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Product-Service Systems across Life Cycle

Systematic eco-innovation in Lean PSS environment: an integrated model

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Abstract

New methodologies and tools to improve the performance of PSS design have been proposed in literature. In this sense, this paper accompanies the development of a proposed model that allows for systematic analysis in order to identify waste or contradictions and their elimination or reduction, through the joint use of analytical tools wit impact in eco-innovation based on TRIZ and Lean PSS. It has been shown that the methodologies complement each other. The TRIZ with its aspect of innovation and problem solving can make an important contribution in the eco-innovation in a Lean PSS design aiming application in real systems.

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Keywords: Eco-innovation; Lean; PSS; TRIZ.

1. Introduction

Is possible see in nowadays the importance of the eco-innovation, as driver of environmental policies, particularly in the context of sustainable development, energy, climate change and management strategies for waste reduction in production systems. Is possible say that one of mains areas of eco-innovation are energy and material efficiency, with special emphasis on renewable energy.

In the current economic context, the natural approach to eco-innovation is to foster resource efficiency solutions focused on energy and materials through rationalization of its use and recycling. In this scenario, it can be stated that the needs and challenges of eco-innovation for organizations and industrial companies currently focus on three objectives: (i) improvement of material efficiency; (ii) improvement of energy efficiency; (iii) creation of new sustainable products, services and integrated product-services.

The need to study the environmental impact of a product throughout its life cycle and during its design process makes issues such as eco-design, product eco-innovation and application of these concepts as relevant. Is not about exclusively of environmental technologies includes all changes that reduce the use of resources throughout the life cycle regardless of whether these changes have environmental intent or not, going to be able to appear on all economic activities.

Organizations need to look for new methods and techniques that can help in getting better results in continuous pursuit to minimize the inefficiencies in design and production processes, in order to reduce costs and increase profitability so that they can ensure their survival in the current economic scenario.

In this sense, Lean is traditional management philosophy focused on reducing the seven mains types of waste (overproduction, waiting time, transportation, over-processing, inventory, motion and defects). Lean is basically all that concerns getting right materials at the right place in the right amount, minimizing waste, being flexible and open to change. Thus, it is ensured that only produces what is needed, when needed, as appropriate. In this domain

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could be applied the TRIZ and the Lean, as tools that help in innovation and responsiveness to market changes. Product-Service System (PSS) has been defined as a set of marketable products and services able to jointly meet the user needs. These new approach generates an impact on society: less use of raw materials, a reduction of resource consumption, increased productivity and, consequently, a reduction of environmental impacts.

In the current complex and dynamic competitive scenario, the enterprises need to develop new approaches to improve the PSS development process performance in a more systematic way. Systematic and pragmatic methods can help companies to prevent failures, eliminated losses related to time and of customers and improve the competitiveness in the face of competitors. We can say that the Lean identification of wastes and the Lean focus on the value can significantly contribute to leverage the performance in PSS design. We can say that the main points of symbiosis between Lean and PSS design are: (i) customer focus from an effective value proposition based on customer experience; (ii) the reduction of Lean losses and the sustainability vision of PSS design, which is leveraged by reducing losses belong the processes and interfaces of product-service system developed; (iii) the need of continuous improvement, held from incremental or more radical innovations. The combination of continuous improvement of Lean with the PSS configuration models also can help develop appropriate combinations of products and services [1].

As well as, the Lean standardization practices could be able to improve the PSS development level. A Lean PSS environment needs forms of innovation aimed at sustainable development, through the reduction of impacts on the environment, enhancing resilience to environmental pressures and more efficient and responsible use of natural resources. Eco-innovations in a Lean PSS environment are also an opportunity for businesses because its contributes to cost reducing, enables new possibilities for growth and reinforces the corporate image with customers. Based on these preliminary points, the main objective of this research is to make the proposition of an integrated model focused on the systematic generation of eco-innovations in Lean PSS environments. In this sense, the paper was organized as follow: section 1 shows the research problem and justifications; the literature review discussing the main concepts of eco-innovation, PSS, Lean PSS and eco-innovation in Lean PSS is presented respectively in section 2, 3, 4 and 5; from these discussions, the proposed model is detailed and presented in section 6; section 7 shows the conclusions and main directions of future research.

2. Eco-innovation

It is necessary to understand the evolution of eco-innovation concepts to our discussion. In this sense, one of the first definitions to eco-innovation was the follow: “eco-innovation is considered a new product or process that adds value to the business and to the customer, significantly decreasing the environmental impact” [2]. To Arundel [3] eco-innovation can be defined as the production, application or exploration of goods, services, production process, organizational or management structure or method of business that is new to the company or to the user. The results are reduction of environmental impact, less pollution or negative impacts from the utilization of resources, compared with corresponding alternatives.

The eco-innovation also can be defined as innovation that is capable of attracting green income in the market, reducing the net environmental impact, and creating value to the organizations [4, 5]. Or still, as the Oslo manual: “represents an innovation that brings about a reduction of the environmental impact whether such effect is intentional or not” [6].

Is possible say that, according to most definitions, eco-innovation reduces the environmental impact caused by consumption and production activities, regardless of whether this is the main motivation. Taking many forms, eco-innovation varies from incremental eco-efficiency improvements to fundamental change replacing a system.

Furthermore, for the purpose of our research it is also important to understand the main types of eco-innovation. The following classification is proposed to comprehend the eco-innovations: (i) environmental technologies: pollution control technologies including waste water treatment technologies, cleaning technologies that treat pollution released into the environment; cleaner process technologies: new manufacturing processes that are less polluting and/or more resource efficient than relevant alternatives; (ii) organizational innovation for the environment: the introduction of organizational methods and management systems for dealing with environmental issues in production and products; (iii) product and service innovation: offering environmental benefits: new or environmentally improved products and environmentally beneficial services; (iv) green system innovations: alternative systems of production and consumption that are more environmentally benign than existing systems; biological agriculture and a renewable-based energy system are examples [7].

3. PSS

A Product-Service System (or combination of products and services) is a set of marketable products and services jointly capable of fulfilling a need for a client. [...]. The PSS may lead to a benefit for the environment in connection with the creation of a (new) business [8].

PSS is a system of products, services, networks of actors and supporting infrastructure that continuously seeks to be competitive, satisfy customer needs and have a lower impact than traditional business models [9]. PSS is result of an innovation strategy focused on the design and sale of a system of products and services that are jointly capable of fulfilling a specific customer demand [10].

A PSS consists of tangible products and intangible services designed and combined so that they are jointly capable of fulfilling specific needs of customers [11]. Recently, the follow PSS concept was proposed: “PSS are a specific type of value proposition that a business (network) offers to (or co-produces with) its clients and one definition of PSS is a mix of tangible products and intangible services

designed and combined so that they are jointly capable of fulfilling final customer needs" [12].

A PSS can belong three categories. The first category is product-oriented services. Here, the business model is still mainly geared towards selling products, but some additional services are added. Sub-categories are product related services (e.g. insurance or maintenance contracts) and advice and consultancy.

The second category is use-oriented services. Here, the traditional product still plays a central role, but the business model is not geared towards selling products. Third, are the result-oriented services. Here, the client and provider agree in principle on a result and there is no predetermined product involved. Sub-categories are activity management or outsourcing (e.g. catering services), pay-per-service unit (e.g. payment per copy made in copying; per km driven in fleet management; or per airplane landing in tire management services), or functional result [12].

4. Lean PSS integration

Despite of the great involvement of the academic context in PSS design, the scientific contributions as well as the industrial experiences considering also the potential role Lean Product Development methodologies and tools are still scarce [13]. Analyzing several tools and methodologies for designing a PSS, Baines et al. [1] identified that there is a strong generic flavour to these methodologies with many having a clear heritage in Concurrent Engineering and Lean Product development methodologies, like: (i) in the identification of customer value; (ii) the early involvement of the customer in the system design; (iii) the need of effective communication; (iv) the information sharing, and; (v) the continuous improvement practices.

An example in this sense is the study of Baines et al. [14] that proposed a framework to help manufacturing firms to configure their internal production and support operations to enable effective and efficient delivery of products and their closely associated services. The framework captures a set of operations principles, structures and processes which can guide a manufacturer in the delivery of product-centric servitized offering. These are illustrated and contrasted against operations that deliver purely product (production operations) and those which deliver purely services (services operations).

There is room for performing further studies and which could be the challenges to be addressed, as for example: which is a proper definition of what is waste and what is value in a PSS design process? How muda and value-added activities should be detected? What are the best practices for eliminating wastes in PSS design? [13].

Proposing a theoretical framework to Lean operations in product-oriented PSSs, Resta et al. [15] states that to new product and services, Lean PSS tend to have a core cross-functional team that is responsible for the development of new products and supporting services, with input from the customer and key suppliers.

In regarding to customer relations, tend to focus on customer value which requires close contact with customers. Wasteful (non-value adding) activities are systematically identified and eliminated. Customer-focused value creation is the main criteria for Lean PSS, and customers are an integral part of Lean PSS operations [15].

5. Systematic eco-innovation in Lean PSS

According to Ikovenko and Bradley [21], TRIZ (Theory for Inventive Problem Solving) is one of the most powerful inventing methodologies for systematic innovation. It is a scientifically-based and empirically-derived method that originated for the analysis of the world patent collection. Its strongest side is in the conceptual stage of design, while the analytical stage is not completely and effectively covered, at least in what is known as classical TRIZ.

Barker et al. [24] suggests the following aspects about the TRIZ and Lean Sigma integration: (i) innovative methodologies, based on TRIZ and Lean Sigma, are not mutually exclusive, but may complement each other; (ii) a TRIZ enhanced Lean Sigma methodologies work effectively when we have the resources for system or process optimization; (iii) TRIZ based tools for solving contradictions are effective when there are no available resources for system or process optimization; (iv) the proper use of optimization and disruption techniques may increase the efficiency of both, Lean Sigma and TRIZ.

When analyzing the topic was identified a parallelism between TRIZ and Lean [16]. The first step in the solution of a problem by TRIZ consists of analyzing the problem

Table 1: Comparative elements

Category	Lean	TRIZ	PSS
Tool	Takt time	Rhithm coordination approach	Customer service time
	Standarized work	Inventive principles, Standard solutions	Standards setting in service project
	5S	Transition to supersystem, Trimmimg, Standard solutions	Continuous improvement
	Work balancing	Function model, function re-allocation, new function architecture	Design of product functions and services
	Leveled production	Transition to supersystem	Analysis of capacity and demand of PSS
	Value stream map (current)	Function model of Process	Analysis of process and subprocess of PSS
Waste analysis	Overproduction	Excessive functions	Unnecessary functions or activities in a PSS
	Inventory	Corrective functions	Excess of raw material or information in a PSS
	Extra processing	Provide and corrective functions	No added value time in providing service
	Motion	Provide and corrective functions	Custumer flow in the PSS
	Defects	Insufficient, excessive or harmful functions	Quality of product and service function
	Waiting	Insufficient functions	Waiting time in the service stream
	Transportation	Provide functions	Product, ideas and information flow in the PSS

trying to find ways to fit in order to create an ideal solution. Through the TRIZ is sought that the problem have an Ideal Final Result as a solution that avoids waste and unnecessary damage [17]. As an example, in the automotive industry, the Ideal Final Result is the car ready for the customer, without it having to think about quality, hand labour, raw material or supply chain involved. It is a result that comes under the Lean practice, in particular the fifth principle of Lean thinking, perfection. Lean is popular in many companies, and is perhaps the most important innovation tool for most.

In this context, eco-innovation does not compete with other methodologies nor is it intended to replace them. But it can be used to highlight its weaknesses, can supplement other methodologies, including Lean or PSS. But starts to have the notion that eco-innovation can complement the weaknesses of the Lean and PSS. While Lean PSS is efficient at finding problems which require solution, TRIZ is quite effective to overcome the contradictions. Lean PSS is efficient to determine the main factor of the problem, but it cannot always respond to the question "How to solve it?" [18].

With Lean can be improvement solutions in the need to make the commitment. TRIZ avoids having to make this commitment, for example through the matrix of contradictions. However, TRIZ methodology is also infrequently brought to Lean PSS context which, according Thumes [19] is difficult to understand, since TRIZ focuses on the improvement of systems, whether such systems are products or processes.

Other analysis about the use of tools TRIZ in eco-innovation make reference is done particularly to the analytical part, which they consider not be completely and effectively covered by TRIZ, at least in its classic version. It is stated that that insufficiency can be overcome with the integration of TRIZ with other methods, such as Lean. By addressing this issue [21], very similar to what was previously written, states that the stronger side of TRIZ lies in the conceptual part of the design, for example in the context of eco-design, while the analytical part is not completely covered. One of the first lessons of Lean Thinking is to understand the applications of five lean principles to your business, its key customers and suppliers. The application of the approach will be influenced by a number of factors. The implementation and deployment of Lean Thinking within an organization will be more sustainable if the Lean approach is supported by an effective set of systematic tools such as TRIZ [21].

6. Model: systematic eco-innovation in Lean PSS

Eco-innovation is not just a concept, and is also a methodology and philosophy, together with the Lean PSS. The purpose of the integrated in a model systematic eco-innovation principles and Lean PSS consists in creating a solution to problems through the analysis of a system in a step-by-step process.

Upon arrival at the end of the application of the model, the solution of the problem will be identified and ready to be implemented. In our proposed model Lean and eco-innovation tools are applied in parallel, which, to complement each other, allow a more efficient process. However, at a certain point of the model, when complex problems are be solving, we are led to a resolution exclusively through TRIZ, because this has a greater creative potential and greater capacity for problem solving compared to Lean PSS.

The proposed model can become more effective and simplified the application of eco-innovation and Lean PSS methodology. It is more effective because takes the form of flow chart. This way there are several hypotheses for solving problems, and the problem is always kept in perspective. After identified a waste or contradiction, the problem is formulated, clarified and a network of causes and effects is provided, and it is then selected what to change and how to change [22].

It is identified what is damaging, what the guidance to take, and what are the technical contradictions. In Figure 1 it can be seen in which phase of this process the proposed model is. The Table 1 shows the synthesis of elements that provided the insights for the design of the proposed model based on literature review [19, 21, 23, 24]. In this sense, is possible say that this model outlines and puts into perspective the combined use of eco-innovation in TRIZ with Lean PSS.

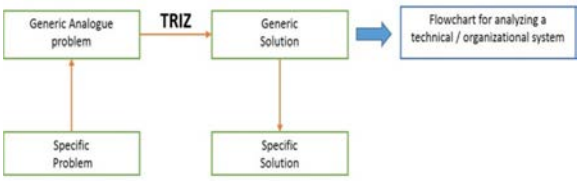

Fig.1. Phase in which the model is introduced.

The model enables an analysis of the existence of a waste or contradictions in the system, i.e., the existence of a problem. It can be applied to technical and organizational. For the description of the model the layout is divided into four zones A, B, C and D (Figure 2).

Zone A: the analysis of a system in zone A are arranged three activities. Two of them, the value stream mapping and constructing a spaghetti diagram, are preceded by a brainstorm. This one will later analyse the results in both activities preceded and so is then decided the end result of these two activities. The third activity started with the analysis of a system, consists in a brainstorming which will form the basis for the construction of the Ideality Matrix and the Ideal Solution, and to build the Matrix of contradictions. The Ideality matrix is constructed with the aim of analyzing the parameters entering in a negative iteration, which constitute a contradiction.

Zone B: if it was detected no waste or contradiction by the tools used, the analysis is finalized. On the other hand, if it has been identified a waste or a contradiction, it continues to go through the flowchart to the phase of Classification and Problem Formulation. This model suggests the preparation of two activities for this phase. In one hand, resorting to Analysis Substance-Field, a TRIZ tool, and simultaneously, it is suggested to apply techniques of causes analysis.

Zone C: with the problem already classified and formulated, in this stage it is possible to sense whether it is a complex problem, or a simple problem. The decision made in this point is not definitive, since in the case of consider the problem as non-complex, and in fact so it is not, in this flow chart this will be detected later. If it is considered that this is a complex problem, it starts to generate the problem of solutions through the TRIZ tools. If it is considered that it is not a complex problem, it can be opted for more direct solutions, using both TRIZ and Lean tools. So, are used simultaneously Causes and Effects Databases, which include for example online databases, the 40 Principles of Invention, and a set of Lean tools. This set is dynamic and it is advised that the largest possible number of tools are applied to confirm the result. These tools may be, for example, a visual management tool, 5S, Line Balancing, and the kanban, among others. After application of these tools, a solution is obtained.

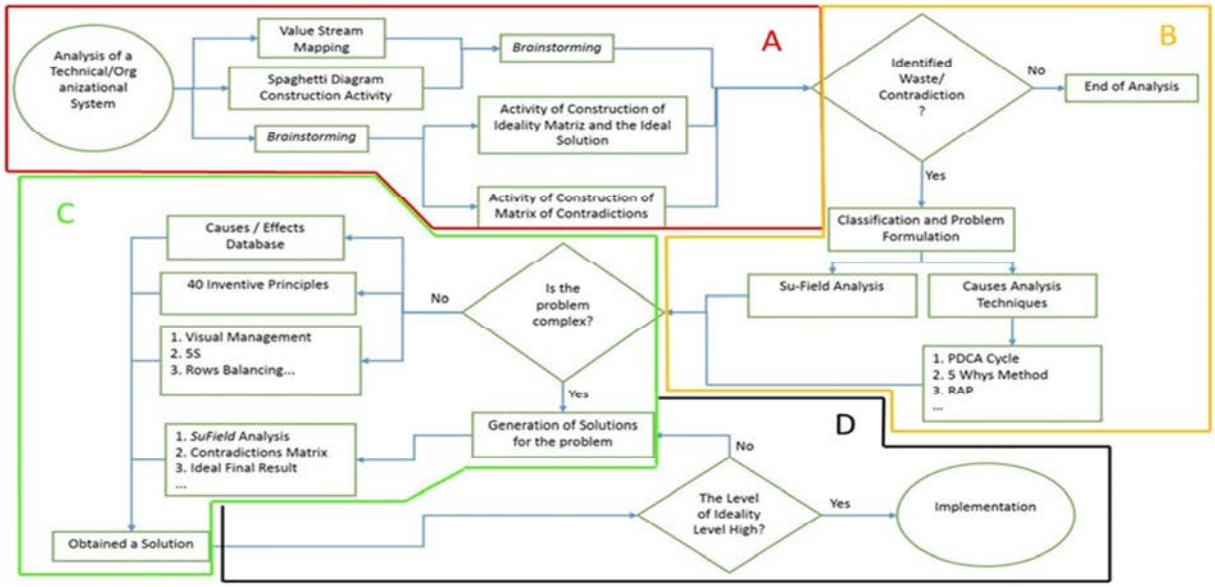

Fig.2. Integrated model.

Zone D: once obtained a solution to the waste or contradiction, the next step is to evaluate whether the solution is close to the ideal solution or not. In this stage it is applied the TRIZ ideality level. In the terminology of TRIZ methodology, a solution with a high level of ideality does not make it the ideal solution, since there are no ideal solutions. But from the perspective of TRIZ there are certain characteristics of a near ideal solution. On the other hand, a low level ideality means that there are still contradictions/waste unresolved. Following the analysis of a system using this flowchart, in the case of the solution obtained presents a high ideality level, and if it is determined that the system remained close to the ideal, then the next step is to implement the solution. The analysis cycle is now closed and it is resolved and the waste or contradiction identified. If the solution does not present a high level of ideality, the process should return to the Generation of Problem Solutions, considering now the problem as complex one, even if in the first place it was not considered as such. Since a near optimal solution was not obtained, the flowchart leads again to a resolution of the problem, but this time as a complex problem, using the generation of problem solutions through the TRIZ tools.

7. Conclusions and research directions

Eco-innovation is crucial for increasing the efficiency of organizations, to improve competitiveness and profitability. With rapid changes occurring in the industry, as well as in the services as in all human activities in the world today, a constant need for eco-innovative solutions is felt. It is necessary to improve products and processes progressively and continuously. In this sense, organizations need to have appropriate analytical tools to implement systematic eco-innovation and greater creativity. One of the important factors for the success of industrial activities is the creation of ideas and eco-innovation.

Eco-innovation and Lean PSS are applied to this field, because they consist in tools of innovation and continuous improvement and significantly increase responsiveness to market changes. Lean PSS aims to continuously improve processes by reducing waste and increasing efficiency. In a Lean PSS deployment environment is assumed the use of various analytical instruments and various methodologies such as Value Stream Mapping, Kaizen, Total Productive Maintenance, Pull, kanban, among others. However, lack analytical tools for the generation of solutions.

TRIZ aims to inventive problem solving in engineering and management. It has a set of different analytical instruments and techniques used to generate solutions to detected problems or fault analysis. Various techniques and concepts of Lean PSS may be used with the instruments of eco-innovation [23]. So, as solutions generator, TRIZ can assist in the creation and development of Lean PSS management environments. The combination of Lean PSS

analytical tools with the creative capacity of eco-innovation could provide important advantages for organizations.

Eco-innovation is being disseminated and increasingly used in academic and industrial environments. Some large international economic groups are increasingly using eco-innovation concepts, such as Ford and Daimler-Chrysler, Johnson & Johnson, the aircraft manufacturer Boeing, NASA, and technology companies Hewlett Packar, Motorola, General Electric, Xerox, IBM, LG, Samsung, Procter and Gramble, Expedia and Kodak.

Other companies are also experienced users of the Lean PSS methodology. Thus, the new model could be useful for these companies. This study of joint use of analytical tools of Lean PSS and eco-innovation has shown great potential for practical use. The model combine the analytical tools with the inventive ability of eco-innovation, present real advantages, specially integrated on applications with organizational methods like Lean PSS.

Finally is possible say that our study has some limitations that could be considered. In this sense, these limitations can generate future researches. First, we suggest that the model be refined by other researches and mainly from case studies validation. Other opportunity could be in order to specify segments of enterprises with best fit for the model application. Finally, evaluate other tools for the model is a possible hypothesis. This research is the result of an initial effort on the integration of eco-innovation in systematic Lean PSS field. Although there are limitations, this study identified some insights that could be analyzed in future researches and might contribute to expand the PSS theory on systematic eco-innovation.

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