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TIME-EFFICIENT ECO-INNOVATION WORKSHOP PROCESS IN COMPLEX SYSTEM INDUSTRIES

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1. Introduction

Managing both innovation and environmental dimension is a promising and exciting field for industrial companies [OCED 2010]. Indeed, eco-innovation is an efficient solution for reducing environmental impact, as well as for improving brand image and for getting marketing advantages in front of competitors.

Thus, industrial companies increasingly want to initiate and develop eco-innovation in their projects. For most complex industrial system companies, multinational as well as SMEs, starting such an eco-innovation approach on their product is not an easy task. In a survey conducted within 12 French industrial companies practicing eco-design, the authors highlight there is still a large gap between the development of eco-innovation methods and tools in academia and their appropriation by companies to go further eco-design and to move towards eco-innovation [Cluzel et al. 2014]. The identification of suitable methods and tools in an eco-innovation process for a given company should contribute to reduce this important gap. Indeed, complex system design and development involve many stakeholders (e.g. different departments within the same company, outsourced suppliers) and it is complicated to shift employees' habits and current companies' practices. Moreover, many companies do not have any eco-design experts in their own structure, and employees, whose workload is already heavy, do not have a lot of time allotted to eco-innovation formations or workshops.

Based on relevant literature review and industrial reality, this paper adapts existing eco-innovation workshop to meet companies' needs and constraints in the development of their eco-innovation approach. Indeed, design creativity and innovation clearly must not be separated from realities of companies because there are the first beneficiaries of the practical perspectives [Yannou 2013]: getting effective methods in companies to develop even more innovative products and services, and considering all the barriers and constraints employees have to deal with, such as limited time and resources available. Provide an eco-innovation workshop process that is truly effective for complex system industries is hence a core issue.

Regarding major companies' constraints and barriers mentioned above, a new process supporting efficient and short time-consuming eco-innovation workshop is proposed and applied on the industrial ground at Liebherr Machines Bulle (LMB). This eco-innovation workshop process for environmental improvements purposes is experienced on a new emission control device, namely the SCR (Selective Catalytic Reduction) Filter System, developed by LMB. Different departments within LMB and outsourced suppliers are involved in this project. Moreover, the company do not own eco-design expert and have strict constraints regarding time and resources available for eco-innovation. The main intellectual merit of the present manuscript relies on the three following points: i) before the workshop, the use of 10 criteria to select a relevant multidisciplinary working group within an eco-innovation workshop; ii) during the workshop, the adaptation of existing eco-innovation workshop to be time-efficient and thus meet companies' context; iii) at the end and after the workshop, the introduction of KEPI (Key Environmental Performance Indicators) to ensure an friendly and convenient environmental follow-up to selected ideas, concepts or solutions.

This article is organized as follows. Section 2 discusses the relevant literature for conducting an efficient eco-innovation workshop, from the selection of a suitable multidisciplinary working group to the environmental follow-up of selected ideas, through eco-ideation and eco-selection stages. It is followed by a detailed explanation of the proposed eco-innovation workshop process in Section 3. Section 4 illustrates the proposed approach thanks to its application on the industrial ground and discusses the results of the eco-innovation workshop process. Section 5 summarizes the article and opens up new research prospects.

2. Literature review

In this section, inspirations for the proposed method from prior scientific literature are reviewed. Based on this state-of-this-art and regarding company's context (needs, constraints and features), research questions have then emerged to adapt existing eco-innovation workshop process to a new one which best meets company's context. Thus, investigations have been performed at three different stages of the workshop organisation (before, during and after the workshop), as presented in Figure 1.

Figure 1. Research questions studied for an adapted and efficient eco-innovation workshop

2.1 Multidisciplinary working group within eco-innovation workshop

Complex systems design and development involve manifold actors, each with their own backgrounds, skills and sensitivities about environmental issues. That is the reason why it seems important to intelligently gather these stakeholders so that all the actors of the eco-innovation approach collaborate and carry out their work in the same direction. For numerous authors multidisciplinarity is clearly a key of success [Pujari et al. 2010], [Bocken et al. 2011]. So, the first question to solve to organise such a workshop is "how to select stakeholders to form a multidisciplinary workshop in order to generate relevant environmental improvement projects?" Using large samples of research projects, Lee et al., examine the drivers of creativity in team building, in particular the effects of team size, field variety and task variety on both novelty and impact on creativity [Lee et al. 2014]. In 2015, Svalestuen and his collaborators try to find out what characterizes a highly efficient building design team and identify twelve key elements that influence the performance of a building design team [Svalestuen et al. 2015]. Although recent studies evaluate the impact of many teambuilding criteria about on creativity and efficiency inside design and multidisciplinary working team, these criteria do not consider the generation of environmental ideas. In eco-design and eco-innovation research fields, existing works give some recommendations and advices about the formation of multidisciplinary working group but there is no framework or systematic and quantified approach to evaluate stakeholders' relevance and select participants for an efficient eco-innovation workshop. In fact, particular attention must be given to form this team [Le Pochat et al. 2007]. One representative per function or skill is at least recommended. For the authors, in addition to the skills connected with the design (e.g. R&D, manufacturing departments), it is necessary for other departments to be represented (e.g. purchasing, marketing, logistics departments). This means that people of strategic importance and exerting considerable weight in decision-making must be involved. Eventually, the integration of eco-design expertise in the company must be done by people who are convinced that the approach is well founded. On the other hand, Cluzel et al., recommend also that the selection of the working group members should not be neglected, but without giving any criteria to select the participants [Cluzel et al. 2015]. In the proposed method, ten criteria are experienced to assess stakeholders' relevance within a multidisciplinary working group for environmental projects creation purposes.

2.2 Eco-innovation workshop process in complex system industries

Once the multidisciplinary working group is formed, the next question is "how to facilitate eco-ideation, then eco-selection of ideas during the workshop regarding company's features, needs and increasing constraints on time and resources?" An important aim of Jones' research was to facilitate the generation of radical environmental ideas and to help developing these ideas into appropriate solutions that have the potential to be taken up in industry [Jones 2003]. The eco-innovation process developed by Jones has six major steps (early stage workshop; select promising ideas; develop concepts; select promising concepts; project taken up in industry; product to market) to lead to the burgeoning of eco-innovative concepts. In this paper we focus first on the four primary steps of Jones' process. Compared to Jones' eco-innovation process, the proposed workshop will mutualise "creativity session" and "evaluation session" into one single session including eco-ideation and eco-selection phases. Jones' approach is global and does not provide much detailed about the organisation of workshop except the recommendations of two tools (PIT diagram and TRIZ). Finally, Jones does not provide a time scale to guide and monitor the realisation of the process. On the other hand, Rocchi experienced two eco-innovation workshops within Philips company in 2005 with the aim of generating value-created Product Service System and focusing on three aspects of sustainability (economic, environmental, social) [Rocchi 2005]. His approach consists on a complete 12-step process (2 steps before the workshop, 8 steps during, 2 steps after) but which requires a lot of time (3 full days of workshop) to be set up and is hardly applicable on external company due to the lack of specific explanation about the progress of each step. Recently, Tyl and Cluzel propose respectively two approaches of eco-innovation workshop with different tools and format used. Tyl proposes also a workshop process in four steps (awareness; preparation; ideas generation; ideas selection) for facilitate the eco-ideation and eco-selection of ideas. According to the recommendations of Tyl's method, such a workshop would last between 3h50 and 8h30 (without the consideration of any break) [Tyl 2011]. Cluzel generates environmental portfolio projects thanks to a multidisciplinary working session at Alstom Grid [Cluzel et al. 2015]. (Considering the constraints associated to complex industrial systems, Cluzel gives seven key recommendations for an adapted eco-innovation process.) Even though Cluzel eco-innovative process is rather time-efficient, the number of sessions (3 or 4) and the total duration of all participants presence required (about 10 hours) could remain high for companies with limited resources in available time and persons allotted to eco-innovation. That is particularly the case for Liebherr Machines Bulle, where the present process is applied, which could not afford and ensure the participation of all experts involved in the project at several eco-innovation sessions. Thus, the proposed eco-innovation workshop process has the main advantage to last 3 hours in a single workshop.

2.3 Tools for eco-innovation workshop

2.3.1 Eco-ideation

Eco-design tools have been intensively studied and classified in literature. For instance, Bovea & Pérez-Beliz put forward exhaustive state-of-the-art of available eco-design tools, both for assessment and improvement purposes [Bovea and Pérez-Beliz 2012]. Some tools are designed to cover the whole eco design approach from the definition of the project to environmental improvement through environmental assessment. Although many of these tools present keys to find environmental improvement directions, they are too general and not really fitted to be used for creativity session and eco-ideation [Bocken et al. 2011]. Bocken and her collaborators define eco-ideation as "generation of ideas that particularly aim to reduce environmental impacts". They also review several methods developed for the specific purpose of eco-ideation and state the difficulties for a broad range of actors across different functions to generate eco-innovative ideas through those methods. More precisely, Tyl makes a comparison review of eco-innovation tools for creativity purposes (e.g. Eco-compass; LiDS Wheel; PIT Diagram; Eco functional matrix; ecoQFD; Information-Inspiration; TRIZ; EcoASIT; Eco MAL'IN) [Tyl 2011]. Based on this state-of-the-art, on previous works and on authors' experience in eco-innovation, most relevant tools have a priori been pre-selected in Table 1. Thus, remaining tools will be compared to select the most suitable eco-innovation tool to fit the eco-innovation workshop and guide creativity session regarding company's context. In fact a prior industrial diagnosis has been done at Liebherr Machines Bulle to assess the company's needs, features and constraints.

Table 1. Comparison of eco-innovation tools for eco-ideation regarding company's needs

Company's context	Ideal eco-innovation tool	LiDS	EcoASIT	PILOT	edTool
Poor eco-design skills	No prerequisite. User-friendly	+++	+++	+++	+
Little time & resources	Quick to master (half a day)	+++	+++	-	-
Low eco-innovation budget	Free. Open Source	+++	+++	+++	+++
Multinationality	In English	+++	+	+++	+++
Long term approach	Data storable, reusable	+	+	-	+++
Collaboration with suppliers	Data exportable, online	+	+	+	+++
Life Cycle thinking	Covers the whole Life Cycle	+++	-	+++	+++
End-of-Life almost unknown	End-of-Life recommendations	+	-	+++	+

+++	+	-
Best tool to fill the requirement	Fill the requirement	Do not fill the requirement

LiDS Wheel has the main advantage to fulfil all requirements. In fact, this eco-design wheel is free, user-friendly, covering all life cycle [Brezet and Van Hemel 1997] and could easily been storable and exportable thanks to an Excel worksheet for example. Also, this tool has already been used with success within a multidisciplinary working group session for eco-improvements at Alstom Grid [Cluzel et al. 2015]. However, one must keep in mind LiDS Wheel has a low capacity to support radical innovation [Tyl 2011] but that is not a detrimental factor for non-eco-design expert company which have just started to considered environmental dimension. Hence, LiDS Wheel will be used for the eco-ideation part.

2.3.2 Eco-selection

Recently, Leroy and his collaborators review a wide range of criteria to classify ideas. They underline ideas must also be assessed with a multi-criteria approach which could be selected and customized depending on the typology of the project [Leroy et al. 2015]. In the RID (Radical Innovation Design) method developed by Yannou, four indicators (Usefulness, Newness, Profitability, Proof of Concept) are used to ensure that ideas or projects generated will lead to the creation of added value for the user and the company [Yannou 2013]. Different management methods to evaluate and select R&D projects are reviewed and synthesized in [Cluzel et al. 2015]. Particularly, in its eco-innovative process, Cluzel proposes a first screening of ideas during the "convergent phase" that lasts 2 hours where ideas are discussed and sorted out according technical, economic and clients' aspects. Then, eco-innovative project selected are prioritized through a second filter considering six dimensions (project nature; potential environmental benefits; feasibility; clients' value; time horizon; project perimeter). Such an evaluation lasts several days (10 days for 16 projects in Cluzel's study case) and is therefore not adapted for our time-efficient workshop. On the other hand, the EcoASIT method developed by Tyl proposes four criteria (feasibility; environmental relevance; social relevance; originality) with a simple scoring system to evaluate quickly generated ideas [Tyl 2011]. In the proposed eco-innovative workshop, these four criteria will be adapted (in Section 3.3.3) to a fast eco-selection of ideas regarding company's context.

2.3.3 Environmental follow-up of ideas, a KEPI-based approach

Key Environmental Performance Indicators (KEPI) were developed considering the perspective of a designer who may like to improve the environmental performance of the products but has limited resources and understanding of complex environmental issues [Singhal et al. 2004]. Thus, one simple-yet-effective solution to ensure environmental follow-up is to define appropriated KEPI. Different definitions, types and characteristics of EPI (Environmental Performance Indicators) have been reviewed [Hourneaux et al. 2013]. The authors point out the existence of several ways to define and classify EPI. Then, to help numerous non-eco-design expert companies to choice right indicators among long list of 261 generic EPI (retained after filtering literature complete review on the subject), Issa and collaborators try to bring a systematic approach to select and apply relevant EPI [Issa et al. 2015]. According to system's features and the Life Cycle Assessment (LCA) results, appropriate KEPI, that is to say indicators who cover most important environmental impacts of the system, will be defined before the workshop. The multidisciplinary group could therefore define feasible and suitable environmental targets to achieve at the end of the workshop.

3. Proposed method

Regarding companies' context and limited time allocated for eco-innovation, the eco-innovation workshop have to pool efforts and resources efficiently: introduction, eco-ideation, eco-selection and KEPI allocation steps have been mutualised into one single eco-innovation workshop. Figure 2 presents the eco-innovation workshop process proposed and experienced in this paper.

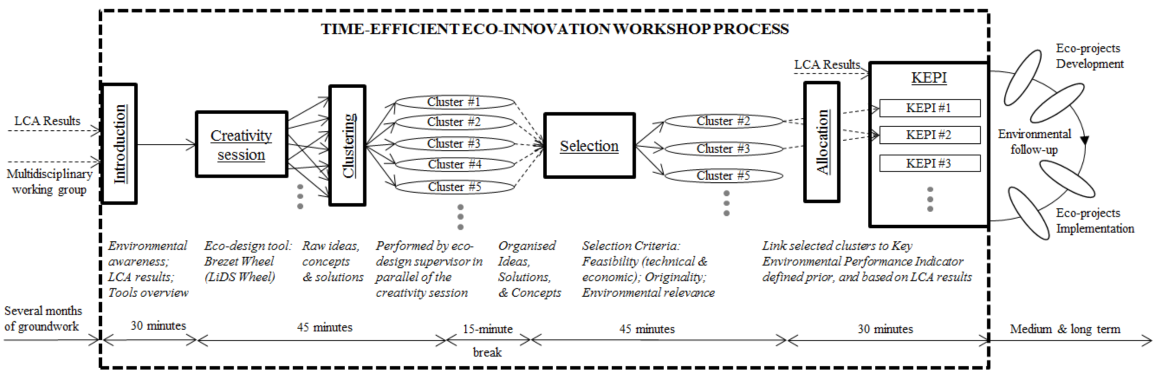

Figure 2. 3-hour eco-innovation workshop process

Following sub-sections will detail each step of the proposed eco-innovation workshop.

3.1 Prerequisites

Before starting the organisation of the proposed time-efficient eco-innovation workshop, three main prerequisites are required:

- The identification of system's main stakeholders (here the SCR Filter System);
- An environmental assessment of the system, for instance, a Life Cycle Assessment (LCA);
- An eco-design expert to prepare, animate and supervise the workshop.

3.2 Before the workshop: Proposition of a systematic approach to form a relevant multidisciplinary working group

Regarding company's internal organisation and guided by recommendations in above literature review, ten following criteria and their corresponding scores, as shown in Table 2, have been experienced to select most relevant participants within a multidisciplinary working group for an eco-innovation workshop.

Table 2. Ten criteria to assess stakeholders' participation relevance and related scoring system

Criteria / Score	1	2	3
1. Eco-design skills	None	Basic	High
2. Involvement on environmental considerations	None	Basic	High

3. Knowledge level on the issue (project or system considered)	Low	Basic	High
4. Part of this issue in their work	Daily	Weekly	Yearly
5. Actor in the design & development of the system	No	-	Yes
6. Actor in the purchase and/or selling if the system	No	-	Yes
7. Number of life cycle phases covered in their work (out of 6): raw materials; production; packaging; distribution; use & maintenance; recycling or disposal.	0	1 - 3	> 3
8. Impacted degree by any change on the system	None	Minor	Major
9. Responsibility level in the company or within the department	Low	Medium	High
10. Decision power in the company or within the department	None	Medium	High

Within each department, and for each supplier or customer concerned by the system, the (available) employee receiving the highest total score will be selected for participating in the eco-innovation workshop. To validate or not this method of selection, the ranking of each participants according to these ten criteria will be compared to the ranking of their real contributions during the workshop.

3.3 During the workshop

3.3.1 Introduction

The eco-innovation workshop begins with a 30-minute introduction, which contains:

- The environmental awareness (5 minutes);
- The explanation of current eco-innovation workshop objectives (5 minutes);
- The presentation of LCA results (10 minutes);
- The presentation of the eco-innovation tool used (10 minutes).

3.3.2 Eco-ideation

The eco-design tool selected to enhance creativity during the eco-ideation phase is the LiDS Wheel. All the axes of LiDS Wheel are used here to generate a maximum of ideas through all product lifecycle. Indeed, some axes relate to the product component level (axes 1 & 2), some to the product structure level (axes 3, 4 & 5) and others to the product system level (axes 6 & 7). The last axis "@ New concept development" is different, since it relates to a more innovative strategy than the others.

Table 3. 8 axes of the LiDS used and associated words to boost eco-ideation

8 axes of the LiDS [Brezet and Van Hemel 1997]	Words broadcast to boost creativity during workshop
1. Selection of low-impact materials	Cleaner materials - Renewable/Recycled materials
2. Reduction of materials usage	Reduction in weight - Reduction in (transport) volume
3. Optimization of production techniques	Fewer steps - Lower energy - Alternative techniques
4. Optimization of distribution system	Less/Reusable packaging - Energy-efficient logistics
5. Reduction of impact during use	Cleaner energy source - Fewer consumables
6. Optimization of initial lifetime	Easier maintenance and repair - Product-user relation
7. Optimization of end-of-life system	Reuse - Remanufacturing - Refurbishing - Recycling
@. New concept development	Dematerialisation - Product-service - New technology

The working team has got 5 minutes by axis to generate ideas. For each axis, one slide containing short expressions, as presented in Table 3, in relation with the axis is broadcast to boost eco-ideation. Selected participants write all their ideas individually on Post-it® and could freely discuss to each other or question the supervisor. Thus, eco-ideation step lasts, in all, around 45 minutes, considering transition time between the axes. At the end of each axis, the supervisor collects all ideas to start the clustering of same or similar ideas in order to facilitate the next step, namely ideas eco-selection.

3.3.3 Eco-selection

The eco-selection step is inspired from EcoASIT method [Tyl 2011]. In fact, this method suggests a quick evaluation of ideas thanks to four criteria (environmental relevance; social relevance; originality; feasibility) and a simple scoring system. In the proposed eco-selection process, some criteria have been modified to best fit with complex system industries requirements. "Social relevance" criterion has been removed due to its difficulties to assess rapidity. "Feasibility" criterion is detailed in "economic feasibility" and "technical feasibility" criteria, judge as fundamental issues for industrial companies. "Environmental relevance" and "originality" criteria have been conserved.). Thus, based on the four criteria detailed in Table 4, each cluster of ideas is scored from 1 to 3 by every selected expert. The eco-selection should last a total of 45 minutes. Finally, the use of an average allows the ranking of generated ideas clusters. The company could then choose the number N of best ideas clusters for further and future development according to its strategy.

Table 4. Four eco-selection criteria with scoring system

Criteria / Score	1	2	3
Economic Feasibility (EF)	Too expensive for company's budget.	Investment possible but not sure of profitable return on investment.	Required slight investment, could lead to great economic benefits.
Technical Feasibility (TF)	Not feasible (with current technology).	Feasible but with modification of current industrial practices.	Perfectly applicable on industrial ground.
Environmental Relevance (ER)	No environmental benefits.	Reduction of environmental impacts but risk of negative impacts transfer.	Great potential of environmental impacts reduction.
Originality (O)	No originality.	Interesting but already seen at competitive companies. Do not need a creativity session.	Very original. Never seen before.

3.4 After the workshop: Facilitate the environmental follow-up of selected ideas with KEPI

At the end of the workshop, the N best clusters of ideas are associated with pre-defined KEPI under the direction of the eco-design supervisor. Also, during the last 30-minute of the workshop, the multidisciplinary working group of experts could set quantified targets to achieve so as to ensure environmental follow-up of selected ideas.

4. Application & results

4.1 Application at Liebherr Machines Bulle (LMB)

This eco-innovation workshop process has been experienced on the industrial ground, at LMB, in Switzerland, within the After Treatment System (ATS) department for Non-Road Mobile Machinery (NRMM). Since 2014 stricter emission regulations for diesel engines have been in force in the USA and the EU. A new restriction of emission standards is forecast for 2019. Therefore, NRMM constructors such as Liebherr are increasingly concerned by those issues. In fact, LMB, which has no specific background in eco-design, wants to go further emissions regulations by starting the development of an eco-design approach for the next generations of their innovative exhaust gas after treatment system: the SCR Filter System. The SCR Filter System is an innovative emissions control device that converts toxic pollutants (e.g. NOx and particles PM) in exhaust gas to less or non-toxic pollutants. The SCR Filter System is a complex industrial system, according to Cluzel's definition [Cluzel et al. 2015]. Indeed, the main features of the SCR Filter system are the following: a range of SCR Filter systems depending on the engine power; a long list of suppliers; a global supply chain with an outsourced production; the use of precious metal (e.g. platinum); an end-of-life almost unknown and a poor traceability after sales. Moreover, SCR Filter System design and development involve not only different departments from LMB (ATS, Engine Development, Quality, Purchases and Sales departments) but also suppliers and customers' requirements. This point underlines the importance to gather all these stakeholders inside a relevant multidisciplinary working group for the eco-innovation workshop proposed. The multidisciplinary team was composed of 8 participants selected and ranked according the ten criteria proposed: seven industrial persons representing LMB's business direction (Expert #1), ATS department (Expert #2), Sales department (Expert #4), Engine Development department (Expert #5), Quality department (Expert #6), one main supplier (Expert #3) and one key customer (Expert #8); one academic junior eco-design expert (Expert #7). Before the eco-innovation workshop, appropriate KEPI have been defined with their current values. Indeed, 9 KEPI, that cover the significant environmental impacts of the system, have been defined to measure environmental continuous improvements, and grouped into 3 following categories:

- 4 KEPI resulting from LCA (using Impact2002+ method): Global warming (kg CO2 eq.); Human health (DALY); Eco-system quality (PDF/m2/y); Resources materials (MJ eq.).
- 3 KEPI related to system technology: Diesel consumption (L); AdBlue® consumption (L); DeNOx efficiency (%).
- 2 KEPI concerning the end-of-life: Waste to landfill (%); Collection rate of platinum (%).

4.2 Generation and selection of ideas

During the 45-minute eco-ideation phase, a total of 106 raw ideas were generated following the process described in Section 3.3.2. In parallel and during the 15-minute break following the eco-ideation phase, the supervisor of the workshop grouped similar raw ideas in 27 distinct clusters to facilitate the next 45-minutes of ideas selection. At the end of the workshop, 10 clusters of ideas with the highest score were selected for further development and implementation.

Considering the time allotted to the proposed workshop, and thanks to the formation of a relevant multidisciplinary working group of complementary experts, results are very satisfactory. In terms of quantity; an average of 2.65 ideas/minute or 0.33 ideas/minute/person have been generated, which is higher to what other eco-innovation workshops studied in literature review have performed. Moreover, the 10 selected environmental projects cover a wide range of tasks. On one hand, 3 projects deal with short-term, 4 with middle-term, and 3 with long-term issues. On the other hand, 3 projects concern only LMB, 2 projects deal with LMB and one supplier and 5 projects involve more stakeholders.

4.3 Evaluation of the multidisciplinary working group

After the workshop, each participant's performance is evaluated and ranked according to three criteria:

- Creativity, corresponding to the number of raw ideas generated per participant;
- Utility, corresponding to the number of ideas selected per participant;
- Efficiency, corresponding to the ratio of the number of ideas selected to raw ideas generated.

Thus, this ranking allows to check, in Table 5, if the relevance of each participant, assessed before the workshop with the ten proposed criteria, effectively matches with their current and real contributions.

Table 5. Evaluation of the multidisciplinary working group of complementary experts

Rank	Relevance (/3)	Creativity (raw ideas)	Utility (ideas selected)	Efficiency (ratio)
1st	Expert #1 (2,8)	Expert #2 (20)	Expert #1 (11)	Expert #2 (0,65)
2nd	Expert #2 (2,4)	Expert # 1 (17)	Expert #2 (10)	Expert #6 (0,64)
3rd	Expert #3 (2,3)	Expert #3 (15)	Expert #6 (9)	Expert #2 (0,5)
4rd	Expert #4 (2,3)	Expert #6 (14)	Expert #7 (7)	Expert #4 (0,5)
5rd	Expert #5 (2,2)	Expert #5 (14)	Expert #3 (5)	Expert #7 (0,5)
6rd	Expert #6 (1,9)	Expert #7 (14)	Expert #4 (4)	Expert #3 (0,33)
7rd	Expert #7 (1,7)	Expert #4 (8)	Expert #5 (3)	Expert #8 (0,25)
8rd	Expert #8 (1,7)	Expert #8 (4)	Expert #8 (1)	Expert #5 (0,22)

Results are mainly matching with prediction (prior relevance assessment). This is particularly true at the both extremes of the ranking. Indeed, contributions (creativity, utility and efficiency criteria) of Experts

#1 #2 #8 correspond to what was expecting (relevance criterion). However, some participants have contributed quite more (Expert #6) or less (Experts #3 #5) than the ten criteria could predicted.

5. Discussion & conclusion

In complex system industries, eco-innovation workshop outcomes are mainly conditioned by participating persons. The formation of the multidisciplinary group is therefore a major milestone. But bringing together all different experts involved in a complex system project is a not an easy task and time needed is often a crucial matter. The broader impacts of our work have the potential to encourage industrial and non-eco-design expert companies, such as Liebherr Machines Bulle, to initiate eco-innovation workshop. The proposed approach demonstrates it does not require much time and lead to the generation of great environmental improved ideas shared and selected by main stakeholders of the project.

The interest of this study lies in the fact that it proposes a time-efficient eco-innovation workshop which includes principally a 45-minute eco-ideation step based on the LiDS Wheel and a 45-minute eco-selection step based on four criteria. Moreover, the present approach suggests also ten criteria to select most relevant participants within such an eco-innovation workshop. Last but not least, at the end of the workshop environmental targets are defined, with the help of the eco-design supervisors and the opinion of all present industrial experts through pre-defined KEPI. Indeed, these KEPI are useful for non-eco-design expert companies to ensure environmental follow-up of selected ideas. The application on the industrial ground at Liebherr Machines Bulle went very well. Participants were pro-active and appreciate particularly the form - rapidity and efficiency - of the eco-ideation and eco-selection stages.

The ten criteria actually experienced to assess participants' relevance of an eco-innovation workshop provide only a trend when predictions are compared to real contributions. Thus, this approach needs further tests to be validated. A more detail analysis about the ideas generated by each participant (e.g. in terms of novelty, variety, quality, quantity [Shah et al. 2003]) could provide more information to identify best profile for relevant ideas generation within an eco-innovation workshop. Moreover, other criteria could be added to consider the group dynamic and the connection between participants during the workshop.

During the eco-ideation phase, note that some ideas were generated within a none appropriate axis of the LiDS. This is not a problem as the main goal is to generate a maximum of ideas, no matter in which axis the idea belongs. Axes were only here to boost creativity and ensure whole life cycle of the system is exploited. During the eco-selection phase, participants give feedback about the four criteria chosen. In fact some industrial experts do not find suitable to consider Originality as the same level as Economic Feasibility, Technical Feasibility or Environmental Relevance. Indeed, they think about efficient results (a solution feasible that works) and do not care, in a first place, if the solution is new. Moreover, originality depends on the technological knowledge and background of each participant. It is seen as a highly subjective criterion: a same solution could be original for one participant and quite common for another. Authors do agree with these objections but think originality is still an important criterion it could be a great marketing argument. On the other hand, the idea with best Environmental Relevance score was not selected due to a low Technical Feasibility score. As the four selection criteria count for the same weight, one solution could be to let the decision makers (e.g. company direction or team leader of the project in the company) choosing weighting coefficients between criteria to best fit with company vision and objectives.

In our approach, we proposed and tested a very time-efficient eco-innovation workshop process and made eco-innovation possible even for complex industrial system companies which want to implement eco-innovation on their project, but with very strict constraints on time and resources available. Though, one must bear in mind not to rush things during the first steps of the eco-innovation process. According to the time allotted by the company to eco-innovation, other process could be preferred to spend more focus either on the generation, on the evaluation or on the selection still regarding company's context, skills and maturity in eco-innovation. To deal with such trade-offs, future researches could develop systematic framework for eco-innovation workshop in complex industrial system companies.

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