yang and Song, 2006
Multiphase	13	25%	ABNT, 2004, Baumann et al., 2002, Dewulf and Duflou, 2004, Donnelly et al., 2006, Ghazilla et al., 2008, Handfield et al., 2001 , Jones et al., 2001, Le Pochat et al., 2007, Lewandowska and Kurczew, 2010, Nowosielski et al., 2007, Sherwin and Bhamra, 2001, Vezzoli and Manzini, 2008, Waage, 2007
Stage-gate	9	17%	Bucci et al., 2012, Crul et al., 2009 , Goffin, 2012, Jeganova, 2005, Ölundh, 2006, Pigosso, 2012, Poyner and Simon, 1996, Ritzén, 2000, Tingström, 2007,
Multiphase funnel	2	4%	Bhamra, 2004, Hassi et al., 2009,
PDCA	1	2%	International Standard, 2011
Specific	1	2%	Keskin et al., 2013
Total	52	100%	

4. Discussion of results

4.1. Systemic perspective of integration levels

The systemic perspective of integration, explored in this work, was confirmed as an interesting filter to analyse and compare the models. Observably, there is no unanimity in the number and boundaries of the levels under consideration as there are several publications and models with three levels of distribution (Dewulf and Duflou, 2004; Kara et al., 2005; Stevels, 2001; Van Hemel, 1998), with four (Baumann et al., 2002) or up to five levels (Robert et al., 2002). An additional level refers to the company's relationship with external systems (e.g., groups of companies, public policies...). It was decided to not emphasise this level in the assessment because the objective is focused on the internal management of environmental sustainability and innovation.

The segmentation used in our analysis can be considered as the most common and in line with recognised principles of innovation management, very similar to the model proposed by Kara et al. (2005), which describes the three levels as strategic, tactical and operational.

Looking at the evolution of the levels considered in the models (cf. Fig. 5), somehow there is a trend toward greater or more in-depth detail of the subject in the publications, for example the number of references cited and the number of ecodesign tools considered in the articles (e.g., Bovea and Perez-Belis, 2012; or Ramani et al., 2010, with 218 references analysed).

However, such approaches bring limited progress on the issue of ecodesign integration, as Baumann et al. observed in 2002, who already pointed out an excess of tool development, but little connection between strategic intent and content; little about the broader context of product development and limited recognition of systemic perspectives in policy formulations.

Returning to the initial definition of ecodesign integration concept, it can be observed that the “micro” level corresponds to the first definition of ecodesign integration (integration of environmental aspects in product design and development, commonly focusing on the technical, practical and tools aspects); the other definition that addresses the organisational dimension relates to “meso” and “macro” levels in PDP and other related business processes, including strategic planning.

4.2. Reference PDP

With regard to the PDP in the integration models, the data in Table 5 point out that most of the articles do not specify a reference PDP. Publications considering a PDP with various steps are the minority and only 17% consider a predefined process with formal steps and approval requirements at gates such as stage-gate model (Cooper et al, 2002).

In some cases, the explanation for this lack of formal PDP can be related to the business context: for example, in SMEs (Small and Medium Enterprises), such informal situation is relatively common, as argued in the TR 14062: “In large companies the product design and development process may be a formalised approach with fixed milestones and gateway management, whereas in small companies one or several people, working in an informal and more intuitive manner can carry out product development.” (International Standard, 2002, p.14). However, such formalisation is possible and even recommended, as reported by Le Pochat in SMEs (2007).

Another explanation for the low definition of PDP is a tendency by the authors to focus on propositions aimed at environmental approach and management, without necessarily considering the basic principles in the area of innovation management.

Goffin (2012), a renowned English expert in this specific area, recently addressed the question of "Sustainability and new product development", and argues: "proposing a new process ignores the comprehensive body of knowledge of NPD that has been developed from practice and research over several decades" (p. 112). Berchicci and Bodewes (2005) already had a similar observation. Goffin (2012) concludes with the recommendation that the stage-gate process can be expanded to include sustainability issues.

4.3. Integration and change management

Since the publications of the 1990s, experts have debated that incorporating ecodesign requires not only a set of tools and techniques, but also that its implementation takes place within a system integrated to the product development cycle (Fiksel, 1993) and to the company's operations, in three levels (Dewulf and Duflou, 2004).

One of the lines developed to lead to change management in the integration models follows the principles of quality management extended to environmental management (Ammenberg and Sundinb, 2005, Arana-Landin and Heras-Saizarbitoria, 2011, Dewulf and Duflou, 2004, Donnelly et al., 2005 International Standard, 2011, Simon et al., 2000). Initiated in Europe in the 1990s, these models have used the acronym POEMS (Product Oriented Environmental Management System) with its pillars based on the PDCAimprovement cycle *(*Plan-Do-Check-Act)or Deming cycle, whichis also the basis for ISO 14001 and ISO 9001 (Ammenberg and Sundinb, 2005).

With the maturing of the systemic view, it became clear that the implications and changes needed surpass the technical dimension and the PDP frontiers to effectively implement ecodesign. However, this formal normative approach, suitable for system quality or site oriented environmental management systems, does not appear to have conquered the PDP universe.

One explanation is that the innovation process and its instrument (PDP) do not follow a PDCA like formal repetitive logic given its unique project oriented nature, which includes a number of sub processes with their own cycles of evolution and feedback (strategic planning, funnel and pipeline management, portfolio management, project management). In this context it leans more to a contingency approach (Shenhar, 2001), in a more customised approach. Thus, another line proposed in the direction of promoting changes in business gave more emphasis to socio-organisational and human issues.

The views and concerns of all stakeholders should be part of the designer's concern towards sustainability (Howarth and Hadfield, 2006). According to Tingstrom (2007), there is a multifaceted interest in integration that must have the ability to accommodate a diverse range of activities and individuals in order to build a view of how environmental considerations should be integrated into a company's work and product development. To Sherwin and Bhamra (2001) the concept of integration refers to the principles of concurrent engineering, which promotes dialogue and communication at the early stages and throughout the development process in order to improve the quality, cost and development time reduction, and more recently, extending to environmental issues.

As shown in section 3, a strand of publications has extended this socio-psycho-organisational integration of ecodesign, or "soft side" (Boks, 2006). Hassi et al. (2009) insisted on people and behaviour (attitudes, motivation) to develop a set of techniques that are suitable for the transformational change required for sustainability concerns. Some authors suggested an "integrated and holistic view" (, Spangenberg et al. 2010, Verhulst and Boks, 2012). Spangenberg et al. (2010) focused on skills, roles and learning, implemented through an interdisciplinary, integrative methodology and transdisciplinary project.

This line usually follows a change management approach in search of a process to implement life cycle and sustainable product development adapted to the company's culture, considering a number of human factors, including employee participation, training, resistance to changes and so forth.

5. Proposed integrative conceptual model

The systematic literature review pointed out several literature gaps, as well as potential synergies and complementarities. Insights emerging from the content analysis brought the material necessary to build an integrative conceptual model aligned to the goal of the work, through an inductive process.

Within the scope of enterprise innovation and sustainability management studied in this work, a variety of qualitative and intuitive models and frameworks were found. Bhamra (2004) explains that "models are often understood as simplistic ways of representing and/or understanding the world, usually having the purposes of being descriptive or prescriptive. They have the potential to summarise complex information in a manageable and understandable manner and for ecodesign represent a range of its characteristics, fields and practices" (p. 559).

The pioneering view of the protagonists of ecodesign in the 1990s should be remembered, such as Fiksel (1993) who stated:

> "The emergence of the DFE is a convergence of two pervasive thrusts that are transforming the nature of manufacturing businesses throughout the world*: enterprise integration and sustainable development.* Enterprise integration is re-engineering business processes and information systems to improve teamwork and coordination across organizational boundaries, thereby increasing the effectiveness of the enterprise as a whole" (p. 126).

Corroborating with these statements and taking into consideration the best practices in innovation management can be an effective basis for developing a broader ecodesign integration model, following Goffin (2012), but adding other dimensions and considerations.

The proposed model comprehends five integration lines. The first is a systemic approach with three levels (macro, meso and micro). The second one, "macro" level, is the incorporation of the strategy and goals for innovation and environmental sustainability. The "meso" level is the third integration line, which introduces the formal environmental requirements to PDP and portfolio management. The "micro" level, the fourth integration line, proposes the implementation of customised ecodesign tools and integration of environmental aspects in project management, a missing link pointed out by Brones et al (2014). The fifth and last line brings a complementary transversal approach to the three levels aimed at the soft side of ecodesign and change management, with an emphasis on company culture and human factors within a multifunctional view (Fig. 6).

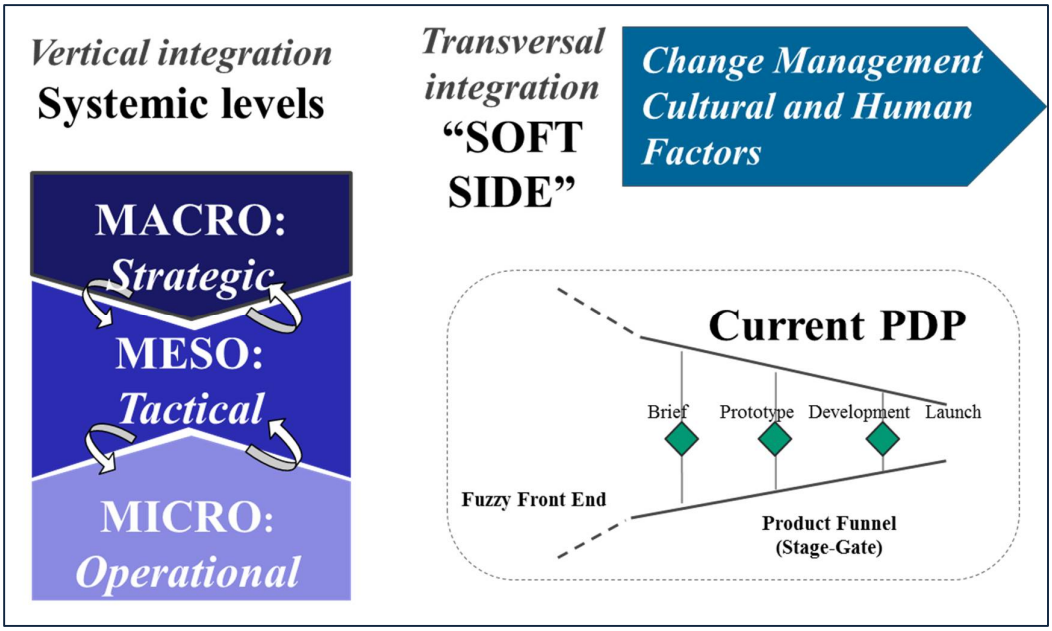

Fig. 6: Ecodesign integration model: combining vertical and transversal integration axes into the existing PDP

The analysis and discussion of the proposed integration ecodesign model follows these five lines.

1. **Construction of a systemic approach with three levels (macro, meso and micro)**, for coherent articulation between initiatives and principles at the different levels, which Olundh (2006) called "vertical integration of ecodesign". The expected inter-level requires combined integrative forces in two convergent movements:

   - "Top down" deployment and alignment between strategy and corporate objectives, from the stimulus of the company's executive management, as recommended in ISO 14006 (International Standard, 2011).

   - "Bottom up" knowledge building associated with pilot projects and team empowering (Kara et al., 2005).

2. **Macro level:** strategy and corporate objectives in innovation and environmental sustainability, based on life cycle thinking principles (Jensen and Remmen, 2006), promoting internal direction, including any existing business units, with ecodesign

and/or environmental, global and deployed goals (Olundh, 2006). This line, besides strategic planning and sustainability strategy, may also include internal and external communication strategy and initiatives in ecodesign.

3. **Meso level**: aimed at PDP and portfolio management

- Alignment and insertion of formal environmental requirements in PDP throughout the key stages and gates for decision making, from the early and particularly decisive stages (Goffin, 2012).
- Integration of ecodesign in portfolio management, including decision/trade-offs criteria associated with the environmental dimension; quantitative environmental life cycle indicators (Pigosso et al., 2013), relationship between units within the company.

4. **Micro level** includes ecodesign tools and project management.

- The broad theme of ecodesign tools has not been explored in detail in this review, given that it is the most discussed aspect in the literature, but we pointed out some key publications. The Ecodesign Maturity Model (Pigosso, 2012, Pigosso et al., 2013) can be a highly interesting tool to diagnose the company´s need, in terms of practices and ecodesign tools and associated management practices. To cite a few referencesclassical tools include ecodesign guidelines (Brezet and Van Hemel, 1997; Fiksel, 1993), environmental assessment tools, based on life cycle assessment, (Donnelly et al., 2006; Kara et al., 2005) and verification tools (Fiksel, 1993). Ecodesign tools customisation, however, should be emphasised in this model proposal, taking into consideration the specificities of PDP and the company's culture. The principle of customisation appeared as a recommended best practice in a number of publications (i.e.: Knight and Jenkins, 2009, Luttropp and Lagerstedt, 2006, O´Hare, 2010, Ritzen and Lindahl, 2001), but is still a challenging task for effective integration.

- The integration of ecodesign in project management, complementing more global portfolio guidelines (meso level), calls for new approaches such as project success factors and "trade-off" solutions between the various dimensions (quality, cost, time and environmental sustainability), the multifunctional teamwork, covering

the perspectives of life cycle of products and the various stakeholders of the value chain (as we explore in a separate publication).

5. **Change management and "soft side" of ecodesign**, considering the company's culture through human factors, including and promoting the participation of employees and areas, training and knowledge management, overcoming resistance to change (Boks, 2006, Verhulst and Boks, 2012). This transversal approach has to go through the three aforementioned levels of integration, seeking to ensure the progress of processes and practices.

Finally, these five integration lines of the ecodesign integration model will have to take into account several requirements induced from the set of models studied:

- Applicable to various types of companies / versatile.
- Easy to understand visual representation, easy to remember and communicate to different potential users of the model, incorporating already established elements such as the funnel or stage-gate PDP.
- Vocabulary / keywords to assist memorisation.
- Trade-offs between level of detail and completeness of the model and clarity.

6. Conclusion

The objective of this study was to map the state of the scientific art on ecodesign integration from a comprehensive review of international publications. The main studies in this area were classified and coded in terms of the level of analysis, publication type, PDP type, research country, and the temporal evolution of the studies.

Next, 52 integration models were identified and analysed in depth. These models feature a wide variety of approaches and representations. However they are usually the result of relatively specific works, supported by case studies, and take into consideration the extensive fields of knowledge from innovation and sustainability management in a limited way, and only a few previous models. It is observed that they rarely refer directly to the most accepted models of innovation management in companies, such as stage-gate, although this is quite recommended by some experts in the topics.

As a result of the systematic literature review, relevant gaps were found that may explain why ecodesign integration still remains a challenge, particularly in the innovation management processes and generally in operations management. The literature analysis enables to merge some of the best theoretical constructs and practices in a systemic and integrative perspective, as a promising approach towards more effective ecodesign integration. Thus, a new ecodesign integration model was presented as a synthesis of these analyses. The proposed conceptual framework connects three systemic levels (macro, meso and micro), with top-down and bottom-up flows that promote vertical integration, while the transversal integration axis occurs through change and people management within a perspective of the organisation's culture. Both axes are based on established innovation management practices, including the development pipeline and stage-gate process, and are consistent with product oriented life cycle management practices.

As implied in the challenges of undertaking a literature review on this topic, such as the lack of vocabulary alignment, dispersed literature and organisational aspects and complexity, the main limitations of this review regard the fact that some studies may not have been identified in the search processes.

The models and framework are widely dispersed in the literature, and some interesting publications were indirectly found. Therefore, not all possibilities were covered, and our survey is not expected to have a quantitative representativeness, but can be considered as an in-depth exploratory study.

Another potential limitation was the subjectivity in the analysis of the models, regarding the levels and types of PDP. The presented evaluation (systemic levels and PDP) does not intend to cover all of the depth and richness of approaches used in the publications, and a more detailed content analysis is underway.

However, the study objectives were achieved and opened a promising path to consolidate ecodesign knowledge. The synthesis based on scientific constructs associated with the success factors of innovation management coupled with the dissemination of environmental sustainability principles can be a significant contribution to the body of ecodesign and product oriented life cycle management themes.

Besides the formalisation and more detailed representation of the model in a future work, these propositions should be further developed and tested in subsequent field studies through Action-Research, a path suggested by Ritzén (2000), deemed as necessary yet little practiced

in ecodesign, which was only found in the O´Hare (2010) work on the narrower scope of simple tools development for SMEs.

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Appendix 1a: Summary content of the publications and models identified (from 2009 to 2013)

Year	Reference	Country	Pub	Main focus	Levels			PDP
					Micro	Meso	Macro	
2013	Keskin et al.	Holland	J	Sustainable innovation process in new business ventures; Internal and external factors		X		Specific (3 phases)
2012	Bucci et al.	Brazil	C	PDP, Reference model. Focus on packaging and product development	X	X		Stage-gate
	Goffin	UK	B	Sustainability issues and requirements in phases, and potential conflicts. Role of executive management	X	X		Stage-gate
	Verhulst and Boks	Belgium	C	Change management, human factors and business culture			X	ND
	Ferrer et al.	France	J	Problem solving; process and tools	X			ND
	Bovea and Perez-Belis	Spain	J	Choosing environmental evaluation and integration tools with other requirements	X			ND
	Pigosso	Brazil	T	Maturity assessment in ecodesign with 61 indicators: PDP practices/management, operational practices and methods and tools; improvement tool (roadmap)	X	X	X	Stage-gate
2011	International standard	Switzerland	S	ISO 14006: Guidelines to incorporate and implement a systematic and structured ecodesign process in an Environmental Management System	X	X	X	PDCA
	Arana-Landin and Heras-Saizarbit.	Spain	J	PDCA implementation approach for ecodesign		X		ND
	Kengpol and Boonkanit	Thailand	J	Applied ecodesign process, detailing tools and methods	X			ND
	Trappey et al.	China	J	Applied ecoinnovation process using various methods and tools	X			ND
2010	Dusch et al.	UK	C	Relationship between innovation and sustainability			X	ND
	Spangenberg et al.	Germany	J	Global / holistic approach; skills, roles and learning			X	ND
	Ramani et al.	USA	J	Overview of sustainability issues related to product development systems in the U.S.	X		X	ND
	Carrillo-Hermosilla et al.	Spain	J	8 Key dimensions to characterise ecoinnovation: design, user, services/products and governance.			X	ND
	Lewandowska and Kurczewi.	Poland	J	Ecodesign procedure based on ISO 14062, focusing on applications and tools in the early stages of the project	X			Multiphase
	Hallstedt et al.	Switzerland	J	Top-down systemic view with development of incentives and systematic control and tools for decision making at all levels	X		X	ND
2009	Crul et al.	Holland	B	10 steps for integrating sustainability into standard PDP in pilot projects with classic tools	X		X	Stage-gate
	Hassi et al.	Finland	C	"who" and "what": people and behaviors, to develop a set of techniques suitable for transformational change for sustainability.	X		X	Multiphase funnel

Appendix 1b: Summary content of the publications and models identified (from 2005 to 2008)

Year	Reference	Country	Pub	Main focus	Levels			PDP
					Micro	Meso	Macro	
2008	Ghazilla et al.	Malaysia	C	Incorporate modified versions of various tools to improve the integration and implementation of ecodesign	X			Multiphase
	Vezzoli and Manzini	Italy	B	Information technology to deal with the complexity and amount of data	X	X		Multiphase
2007	Le Pochat et al.	France	J	Demonstrative methodology for SMEs with support from external experts, bringing expertise	X	X		Multiphase
	Nowosielski et al.	Poland	J	Generic method of ecodesign in 6 steps, indicating the essential activities and tools for each step	X			Multiphase
	Waage	USA	J	Approach for "developing sustainable strategy" to ensure consistency between view, strategies and appropriate tools, and between short and long-term	X		X	Multiphase
	Tingström	Sweden	T	4 main integration factors: Leadership Team; DfE mindset, DfE tools, PDP.		X	X	Stage-Gate
2006	Yang and Song	Singapore	C	Integration of methods and lifecycle tools in PDP, focus on flow and data management	X			ND
	Ölundh	Sweden	T	Modernising ecodesign with more strategic approach, deployed in the organisation (vertical integration), depending on the existing PDP.		X	X	Stage-gate
	Donnelly et al.	USA	J	Product based Environmental Management System with PDCA principle, integration in business and PDP processes through checklist and LCA	X	X	X	Multiphase
	Lofthouse	UK	J	Requirements to develop appropriate tools for industrial designers: guidance, education and information, appropriate content and presentation, easy access	X			ND
	Howarth and Hadfield	UK	J	To assess product sustainability aspects, along with manufacturing aspects, considers 13 types of interested stakeholders interacting with the designer	X		X	ND
2005	Berchicci and Bodewes	Holland	J	3 factors to integrate the environmental dimension in PDP: product design specifications and trade off; coordinating multi-functional teams, management support		X		ND
	Jeganova	Sweden	C	Systemic integration approaches at each PDP stage, with high or low priority level; adaptive feedback; everyone's skills and engagement.	X	X		Stage-gate
	Hermenau et al.	Germany	C	Strategic Planning; PDP (requirements and flows); dedicated people; adaptation of tools, creation of information base, supply chain integration		X	X	ND
	Kara et al.	Australia	C	3 levels: strategy; tactic; operations. 5 key points: environmental goals and top-down approach, performance based on LCA; early stages; simple bottom up practical application	X	X	X	ND
	Ammenberg and Sundinb	Sweden	J	Product-oriented Environmental Management System (POEMS), type of PDCA cycle; connects environmental considerations in PDP and in business management system	X	X		ND

Appendix 1c: Summary content of the publications and models identified (from 1993 to 2004)

Year	Reference	Country	Pub	Main focus	Levels			PDP
					Micro	Meso	Macro	
2004	Bhamra	UK	C	5 Main factors: initial and maintained motivation; communication and information flow; holistic thinking; practical ecodesign, global positioning	X	X		Multiphase funnel
2004	Alakeson and Sherwin	UK	B	8 recommendations to create a sustainable innovation system considering broader external interactions, and internal culture (leadership, values, people). 4 integration stages		X	X	ND
2004	Dewulf and Duflou	Belgium	B	Integration in 3 levels (project, company, industry); PDCA approach at each level	X	X	X	Multiphase
2004	ABNT (ISO TR 14062)	Brazil	S	Indicators for ecodesign integration in PDP and design (2 levels assimilated) in a progressive way, top down or bottom up	X	X		Multiphase
2002	Baumann et al	Sweden	J	4 levels: PDP; company; supply chain; society. Promotes systemic perspective, multilevel and less focus on tools	X	X	X	Multiphase
2002	Van Hemel and Cramer	Holland	J	Importance of social and economic factors to integrate in SMEs (barriers and stimuli) and internal motivation			X	ND
2002	Robert et al.	Sweden	J	Systemic and strategic approach to sustainable development in organisations, split into 5 levels	X	X	X	ND
2001	Handfield et al.	USA	C	Roadmap with 7 steps linking global corporate strategy with goals, PDP tools and monitoring	X	X	X	Multiphase
2001	Stevels	Holland	C	An integration process with 3 levels (strategy, development and tools), evolving to internal and external multistakeholder approach		X	X	ND
2001	Neal and Heintz	USA	C	Business model based on expert system and internal knowledge	X			ND
2001	Sherwin and Bhamra	UK	J	Integration in PDP in the early stages, with "Top down" approach and not "bottom up" as previously recommended (PROMISE)		X		Multiphase
2001	Jones et al.	UK	J	2 ecoinnovation tools for generating ideas at the beginning of PDP	X			Multiphase
2000	Simon et al.	UK	J	"ARPI framework": 4 steps (Analyse, Report, Prioritize, Improve), similar to PDCA, for ecodesign practice at strategic and operational level.	X		X	ND
2000	Ritzén	Sweden	T	Cyclical Implementation: set goals, develop knowledge, adapt resources, tying at all levels, focusing on individuals	X	X	X	Stage-Gate
1998	Van Hemel	Holland	T	In SMEs, identified factors related to DFE performance: B to B , owner's support, external support, innovation capacity and internal organisation	X	X	X	ND
1996	Poyner and Simon	UK	C	DFE tools integrated into PDP , with guidelines for each project stage and gate	X	X		Stage-Gate
1993	Fiksel	USA	C	DFE as a convergence of integration processes in the company (simultaneous engineering) and sustainability. Requires: metrics, guidelines and verification methods, with system-oriented development.	X	X		ND

PUBLICATION # 4: Reviews, action and learning on change management for ecodesign transition

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Reviews, action and learning on change management for ecodesign transition

Abstract

Corporate sustainability, which has become essential to most companies during the last decades, prescribes that environmental requirements should be incorporated into diverse business processes. In order to effectively integrate environmental aspects into product innovation processes, companies might have to significantly change some of the practices and habits of all involved stakeholders and organisation. To complement the extensive literature on the (technical) “hard side of ecodesign”, this article explores the promising “soft side” that considers company culture and human factors, through a multiple steps literature review associated with a longitudinal action research in a large cosmetics company. Whereas a consistent prescriptive change model is still lacking in ecodesign literature, a strong convergence and complementarity is observed between previous conclusions on ecodesign integration models and the emerging Transition Management approach designed for sustainability issues facing organisations. The principles of an “ecodesign transition framework” are proposed, combining a three-level systemic approach, considering both top-down planning and bottom-up innovation, through new types of interaction and dynamic cycles of action and learning, with a deep stakeholder management. This new framework was developed and positively applied during a five-year-long company experience to face the complex transition process. Such approach could be capable to positively address change management issues and help companies evolve toward a more effective sustainable product innovation process, in the context of evolving business management practices that require more human based and progressive change strategies.

Keywords: Ecodesign; integration; change management; transition; sustainability

1. Introduction

Along the last two decades corporate sustainability has become more global and fundamental to the success for most companies, evolving from expressing good intentions to addressing critical business issues linking economic, social and ecological performance (Kiron et al., 2015). Such "megatrend", directly affecting the competitiveness and even the survival of their organisations, entails companies to update traditional business tools to consider the specialised requirements of environmental sustainability (Lubin and Esty, 2010).

Defined as the integration of environmental aspects into product development, with the aim of reducing environmental impacts of products throughout their life cycle, ecodesign has emerged in the 1990s (Brezet and Van Hemel, 1997; Charter and Tischner, 2001). ''Design for sustainability'', or other similar designation, has been recommended for supporting companies in facing both the ever growing environmental and social pressure and fulfil customers' needs, and therefore responding to the increasing demand for sustainable product design (Fargnolia et al., 2014). According to Vogtlander et al. (2013), greening of products of existing companies is far more promising for a fast transition towards sustainability, than start-up of new companies with new green products. However, most companies still face substantial challenges for dealing with the effective implementation of ecodesign principles and tools into their product development process (PDP), and related activities, as confirmed by recent studies and surveys (Brones and Carvalho, 2015; Wolf, 2013).

To interpret this situation, researchers have suggested that a potentially excessive emphasis was given to the technical aspects or "hard side of ecodesign", essentially deriving from the field of industrial design, engineering and environmental sciences. Most ecodesign research and literature predominantly addressed the hard side, focusing on tools and based on theoretical academic experiences or pilot projects (Charter and Tischner 2001; Stevels, 2007).

Hence, commonly recommended approaches resulting from the hard side have been questioned as poorly relating environmental activities with other business aspects, and lacking a more systemic perspective (Baumann et al., 2002). Such approach often led to little "change in practice" (Boks, 2006). Thus, a gap has been pointed out in the literature on how to deal with non-technical aspects, which gave rise to a novel research trend named the "soft side of ecodesign", an expression coined by Boks (2006). To fill the gap on soft aspects of ecodesign toward more systematic and durable application at firm level, new propositions are needed to address recurrent challenges observed in numerous studies, and to complement previous research toward a more systemic and effective incorporation of environmental sustainability into the product innovation process at company level (Brones and Carvalho, 2015).

Indeed, changes towards sustainable consumption and production are recognised as fundamentally complex (Tukker at al., 2008b). The road to sustainability requires a joint search agenda that entails a process of mutually enforcing actions for change (Tukker et al., 2008a). Sustainability has been named a "wicked problem" that requires an essential change in the whole system (Schäpke et al., 2013). Such situation will only be resolved by systemic changes involving technology,

economy, culture, ecology, institutions and organisation (Loorbach and Wijsman, 2013). A new change management concept is needed to evolve towards the "eco-innovation paradigm", where life-cycle thinking and ecodesign would be two key principles for decoupling growth and degradation (De Vries, J.and te Riele, 2006).

Following such views, change accompanying ecodesign integration could be seen as a process to be constructed, and not only a result of expected progress associated with the imposed adoption of more sustainability adapted technical practices. According to McDermott et al. (2008), academics and practitioners interested in change processes will find an extended literature, but also complex and fragmented. To face such complexity, European researchers have argued that new concepts were needed toward sustainability transitions, defined as long-term, multi-dimensional, and fundamental transformation processes through which established socio-technical systems shift to more sustainable modes of production and consumption. Transition Management (TM) has emerged as one of the main research strand in this context (Markard et al., 2012), initially applied at the macro level, as part of national sustainability policy in The Nederland's (De Vries and te Riele, 2006),
TM concept has been built on the complex systems approach, new forms of governance and social theory, and was translated into descriptive and prescriptive models (Kemp et al., 2007). However, empirical knowledge, based on practical experience, needs to be developed (De Vries and te Riele, 2006), and TM is only emerging at company level (Loorbach and Wijsman, 2013).

Therefore, pursuing the goal to formulate a framework capable to help companies evolve toward more sustainable product innovation processes, this paper explores and deepens the soft side aspects of ecodesign. Both change management and transition management potential application are considered for ecodesign integration, in order to address organisational, human and temporal transformations needed to operate such evolution at firm level. The aim of this paper is to bring new insights and propositions linking knowledge from operations and environmental management with general and recent social theories. Also, such propositions should be consistent with real long term in-company experiences, which could be addressed by action research, considering that change is a key component of action research approaches (Burnes, 2004).

Hence, this research intends to build a relevant part of new ecodesign integration principles based on a multistep literature review, synthesis of previous scientific recommendations, and analysis of empirical observations in real company conditions. To present such construction, the article is structured in six parts. Section 2 summarises the different methodologies that were used. Then, the central sections develop the results of multistep bibliographic reviews conducted in several perspectives and leading to the proposition of the "ecodesign transition" concept (3), and show the application of such propositions in the context of a field experience (4). The following section (5) discusses the results and propositions, before concluding remarks and perspectives (section 6).

2. Methods

2.1 Overall methodological approach

This paper explores the soft side of ecodesign integration, considering both change management and transition management approaches, in order to deepen and complement previous researches. For such purpose, the methodology used several phases of reviews of existing literature on ecodesign management, change management and sustainability transition, as represented in Fig. 1. These theories were analysed and confronted with the experience of a longitudinal study conducted in action research (AR) within a consumer goods company. Such approach follows "the theory-building process [that] occurs via recursive cycling among the case data, emerging theory, and later, extant literature" (Eisenhardt and Graebner, 2007, p.25). Consequently, this article combines a multistep literature review and analysis (steps 1 to 4), with an action research approach (developed in two cycles), as briefly shownin Fig. 1 and described in the following sections.

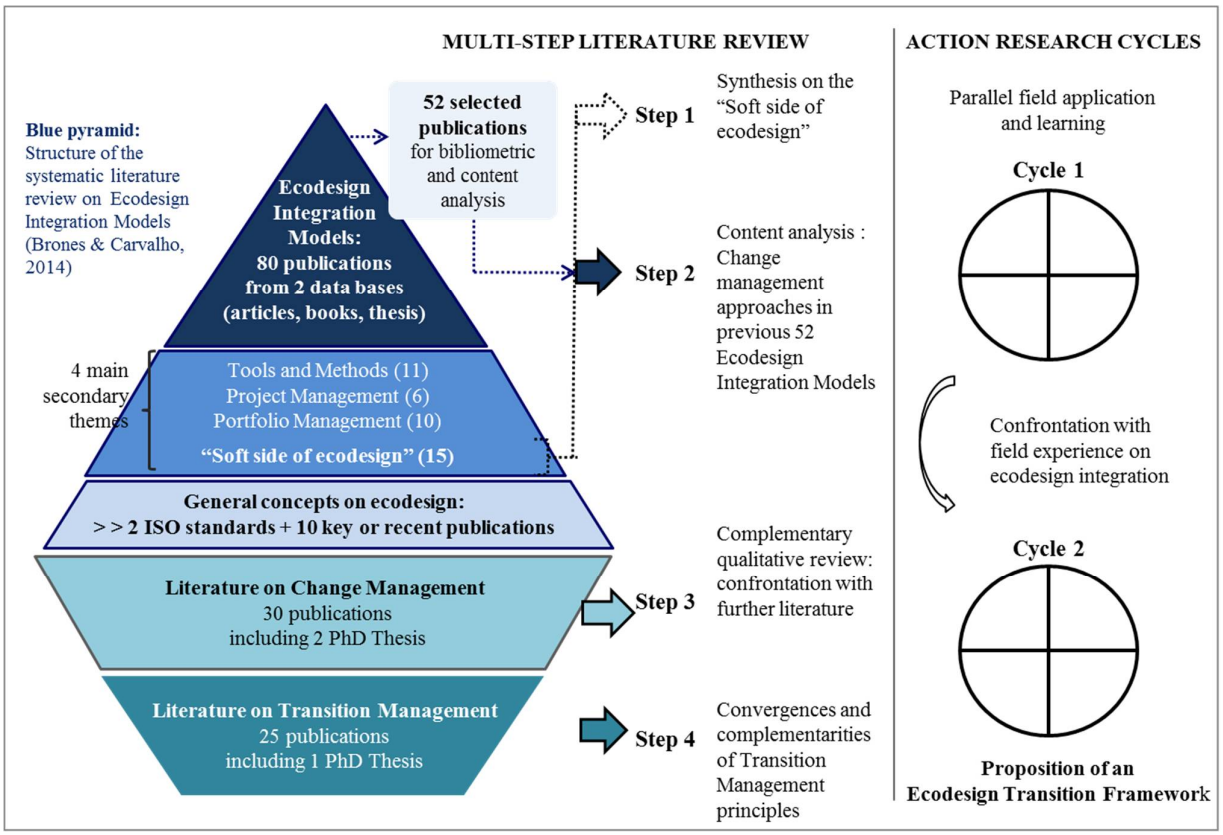


Fig. 1. Research Design.

2.2 Multistep literature review

As a starting point, the challenges and basic principles associated with the "soft side" of ecodesign management were analysed in established ecodesign literature (step 1).

Step 2 deepens the soft dimension of a previous systematic review, following Webster and Watson´s (2002) recommendation, in search of a thorough understanding of the considered literature. The previous review had given an overview of the state of the scientific art of ecodesign integration, focusing on previously published models (Brones and Carvalho, 2015) and led to the proposition of a systemic ecodesign integration model. Additional bibliometry techniques and content analysis were used in this complementary study, including simple statistical treatments and graphs to analyse the content of internal information, after encoding with the main constructs identified in step 1.

The management approach of integration were encoded in order to analyse their distribution and evolution (Carnevalli and Cauchick, 2008; Prasad and Tata, 2005). This set of models, considered a relevant sample of ecodesign integration literature since the 1990s, was studied in depth taking into consideration the "soft side" integration approaches cited in the models and associated content of the articles, in order to systematise and synthesise the contributions to the research topic and to enable discussing the key constructs found. The publications were also classified according to the level of relevance perceived for this specific study.

To further progress in understanding how human aspects can be considered for ecodesign implementation, step 3 explores complementary qualitative reviews conducted on change management approaches, from different trends of social sciences.

Step 4 explores an additional layer of publications through a specific search on the new concept of Sustainability Transition and Transition Management. This process, linking with the conclusions from previous researches, led to identify new propositions and recommendations for ecodesign integration seen both as a business objective and research object.

The main sources and references for the reviews conducted on change management issues in steps 1, 3 and 4 are listed in table 1. In a parallel perspective, such propositions were considered in an applied field study on ecodesign integration, following AR principles and methods, as presented in next section.

Table 1
Main sources and references for change management issues (steps 1, 3 and 4)

Step 1	**ECODESIGN MANAGEMENT/ SOFT SIDE**		
	Boks, 2006 Boks, 2008 Charter and Tischner, 2001 Cohen-Rosenthal, 2000 Jabbour, 2013 Jabbour et al., 2013	Kerga et al. , 2011 Lenox and Ehrenfeld, 1997 Lofthouse 2003, Lofthouse 2004, McAloone and Evans, 1999 Murillo-Luna et al., 2011	Petala et al. 2010, Stevels, 2007, **Verhulst, 2012 (R)** Verhulst and Boks 2012 Verhulst et al., 2007 Zahari and Thurasamy, 2012
Step 2	See section 3.2: analysis of 52 references with integration models (selected from an initial pool of 80 references identified in database searches and a recycling process of other publications)		
Step 3	**ORGANISATIONAL THEORY**	**BEHAVIOURAL THEORY**	**NUDGING**
	Ajzen, 1991 Bascoul and Moutot, 2009 Bititci, 2007 Burnes, 2004 Erhenfeld, 2008 Ford and Ford, 2010 Groysberg and Slind, 2012 Loorbach et al., 2009 **Verhulst, 2012 (R)** **Vladimirova, 2012 (R)**	Amabile, 1993 Armitage and Conner, 2001 Gollwitzer, 1999 Guagnano et al., 1995 Ibtissem, 2010 Kahneman et al., 1991 Mazar and Zhong, 2010 Ones and Dilchert, 2012 Osbaldiston and Schott, 2012 Rise et al., 2003 Ryan and Deci, 2000 Stern, 2000 **Szeler and Melberg, 2014 (R)** Unsworth et al., 2013	Dolan et al., 2011 Hausman and Welch, 2010 Johnson et al., 2012 Oullier and Sauneron, 2011 **Szeler and Melberg, 2014 (R)**
Step 4	**TRANSITION MANAGEMENT**		
	Boons and Wagner, 2009 Buysse and Verbeke, 2003 De Vries and te Riele, 2006 Geels and Schot, 2007 Kemp et al., 2007 Kern, 2012 **Loorbach, 2007 (R)** Loorbach and Wijsman, 2013	Loorbach et al., 2009 **Markard et al, 2012 (R)** Mulder, 2007 Roome and Wijen, 2006 Rotmans and Loorbach, 2009 Ryan, 2004 Schäpke et al., 2013 **Seuring and Müller, 2008 (R)**	Sondeijker et al., 2006 Steurer, 2006 Stubbs and Cocklin, 2008 Tukker et al., 2008(a) Tukker et al, 2008(b) Van der Brugge and van Raak, 2007 Van Kleef and Roome, 2007 Verhulst, 2012

Legend: (R) = Review from previous literature on the subject

2.3 Action research approach

Though increasingly recommended in Operations Management (OM), AR has scarcely been documented for ecodesign studies (O´Hare, 2010), as confirmed by searches in Scopus data base, with less than ten studies using AR in the field during the last 20 years. However, this methodology should be considered as mature, since Lewin and his colleagues coined the expression and principles in the 1940´s as a way of learning about organisations through trying to change them (Lewin, 1946).

Westbrook (1995) claimed that AR, though it can be seen as a variant of case research, brings a real new paradigm for research in OM, which Coughlan and Coghlan (2002) latterly developed, arguing its relevance and validity to address the operational realities experienced by practicing managers while simultaneously

contributing to knowledge. According to Karlsson (2002) “there are incomparable potential benefits of deep insight also on causality and the possibilities of experiments on the field are rather unique. This will well compensate for criticism for lack of generalizability”.However, different approaches applied in research on change have been subject to durable critiques regarding their neglect of the context and process of change, as well as the relationship between researchers and practitioners within the research process (McDermott et al., 2008). According to many specialists, AR was claimed as especially suited to organisation change projects (McDermott et al., 2008, Williander and Styhre, 2006).

Thompson and Perry (2004) recommended, for quality AR, to include two related but distinct views – the core in-company field research project and the generalising research project. Accordingly, this research combines general AR principles and specificities from Insider Action Research in a longitudinal study to capture the change and transition aspects of the soft side.

The field research was performed along five years, within a study associating University of São Paulo and a leading Brazilian cosmetics company - the first author of this article being attached to both organisations, in a situation characteristic of insider action researcher (Coghlan 2007; Holian and Coghlan, 2013).

The company has been recognised by different types of stakeholders in Latin America for its strong commitment to sustainability, as embedded in the company´s values and identity (Sahota, 2014). In line with these compromises, the firm has launched a company-wide ecodesign programme in 2011. Indeed, the company had already implemented many corporate and product initiatives towards the reduction of associated environmental impacts for several decades, but had not yet considered ecodesign in a systematic way.

This programme, or the applied side of the AR study, allowed a change management experiment in real field conditions, and was conducted in two implementation cycles of planning, action, and fact-finding about the result of the actions (as recommended by Coughlan and Coghlan, 2002), conducted from 2011 to 2015. The main activities led within cycles 1 and 2 followed a “Plan-Do-Check-Act like process”, for selection, customisation and implementation of ecodesign practices considering both hard and soft sides, and this article exploits the change management aspects of such experiment.

The summarised results were based on multiple sources of data and evidences collected during the five-year period, including several sets of workshops and individual interviews of different publics, observations during tools development and applications, and along eight associated product development projects. Also, a meta-analysis and monitoring of the AR was conducted at different stages and between the cycles (Coughlan and Coghlan, 2002), using an Ecodesign Maturity assessment (Pigosso et al., 2013) as well as formal presentations and discussion of on-going work and partial results in international conferences and with academic experts from several Brazilian and European Universities. Data analysis included triangulation of different sources, critical analysis and confrontation with previous theory in search of stronger validity, for such reflexive, collaborative and interventionist study typical of AR (Coghlan, 2007).

3. Results

3.1. Learning from the "soft side of ecodesign"

The concept of "Soft Side of EcoDesign" has been formalised by Boks at Delft University of Technology, referring to a variety of sociological, psychological and even intangible factors that ecodesign research should address (Stevels, 2007). Stevels narrated how this innovation has been presented at the Electronics Goes Green Conference in Berlin in 2004, with the provoking title "EcoDesign in Industry is not an Environmental Issue": "It shocked part of the audience but it has been an eye-opener for some participants as well" (Stevels, 2007, p.176).

Based on a literature review, Boks (2006) concluded that previous publications did not provide enough insight to understand the role of socio-psychological factors in the context of ecodesign operationalization. Additionally, through a series of interviews with major electronics multinationals in Japan and South Korea in 2003, he identified the main perceived success factors and obstacles for dissemination of ecodesign information, and concluded that the most important hurdles appear to reflect more social-psychological issues: the gap between proponents and executors, organisational complexities, and unwillingness to cooperate (Boks, 2006).

Going back to the origins, ecodesign management and organisation principles have emerged as secondary insights to the (technical) principles of ecodesign consolidated during the late 1990s. For example, Lenox and Ehrenfeld (1997) explored the "environmental design capabilities", based on a literature review and four case studies. In an exploratory study on implementing ecodesign principles in several companies, McAloone and Evans (1999) introduced the overall concept of an observed sequence of change facing change management issues. Charter and Tischner (2001) featured that it is "important to consider 'soft factors' such as organisational structure, systems, communications and corporate culture", and that 'soft issues', aimed at gaining involvement from business functions are essential to address.

Nevertheless, this trend has further progressed relatively slowly, even after Boks´ initial studies. For instance, Kerga et al. (2011) argued that companies should develop capabilities and resources to face these observed challenges. Such view is also found for the "greening of companies" more broadly, recognising that technical changes related to environmental management require human and organisational commitment (Jabbour et al., 2013).

Ecodesign integration can follow top-down approaches driven by management leadership or alternatively bottom-up initiatives - technical projects emerging from the field (Charter and Tischner, 2001; Stevels, 2007). Complementary knowledge should be brought from social sciences on wider change management perspectives to give rise to novel and more effective approaches on ecodesign integration, strongly connected to industrial contexts. Such new trends will be explored hereafter, identifying the main constructs and bringing theoretical references from other disciplines.

3.2 Change management approaches in previous ecodesign integration literature

The content referring to change management has been recently analysed in the corpus of 52 integration models, through an in depth analyse conducted by Brones and Carvalho (2015), in a systematic literature review. Table 2 presents the compilation of these approaches encoded following the main types of integration approaches as commonly discussed within literature (top-down, bottom-up, or mixed). The references were also classified according to their level of alignment for the purpose of this research, i.e. if they introduced instructive integration principles in one or several of the considered dimensions (systemic levels, consideration of innovation management principles and detailed change management approaches).

The analysis reveals that 44% of the models do not consider change management issues at all, which confirms the general priority given to technical aspects. Then, the most common approaches recommend top-down ecodesign implementation or mixed approaches (23 % each), more frequently than bottom-up integration (10%), as indicated in Table 2.

Additionally, Fig. 2 represents the evolution over time of the change management approaches considered in the 52 models. This distribution does not show an increase of any particular type of approaches along time. The first mixed approaches have been mentioned since 2000, but have not increased in more recent publications. The qualitative content analysis of these publications is summarised in Table 3.

In the 52 models, several important barriers or success factors associated to change management principles were mentioned. For example, from top-down strategies, risks of inter-functional conflicts, multifunctional implementation team with top management support; goal setting are important issues. From bottom-up initiatives, awareness raising and training, pilot or demonstration project, new behaviours needed combining creativity and motivation, multi-stakeholders networking and action learning are a set of propositions for successful ecodesign integration. Even if some sensible general advices are provided (e.g: “need for systemic transition with technological, social and cultural changes; importance of inter-disciplinarity”, by Vezzoli and Manzini, 2008), change management recommendation from these models appear as quite fragmented and lack an organised and coherent structure.

From this content analysis, it was concluded that the change management perspective is a secondary perspective for most of these models, except for Verhulst and Boks (2012), which represents the recent expression of the “soft side” research trend. Indeed, this was the only model of the analysed group that was specifically built toward this dimension of the ecodesign integration challenges.

Verhulst and Boks´ model (2012) is a circular framework primarily based on Levin’s three-stage change process (unfreezing, changing and refreezing). The authors presented it as a descriptive model, with limited prescriptive function, as confirmed in Verhulst´s PhD thesis (Verhulst, 2012), recommending further research in this direction.

Hence it is difficult to raise any convergences or tendencies from the diversity of suggestions indicated in this fragmented set of models and publications. Above all,

this corpus of ecodesign literature provides almost no indication on how to conduct and follow up such change management processes, and does not report detailed application examples of such field experience. Finally, this overview confirmed that the arena of change management for ecodesign integration is still a challenging issue where other knowledge and experiences could be more deeply explored from social sciences.

Table 2
Classification of change management approaches in the 52 ecodesign models.

Change management approach	**Not addressed**	**Bottom up**	**Top down**	**Bottom up + Top down**	**Total**
# of Models (1993-2012)	23	5	12	12	52
% of Models	44%	10%	23%	23%	100%
References					
Higher alignment	Van Hemel, 1998.	Hassi et al., 2009.	Dewulf and Duflou, 2004; Goffin, 2012;Hermenau et al., 2005; Ölundh, 2006; Pigosso, 2012.	ABNT, 2004; Crul et al., 2009; Handfield et al., 2001; Kara et al., 2005; Ritzén, 2000; Stevels, 2001; Verhulst and Boks, 2012.	
Medium alignment	Alakeson and Sherwin, 2004; Baumann et al., 2002; Berchicci and Bodewes, 2005; Robert et al., 2002; Van Hemel and Cramer, 2002.	Fiksel, 1993; Vezzoli and Manzini, 2008;	Ammenberg and Sundinb, 2005; Donnelly et al., 2006; Hallstedt et al., 2010; International Standard, 2011; Jeganova, 2005.	Bhamra, 2004; Le Pochat et al., 2007; Simon et al., 2000; Tingström, 2007.	
Lower alignment	Bovea and Perez-Belis, 2012; Bucci et al., 2012; Dusch et al., 2010; Ferrer et al., 2012; Ghazilla et al., 2008; Howarth and Hadfield, 2006; Jones et al., 2001; Keskin et al., 2012;Lewandowska and Kurczewski, 2010; Neal and Heintz, 2001; Nowosielski et al., 2007; Poyner and Simon, 1996; Ramani et al., 2010; Spangenberg et al., 2010; Trappey et al., 2011; Waage, 2007; Yang and Song, 2006.	Carrillo-Hermosilla et al., 2010; Lofthouse, 2006.	Arana-Landin and Heras-S, 2011; Sherwin and Bhamra, 2001.	Kengpol and Boonkanit, 2011.	

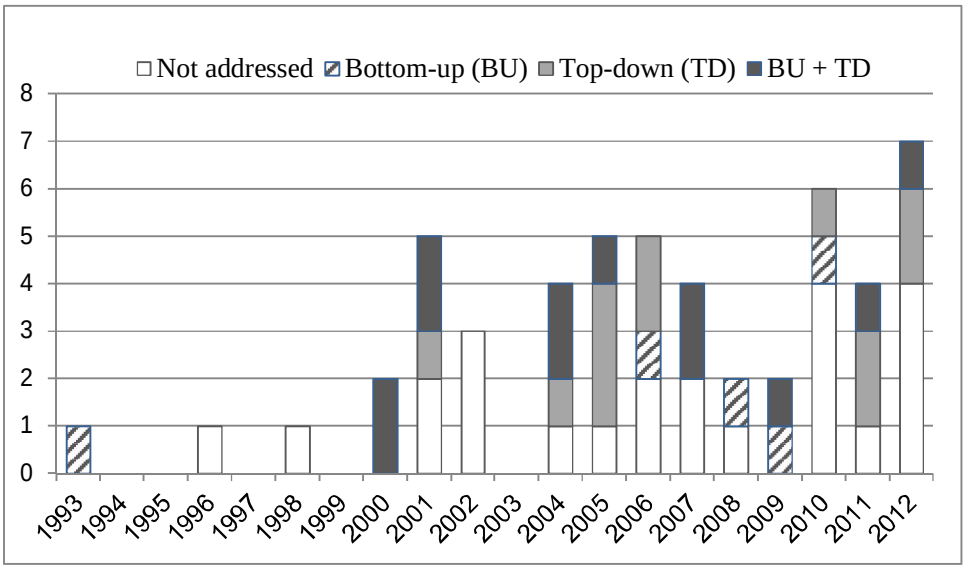


Fig. 2. Evolution of change management approaches in ecodesign models (1993-2012)

Table 3:
Change management approaches in ecodesign integration model: synthesis of classified content (main observations are indicated in bolt).

BOTTOM UP	TOP DOWN	BOTTOM UP + TOP DOWN
• Transformational change towards sustainability require **people** with adapted **profiles** (eg profile T) and new **behaviours**: creativity, motivation, multistakeholders networking ... (Hassi et al., 2009) • Develop new **capabilities** incrementally to ensure that they are properly adapted to the **culture** and existing organizational processes (Fiksel, 1993) • Need for systemic transition with technological, social and cultural changes; importance of **interdisciplinarity** (Vezzoli and Manzini, 2008) • Providing **information** to support ecodesign education to build up **tacit knowledge** for designers. Importance of meeting the cultural requirements of designers (Lofthouse, 2006)	• Top management role; risks of **inter-functional conflicts** (Goffin, 2012) • **Awarene**ss raising and **training** included in management practices (Pigosso, 2012) • Top-down approach to **deploy Strategy** to the projects (Olundh, 2006) • Group of people responsible to transfer Life Cycle Design into company practices; generate sufficient **knowledge**. (Hermeneau et al., 2005) • Importance of sustained management **support** (Dewulf and Duflou, 2004; • Top management **suppor**t; **cross-functional** teams; education and **training**, support of environmental specialists (Ammenberg and Sundinb, 2005) • Environmental policy driver for implementing and improving management system (POEM). Top management **support**; management group provides qualified personnel, technology and financial **resourc**es for implementation and continuous improvement; **mandatory e.learning** program (Donnelly et al., 2006) • Senior management role with **incentives** and systematic **control** and indicated tools. Importance of **communication** between organizational levels with a common language (Hallstedt et al., 2010) • Top management role; ensure **cross-functional** approach and involvement of the whole value chain; promote internal and external **communication** (International Standard, 2011) • Main driving force**: commitment** and motivation of senior management. Internal motivators: **knowledge, communication**, attitude and environmental awareness (Jeganova, 2005)	• Paths and approaches **depend on the company**; 3 main human factors: employees´ **participation**, **training**, **resistance to change** (Verhulst and Boks, 2012); • **Multifunctional** implementation team with top management **suppor**t, starting with **pilot** / demonstration project (Crul, 2009) • Top-down approach associated with the practical application, bottom up with simplicity. Different users/level: designers; product manager; senior management (Kara et al., 2005) • Top management **support** necessary; bottom up or top down integration (ABNT, 2004) • Need for corporate sponsor and support of middle and upper management. **Celebrate** successes; learn from the **pilot** and apply in other projects. (Handfield et al., 2001) • **Competence** acquisition, change of mind necessary. Evolution of company **culture** and interaction with stakeholders (Stevels, 2001) • Identification of the organisational change field, and consistent management behaviour. Key implementation factor: **goal setting, knowledge** development, adequate **resourc**es, anchoring at all levels, and focus on **individuals**. Action learning for knowledge and skills building**. Commitment** to desired change must be created to make sure changes are accepted and durable. (Ritzén, 2000) • Demonstration **pilot** with **external experts** support, bringing expertise and help in the initial change; focus on R & D department, involving other functions (Le Pochat et al., 2007) • Need to develop an "ecodesign mentality", involving **motivation**, commitment, **learning**, education and creativity; importance of high and middle management support (Tingström, 2007) • Initial and sustained **motivation**; "environmental **champion**s" and **engagemen**t of senior management (Bhamra, 2004) • Conceptual ARPI framework (Analyse, Report, Prioritize, Improve) aims to break some common **organisational barriers**. Environmental **Champions** have a **training** and awareness-raising role (Simon et al., 2000)

3.3 Bringing additional knowledge from change management literature into the specific challenge of ecodesign integration

In order to consolidate and complement previous findings, a wider qualitative review of literature on change management brought additional knowledge from social science theories to give rise to novel insights applicable at firm level.

Promoting change in organisations is recognised as complex task, as seen through failure rates of change projects estimated between 50 and 80% (Ford and Ford, 2010; Verhulst, 2012; Vladimirova, 2012). According to Boks (2006), change management has mainly to face individual and organisational resistance to change processes. As a key concept from organisational studies, the "status quo bias" states that people are reluctant to change because the disadvantages of leaving the current situation appear larger than the advantages of the change. More recently, social scientists have brought new insights on behaviours to overcome such barrier seen as a key challenge and opportunity to evolve to a successful change (Ford and Ford, 2010).

Several authors tried to bring organisational change management approaches to sustainability programmes, using the Change Wheel Model (Kanter), including nine drivers, or the Morgan Model, based on three essential steps: change intentions and attitudes; define and shape target behaviours; structure means to obtain the behaviours. In her review, Vladimirova (2012) compared different models addressing the process of change (How). The original model from Lewin is still the major reference but should not be seen separately from the other three elements which comprise his "Planned approach to change", i.e. Field Theory, Group Dynamics and Action Research (Burnes, 2004).

Verhulst´s (2012) study of the human side of sustainable design implementation from the perspective of change management approached change at an organisational level, though she recognised that such evolution would also require changes in behaviour on a personal level. Organisational change management intends to take an organisation through the transition from today to a new future state. A successful enterprise transformation requires a holistic and systematic approach that crosses organisational boundaries and integrates viewpoints of multiple stakeholders, methods, and tools (Vladimirova, 2012). If sustainability perspectives call for such strategic transformative change, to fully address the complexities of such evolution it is necessary to consider several dimensions, including content, context, and process. Vladimirova (2012) proposed three models to address the content (What), such as the second-order change from Levy, (1986) and Mintzberg´s change cube of 1998. More recently, the business transformation model (Bititci, 2007) comprehends eight necessary business components: value streams, strategy, organisation, people, processes, systems and resources, leadership and performance measurement.

From this overview, three main implications can be proposed. Firstly, though some convergence in general principles can be seen (transformative process, necessity of a systemic/multilevel approach involving organisational and individual dimensions), there is still a lack of consensus on how to plan and implement such change process at firm level for sustainability integration. Secondly, the

behavioural dimension (e.g. expectations, intuition and judgment, individual decision-making processes, biases, power conflicts) has scarcely been studied for ecodesign integration (Szeler & Melberg, 2014), which was confirmed by the content analysis presented in section 3.2. Thirdly, there is still a lack of prescriptive methods applicable for organisations, which could guide the introduction of sustainability concerns.

Looking at the individual dimension, recent works from psychological experts have highlighted opportunities of using behavioural theory for policy-making, in order to encourage lifestyle change considering sustainability requirements. A new approach named "green nudges" has emerged.
Nudging refers to new types of incentive strategies, capable of leading individuals to make choices in the collective interest, without being seen as prescriptive or guilt-inducing (Oullier et al., 2011; Selinger and Whyte, 2010; Thaler and Sunstein, 2008). This approach makes use of shortcomings or "biases" in human decision-making or non-rational choices. A wide range of influences can affect decision-making and guide behaviour, but there is no formal guide on how to apply the influences and the execution in different contexts.

No previous study has been found using nudging techniques to influence professional attitudes and choices in the direction of sustainable innovation. Such an approach of using behavioural knowledge, including green nudges, could be an original route towards encouraging ecodesign integration at individual level.

An initial original experiment of green nudging in a private company context was conducted in 2013 in cooperation with the Technical University of Denmark (Brones et al., 2014). Employees´ motivations in combination with behavioural influences were tested, in order to positively affect the intention to practice ecodesign. The study helped better identify the gaps and challenges for broader ecodesign diffusion at individual level, and showed the complexity to lever and measure individual intentions – and even more their real behaviours.

However, such approach may be necessary to turn change strategies more effectively in complex business and human organisational situations, where management styles evolve and rely on more autonomous individuals and teams. The study concluded that further research and application on sustainable changes would benefit from considering individuals' engagement, including behavioural aspects, interaction with project teams and higher level business organisations.

Acknowledging the challenges identified for positively applying change management strategies to promote sustainable practices at firm levels, recent social theories coming from wider sustainability studies can help fill such gaps, as proposed in next section.

3.4 Transition Management, a complementary approach for sustainability challenges

The concepts of transitions have initially been developed for large-scale socio-technical systems like energy supply, transport, etc., motivated by public policies toward sustainability in Europe. A comprehensive review on transition studies showed such development within the last fifteen years, with a new field of

"sustainability transitions" represented by up to 100 scientific papers per year, and Transition Management (TM) as one of the main strand (Markard et al., 2012).

The Dutch TM concept was rooted in the complex systems theory and recent social models, and originated operational principles both descriptive and prescriptive. TM was designed to deal with key problems observed in sustainability transitions (complexity and distributed control; short/long term; danger of lock-in; political myopia) in an integrated way. TM is based on complementary elements: 1) development of long-term sustainability visions and overarching joint strategies, 2) organisation and mobilisation of a multi-actor network, execution of projects/experiments, and finally 3) monitoring and evaluation as inputs to the collective learning process (Kemp et al., 2007).

Few pioneering companies have reported to move beyond traditional Corporate Social Responsibility to transform their value chains and markets along with their internal organisation. Such a systemic perspective on transformative business strategies is so far lacking in the literature (Loorbach and Wijsman, 2013). It is proposed here as a useful and original source toward a more effective ecodesign integration.

3.5 Towards an ecodesign transition framework

The intended synthesis of different knowledge areas is represented in Fig. 3, with the necessity to determine how TM approaches could address ecodesign integration challenges. A deeper understanding of sustainability transition gave rise to TM as a governance approach including a framework for experimental implementation. TM is based on a central multi-level concept that describes the dynamics of a transition as the interactions between strategic, tactical and operational levels. One of the claimed advantages of TM is the possibility to bridge the gap between top-down planning and bottom-up incrementalism, through new types of interaction and cycles of action and learning, with a deeper stakeholder management (Loorbach and Wijsman, 2013).

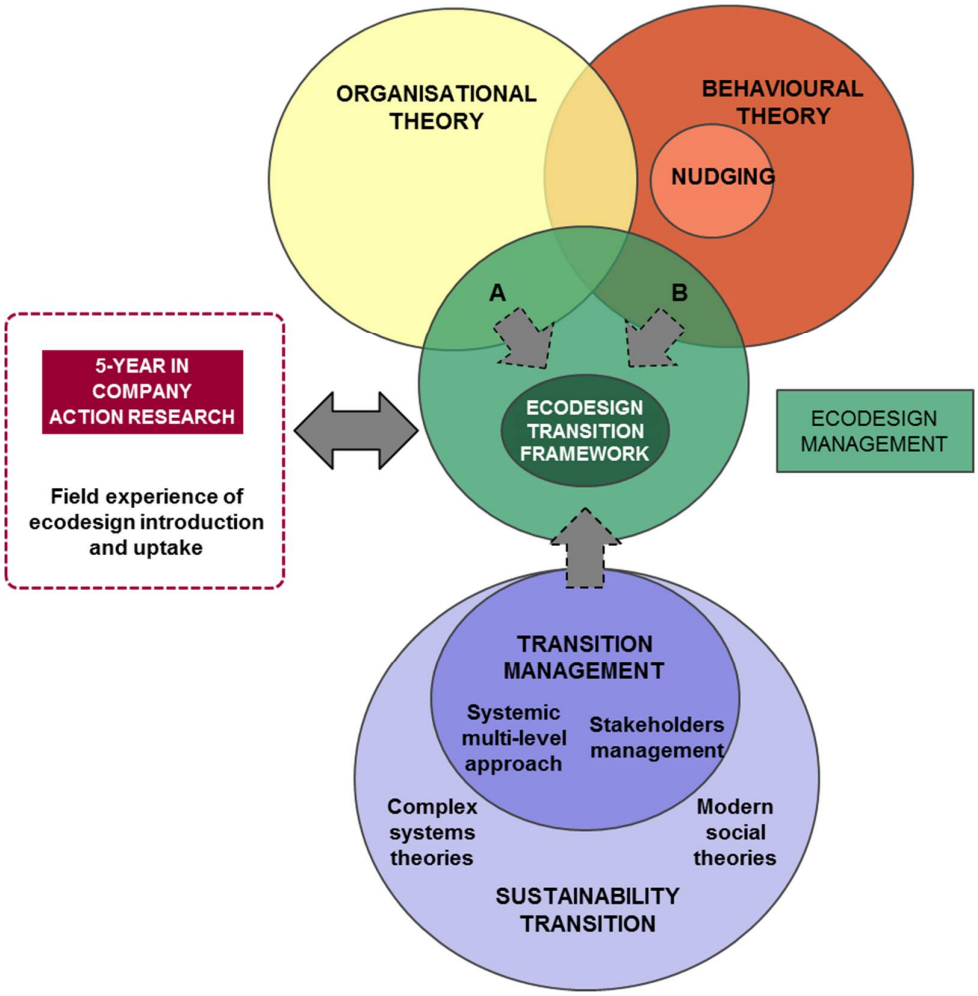
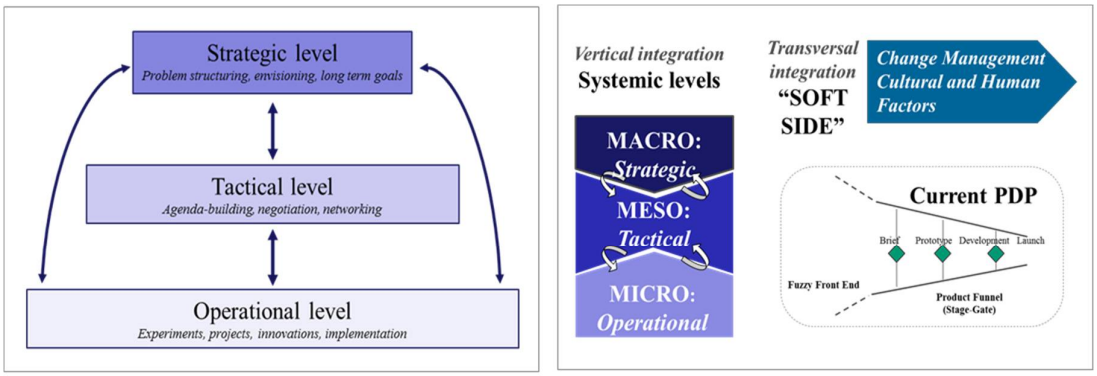


Fig. 3. Joining several change management approaches for ecodesign integration. A, B: "soft side of Ecodesign"; A: sociological - organisational approaches; B: psychological approaches

Interestingly, the principles of TM present high convergences with the ecodesign integration model previously elaborated (Brones and Carvalho, 2015), based on a synthesis of ecodesign literature and previous field experiences, as represented in Fig. 4. This framework associates the same three systemic levels (macro/strategic, meso/tactical and micro/operational), calling for complementary top-down senior management supported activities and bottom-up initiatives conducted by field teams, and a complementary transversal axis focusing on change management and the "soft side" of ecodesign.



Multilevel approach in transition management (Kemp et al., 2007)

Full ecodesign integration model: Combining vertical and transversal integration axes into the existing PDP (Brones and Carvalho, 2015)

Fig.4. Systemic multi-level approaches from transition management and ecodesign integration

Thus both models share the multi-level principle, same three levels definitions (strategic, tactical and operational) applicable in company context, and the complementarity of top-down and bottom-up transformation dynamics. Another strong similarity is that both approaches were developed through action research.

Hence, building on such coherent and synergies between TM principles and the conclusions from previous studies on ecodesign integration, a framework was progressively elaborated, complementing and refining previous propositions (Brones and Carvalho, 2015). This proposition could help fill the gaps found on earlier attempts to bring change management notions to the challenges of ecodesign implementation, and could be applicable to organisations interested to promote ecodesign implementation, oriented on the soft side (organisational and behavioural).

Table 4 proposes an adaptation of TM approaches applied to the context of product development challenges in a company background. TM at Strategic, Tactical and Operational levels (left column), translates into general principles and activities and needed capabilities described in the three central columns (Loorbach, 2007). These recommendations were converted into a series of principles applicable for the more specific purpose of introducing environmental concerns into product innovation related activities at firm level, as summarised in the right column. These guidelines were formulated in order to help a company build its own pathway toward a more sustainable product innovation. The main topics have been labelled through five key constructs in order to encapsulate and facilitate memorisation of the proposed principles: Planet at the strategic level; Public and Programme at the tactical level; and Pilot and People at the operational level.

Thus, this set of principles were developed within the whole action research to compose a full "ecodesign transition framework" (ETF), to complement previous findings and propositions that addressed the technical aspects of ecodesign integration. Besides summarizing the key findings from multistep literature reviews presented in the previous sections, this proposition of TM principles was also applied in the company field study, within the empiric part of the action research undertakings, as shown in the next section.

Table 4
Transition Management Principles adapted to ecodesign integration

Level	TM principles	TM activities & capabilities	PATHWAY: applying transition principles into ecodesign integration	
Strategic Defining corporate and long term objectives in innovation and environmental sustainability, based on life cycle thinking principles	Problem structuring, envisioning, long term goals	System thinking Envisioning Creativity Communication and network skills	**Planet**	• Define or update the long term ambition of the organisation in environmental sustainability • Align Product innovation strategy with the environmental ambition • Monitor the long and midterm plan, and maintain coherence between corporate vision and business processes
Tactical Deploying and piloting the environmental strategy into the innovation processes and instruments	Translating, agenda-building, networking	Negotiation Coalition building Communication and consensus building	**Public**	• Engage/influence the different groups involved in the deployment of environmental goals and procedures (middle management)
			Programme	• Formalise a plan for progressing toward a higher integration of environmental sustainability within Product innovation processes • Monitor and evaluate results, progresses and gap.
Operational Applying ecodesign principles into all related activities for decision making and product performance	Experiments, implementation, mobilising actors	Learning and communication Project Management	**Pilot**	• Adapt and experiment ecodesign tools and practices to company culture in pilot projects
			People	• Engage the different groups involved in product development to understand and apply ecodesign principles and tools (internally and externally/ supply chain and innovation partners) • Capacity building and associated monitoring

4. Action research results and analysis

During the initial planning of the applied research programme, the development and implementation of more structured ecodesign practices inside the company were initially perceived as essentially technical objectives and tasks. However, during the programme execution, the diffusion challenges rapidly came out as key challenges for the success of the initiative. Corroborating the statements from the promoters of the soft side of ecodesign as indicated in the literature and as confirmed through several exchanges with specialists from Brazilian and European universities, the change management dimension called for a greater attention than initially expected.

During the five years of the programme, resources from previous experiences reported in the literature as well as more theoretical principles were used to promote the adoption of ecodesign, bringing a return on experience of such principles. The Transition Management approach and format presented in the previous section appeared to be suitable to structure and report such efforts, as shown in Table 5, which recapitulates the main ecodesign integration initiatives, conducted in the company within the two cycles of the implementation programme.

Cycle one was more focused on tool creation, to complement the existing quantitative environmental calculator used since 2010, with an expectation of progressive and voluntary adoption of the new tools and practice based on positive results. Such options were chosen considering an early phase of analysis of current practices and discussion with specialists, and particularly the Ecodesign Maturity assessment realised in 2011 (Pigosso et al., 2013) that formalised strengths and points of improvement of the situation at the beginning of the initiative.

Also, the choice of a more “bottom-up” approach was dictated by the recommendations of the project sponsors from R&D management, and considered the culture of the company and management styles. During this first cycle, no activities were engaged in the “Public” dimension, which can be considered as a weakness, *a posteriori*.

After an intermediate evaluation of the results, realised at the end of cycle 1, cycle 2 was more focused on application and diffusion of the tools developed during cycle 1. This explains why more diverse “soft” initiatives were conducted, together with the fact that the concept of TM for ecodesign gained consistency during this period. The right column referring to cycle 2 shows the broad range of initiatives that were conducted in order to strongly incorporate advanced ecodesign, purposefully covering the three levels and different actors involved in the product innovation activities. Also the nudging experiment helped the organisation get more aware of the limited intake of ecodesign after cycle 1.

Hence, the integration plan included several channels to reach and engage the target groups of marketing and product development, involving intermediary management and giving priority to direct contacts and participative flexible interactions, which must be compatible with each group’s priorities and busy agendas. Different media were used, such as e-learning, diffusion of video material, face to face and group meetings.

Table 5
Ecodesign Transition Management principles applied in the company field study

Level	Key themes	MAIN ECODESIGN TRANSITION INITIATIVES CONDUCTED IN-COMPANY	
		CYCLE 1 (2011-12)	**CYCLE 2 (2013-15)**
Strategic Problem structuring, envisioning, long term goals	Planet	• Support of R&D and directors as sponsors of ecodesign initiative. • Alignment with Sustainability Strategy	• Ecodesign progressively recognised and adopted in the Sustainability Vision and Strategic Plans. • Plan elaborated with high level management to better articulate and deploy corporate goals with New Products Portfolio within Business Units.
Tactical Agenda-building, negotiation, networking	Public		• Ecodesign diffusion challenges considered with Development Managers and Innovation directors and innovation top management aiming at positively influencing users from Development and Marketing. • Collaboration with group in charge of PDP management to incorporate ecodesign rules in PDP with macro guidelines.
	Programme	• Formal ecodesign programme initiated with initial Maturity assessments and intermediate reviews, with a technical team and budget. • Initial focus on tools, customisation • Collaboration with external experts.	• Formal Ecodesign programme continued. • Focus on capacity building, dissemination and engagement. • Maturity assessments and final review planned in end 2015
Operational Experiments, implementation, mobilizing actors	Pilot	• 3 new tools experimented in 2 product development projects. • Collaboration and training in collaboration with an external Design agency	• Ecodesign tools and principles applied in 6 other Development projects, with formal follow-up and support by the ecodesign team. • Ecobenchmarking tool developed in 2015 and applied in Development project as a pilot. • Collaboration and training of external Design agencies partners.
	People	• Interviews and workshops to understand expectations and barriers from Developers and Marketing • Communication activities: ecodesign exhibition (300 + visitants), training courses, lectures with specialists. • Marketing audience seen as more complex to engage.	• Gatekeepers training with focus on motivation (but with limited results). • Emphasis on diffusion activities: e.learning material and course; networking; mini exhibition on tendencies for ecodesign. • Nudging workshops and experiment conducted in 2013.

5. Discussion

This exploratory research has led to combine TM principles with a systemic ecodesign integration model to elaborate a promising "ecodesign transition framework" (ETF). Such approach was not reported in previous literature, which was confirmed by a search in Scopus database, where no article was found combining TM and ecodesign or synonymous expressions. This proposition is seen as a new synthesis of diverse sources from the engineering literature and social sciences, building on similarities and complementarities.

Adapted TM principles are expected to permit analysing and influencing the evolution of innovation practices considering sustainability requirements in a more effective way than former change management attempts, as observed in the review of the literature and published models. In fact, TM approach was cited in a recent review on sustainable innovation, but was considered as unsuitable to a company context (Verhulst, 2012). Based on a new and deeper exploration into the field of TM, which has recently extended over from the initial application on larger societal systems (like cities or regions), a different conclusion can be stated, that TM principles can also be applied at firm level.TM brings a new management approach, with a framework for 'guided evolution', seeking to balance emergent changes, bottom-up innovation, guiding visions and collective agenda-building processes, which can address company challenges (Loorbach and Wijsman, 2013). Also, TM presents remarkable convergence with a previous company oriented systemic synthesis on ecodesign best practices and principles.

Moreover, TM recommendations can be related to broader business management tendencies. Groysberg and Slind (2012) concluded a recent research project that focused on the state of organisational communication in the 21st century, that the command-and-control approach to management is no more viable and that lateral and bottom-up communication has become as important as the top-down one. Such view strongly echoes a trend that emerged in the 1990s, with the 5th Discipline based on systems thinking and organisational learning. Senge and Sterman (1992) have identified the development of new modes of organisation, more flexible and less hierarchical and authoritarian, giving increasing space to individual decision-making and innovation. Managers were advised to become 'systems thinkers' as well as better learners, forming collaborative action research partnerships to develop new tools to accelerate learning. Applying those tools embedded in systems thinking in real organisations would convert companies into learning organisations (Senge and Sterman, 1992).

The parallel field observations inside the company also influenced the emergence of the ecodesign transition framework. For example, a potential effective concept that arose from the nudging experiment and behavioural background was to look at the company organisation from a different perspective, considering each target group (marketing leaders, product development, internal and external designers groups etc.) with the following question: through whom and how could this group be positively influenced to adopt new ecodesign practices? Thus the necessity to combine bottom-up and top-down integration became more obvious, and the most adapted approach was to identify influencers and try and involve them to reach the main final users (Product Developers, Marketing Managers and Designers).

Also, along cycle 2 implementation phase, within the debates with Innovation and Sustainability Managers on how to promote more sustainable practices and accelerate reduction of environmental impacts, many decisions expected to be part of a classical product ecodesign approach were widely discussed at portfolio level (choice of more eco-friendly material, refill options, etc. for future projects). Such tendency reinforced the perception that the intermediate tactical level considered in the ETF was quite relevant, though very few studies have approached this side of ecodesign integration (Brones and Carvalho, 2015).

Interestingly, the set of change management approaches in the ETF, emerging from the TM principles and field experience, may contribute to address the most important obstacles reflecting social-psychological obstacles identified by Boks (2006): the gap between proponents and executors, organisational complexities, and unwillingness to cooperate.

However, it is worth noting that after almost completing the second cycle of the initiative in the company, ecodesign integration is still seen as a complex, challenging and slow evolution even in a quite favourable context where sustainability issues are strongly recognised within the company strategy. Hence, even if the observations reported from the company´s experience are consistent with the main success factors and obstacle identified by Boks (2006), the integration was still a progressive evolution, presumably limited by second order barriers, associated with classical change challenges, such as prioritisation issues, individual and collective interests and concerns, or “organisational entropy”.

Nonetheless, the company´s maturity in ecodesign seems to be consistently evolving, as part of a series of activities to consolidate its leading role in the Sustainability arena, involving corporate initiatives and product innovation. Such engagement characterises what Loorbach and Wijsman (2013) call “frontrunner businesses”, which explore such transition experience and thus could take a favourable position in sustainable markets and develop a competitive advantage.

At the same time, from a more global perspective, this scenario could be part of the answer to the need for a ‘triangle of change’, as argued by Tukker at al. (2008a), in which businesses, consumers and governmental policies perform their complementary roles. Such systemic transition in society would mean a discontinuity in production and consumption patterns which is a central challenge for Sustainable Operations research.

6. Final considerations

The main contribution of the research covered in this article, combining multistep reviews and action research and learning, is a novel ecodesign transition approach and framework for managing the soft side of ecodesign integration.

The construction and application of an ETF, as presented above, has permitted to materialise the need for a more structured change management approach applicable to ecodesign, missing from previous publications. This framework includes five key constructs (Planet, Public, Programme, Pilot, People) proposed to compose a

Transition Pathway in a systemic perspective including the three essential levels (Strategic, Tactical and Operational) and synergising bottom-up innovation and top-down planning.

In the new context of businesses facing Sustainability challenges, where management practices nowadays give more space to individual and team autonomy versus directive processes, the application of such TM principles for ecodesign integration could permit fostering more effectively sustainable changes, considering individuals' engagement, including behavioural aspects, interaction with project teams and higher level business organisations in a multi-level approach. Thus, the possibility to more successful and global integration of ecodesign in product innovation processes of companies could be facilitated.

Such research, bringing knowledge from social science, has tried to consider the real complexity of businesses as human organisations, and recognised the importance to give to "soft" issues and the probable necessity to use "softer" change management approaches. As Ehrenfeld (2008) argued, the sustainability challenge for business is to adopt a new set of values and beliefs, facing inherent firms' conservative cultural system, which may represent one of the main resistances to change.

The ecodesign transition approach was proposed as a logical application and adaptation of the TM principles, building on its systemic structure, and has appeared as a useful instrument to organise, deploy and monitor soft aspects of ecodesign integration, both organisational and behavioural. Transition cycles, as experienced in the company context, can be translated into flexible and polyvalent planning and application principles, which could be adapted and applied in diverse specific organisational configuration, in different companies, sectors and countries, considering cultural specificities. For example, the dosage of top-down and bottom-up integration efforts should definitely be chosen according to each company context.

Such adaptation will be necessary to overcome the limitations of this research, based on qualitative exploration and in-company observations. The diverse specific organisational contexts will certainly modulate how such observations and strategies may be applied. Noticeably, this study is also limited by the single company context, acknowledging that it is the condition to access a business organisation from inside and to have the possibility to really experiment new solutions in a long period of time.

On-going research will consolidate, formalise and operationalize the diverse aspects of ecodesign integration, both hard and soft, into a complete and coherent "ecodesign transition framework" in order to further contribute to more sustainability integrated product innovation processes. Hopefully, such participation to expand knowledge in Sustainable Operations may be a useful contribution to broader transitions in society.

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PUBLICATION # 5: Ecodesign Transition Framework toward companywide sustainable product innovation

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ABSTRACT

As corporate sustainability becomes a fundamental concern, most companies have to incorporate environmental requirements into their processes, and ecodesign has been argued as a central avenue for such integration into the innovation process. However, thorough ecodesign implementation is still a substantial challenge for most firms. This paper explores a full action research designed to study how to evolve toward broader integration of ecodesign considering both technical and "soft side" - aimed at organisational and human aspects - through a five-year long experiment within a leading Brazilian cosmetics company, involving two main implementation cycles. The outcomes of these cycles are analysed including customisation of ecodesign tools and related application, and views and behaviour of different stakeholders. As a result of broad reviews of previous literature from environmental, innovation and change management (including more than 50 ecodesign models) combined with field observations, an "Ecodesign Transition Framework" was elaborated. The so-called "15Ps ETF" associates within a systemic three-level structure (Strategic, Tactical and Operational), two complementary perspectives: Eight constructs of a mature ecodesign Pattern (Purpose, Portfolio, Process, Platform, Pipeline, Practices & tools, Procedures and Project management); and a complementary Pathway module based on five key constructs (Planet, Public, Programme, Pilot, People) for conducting the necessary transition, engaging stakeholders, and synergising bottom-up innovation and top-down planning. This new framework intends to support a far-reaching approach to better plan, implement and monitor the integration of environmental considerations in the whole innovation process of a company, through a systemic action learning process for sustainable change.

Keywords: Ecodesign, product development, change management, transition, sustainability.

1. Introduction

Sustainability has become an essential topic to most companies, and has gained increasing attention from scholars over the past two decades. Tukker et al. (2008) called for the need for a 'triangle of change', in which businesses, consumers and governmental policies would perform complementary roles. Concomitantly, a broader integration of sustainability criteria in business processes has developed over another trinomial composed of Business Management, Operations Management (OM) and Innovation Management.

From the business perspective, corporate sustainability has evolved from expressing good intentions and looking for internal operational efficiencies to addressing critical business issues, and sustainability concerns have become more global and pivotal to the success of most companies (Kiron et al., 2015).

Longoni and Cagliano (2015) agree that sustainability issues are becoming key competitive priorities for companies, but the way in which they are integrated in operations strategies remains an open issue. Similarly, Drake and Spinler (2013) discussing why sustainability is gaining growing interest, argued that sustainable OM potentially has an important role to play in contributing to solutions for the sustainability challenges that our society currently face, since firms' OM decisions are principle contributors to anthropogenic effects on ecosystem. Achieving a sustainable society will probably require changing how all our products and services are manufactured and delivered (Lovins, 2008).

The OM literature, at the intersection of product design and sustainability, has the potential to focus on such design choices (Drake and Spinler, 2013). As product design is said to be central to the success of most companies (Ulrich, 2011), Alblas et al. (2015) have called for further research on sustainability and New Product Development (NPD) processes, or how to manage sustainability proactively rather than reactively. Vogtlander et al. (2013) even claimed that big companies have a moral obligation to our society to accelerate the greening of their products.

In this context, ecodesign (also referred to as sustainable design, environmental design, environmentally conscious design, etc.), dealing with the integration of environmental aspects into product design and development (International standard, 2011), has gained increasing interest in recent years. But the application of this concept is still rather narrow, as recognized by a recent report (European Commission, 2014).

Despite a vast academic literature, technical ecodesign principles still represent a substantial challenge for thorough implementation into most firms' innovation processes, as indicated by recent surveys and studies (Brones and Carvalho, 2015; Wolf, 2013). Also, reports of long-term experiences in the industry, supported by systematic application of ecodesign at company level, are missing in the literature. Moreover, such integration challenge involves not only the technicalities (hard

side), but also the more recent “soft side” of ecodesign studies, aimed at organisational and human aspects addressing necessary changes (Boks, 2006).

Considering this scenario, this paper synthetises a research conducted in order to propose a framework for broader integration of environmental sustainability into industrial product innovation. Action Research (AR) methodology was chosen for the purpose of studying how to holistically promote ecodesign integration into the whole product innovation process of a Brazilian company. This method was also recommended to deepen the change management dimension in OM (McDermott et al., 2008), identified as a central issue in ecodesign implementation with limited previous research.

Along the research, new theories have been considered, addressing sustainability transitions - defined as long-term and multifaceted transformation processes through which socio-technical systems shift to more sustainable modes of production and consumption (Markard et al., 2012). Transition Management (TM) principles have been built on the complex systems approach, new forms of governance and social theory, and were translated into descriptive and prescriptive models (Kemp et al., 2007). Though only emerging for company application purpose (Loorbach and Wijsman, 2013) TM has been integrated in this research, giving rise to an original Ecodesign Transition Framewok.

The whole underlying research combined broad reviews and synthesis of previous scientific literature and recommendations from complementary knowledge areas, and a full analysis of empirical observations of a five-year long experience in real company conditions. This paper presents the proposed framework, supported by a consistent description of how AR was developed and applied, and analysing a large set of empirical observations and learning from the company experience.

The article is composed of five sections. Section 2 presents the methodology that was developed for the whole research. Then, the main results of the study are presented in three parts, covering the field application, the construction process and the proposed framework (3). The following section (4) discusses the results and propositions, before concluding remarks and perspectives (section 5).

2. Research method

The overall study uses action research – a methodology developed by social scientists since the 1940s (Glassman et al., 2013) as a way of learning about organisations through trying to change them (Lewin, 1946). According to Westbrook (1995), AR is a real new paradigm for research in production and operations management (OM).

In a bibliometric study of 361 articles of the International Workshop Advances in Cleaner Production in 2007, 2009 and 2011, AR was the less frequently used research method, with less than 1% of the publications (Oliveira Neto et al., 2013). Some researchers have observed that AR is not commonly used within the

engineering design research community and hence the associated findings may not be fully accepted (O´Hare, 2010; Miguel, 2011).

In a quick search conducted in Scopus database in July 2013, while AR was relatively well represented methodology (8625 papers), only 79 articles were found combining AR and "product development", and hardly eight papers containing simultaneously "product development" and "sustainability" or "sustainable" expressions with AR. Considering this relative scarcity, the principles and references are developed in the following sections.

2.1 Action Research, an adapted and challenging methodology

AR was considered as the method most adapted to the objectives and context of the research. Firstly, such methodology permits to attend complementary practical and theoretical objectives: to solve a problem and to contribute to theory building (Lewin, 1946). In our case, both interests were shared by the first author, with a dual position as a researcher at the University and within a large company.

Secondly, the research subject and objective conducted to investigate the Product Innovation Process of a company as close as possible from reality. Some previous ecodesign researches have suggested studying such process as a "Trojan horse" - an external observer and influencer inside the company (Reyes and Millet, 2013). However, such metaphor can call attention on the complex relationship that should be considered between researchers and practitioners within the research process (McDermott et al., 2008). AR, if well designed and executed, could allow addressing both objectives and points of view with a more transparent approach.

As a variant of AR recognized in the last decade, Insider Action Research (IAR) describes the process when a member of an organisation undertakes an explicit AR role in addition to the normal functional roles hold in an organisation (Holian and Coghlan, 2013). Such approach was claimed to potentially bring superior value (Williander and Styhre, 2006).

Indeed, AR could offer the possibly to reduce the relevant gap between theory and practice as commonly pointed out in ecodesign literature. However, AR can be seen in opposition with positivist science, mainly because "the principal threat to validity for AR is the lack of impartiality on the part of the researcher" (Coughlan; Coghlan, 2002, p.237), which is balanced by "incomparable potential benefits of deep insight also on causality and the possibilities of experiments on the field" (Karlsson, 2002).

Numerous references were considered in order to elaborate an adapted research method compatible with the previous conditions and objectives and responding to quality requirements, as summarised in Table 1 and described in the following section.

Table 1: Main sources and references for action research and associated methods

Type of Resources	Action Research	Insider Action Research	Other Qualitative Methods
Resources and inspiration for Action Research methodology and history	Burnes, 2004 Cassell and Johnson, 2006 Coughlan and Coghlan, 2002 Feldman, 2007 Glassman et al., 2013 Karlsson, 2002 Lewin, 1946 Masters, 1995 McDermott et al., 2008 McGrath and O'Toole, 2012 Miguel, 2009, 2011 O'Brien, 2001 Singh, 2008 Thompson and Perry, 2004 Turrioni and Pereira Melo, 2010 Westbrook, 1995 Wilson, 2004 Zuber-Skerritt and Perry, 2002	Coghlan, 2007 Holian and Coghlan, 2013 Kumar, 2013 Williander and Styhre, 2006	Boje, 1995 Denzin, 2012 Eisenhardt, 1989 Gephart, 2004 Jick, 1979 Kelle, 2001 McCutcheon an Meredith, 1993 Meredith, 1998 Miguel, 2010 Schultze, 2000 Voss et al., 2002
Resources and inspiration for Action Research application ("benchmarking")	Bhamra and Evans, 1999 Evans et al., 2007 Hallstedt et al., 2010 Miguel, 2009, 2011 Montana Hoyos et al., 2011 Pereira, 2013 Shaw et al., 2001 Simon et al., 2000	Kumar, 2013 Williander and Styhre, 2006	Hargadon and Sutton, 1997 O´Hare, 2010 Stevels, 2007 Verhulst and Boks, 2012

2.2 Overall research methodological approach

The methodology combined general AR principles and specificities from Insider Action Research. AR was described as research in action (Karlsson, 2002), rather than research about action (McDermott et al., 2008), and is characterised by its reflexive, collaborative (or participative) and interventionist nature, and consciously cyclical process (Coghlan, 2007, McDermott et al., 2008; Williander and Styhre, 2006). Also, AR often takes the format of a single case longitudinal field research (Karlsson, 2002).

Fig. 2 represents this original combination in a triangular shape, associating main features of AR (left side of the triangle) organized within the six key principles recommended by O´Brien (2001) as a synthesis of AR guidelines, with three IAR specificities (upper central part), and putting in perspective the main strengths and benefits that can be expected from good IAR (right side of the triangle).

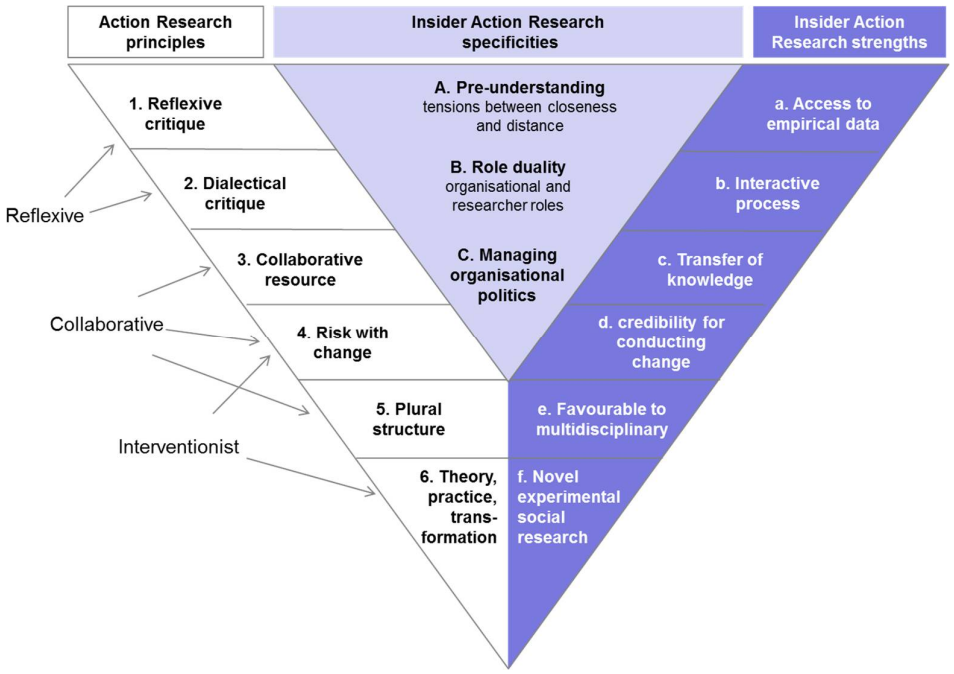

Fig. 2: Relating action research principles with insider action research specificities and strengths

Critical reflection, described by Coughlan and Coghlan (2002) as “the process of stepping back from experience to process what the experience means, with a view to planning further action” (p.235), plays a central role in the methodology. Moreover, the shape of Fig. 2 reminds a key concern in search of stronger internal validity through triangulation (Cassell and Johnson 2006).

The concept of triangulation originates from a metaphor of navigation and military strategies that use multiple reference points to locate an object's exact position (Jick, 1979). Similarly, organisational researchers intend to improve the accuracy of their judgments by collecting different kinds of data, to produce a more complete picture through the integration of different perspectives (Kelle, 2001). Nonetheless, the value of triangulation depends more on the critical interpretation than the number of qualitative data (Denzin, 2012).

In the context of AR and OM, triangulation translates into the attention upon transparency on the objectives and methodology, use of data of multiple nature, reports from diverse actors, within and outside the organisation, without hiding the complexity or contradictions that may occur in the reality of organisations (Turrioni Pereira and Melo, 2010): “Stories and results; self-reflection and learning of the action researcher; reflection on the story in the light of experience and the theory" (Coughlan and Coghlan, 2002, p.236).

The application of these methodological guidelines involves two additional principles. The cyclical approach recalls Lewin´s original view: “a spiral of steps, each of which is composed of a circle of planning, action, and fact-finding about the result of the action” (Lewin, 1946, p.38). Additionally, Couglan and Coglan (2002) described a meta-step of overall organisation and analysis, which is essential for both practical application and academic exploitation. Hence, following Thompson and Perry´s (2004) recommendation for quality AR, two related but distinct views were clearly distinguished – the core in-company field research project and the generalising research project.

2.3 Methodology application and elaboration of the framework

Thus, a full AR approach was designed and implemented as a collaborative study, with parallel research and application objectives, cyclic macro planning, and within each cycle, a “Plan-Do-Check-Act” like process. The overall research design is summarised in Fig. 3 in a chronological perspective.

The whole research project consisted in a five-year-long study associating University and the company - a leading Brazilian cosmetics company, which will be presented in next section - with complementary theoretical and practical intentions, and allowing a change management experiment in real field conditions.

The applied side of the study was conducted in two implementation cycles, led from 2011 to 2015. The main activities of cycles 1 and 2 followed a process of planning and monitoring, for selection, customisation and implementation of ecodesign practices considering both hard and soft sides as will be described in section 2.5 and Table 3.

Along these 5 years, a more theoretical research was conducted in parallel. Combining investigative (through literature reviews) and empirical (AR) analysis, the Ecodesign Transition Framework was constructed following a cyclical theory-building process as suggested by Eisenhardt and Graebner (2007) and Fleury (2010), via recursive cycling among the field data, emerging theory, and existing literature. According to Meredith (1998), field research is recommended for building new operations management theories, as bringing the advantages of high relevance, understanding and exploratory depth.

Following Wacker´s (1998) orientations for theory-building, the research sought similarities and complementarities across different domains to increase the completeness and abstraction level. The findings from previous literature were completed by the empirical action research to develop insightful relationships within company´s observation, and using data to form the conceptual interpretation and construction of the framework.

As will be presented in section 3.2, the framework´s creation resulted from four sources: Three sets of conclusions derived from literature reviews (on ecodesign literature and integration models; change management; and innovation

management) and a fourth source of complementary insights derived from the field AR study.

Within the different sources, the main data collected (content analysis and field data) were classified, clustered and organised using affinity diagram or Kawakita Jiro (KJ) diagrammatic method (Carnevalli and Cauchick, 2008; Mohamedally and Zaphiris, 2009). A bottom-up sorting process allowed transforming dispersed data into information, grouping information into categorical domains, and building on similarities for creating and analysing categorisations of knowledge (Cheng, 2014). This procedure led to the proposition of the framework as a synthesis of the four complementary sources, including the main constructs identified from the reviews conclusions and content analysis and interpreted within the field company experience.

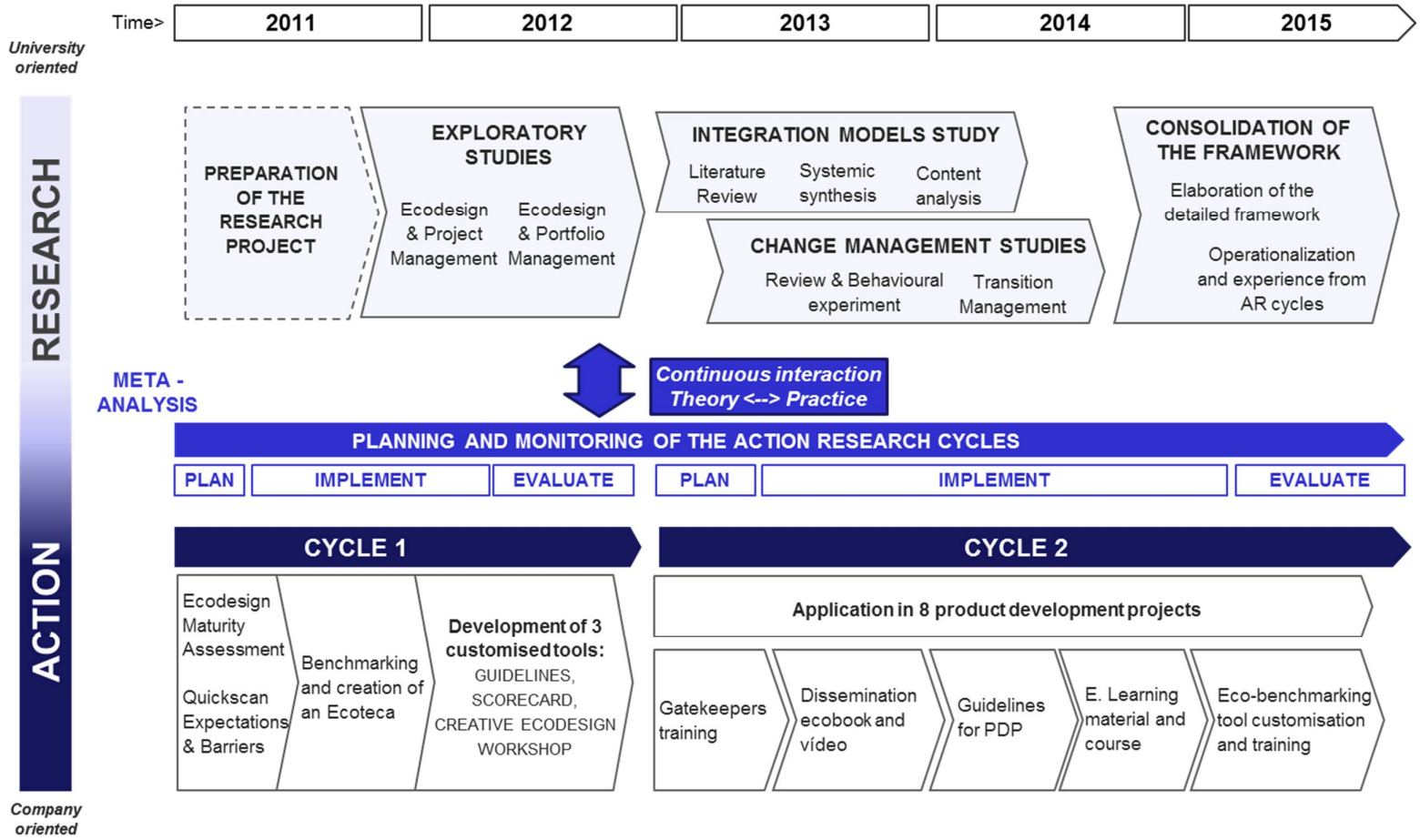

Fig. 3: Overall research design

2.4 Company´s context and profile

The company involved in the research is one of the leaders in the personal care, perfumery and cosmetics sector in Brazil. The company is generally recognised by different types of stakeholders for several features including business performance, innovation and a leading role in sustainability, as embedded in the company´s ethics and identity formalized in the vision, reason for being and values.

Founded in the late 1960s, the firm has shown substantial expansion over four decades by organic growth, and a net revenue superior to 3 billion $ in 2013 with around 7,000 employees. Innovation is the viewed as a main source of value creation within the entire activities and value chain. The business model drives the company to a high level of product innovation and product portfolio turnover (around 30% every year). The company had already implemented many corporate and product initiatives towards the reduction of associated environmental impacts since the 1980´s, but had not yet considered ecodesign in a systematic way. In 2011, an ecodesign research programme was created by the Science and Technology group, to bring new practices into the Product Development Process (PDP).

The company´s PDP, which is internally called the "product funnel", was inspired by the stage-gate model, and was divided in six phases (Pre-Briefing, Briefing, Prototype, Validation, Availability and Evaluation). The ecodesign programme is conducted within a separate "technology funnel", as a part of the Sustainable Technologies portfolio, which is one of the three main research strands of the company.

2.5 Detailed research application

Passing from the general research framework described in section 2.2 to the detailed research application, Table 2 summarises the key principles of the AR activities, methods and references, separating the applied research side (left column) and the more theoretical research side (right column).

For the applied research side, the methodology was directed by best practices that were collected from ecodesign literature and adapted to the company context, with the support of collaborative resources, as described in Table 2 for cycle 1 and cycle 2. The starting point of cycle 1 was a diagnosis based on Ecodesign Maturity Assessment (Pigosso, 2012; Pigosso et al., 2013) conducted in 2011, including more than 15 individual interviews of the main audiences involved in product innovation and sustainability, document analysis, and careful reviews and discussions of the results for triangulation.

Other important activities were directed to tool customisation, and their broad diffusion into the target audience (product development and marketing teams).

For the more theoretical research side, the AR approached followed the six key principles recommended by O´Brien (2001) as commented in section 2.2.

Table 2: Description of the action research application principles and methods used

	ACTION RESEARCH SIDES	
	"ACTION" SIDE (Applied research)	**"RESEARCH" SIDE (Theoretical research)**
OBJECTIVES AND MAIN ACTIVITIES (adapted from Zuber-Skerritt and Perry, 2002)	To incorporate "life cycle thinking" and ecodesign of products more broadly in the company´s PDP to contribute to environmental impacts reductions and product innovation. *Planning, acting, observing, reflecting on professional and organisational practices and learning.*	To demonstrate how to incorporate ecodesign effectively – in depth and widely - into the Product Innovation Process of a company. *Planning and designing the overall research and methodology; confronting the results with theories and previous knowledge; elaborating output usable in other contexts, summarised in a conceptual framework, the Ecodesign Transition Framework*
	CYCLE 1	**6 AR principles adapted from O'Brien (2001)**
KEY PRINCIPLES OF AR AND THEIR APPLICATION	Preparatory activities: • overall detailed diagnosis of Ecodesign Maturity in the innovation process: EcoM2 Model (Pigosso, 2012) • "QuickScan" of motivation and barriers: Participative workshop + individual interviews with open ended questionnaire (marketing managers) • Qualitative Benchmarking: selection of inspiring products; creation of an Ecoteca ("library") of ecodesigned products and explanatory material: Inspiration from Crul et al., 2009 ; Ad hoc method, with multidisciplinary group with support of a design agency	**1/ Reflexive critique** Critical analysis of field results based on facts. Evidence the diverse roles of the author, with transparency even on unexpected or even negative results. Inspiration from ethnographic technics (Hargadon and Sutton, 1997) and "confessional account" (Schultze, 2000).
	Tools customisation: 3 qualitative ecodesign tools, to be used in the company PDP, to complete existing environmental calculator: • 4 phases customisation process (Orientation, Selection, Adaptation and Dissemination), adapted from Ritzén and Lindahl, 2001; O´Hare, 2010. • Guidelines adapted from Vezzoli and Manzini, 2008. • Ecodesign workshop adapted from McAloone and Bey, 2009 and Crul et al., 2009. • Ecodesign trainings with international experts	**2/ Dialectical critique** Confronting theory and practice: systemic literature review of previous integration models. Presentation and discussion of partial results in international conferences: • 4th International Workshop, Advances in Cleaner Production, 2013 • Sustainable Innovation Conference 2013 • EcoDesign 2013 International Symposium • Sustainable Innovation Conference 2014 • 5th International Workshop, Advances in Cleaner Production, 2015
	CYCLE 2	**3/ Collaborative Resource** Collaboration with other Universities and ecodesign and OM specialists in Brazil and Europe
	Gatekeeper training: Ad hoc method, with support of an education consultancy	
	Dissemination supports (Ecobook, Video, E.learning): Ad hoc method	**4/ Risk associated with the changeprocess** AR assumed as a challenging experience in OM. Change management experience containing part of unpredictable situations.
	Principles for introduction into the PDP rules: Inspired from ISO TR 14062 and 14006 (International Standard, 2002 and 2011) and Stevels, 2007.	**5/ Plural Structure** Multiple data for triangulation; detailed facts; evidence for changes observed in the processes (individual and organisational): application feedback; observations and quotes; documentation of the process.
	Customisation of Eco-benchmarking tool: 4 phases customisation process (idem Cycle 1); Adapted from Crul et al., 2009.	**6/ Theory, Practice, Transformation** Action directed by theory and best practices from the literature. Inductive process for interpretation of results; confrontation with previous theories.

3. Results

This section covers the main results of the five-year action research experience, beginning with the in-company results, and then showing the parallel construction of the framework, and finally the application of the framework in the company context.

3.1 Applied action research results

The main results of implementation cycles 1 and 2 are summarised in Table 3 in a critical perspective for each initiative.

Cycle 1 started in 2011 with a series of preparatory activities aiming at prioritizing implementation initiatives, including a formal assessment of the ecodesign maturity profile. The company showed strengths in some strategic indicators (i.e.: Environmental commitment and reduction goals, systematic quantitative environmental impact assessment of all products, thanks to an internal calculator; research and technology support in environmental technologies.). At the same time, a high potential of improvement was identified in some operational and tactical practices of ecodesign, such as the need of internal dissemination and understanding of basic concepts and key practices such as simple guidelines.

Additional "Quickscan" interviews revealed expectations and threats aligned with previous literature (Lindahl, 2006). Moreover, a qualitative benchmarking study conducted to the creation an electronic product library, released to inspire the NPD teams with ecodesign examples and explanations. The material includes a set of twelve customised ecodesign focal areas, with visual iconic representations, composed of six main ecodesign practices, selected to influence six environmental impact categories which symbolise the main environmental sustainability principles for product design. The content was successfully diffused internally through an ecodesign exhibition, with over 330 visitors and positive feedbacks.

Then, a set of four new ecodesign tools was customised to the company context and to complement the existing quantitative environmental calculator used since 2010 – three of them during cycle 1 (ecodesign guidelines; scorecard; original procedure combining ecodesign technical principles with creativity based on design thinking practices) - and an eco-benchmarking tool, during cycle 2.

The guidelines were based on six general practices of ecodesign derived from Vezzoli and Manzini (2008), one of which was substituted to adapt to the cosmetics context. These six practices were deployed on a second level into 28 technical design principles that can be applied to cosmetic product content, packaging and product system as a whole.

Complementing this prescriptive tool, the Scorecard was developed to allow assessment of environmental impacts of the life cycle of products in development in the form of a simplified calculator. Thus, this tool brings a broad life-cycle perspective within a semi-quantitative and comparative approach applicable in the early stages of the PDP.

The third tool, called “Creative Ecodesign Workshop” (CEW), consists of an original multistage ecodesign procedure for training and practicing ecodesign in multifunctional teams of NPD projects. Initial experimentations showed that this activity must take place during the earlier phases. The two-day CEW integrates technical tools based on lifecycle engineering approaches and creative practices of Design Thinking. This initiative was recognised by an IDEA Brasil 2014 award, in the strategic design category.

Cycle 2 was conducted from 2013 to 2015, with the main intention to consolidate and broaden the implementation process at company level. Additional diffusion activities were prioritized with NPD managers, including different capacity building formats and process guidelines. These rules define the recommended ecodesign practices within the specific company PDP specifications, considering practical aspects such as: Types of activities recommended at each phase of the Funnel, roles of the different team members, tools to be used. They also differ on the different project types, following a categorisation already used in the company, based on project complexity and impact.

Additionally, a technical support was directed to apply the ecodesign practices to eight product development projects, as represented in Fig. 4, covering the different business units and products categories. A high number of quality concepts and ideas produced during the CEW for all the projects, and the team members gave favourable final evaluation of the approach. Two ecodesign application cases were produced which, however, represents only 25% of the projects still alive after the internal project selection process.

Hence the results present positive observations of concrete applications confirming that the tools, practices and diffusion strategies were adapted to the company context thanks to the customisation and dedicated support. Nonetheless, many challenges were also faced reflecting the difficulties to find the right diffusion channels and to reach the different audiences. This dialectic progression also fed the maturing of the associated theoretical reflection, as presented in the following sections.

Table 3: Main activities and results analysis in cycles 1 and 2

	CYCLE 1						CYCLE 2					
ACTIVITIES	**PREPARATORY ACTIVITIES**			**3 TOOLS CUSTOMISATION**			**Gatekeepers training**	**Diffusion materials: ecobook and video**	**Guidelines for PDP**	**E. learning**	**Eco-benchmarking tool**	**Application in 8 product development projects**
	EcoM2	**Quickscan exp. /barriers**	**Ecoteca**	**Guidelines**	**Scorecard**	**Creative Ecodesign Workshop**						
POSITIVE RESULTS	Useful to orientate technical activities and create internal knowledge			Effective customisation process			Creation of an original format of training based on the ecodesign tools and participative exercises. Positive feedbacks from the participants (mainly Development).	Original and appreciated materials created. Strong visual identity.	Necessity of such support identified during implementation, to define use of the tools, roles and outputs along PDP. Involvement of Innovation management team.	Didactic material created for easy diffusion. Re-use of previous materials (Ecobook and video).	Complementary technical tool. Interest from Marketing public as connected to market issues	Positive replication of CEW to 5 new projects with rich production and highly favourable evaluations. Development with eco-concepts in all the active projects after CEW. Coherence with PDP and Environmental calculator confirmed.
	Objective diagnosis of the current situation; multi-dimensional assessment ; confirmed most perceived necessities	Results in line with literature: expected improved company & brand image, and cost reduction. Threat: increase project cost and time to market	Useful exercise and material; Well received, turning ecodesign more intuitive and visualising application to different audiences	Classic and useful instruments; format well accepted and integrated in the CEW	Useful in the convergence phase of the concept creation, with a multi-criteria principle	Most original of the 3 tools; very positive results in tests. Capacity building and application in projects						
CHALLENGES	Roadmap not obvious to define; May benefit from synthesis by sub topics	Declarative results may be questionable resistances; difficult to access resistance	Time consuming work Need future update with faster production process	Need more examples; More detailed or specific version maybe necessary	Need improvement; broader application; Adapt to more complex products	Improve the recording of the all production and results. Need broader dissemination into Business Units (BU)	Involve other functions (e.g.: Supply). Increase time to applied activities such as Role Play. Limited visible results.	Time consuming activities with only indirect benefits	Non-compulsory rules have limited effect. Need to engage management and team with other strategies.	Application not guaranteed to all target public as non-compulsory in company culture. Low adhesion from Marketing audience (BU).	Initial implementation phase only; need time to disseminate and integrate into PDP	High proportion of projects stopped for Company or Portfolio reasons, reducing potential of visible results. Long all-over time-to market delays business benefits demonstration.

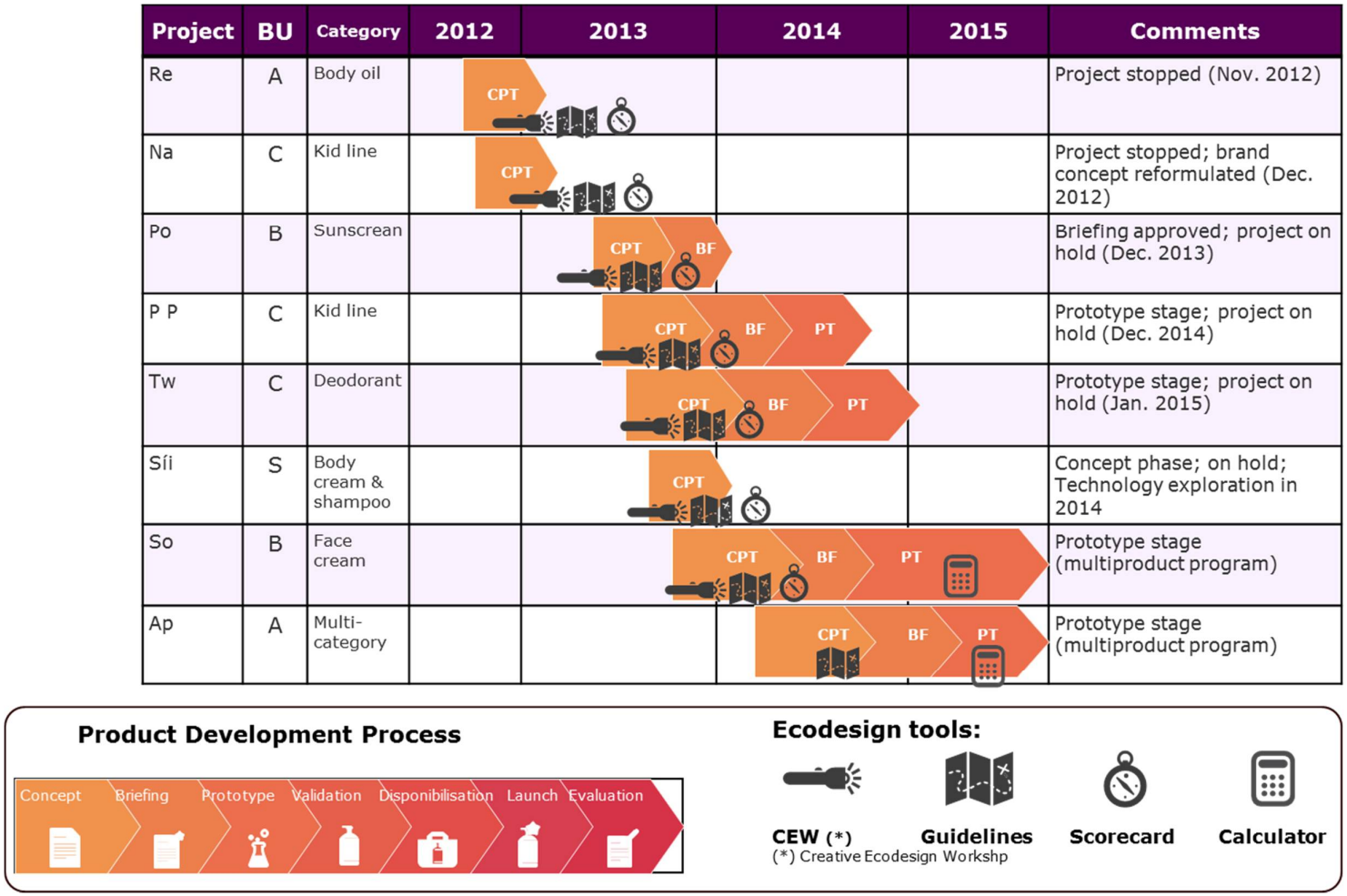

Fig. 4: Overview of ecodesign application in 8 development project

3.2 Proposition of a conceptual framework, the 15Ps ETF

As introduced earlier, along these five years, a theoretical research perspective was developed combining analytical (through literature review) and empirical (AR) theory-building procedure that led to the proposition of the ETF. The construction of the ETF in a step by step process, aiming at building and testing a new integration model, explored the potential of the action research method. Fig. 5 represents how four main sources were developed in order to elaborate the proposed framework.

First, an initial systematic literature review revealed three gaps pointed out from previous studies: Need to develop the soft strategies and especially change management aspects (Boks, 2006); necessity to consider the whole innovation process (Goffin (2012); and need to better relate the general recommendations to business field reality (Deutz et al. 2013).

Within this important first step, a systemic synthesis of previous ecodesign literature and integration models from a systematic review from 1993 to 2013 brought the foundations for the framework (Brones and Carvalho, 2015). Other recent publications present convergent conclusions and propositions (such as the 3-level system from Zhang et al., 2013), but with a more limited scope. From this source emerged the three levels of the ETF (strategic, tactical and operational), as represented in Fig.6.

The second source was composed of a multistep literature review of the soft side of ecodesign management. Substantial convergence and complementarity was revealed between the previous conclusions on ecodesign integration models and the emerging Transition Management (TM) approach designed for sustainability issues facing organisations. This source conducted to discriminate two main blocks in the ETF: a central “pattern” that will represent a mature ecodesign structure; and a “pathway” component for conducting the necessary transition addressing soft side requirements. The constructs of the transition process were also developed with the findings of this part of the research, including the cyclical planning and stakeholders management, and detailing the complementary bottom up and top-down integration processes.

The third source derived from qualitative reviews and exploratory searches on Product Innovation management, in order to fill a knowledge gap with sustainability management (Goffin, 2012). Product innovation, described as a complex and multi-facetted business process at the interface between the company and its market (Rozenfeld et al., 2006), requires formal NPD procedures to enhance innovation and business performance (Goffin and Mitchell, 2010). Similarities have been observed between several PDP models (Katz, 2011, Larsson, 2007) with a consensus on general recommendations associated with the stage-gate models (Cooper, 2008), or complementary Product Development Funnel (Clark and Wheelwright, 1992). Further PDP best practices and associated instruments, such as portfolio and pipeline management, and their links to strategy and project concerns completed the construction process (Larsson, 2007; Ulrich and Eppinger, 2004). Such considerations brought a clear insertion of the PDP (stage-gate based) at the centre of the ETF, with its articulation with other complementary management instruments (Strategic Planning,

Portfolio, Pipeline, Technological Platform) and linking with the more operational activities at the bottom of the "pattern".

Complementing the three previous theoretical foundations, a forth source of inspiration came from the in-company observations, where the ecodesign tools customisation approach was applied, and the dynamic integration process experienced to address company complexity, and considering internal factors such as culture, resistance to change and "organisational entropy". This field served as a laboratory for ecodesign integration, and was a useful screen to select the relevant constructs and their concrete expression as far as environmental considerations are concerned, in addition to classical innovation requirements (quality, cost, time to market).

Thus, the proposed descriptive and prescriptive model was progressively refined integrating inputs from the indicated knowledge areas and company experiences, and was finally named "15Ps Ecodesign Transition Framework (ETF)", as represented in Fig. 6.

This model combines three main elements: The systemic multilevel structure; eight main constructs of a mature ecodesign "pattern"; and a "pathway" component for conducting the necessary transition addressing soft side requirements, with five constructs.

The overall three-level construction can be remembered as an "Aztec pyramid" shape symbolising the strategic, tactical and operational product related undertakings, inspired from Larsson´s (2007) broad perspective, integrating different activities up to the entire business planning. A classical PDP stands at the centre of the figure, combining a funnel shape and a multi-stage sequence. Based on such commonly recommended process, the inclusion of ecodesign tools is also symbolised as a key (but only partial) feature of ecodesign integration.

Eight constructs of this mature pattern link the overall activities involved in the whole product innovation process, from strategy to field application, namely: Purpose, Portfolio, Process (PDP), Platform, Pipeline, Practices & tools, Procedures and Project management.

On the left side of Fig. 6, the need to combine both top-down planning and bottom-up innovation to link the complementary three levels is represented, which applies both to the mature pattern (central part) and to the transition pathway.

This right part of the framework refers to the integrated Transition Management approach based on five key constructs (Planet, Public, Programme, Pilot, People) proposed to compose the main soft side of the change process, necessary for integrating environmental concerns in a systemic perspective. Such transition pathway encompasses interactions and dynamic cycles of action and learning, with a deep stakeholder management, adapted from the TM literature and experiences (Kemp et al., 2007; Kern, 2012; Loorbach, 2007; Loorbach and Wijsman, 2013; Markard et al, 2012) to ecodesign integration challenges.

The general principles and constructs of the 15Ps ETF are briefly described in Table 4, complementing the more visual representation of Fig. 6.

Besides summarising the key findings from several literature reviews, exploratory researches, and the authors' previous experience, the 15Ps ETF was also forged in the company field study, within the empiric part of the action research undertakings, as presented in next section.

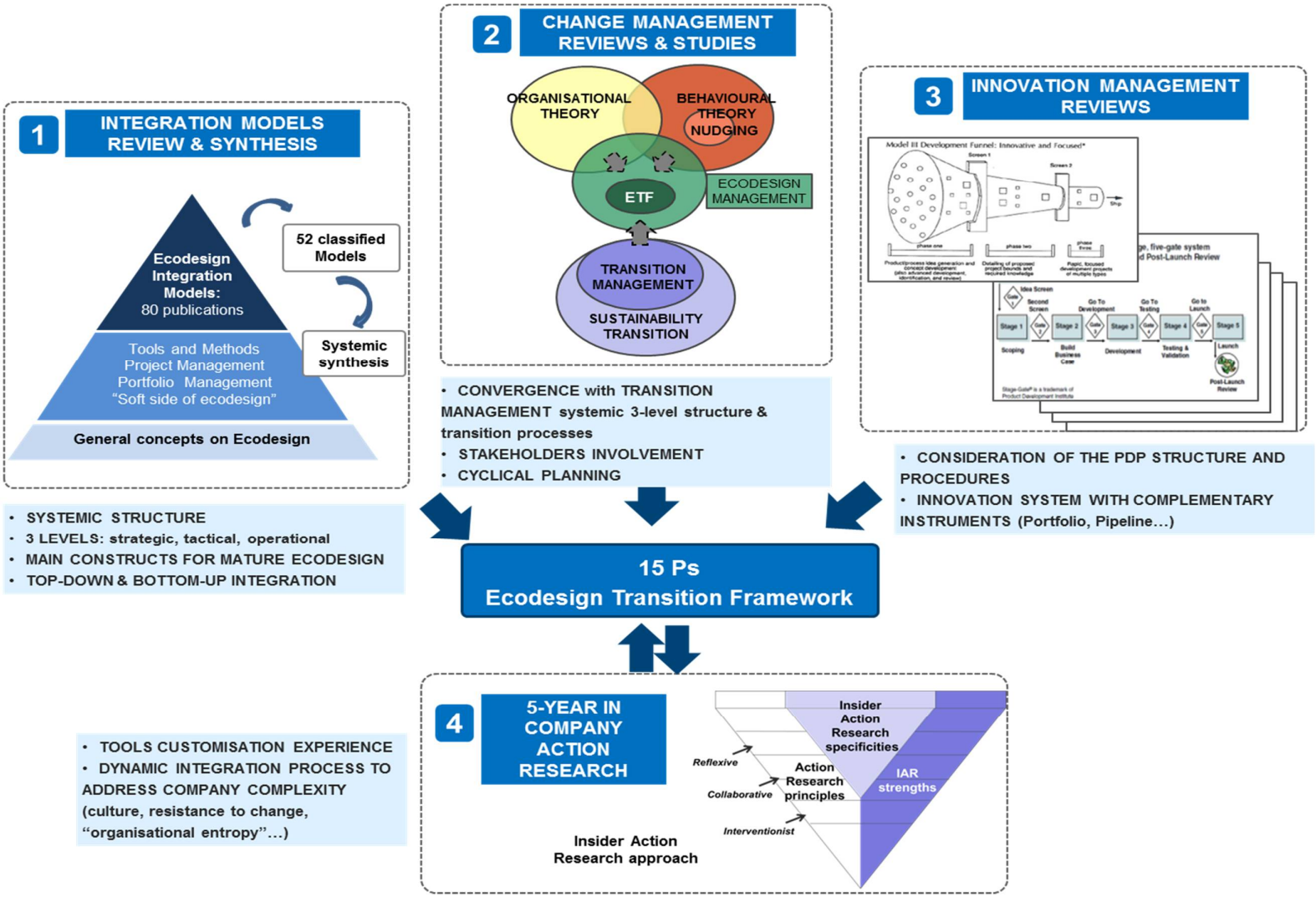

Fig. 5: Four main sources for building the Ecodesign Transition Framework

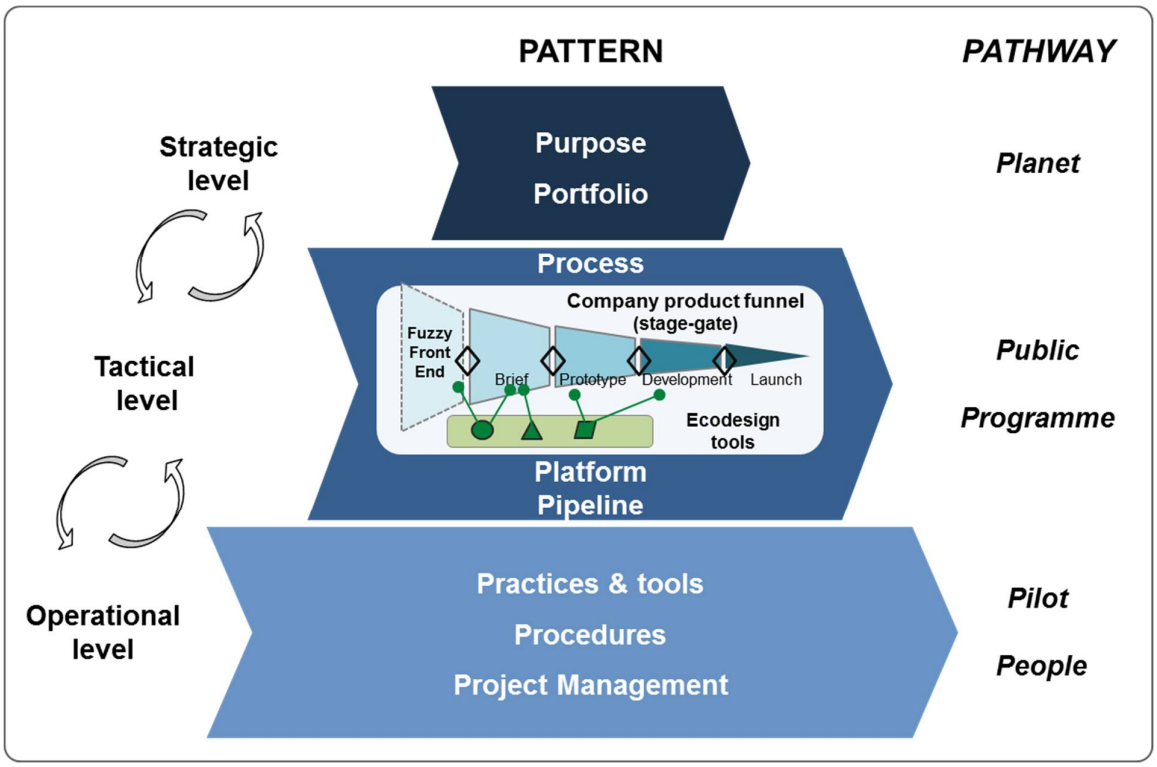

Fig. 6: Representation of the 15Ps Ecodesign Transition Framework

Table 4: 15Ps Ecodesign Transition Framework / constructs description

Level	PATTERN: –capabilities for a mature ecodesign integration		PATHWAY: applying transition principles		
Strategic Defining corporate and long term objectives in innovation and environmental sustainability, based on life cycle thinking principles	**Purpose**	Define and promote company environmental sustainability ambition and direction, including global and deployed goals with clear targets and preferably a set of indicators.	***Planet***	• *Define or update the long term ambition of the organisation in environmental sustainability.* • *Align Product innovation strategy with the environmental ambition.* • *Monitor the long and midterm plan, and coherence between corporate vision and business processes*	*Problem structuring, envisioning, long term goals*
	Portfolio	New products projects portfolio aligns sustainability strategy together with business goals. Quantitative environmental life cycle indicators integrated to allow effective product planning: opportunity identification, project prioritization; resource allocation and planning.			
Tactical Deploying and piloting the environmental strategy into the innovation processes and instruments	**Process (PDP)**	Environmental requirements incorporated throughout the principles and elements of the PDP for decision making, from the early and particularly decisive stages. Integration of ecodesign in portfolio management, including decision/trade-offs criteria associated with the environmental dimension;	***Public***	• *Engage/influence the different groups involved in the deployment of environmental goals and procedures (middle management)*	*Agenda-building, negotiation, networking*
	Platform	Technological/applied research programmes bring solutions applicable at product level (internal or external, depending on organisation size and sector); internal recommendations for applying/deploying such solutions.			
	Pipeline	Qualitative and quantitative environmental indicators integrated in Pipeline Management, with other business and technology factors to deliver results within the company dynamics. Operational reviews and decision making (GO/Kill decisions and resource allocation) consider sustainability goals.	***Programme***	• *Formalize a plan for progressing toward a higher integration of environmental sustainability within Product innovation processes* • *Monitor and evaluate results, progresses and gap.*	
Operational Applying ecodesign principles into all related activities for decision making and product performance	**Practices & tools**	Customised ecodesign tools covering different needs along the PDP, including: Orientation (guidelines, check-lists…), solution generation (creativity tools), productenvironmental performance assessment (quantitative or semi-qualitative).	***Pilot***	• *Adapt and experiment ecodesign tools and practices to company culture*	*Experiments, implementation, mobilizing actors*
	Procedures	Guidelines and capacity building on how to use the tools within the PDP for different kinds of projects. Stage-gate reviews consider the environmental aspects and indicators.	***People***	• *Engage the different groups involved in product development to understand and apply ecodesign principles and tools (internally and externally/ supply chain and innovation partners)* • *Capacity building and associated monitoring*	
	Project Management	Environmental sustainability integrated with other dimensions (quality, cost, time); multifunctional teamwork, covering the life cycle perspectives of products and the various stakeholders of the value chain.			

3.3 In-company application of the ETF

The framework presented above was conceived during and with the experience collected from the applied action research in the company. Hence, the structure and rational fit to the initiatives that were conducted to increase the company´s capacity to include environmental sustainability in the product innovation related activities, as represented in Table 5.

In this table, the central "Pattern" column allows to outline the main interpretation of the initial diagnosis conducted in 2011 based on a formal ecodesign maturity assessment and additional analysis highlighted by the systemic perspective. In the right side of the same table the "Pathway" column summarises the main ecodesign initiatives conducted from 2011 to 2015 to foster the transition toward a more mature system, with a special emphasis on stakeholder management.

Indeed, at the beginning of the company initiative, the development and implementation of more structured ecodesign practices were initially perceived as essentially technical objectives and tasks. During cycle 1, the results of tool customisation was considered as positive, based on the feedbacks received after the training experimentations and further presentations to various representatives of the target audience (NPD teams or managers) and support functions (such as education or sustainability management). However, the diffusion issues rapidly came out as key challenges for the success of the initiative.

Corroborating the statements from the promoters of the soft side of ecodesign as indicated in the literature and as confirmed through several exchanges with specialists from Brazilian and European universities, the change management dimension called for greater attention. The Transition Management principles were perceived as adapted for bridging the identified gaps in a systemic perspective based on a multi-level approach (missing from previous models and literature), and involving different actors and instruments of the whole process.

Also, the choice of a more "bottom-up" approach, or voluntary adoption of the new tools and practice, was dictated by the recommendations of the project sponsors from R&D management, and considered the culture of the company and management styles. During this first cycle, little attention was dedicated to engage the main actors of the PDP ("Public" dimension), which was later considered as a gap to fulfil.

Hence, after an intermediate evaluation of the results, realised at the end of cycle 1, cycle 2 was more dedicated to the application and diffusion of the tools developed during cycle 1. This explains why diverse "soft" initiatives were conducted, together with the fact that the concept of TM for ecodesign gained consistency during this research phase.

Then, a broad range of initiatives were conducted in order to strongly promote the recommended ecodesign practices, purposefully covering the three levels and different stakeholders involved in the product innovation activities, from several functions and hierarchical levels. Also the nudging experiment highlighted a gap between a high intention to practice ecodesign and a low awareness level of the ecodesign initiative

after cycle 1. The integration plan included several channels to reach and engage the target groups of marketing and product development, involving intermediate management and giving priority to direct contacts and participative interactions, adapting to each group's priorities and busy agendas. Different media were used, such as e-learning, diffusion of video material, face to face and group meetings.

Also, a simplified version of the ETF was used to debate with the group of managers, directors and VPs responsible for product innovation and corporate sustainability, on how to progress toward a more sustainability integrated innovation, in line with the strong corporate sustainability commitments and targets. This experience confirmed the adherence of such broad three-level framework with the reality faced in the company context.

Therefore, the five-year long AR experience globally led to the intended outcomes both on the applied side, with an increased diffusion of ecodesign, and on the research side, with the formulation and use of a novel and broad framework. However, the positive results were also associated with serious challenges that highlight the complexity faced for effective diffusion of ecodesign.

Table 5: ETF application in the company

Level		PATTERN: diagnosis in 2011		PATHWAY	
		STRENTHS	CHALLENGES	Main transition initiatives (2011-15)	
Strategic	Purpose	• Strong company commitment including environmental and goals and targets. • Ambitious New Sustainability Vision issued in 2014 with long term and midterm goals.	• Need to clarify interrelations and prioritize different environmental indicators and targets. • Need to build a deployment strategy to disseminate and apply the vision.	*Planet*	• *Ecodesign progressively recognised in the Sustainability Vision and Strategic Plans.* • *Plan elaborated with high level management to better articulate and deploy corporate goals with New Products Portfolio within Business Units.*
	Portfolio	• Environmental targets deployed with business units (carbon mainly)	• Need to improve Portfolio management for business reasons and to better align and balance Corporate Sustainability vision with other business goals and processes		
Tactical	Process (PDP)	• Environmental performance considered in the gates, with project approval rules	• Limited indications in the PDP on how to reduce environmental impacts	*Public*	• *Ecodesign diffusion challenges considered with Development Managers and Innovation directors and VP, aiming at positively influencing users from Development and Marketing.* • *Collaboration with group in charge of PDP management to incorporate ecodesign rules.*
	Platform	• Environmental goals incorporated in technological strategy; environmental technology programmes	• Technology programmes not fully connected with ecodesign in product innovation.	*Programme*	• *Formal Ecodesign programme conducted (2011-2015), with Maturity assessments and intermediate reviews, with a technical team and budget. Focus on tools, capacity building, dissemination and engagement. Collaboration with external experts.*
	Pipeline	• Qualitative analysis conducted intending to connect goals with pipeline.	• Pipeline complex to manage, with frequent revisions of Product Portfolio.		
Operational	Practices & tools	• Environmental calculator includes carbon footprint and other product indicators. • New environmental indicators progressively incorporated into calculator (waste in 2013).	• Ecodesign principles not largely diffused in the company (in 2011 and 2013). No formal guidelines. • Ecodesign not practiced in the early stages of the PDP. • Ecobenchmarking not commonly practiced (internal comparisons only).	*Pilot*	• *3 New tools experimented in 2 product development projects.* • *Ecodesign tools and principles applied in 6 other development projects, with formal follow up.* • *Eco-benchmarking tool developed in 2015 and applied in pilot project.* • *Collaboration and training of external Design agencies partners.*
	Procedures	• Detailed rules and targets for environmental indictors at gates	• Limited procedures; increase of indicators with no clear trade-off principles	*People*	• *Emphasis on diffusion activities: ecodesign exhibition, training courses, e.learning, lectures with specialists.* • *Nudging workshops and experiment conducted in 2013.* • *Marketing audience seen as more complex to engage & influence.*
	Project Management	• Importance of environmental aspects in project management perceived.	• Lack of basic knowledge on ecodesign • Difficulty to face trade-offs with quality/cost /time		

4. Discussion

The results of the action research raised several key questions toward a broad ecodesign integration, which will be discussed around four main themes.

4.1. Tool customisation and integration in the PDP

An abundant literature led to a large list of tools (Baumann et al., 2002), potentially available for developers to fulfil complex environmental activities (International Standard, 2002). Tool *customisation* to the company context emerged as an alternative approach (Luttropp and Lagerstedt, 2006; Ritzen, 2000), which Boks (2006) confirmed as a key success factor for ecodesign integration. However, limited application was reported, except by O´Hare (2010) who presented very simplified Eco-innovation tools experience. This principle was followed in this research, with a pivotal place in the ETF, and positive evaluation in the company context:

"This definitively looks like our company´s innovation; this is how any product development should be" (Marketing Director, end 2012).

In fact, the concept of customised ecodesign tools formalised to the PDP (Funnel) emerged in the company context at the preparation stage and at USP- São Carlos (based on the reference model by Rozenfeld et al., 2006) in parallel presentations, almost simultaneously in 2010, but was not found in other publications during all thereviews.

In this AR experience, the necessity to strongly complement such activity was also showed, in the direction of extensive training and dissemination, and a broader set of integration initiatives recommended in the ETF. This confirms Alblas et al. (2015) observation that "deploying sustainability methods, tools, and metrics, such as a life-cycle assessment or design for environment (DfE), are not sufficient to achieve sustainability in NPD".

4.2 Governance and management styles

As already stated by Boks (2006), even the best tools and knowledge about 'technicalities' can be hindered by communication, relational, or other soft issues. The necessity to combine bottom-up innovation and top-down integration support, as stated in the ETF, highlights a critical question of how a convenient balance can be found, and who decides and monitors such dynamics. This dilemma was also noted in the company context, and stressed by external observers participating to the initiative.

The question of the adequate governance of sustainability transition is raised by the Transition Theory, and echoes the fact that the governance system is also recognised as critical for the PDP best practices and innovation performance as a whole (Cooper and Edgett, 2011). Whereas ecodesign capacity involves a lot of attention toward the operational aspects and tasks, as commonly treated in the literature, in this study the importance of more tactical and strategic approaches has been stressed. However, as stated by Ulrich and Eppinger, (2004), product planning decisions mainly involve the senior management of the organisations. The construction of effective integration of environmental concerns at such level is a relevant challenge for mature ecodesign, considering the limited knowledge and literature in these

areas, and also the fact that such responsible audiences are more difficult to influence even from the inside.

Another expression of the governance challenges lies in the necessary of a broad implementation of new ecodesign tools. The line followed in this study, coherent with TM views, was more of a proactive dissemination of recommended practices, rather than compulsory processes. Though noticeably depending on cultural components of management styles, such choice also reflects more general business management tendencies. The traditional command-and-control approach is increasingly shifting to lateral and bottom-up communication (Groysberg and Slind, 2012), as announced a few decades ago in the 5th Discipline: The emergence of new modes of organisation, more flexible and less hierarchical and authoritarian, giving increasing space to individual decision-making and innovation (Senge and Sterman, 1992). Transition Management brought such approach in order to solve the complex and systemic challenges associated with sustainability integration, arguing that they would be impossible to manage in the traditional sense of planning, command and control (Loorbach, 2007).

4.3. Among the invisible barriers, resistance to change

However, the predominantly "bottom-up" integration approach followed in this research, adapted to company´s culture and TM principles, has met various obstacles, and the integration of new ecodesign practices and tools has been lower than expected initially. TM, by indirectly influencing, adjusting, redirecting and guiding actions, (Loorbach, 2007), will promote (only) a progressive evolution.

In the reality of the organisation, such slow transition was also associated with some kind of "invisible barriers" perceived by the team in charge of the initiative, different from the main obstacles previously identified by Boks (2006): Gap between proponents and executors; Organisational complexities; Lack of cooperation.

An interpretation for such observed resistance to change would be the possible incidence of second order barriers, commonly cited in the change management literature (Ford and Ford, 2010), but rarely studied for sustainability issues.

Such concerns have been noted during the experience, and even clearly expressed by some professionals:

"There are many strategic changes; and also a very high turnover of people; most people in the teams have less than two years' experience, they have little history behind them" (Product Developer, 2012).

"I don´t know how to enable the CEW in my day by day work. I do not have space, time or resources to do so" (Marketing analyst, 2013).

Different factors have been observed, such as prioritisation issues, divergent individual and collective interests and concerns, or "organisational entropy", which interfere against the incorporation of new and more complex practices in the organisation, but are not specific to

ecodesign or sustainability and can play an important role in any change issue (Mash et al., 2013).

According to Frazier (1996), who studied design for environment at Xerox, a key challenge would be to overcome middle management resistance to strategic change, as this group has a key role in the implementation process, yet is the most difficult to convince of the need to pursue a particular strategy.

If the study does not provide such conclusive evidences, middle management can be exposed to important tensions, at the intersection of top-down strategic pressure and bottom-up experimentations, facing the contradictory challenges of sustainable performance (including environmental goals to financial and time constraints) in competitive markets.

4.4. From formal to tacit knowledge

Nonetheless, such resistances and invisible barriers are difficult to identify and manage. At the same time, the progress toward a higher maturity in ecodesign may be more of a collective learning process, as argued by Valleta et al. (2014), as the need for a progressive education to eco-design practice - which is complex to follow and measure.

For example, in one of the product development project (mentioned as “Ap”, in Fig. 4), which is a whole programme including several projects and more than 100 different products, the ecodesign tools where not fully applied in the recommended format. However, speaking with a group of five product developers on their results and difficulties, they expressed that they had done the ecodesign e-learning and proactively tested new technical solutions to reduce the environmental impacts “*following the company commitment in sustainability, more than the demands from marketing*”.

According to Goffin and Koners (2011), NPD is a complex activity that is dependent on knowledge and learning, and “much of the knowledge generated in NPD is tacit”, as opposed to explicit knowledge (following the expression coined by Polanyi in the 1960s).

So far, the tacit side of learning has been scarcely studied for sustainability issues, and only cited in a few researches (Lofthouse, 2006; Trotta, 2010). Trebilcock (2011) has proposed a model for integrating environmental sustainability into architectural education, “developing attitudes, explicit knowledge, tacit knowledge and skills that interweave intuitive, analytical and social dimensions in a holistic manner”, which could be further developed in the broader perspective of general ecodesign integration and learning.

5. Conclusion

This longitudinal AR study illustrates the complexity for integrating ecodesign in company product innovation, which can be seen mainly as a learning progression, with key success factors linked to engaging NPD actors in such process. Along the research, Transition Management has emerged as the most adapted approach for dealing with the change management challenges, and gave rise to the proposition of a systemic Ecodesign Transition Framework, as a synthesis of a wide range of previous works and knowledge from different fields (engineering and environmental sciences, innovation management, and social sciences).

This framework is the main contribution of this research. The so-called "15Ps ETF" combines within a systemic three-level structure (Strategic, Tactical and Operational), two complementary perspectives: A pyramidal Pattern for a companywide mature ecodesign, composed of eight constructs (Purpose, Portfolio, Process, Platform, Pipeline Practices & tools, Procedures and Project management); and a complementary Pathway module based on five key constructs (Planet, Public, Programme, Pilot, People) for conducting the necessary transition, engaging stakeholders, and synergising bottom-up innovation and top-down planning.

As a second proposed contribution, this paper describes how AR approach can bring a strong interaction between academic and applied works, aiming at faster learning loops in the field of sustainable innovation management. Action research principles, also intimately incorporated in Transition Management, stimulate transformative change through a collective learning process (Loorbach and Wijsman, 2013), that can be constructive both for practice and theory. Such approach has been increasingly recognised as an effective collaboration mode between the Academia and companies with mutual benefits in innovation and science (Opresnik and Dolinsek, 2012), which is aligned with OM goals.

The company experience showed congruence with the elements and principles of the 15Ps ETF, though facing the complex transition process. Such framework is proposed as a facilitator to better organise collective efforts necessary at company level to leverage the effective incorporation of sustainability concerns into the innovation process.

As one of the limitations to be recognised, such research relied mainly on qualitative observations. Even after almost five years, direct applications have not come to the market yet, and more quantitatively measurable results will be expected in the following years, through potential business benefits and reduction of environmental impacts, in accordance to other studies that showed that structural implementation of sustainability was positively related to firm performance (Wolf, 2013).

Another limitation of this study is the single company context, which definitely limits the possibility of generalisation. However, it was the condition that allowed to access a business organisation from inside and to have the possibility to really experiment new solutions in a long period of time. Such favourable conditions contrast with the majority of ecodesign research, generally associated with pilot studies with students or external consultants (e. g. Le

Pochat et al., 2007). The passage from pilot studies to companywide introduction was classically referred to as the last step of ecodesign implementation approaches (Brezet and Van Hemel, 1997; Crul et al. 2009), but this study has shown that such scale up is a huge challenge that requires comprehensive integration strategies.

For further validation, similar experience could be replicated in different contexts, considering contingencies such as company size and sector, location and culture, and different types of innovation processes (Ulrich and Eppinger, 2004). Beside such necessary confirmation, future research could address and deepen the additional soft factors raised along the study, such as the governance of sustainability transition adapted to company culture, a better understanding of resistance to change, and the tacit side of ecodesign knowledge diffusion.

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