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## Supporting the development of environmentally sustainable PSS by means of the Ecodesign Maturity Model

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### Abstract

Despite their substantial potential for enabling increased environmental performance, product/service-systems (PSS) are not intrinsically environmentally sustainable. In order to ensure increased sustainability performance, PSS and related business models need to be developed taking into account best practice for ecodesign implementation and management. The Ecodesign Maturity Model (EcoM2) is a management framework that supports manufacturing companies to consistently and systematically implement ecodesign, based on a step-by-step approach. EcoM2 contains a database containing more than 600 practices, categorized into management practices, operational practices and methods & tools. Currently, only two management practices of the EcoM2 address PSS development. This paper aims to identify the best practices for PSS development, based on a literature review, followed by a presentation of a proposal for the integration of the new practices for PSS development into the EcoM2. In total, 17 best practices for PSS development were identified in this research, and integrated into the EcoM2. The proposed *EcoM2 for PSS* model has the potential to support the development of environmentally sustainable PSS.

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### 1. Introduction

The current industrial shift from selling products to providing product/service-systems (PSS) is mainly driven by business motivations. Increased competitiveness, reduced costs, enhanced customer convenience and flexibility, and improved corporate identity [1,2] are some of the business drivers towards PSS. In addition to potential economic benefits, PSS is also seen as a feasible and promising environmental strategy, with the potential of enabling a more sustainable society through the provision of environmentally efficient solutions [3]. In a PSS context, the service provider is often stimulated to use and maintain any related products properly, increasing both efficiency and effectiveness, which leads to several potential environmental benefits [2,4], such as:

- Lower materials and energy consumption during production and use;
- Extension of the manufacturer's responsibility for the product in the use and end-of-life phases;
- Development of more durable and use-intensive products;
- Higher quality end-stock and less down-cycling;
- Optimization of products to their primary function(s), with far better knowledge about the product requirements;
- Collection of end-of-life products, with increased re-use;
- Easier upgrading to more eco-efficient technologies.

PSS breaks the link between production volume and profit, enabling a reduction of resource consumption, an increased motivation to deal with through-life and end-of-life issues as the manufacturer retains ownership of assets, enhanced in-use

efficiency, product longevity/durability, and effective reuse of materials [5,6].

Despite the potential of PSS to enable the creation of more sustainable systems, the mere addition of services to conventional products does not necessarily lead to a reduction of environmental impacts [7–9]. The development of PSS is not intrinsically sustainable and there are also cases in which the environmental impacts are higher, when compared to traditional product systems [4,6,10,11].

With PSS, the physical products are responsible for the majority of environmental impacts. The PSS design process is therefore one of the most influential factors in the development of sustainable PSS [7]. It is essential that considerations of environmental sustainability are integrated into the PSS design and development process, that its market launch is carefully prepared to ensure success, and that the solution on the market is constantly reviewed in terms of economic, environmental and social impacts [12]. In summary, the implementation of ecodesign best practices into the PSS development process has the potential to increase the environmental performance of the developed PSS, supporting the transition towards a more sustainable system [13].

The Ecodesign Maturity Model (EcoM2) is a framework that supports companies to achieve systematic and consistent implementation and management of ecodesign [14] in the product development process. The EcoM2 contains a body of knowledge of more than 600 ecodesign practices, classified into management practices (62), operational practices (458) and methods & tools (120) [15]. Currently, only two management practices of the EcoM2 address PSS development.

This paper aims to identify the best practices for PSS development, based on a literature review, and to subsequently present a proposal for their integration into the EcoM2 with the ultimate aim to support the development of environmentally sustainable PSS.

The following section presents the methodology employed for the identification of the best practices for PSS development and their integration into the EcoM2. Section 3 presents the identified best practices for PSS development. Section 4 presents the integration of the identified best practices for PSS development into the EcoM2, and is followed by discussion (section 5) and conclusion and final remarks (section 6).

## 2. Methodology

The methodology employed for the identification of best practices for PSS development and their integration into the EcoM2 consisted of three main steps, as presented in the following sub-sessions.

### 2.1. Literature review

A literature review was carried out, in order to identify the best practices for PSS development. The review embraced two main scientific databases (Scopus and Web of Science) and comprised of papers on PSS development methodology, business model creation, servitization, value propositions, and PSS design methods and tools. The literature resulted in a total of 27 papers being selected for further analysis.

### 2.2. Identification of best practices for PSS development

The best practices for PSS development were collected in the selected papers, by identifying the necessary activities and tasks to be performed by manufacturing companies, in order to be able to develop PSS considering a broad range of aspects, such as business models, marketing, design and development, network management, etc. Generalizations of the best practices were performed, in order to consolidate similar practices. In total, 17 best practices for the development of PSS, from a managerial perspective, were identified (presented in section 3). Although being important to support the PSS and ecodesign implementation, operational practices and methods & tools were not included in the scope of this research.

### 2.3. Integration of the identified practices into the EcoM2

The identified practices for PSS development were compared to the 62 existing management practices of the EcoM2, in order to identify similarities, complementarities and potential conflicts/trade-off situations. The ecodesign and PSS practices were then consolidated and harmonized, guaranteeing a joint application by manufacturing companies for the development of environmentally sustainable PSS. Subsequently, the PSS practices were integrated into the EcoM2, by classifying them according to the five evolution levels defined by the EcoM2 and to the phases of the product development process [16,17].

The five evolution levels defined by the EcoM2 describe how a company evolves in its integration of environmental issues into product development [adapted from 14]. The evolution levels, presented in table 1, range from a focus on elementary understanding of external and internal drivers, context, barriers, and contextual background; all the way up to the incorporation of environmental issues into the strategic decision making processes and into the way in which the company does business.

Table 1. Evolution Levels defined by the EcoM2 [adapted from 14]

Evolution level	Description
Level 1	Limited experience in ecodesign, focus on elementary understanding of the concept, external and internal drivers, context and barriers
Level 2	Startup of pilot projects and initial test of methods and tools to understand how the implementation can be carried out in practice – establishment of an ecodesign program
Level 3	Experience gained in the pilot projects supports the systematic integration into the product development and related processes,
Level 4	Expansion of the ecodesign implementation to managerial and business areas, in addition to the technical areas. PSS opportunities are explored
Level 5	Incorporation of environmental issues into the corporate, business and product strategies – environment is integrated in the decision making processes and into the business

Furthermore, in order to support the application of the best practices for PSS development in a product development context, the practices were classified according to the group of activities of a reference model for the product development process [16,17], based on a cross-content analysis. The phases and main activities of the reference model are presented in table 2.

Table 2. Phases and main activities of the reference model for product development adopted in the EcoM2 [16,17]

Phases for product development	Main activities
Product strategic planning (PSP)	Define the business strategic plan; consolidate information about technology and market; analyze and refine the portfolio of products
Informational design (IDE)	Revise and update the product's scope; detail the product life cycle and define the main customers/users; identify customers' and product's requirements
Concept design (CDE)	Model the product functions; develop solution principles and alternative solutions; define product architecture; analyze systems, sub-systems and components; define ergonomics and aesthetics; define suppliers and partners for co-development; select product concept
Detailed design (DDE)	Detail the design of systems, sub-systems and components; make or buy decisions; develop suppliers; plan manufacturing and assembly processes; optimize product and process; create support material; develop packaging; plan end-of-life; product test and homologation; share product documentation
Production preparation (PPR)	Gather manufacturing resources; plan pilot production; produce pilot lot; process homologation; optimize production; certificate product; develop production and maintenance process; transfer knowledge
Product launch (PLA)	Develop sales process; develop distribution process; develop customer support services; develop technical assistance processes; promote launch and marketing; launch the product; manage the product launch
Product accompanying and monitoring (PAM)	Evaluate customers' satisfaction; monitor the product performance (technical, economic, production, services, etc.)

Although the development process may vary between different companies and product types, the generic design process (i.e. high-level reference models) can be used to tailor the specific codesign procedures [16,17]. The results of the integration into the EcoM2, presented in section 4, allow the prioritization of practices following the maturity profile of the companies and their strategic drivers.

### 3. Best practices for PSS development

Structured practices for PSS development are needed to enable each process phase to transform the inputs to valuable outputs and to manage the interaction with the different actors throughout the system life cycle [18].

This research focused on the identification of the best practices for PSS design and development dealing with the managerial activities required to develop a PSS. Best practices

are defined as an optimal way currently recognized by industry to achieve a stated goal or objective [19].

The identified best practices for PSS development are presented in table 3. Whenever necessary, similar practices were clustered in a unique practice, so to simplify the set of practices and ensure consistency and robustness. The practices are coded to simplify cross-citation and presented together with the main references to allow traceability. The practices are not presented in any specific order.

Table 3. Best practices for PSS development

Code	Best practice	References
1	Develop a business model that can support the transition towards PSS	[6,20,21]
2	Create networks that foster innovation and promote customer resource integration	[8,20–25]
3	Define PSS offerings and value propositions to be provided to customers and stakeholders	[21,25,26]
4	Add service elements to the portfolio of offerings	[20,21,25,27]
5	Understand customer value creation processes to develop suited and specific value propositions	[8,20,21,23,25,28]
6	Co-create value together with the customers by developing service- and customer-oriented offerings	[8,9,21,27]
7	Identify available offerings in the market	[21]
8	Understand the life cycle of the offerings	[20,23,25,27]
9	Map and visualize the actual activities of the users of the company's offerings	[25,27,29]
10	Focus on value-driven communication of offerings – clearly communicate the value associated with the PSS offer	[6,8]
11	Increase the extent of interactions with customers through the PSS offerings	[8,20]
12	Collect PSS data through increased interaction with customers	[6,8,27,30]
13	Align physical product characteristics with service offer characteristics and vice-versa	[8]
14	Identify preferable product properties to increase the value of the PSS business model	[8,31]
15	Define the level of customization of the PSS offering according to the business model	[8,20,32]
16	Assess strengths and weaknesses of the current product portfolio and markets	[6]
17	Identify the market value of the PSS compared to the competing product in terms of tangible and intangible value	[6,26]

The identified practices present a wide range of considerations that a company must take into account for the development of a PSS: business models, establishment and management of complex networks, new service offerings and value propositions, value creation and co-creation processes, mapping and visualization, value-driven communication, customer interaction, data collection, customization strategies, tangible and intangible values.

The varied range of subjects and knowledge areas highlights the holistic and cross-functional nature of PSS, which may pose

certain challenges for companies not used to engaging with such highly augmented design objects.

None of the identified best practices for PSS development, however, clearly incorporates the environmental dimension in their statements, with exception for practice #8 that embraces the “life cycle” considerations. The lack of environmental considerations into the definition of the identified best practices for PSS development might be one of the determinant reasons for the non-achievement of environmentally sustainable PSS. The integration of those practices in an ecodesign context has, therefore, the potential to overcome this barrier.

#### 4. EcoM2 for PSS development

The integration of the identified best practices for PSS development into the EcoM2 aims to bring the environmental elements into the PSS context, in order to ensure that the developed PSS will actually have improved environmental performance, when compared to traditional products and/or to other PSS solutions that are not designed with environmental issues taken into account.

To allow the incorporation into the EcoM2, the 17 identified best practices for PSS development, presented in section 3, were classified according to the five EcoM2 evolution levels (table 1) and also according to the product development process (table 2), as described in the methodology session. The results of the classification are presented in table 4.

Table 4. Classification of the best practices for PSS development according to the EcoM2 evolution levels and development phase

Code	Evolution level	Development phase
1	Level 5	PSP
2	Level 4	CDE
3	Level 4	IDE
4	Level 3	PSP
5	Level 4	IDE
6	Level 4	IDE
7	Level 3	IDE
8	Level 3	IDE
9	Level 4	IDE
10	Level 4	PLA
11	Level 4	PAM
12	Level 4	PAM
13	Level 3	CDE
14	Level 4	CDE
15	Level 4	CDE
16	Level 3	PSP
17	Level 4	PLA

Furthermore, an analysis of the existing 62 practices of the EcoM2 in light of the identified practices for PSS development resulted in the modification/adaptation of several practices. Particularly, the practices that addressed solely the development of products were replaced by PSS. For example, the practice “Perform external benchmarking for the identification of the environmental performance of products”,

in the first evolution level, was adapted to “Perform external benchmarking for the identification of the environmental performance of PSS”. Although this may appear at first glance to be little more than a slight change in the wording of the management practice, this alteration brings new challenges and opportunities for companies, broadening their scope and area of influence. Additional effort should be employed by traditional product development companies for the joint development of the products and services, together with the infrastructure and/or ecosystem around the product/service.

The *EcoM2 for PSS* model aims to support the managers responsible for PSS development to define strategic roadmaps for the development of sustainable PSS, based on a mature and consistent process. In this context, the *EcoM2 for PSS* supports managers to: a) identify strengths and improvement opportunities for sustainable PSS development, based on a diagnosis of the current maturity profile (i.e. capability level of application of the best practices for PSS development); b) define the vision and to-be maturity profile, based on strategic drivers and goals towards sustainable PSS development; c) deploy a strategic roadmap to integrate PSS and ecodesign practices into the product development process, with the aim to establishing a mature process for the development of sustainable PSS; d) implement and continuously measure the performance of the improved practices. Companies should engage in new diagnosis as many times as needed to keep improving their maturity in sustainable PSS development.

#### 5. Discussion

The classification of the best practices for PSS development according to the product development phases clearly shows the importance of considering PSS in the early stages of the development process: product strategic planning (PSP), informational design (IDE) and concept design (CDE) embrace 13 out of the 17 identified practices. The classification highlights the strategic nature of PSS, their strong influence in the business strategy, and the importance of close links with customers and stakeholders for value creation. Furthermore, it indicates that the traditional process for product development, especially detailed design (DDE) and production preparation (PPR), suffers limited modifications for PSS development in comparison to product development. On the other hand, product launch (PLA) and product accompanying and monitoring (PAM) seems to play a crucial role in ensuring the business success of the developed PSS. It must be noted, however, that depending on the specific product development process of the company, the practices can be applied in different phases. The proposed classification should be considered as an initial guidance and not as a fixed rule.

The classification of the best practices for PSS development according to the EcoM2 evolution levels shows a clear tendency to apply the identified practices in higher evolution levels, from level 3 to level 5. The main reason for that is that the EcoM2 takes as point of departure the improved understanding about how environmental issues can be integrated into business and product development. Being initially based on internal and external drivers for ecodesign implementation, the application based on the EcoM2 follows a step-by-step approach from the

most simple and basic practices that will create the basis for ecodesign implementation to the most complex and advanced ones. From this perspective, it could be argued that companies with a higher maturity on ecodesign implementation will have the highest potential for the development of environmentally sustainable PSS. Furthermore, it is assumed that the implementation of PSS in those companies will contribute to the improvement of the environmental performance of developed products and services.

The adjusted *EcoM2 for PSS* model presents a total amount of 79 management practices. By combining the best practices for PSS development identified in this research (17 practices), with the existing 62 ecodesign management practices of the EcoM2, this research increases the possibility for companies to develop environmentally improved PSS solutions, when compared to other products and PSS solutions. Besides being more comprehensive, the addition of practices to the EcoM2 might be cumbersome and make the application by development companies more complex and time consuming.

## 6. Conclusions and final remarks

Product/service-system (PSS) is a promising business approach that has the potential to increase environmental sustainability performance, when compared to traditional products and services. However, PSS is not intrinsically sustainable – several recent studies have shown that the environmental performance of PSS can actually be worse when compared to traditional products.

The hypothesis advocated in this research is that the implementation of ecodesign best practices into the PSS development process has the potential to increase the environmental performance of the developed PSS, supporting the transition towards a more environmentally sustainable system and society. In order to be able to test the hypothesis, this paper presented a proposal for the integration of PSS and ecodesign based on the Ecodesign Maturity Model (EcoM2).

Seventeen best practices for PSS development were identified and consolidated based on a literature review and further integrated into the Ecodesign Maturity Model (EcoM2), through a classification based on the evolution levels and phases for a reference model for product development. The proposed *EcoM2 for PSS* is a management framework developed to support companies in the integration of environmental considerations into product and PSS development, and has the potential to support companies in the development of environmentally sustainable PSS.

The approach followed in this research for the integration of PSS and ecodesign – based on the EcoM2 – takes ecodesign as the point of departure and implements PSS as a way to ensure higher opportunities for the improvement of the environmental performance of products and services. Another approach for the development of environmentally sustainable PSS would be to take PSS as the point of departure, and then incorporate ecodesign along the way during the implementation. Both approaches must be tested in order to evaluate their benefits and indications for specific cases.

Despite contributing to expanding the knowledge in the development of environmentally sustainable PSS, this research

is only a first attempt at integrating PSS and ecodesign, which therefore has several limitations that must be further explored in future research. The literature review for the identification of the best practices for PSS development should be broadened in relation to the relatively limited review carried out in this case, in order to ensure that all the relevant practices for PSS development are properly identified and consolidated. Furthermore, methods and tools that can support the application of the identified practices should be identified and linked with the best practices for PSS development, building up a comprehensive body of knowledge of PSS practices. Based on the analyzed literature, it could be noted that several operational practices and methods & tools are already available to support their implementation. Furthermore, the classification of the identified best practices for PSS development according to the evolution levels and product development phases should be refined and validated by experts from academia and industry, ensuring consistency and coherence.

Future research should focus on the test of the applicability and robustness of the proposed *EcoM2 for PSS* model in real applications, via action research and industrial case studies for theory testing. Companies with different maturity levels on ecodesign implementation and PSS development, and different strategic drivers, should be targeted in those applications.

The proposed additional research will support the understanding of the applicability of the *EcoM2 for PSS* and the value added to companies.

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