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EXPLORING STAKEHOLDER-CENTRED TOOLS TO IMPROVE THE MATURATION OF THE FRONT-END OF ECO-INNOVATION PROCESS (FEEI)

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1. Introduction

Eco-innovations fosters organizational ruptures which involve to rethink the network of stakeholders from the early stages of development. Actually, there is a lack of tools to support the identification and the construction of new stakeholder's networks during the front end of eco-innovation (FEEI). In this paper, we propose a study to test the effect of different stakeholder-centred tools during the maturation of FEEI process. Two main contributions are surrounded: (1) **Extending the range of actors** present in such tools seems to overcome classic economic rationale and identify new and diverse type of relationships likely to be transformed in more cooperative and sustainable business models. However, this implies a larger combinatorial that leads to consider hybrid typologies of actors according to the context and the level of maturation. (2) We also observe that tools **with adaptable zoom on network and focus intermediary objects** can facilitate the co-exploration of concepts, stakeholder networks and incubation means. In future research, an interactive stakeholder-centred toolkit will be designed and tested to improve the management of FEEI.

1.1 The importance of the Front End of Eco-Innovation process

Today, ecological risk prevention and challenges of sustainable development involved important social system changes. In industrial system, stakeholders require to re-think their activities through new offers, new business models or new uses.

The eco-design approach, is defined by the international standard ISO 14062 (2002) as the integration of environmental constraints in the design and development of products: (1) the product or service has to be considered with its whole life cycle (raw material, manufacture, distribution, use, end of life), and (2) a multi-criteria principle has to be used in order to take into account the complexity of the environment through different environmental impacts. Various tools have been developed to cover the different stages of the eco-design process, from tools to assess the environment impact of a system as LCA, to tool to improve the environmental relevance of the system.

The Front End of Eco-Innovation (FEEI) is becoming an increasingly important area of investigation [Bocken et al. 2014] due to its importance to propose ruptures in project. The more the project progresses, the more the capacity to influence environmental performance on all the life cycle disappears [Jones 2003]. FEEI are characterized by a high level of uncertainty, fuzziness and complexity and often embrace informal and open innovation approaches [Bocken et al. 2014]. FEEI process is generally composed of some cycles of ideation session, allowing the emergence of a portfolio of projects with a strong potential of reducing environmental burdens [O'Hare 2003], [Cluzel 2012]. Various eco-ideation tools as PIT Diagram and more recently Eco-ASIT [Tyl 2011] were developed to improve the exploration of environmentally relevant ideas, going toward radical changes,

through global system approaches. The choice of tools used during an eco-ideation session can evolve according to the maturation of the process and the particular needs of the team (e.g. explore all possible eco-design strategies, focus one environmental aspect, or to challenge some relevant ideas generated in previous sessions). Generally, more time-advanced a team is, deeper and more concrete solutions are. [Vallet et al. 2012] classified tools according to five main eco-design dimensions: life-cycle, multi-criteria approaches, rupture, stakeholder (both industrial & civil) & process. This review of tools indicated a clear difficulty to support organizational ruptures during the FEEI whereas the development of eco-innovations need to rethink the network of stakeholders, their roles, theirs values, their performances and their ability to cooperate in a long-term project.

1.2 Dynamic of stakeholder networks during FEEI

Cooperation during FEEI is distinguished from other types of collective activity insofar as the objectives, criteria of efficiency and resources are not a priori identified: actors desire to explore new fields of eco-innovation together without being contractually engaged. One of the objectives of FEEI is to launch a collective learning process to guide actors toward future actions [Segrestin 2010]. The stakeholder network includes all relevant types of actors capable to protect, support and foster the eco-innovation in the different transition phases. Some complex socio-mechanisms of "interessement" (well studied in the Actor Network Theory [Callon 1998]) influence the dynamic of such networks from the initial stage until eco-innovations are put into the market & accepted by users. The different strategies of behaviour towards sustainability, the eco-design capabilities and ethical principles of each actor add new dimensions influencing the structure and the dynamic of innovative stakeholder networks. They can be source of new synergies or on the contrary create more distances between actors, and potentially new barriers towards cooperation. Deep organizational and cultural changes or ruptures in actor networks are required to overcome such blockages *(see Figure 1a)* [Ceschin 2013]. propose some key steps to facilitate the societal embedding process of eco-innovation : incubation where conditions needed to start the process are set up (identification and involvement of needed actors; discussion and negotiation to achieve a common consensus on the eco-innovation concept as well as on the potential strategies to socially embed the concept), implementation of small scale socio-technical experiments, the development and empowerment of a niche, and the scaling up of eco-innovation. Earlier the necessary changes in stakeholder practices will be identified; more frequently stakeholders could choose to develop radical eco-innovative concepts, faster the incubation of eco-innovations will be possible.

To sum up, three interdependent dimensions composed the FEEI process: the exploration of concepts, the analysis of stakeholder network mutations and the identification of means for project incubation.

The maturity of each dimension is increasing all over the process via collective ideation sessions and more informal practices.

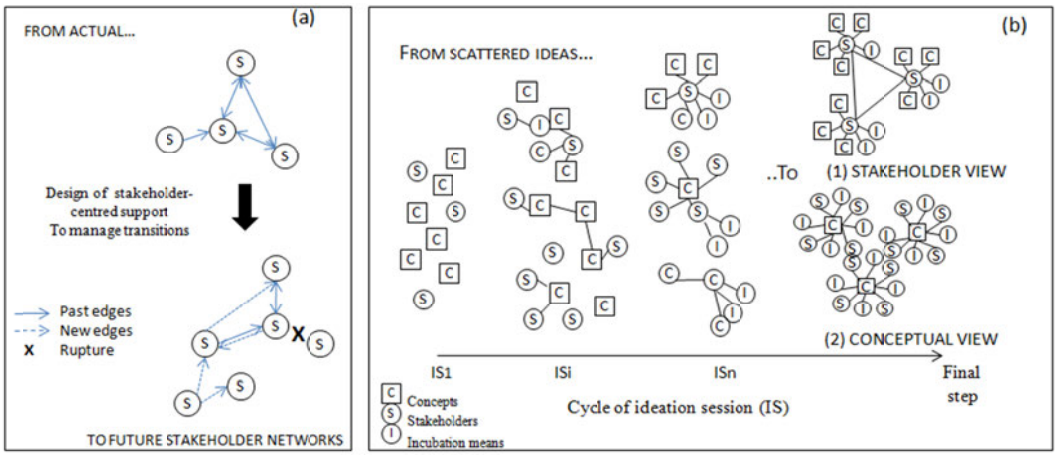

Figure 1. Examples of (a) new dynamics of stakeholder networks faced to eco-innovation and (b) maturation of an FEEI process according to the evolution of (1) concepts (2) stakeholders (3) incubation means

In this paper, we investigate how to design stakeholder-centred tools aimed at defining and rethinking stakeholder networks during ideation sessions. We will analyse their impacts on the maturation of the three FEEI dimensions.

1.3 Exploring stakeholder-centred tools during ideation sessions

Caelen [2009] described ideation sessions as "moments" composed by different objects: objectives, actors, intermediate objects [Jantet 1998] and some procedures (tasks, animation rules). They form a system for interaction and creativity including spaces, items and behaviours that participants explore, manipulate and inhabit. Exploring stakeholder-centred tools consist in analyzing different creative environments facilitating the interaction with stakeholder network representations. Such collective activity is complex and involves the use of a number of manipulated objects in concordance with cognitive capacities. Tools could be different according to the chosen type of involved stakeholders, edges and intermediate objects. Several recent studies proposed different stakeholder-centred methods, co-exploring some FEEI dimensions (*see Table 1*).

Table 1. Example of stakeholder-centred methods

Type of methods	Direction of co-explored FEEI dimensions (from X >> Y)	Type of edges	Type of stakeholders	Intermediate objects
(1) Social Network	S >> S	Affinity	All	Network graph
(2) Stakeholder analysis	S >> S	Power-Interest	All	2*2 Grid
(3) System innovation	C >> S	Influence	All	Scenarios
(4) Business Model	C >> S	Role	Value-chain	Canvas
(5) Service model	C >> S and S >> C		Value-chain	Canvas of actor triplets

(1) Social network mapping use a network graph to represent affinity between people. It is composed by nodes and edges, respectively corresponding to people and their interactions. Low-tech social networks are frequently used in workshops to create a global representation of participant affinities. (2) Classical stakeholder analysis tools as the Mendelow's Power-interest grid are based on a 2*2 or 3*3 grid analyzing dimensions of the interaction between actual stakeholders. (3) [Gaziulusoy et al. 2013] described a systemic double-flow scenario approach aimed to both revisit existing systems, work on future sustainable scenarios and identify involved stakeholders & key resources to develop different relevant projects. (4) The analysis of business models involves assessing how a firm combines a value proposition with supply chain management [Boons et al. 2013]. To develop such approaches, some tools exist such as the business model generation [Osterwalder 2001]. (5) Recently, Chou et al. [2012] proposes a systematic approach to generate service model for sustainability: this approach propose an original method to question the potential roles of stakeholders according to previously identified sustainable values. Four operators are proposed to co-explore the concept values and roles of stakeholders: add, fix, substitute, modify.

This paper proposes an explorative study aimed at detecting weak signals and working path-ways to design stakeholder-centred tools. To do so, we have developed an experiment to evaluate and compare different stakeholder-centred environments during an eco-ideation session. This experiment was carried out during a workshop of the eco-design French network. We supposed that using stakeholder-centred tools (V1) will help the maturation of the 3 FEEI dimensions: it (H1) will not reduce the efficiency of ideation effectiveness, (H2) will encourage teams to better deconstruct the stakeholder network and (H3) identify more and varied means of incubation. We supposed that some differences can appear according to the type of stakeholder items (V2) and the proposed type of intermediate objects (V3).

2. Experimental design

2.1 Presentation of the case-study and participants

This experiment is a part of an action research fieldwork initiated between the authors and an industrial French company, developing fluff based products (jackets, duvet). Several eco-design actions have been set up for the last 3 years: life cycle assessment of fluff pillows and internal fluff process, training on environmental impacts, communications. An eco-innovation process is in progress: a first ideation session was designed using ECO-ASIT, a systemic eco-ideation tool. An important list of concepts was evaluated by environmental experts and company members. One of the top-rated ideas was to design a “life jacket”. The objectives of the second ideation session were discussed with the industrial design team and the chosen idea was finally focused around three life-cycle strategies taken from the LIDS wheel tool: innovation, lifetime and end-of-life optimization. More precisely, teams will be asked to develop the concept of "life jacket or jacket for lives" that would reduce the environmental and social impacts of this jacket made of fluff. The experiment consists in a pre-test of this second eco-ideation session.
The 40 participants with mean age of 35 years were free volunteers recruited from the quarterly workshop of the French network in Eco-Design of sustainable systems (EcoSD). Academics (students, PhD, Professor) and professional eco-design practitioners (consulting or industrial) are equally represented in five groups. The researchers conducted the ideation session (animation & time keeper) and then analyzed the results.

2.2 Variables

2.2.1 Independent variables

The aim of this pilot study was to test the effect of different stakeholder-centred tools on the maturation of FEEI process. Three independent variables are tested: (V1) the presence of a stakeholder-centred tool, (V2) the type of stakeholder, and (V3) the type of intermediate objects *(see Table 2)*.

Table 2. Experimental conditions according to three independent variables

Experimental Conditions	V1- Presence of stakeholder systems (Yes-No)	V2- Type of stakeholders *(primary-P), P+ secondary-S)*	V3- Type of intermediate objects *(network-N, focus-F)*
G1 - Referent	No	None	None
G2 – PN	Yes	P	N
G3 – SN	Yes	S+P	N
G4 – PF	Yes	P	N+F
G5 - SF	Yes	S+P	N+F

(V1) The variable “presence of stakeholder-centred tools” is a binary variable with a positive value when the ideation session is composed by stakeholder network components.
(V2) In the experiment, the manipulated items represent either primary stakeholders (P) or both primary and secondary stakeholders(S). The classification of stakeholders [Damak-Ayadi and Pesqueux 2005] was built by identifying primary stakeholders with Y-company, corresponding to stakeholders who directly benefit from or affected by their activity. Primary stakeholders are suppliers of raw materials, designers (stylist, modelers, and seamstresses), producers (factories workers), and distributors (brands, e-marketing, users (first and second hand-users) and end-of-life actors (collectors...). Secondary stakeholders do not engage in direct economic exchange with the business but are affected by or can affect its actions. (Ngos, certifiers, public policies, medias, banks and others industrials).
(V3) The third variable “type of intermediate objects” is declined in two different supports: (N) the stakeholder network canvas proposes a systemic view of all stakeholders. Participants will interact by

navigating freely in a global view *(see Figure 2a)*. (F) The single stakeholder focus canvas offers to work in detail with some stakeholders one by one: it orientates users to three types of activity (general idea generation, value analysis, interaction with others stakeholders).

2.2.2 Dependent variables (DV)

A new framework is tested to analyze the maturation of the FEEI process. The following dependant variables were selected to compare experimental conditions : ideation effectivness, the capacity to explore the role of stakeholders & new potential partnerships and the capacity to explore means of incubation. Several indicators composed each variable.The process of evaluation is described in the data analysis part *(see section 2.6)*.

2.3 Procedure and equipment

Participants are divided in five homogenous groups, composed of 8 participants and an animator. The study was composed of 4 steps:

Step 0 (P0): the case study was first presented during thirty minutes by the researcher (company's history, fluff process, jacket life cycle, involved primary stakeholders, existing business model, working concept and objectives).

The First Step (P1): after presentations of group members and a creativity game appetizer, participants were asked to write on different post-it all ideas they had in mind to develop the proposed concept.

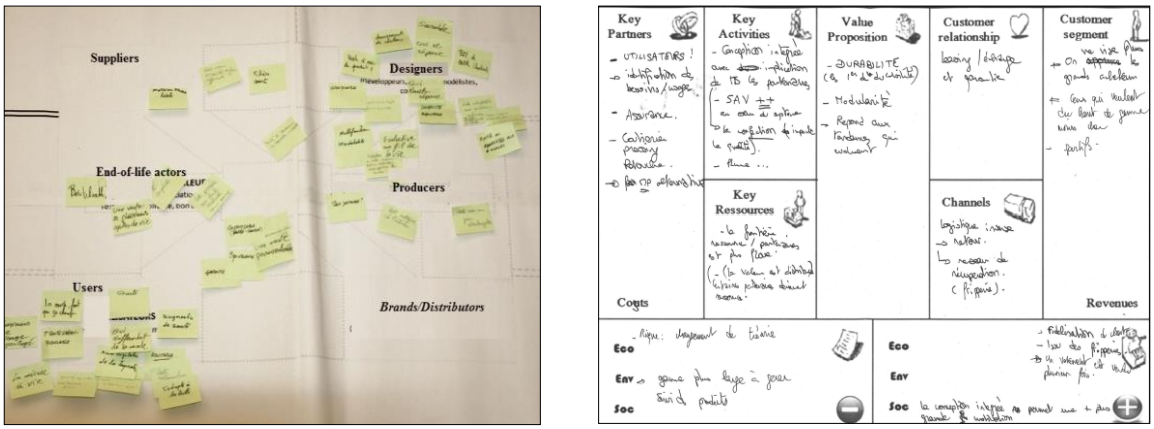

Figure 2. Examples of (a) primary stakeholder network (V3-N) and (b) Business model canvas

After 10 minutes, groups were asked to share their ideas and place them in a particular canvas: positive V1 groups used a network of primary stakeholder canvas *(see figure 2-a)* and negative V1 group used a white wall.

The second step (P2) consisted in a 40 minutes ideation activity with predefined type of stakeholder-centred tools according to experimental conditions *(see Table 1)*. V1-yes group were free to decide intuitively the order, the duration and number of stakeholder items.

The third step (P3) was to generate business models thanks to the Osterwalder canvas during 30 minutes. Finally, participants filled out a post-session questionnaire. It was composed of three parts: participant characterization (age, skill level for creative and value analysis activity), participant evaluation of their own result (relevance, originality, novelty, feasibility, potential reduction of environmental & social impact) and qualitative participant evaluation of the session (quality of animation, difficulties). All groups had the following equipment: two colours post-it notes, pens, black felt-tip pens, an attributed P2 canvas, a business model canvas, the Y-company existing business model slide, the task sheet, a video camera and a recorder.

2.4 Data analysis

2.4.1 Data collection

Data were collected in an excel file and analyzed thanks to Excel, Access & Mind manager. Each group recording was transcript, all post-it were listed, the different supports were digitized and questionnaires were treated. An exhaustive list of ideas was designed from these different supports. Each idea is composed of key attributes which permit to track how it appeared (which group, which part, after which stakeholder item and its positions in stakeholder network canvas). Several coding were performed to measure all dependant variables.

2.4.2 Measures to evaluate the ideation effectiveness (DV1)

Shah et al.[2003] propose four criteria to evaluate ideation effectiveness: quantity, novelty, feasibility and variety. This typology has been adapted for the experiment: the objective of the analysis is to observe the effect of ideation activity carried out in P2. The progression between ideas generated during P1& P2 is evaluated. Thus, measures were adapted to fill out this criterion, using relative data *(see Table 3)*.

Other changes concerns the variety indicators described as the measure of the explored solution space during the idea generation process. Solution space can be categorized through different views because it is based on how different two ideas are from each other. Most of time, authors choose to use only on categorization to evaluate the variety of ideas and use a tree representation: [Shah et al. 2003] proposed a classification of four detail levels (physical principle, working principle, embodiment, and detail levels). The PIT diagram [Jones et al. 2011] proposed to order ideas by following the different stage of eco-design process (trigger, product planning, concept design, embodiment design, detail design, manufacture & launch). Recent ontology based-approach as network view and semantic webs are able to provide different representations of the same group of ideas according to desired semantic categories. In this experiment, three categorizations were used to evaluate the variety of design spaces: (1) the eco-design space (Ves). We assume that the eco-design space can be described with the different strategies of the LIDS tool (innovation, low material, efficient production, distribution, use, lifetime and end-of-life optimizing); (2) the detail level containing three values classified from the more abstract to the more concrete ideas: needs, solutions, means of incubation; (3) the innovation solution space classify solution ideas according to their type of innovation (technological(material or product), marketing (relationship or revenue) and organizational). A double coding was realized to complete the categorization of ideas. Each of the two coders first evaluates separately all idea. Then, they confront their analysis and discuss about divergent points. The rate of divergent evaluation before confrontation corresponds to less than 10 % of ideas.

Table 3. Description of measures for each dependant variable

DV	***Measures***	***Description***	***Formulas***
1	*Relative Quantity (Q)*	Part of idea generated in P2	Q = count(P2) /count(P1+P2)
	Novelty (N)	Individual group discovers or creates ideas that are new to the group	N = count(P2New) / Count(P2)
	Relevance (R)	Part of idea present in business model	R = count(P2 present in final concepts)/P1+P2
	Relative Variety (V)	Part of explored solution space according to categories (eco-design; detail level and type of innovation)	Ves'x) or Vd(x) = count(P2 x)/count(P2) – count (P1x)/count(P1) Vs(x,y) = count P2(x,y)/count(P2y)- count P1(x,y)/count(P1y)
2	*Frequency of stakeholder-concept linkage (Fs)*	Part of concepts(C) linked to stakeholders	Count(P2(C->S))/Count(P2)

	Stakeholder diversity (Ds)	Part of stakeholders in P2	Ds = Count(distinct stakeholder) /Count(stakeholder)
	New potential roles(pR)	Average quantity of concepts(C) linked to each stakeholder	Pr= $\sum_0^n$ Count(P2(C−> Si) /n ; n=count(distinct stakeholders)
	Potential partnerships (pP)	Part of concepts(C) linked to more than one stakeholder	Pp = count (P2(C-> Si+Sj or C-> Si+Sj+Sj))/Count(P2)
	Stakeholder relevance	Part of stakeholders P2 in business model	Rs = count((present stakeholders in both P2 & P3)/ count(stakeholder in P3)
3	*Incubation concepts(IC)*	Part of incubation concepts in P2	Count(P2-IC)
	IC Variety	Part of explored IC space	Vd(IC) = count(P2 IC)/count(P2) – count (P1IC)/count(P1)

2.4.3 Measures exploring the capacity to deconstruct the stakeholder network (DV2)

A qualitative coding identified if groups are frequently linking ideas to stakeholders. Each time an idea is clearly linked to one or several stakeholders, coder noted which ones. This coding permits the calculation of five variables proposing different dimensions to explore the capacity of a group to deconstruct the stakeholder network during P2: the frequency of stakeholder-concepts linkages, the diversity of stakeholders, the identification of new roles for stakeholders; the identification of potential partnerships and the relevance of stakeholders *(see Table 3)*.

2.4.4 Measures exploring means of incubation (DV3)

Different means of incubation were identified in generated ideas: partnership, skills, financial, intellectual property. Two indicators were selected: (1) Part of incubation concepts (IC) and (2) the distribution of incubation concepts according to different means.

2.4.5 Maturity graph

A maturity graph was built to synthesize the main measures of the three dependant variables. Inspired by linkograph approaches, the graph presents both a stakeholder and conceptual view during P2 idea pathways. For visibility reasons, variety in eco-design space and incubation variety do not appear.

3. Results

3.1 Global results

During the first part of the experiment, an average (A) of 45 ideas were generated with a high standard deviation (D = 14) according to groups. During the second stage, the production of ideas was less important but with a higher deviation (A = 35; D = 20). Generated ideas tend to be new (A = 70%), focus on solution detail level (VdP2 (Solution) > 65 %) with a higher part of marketing and organizational solutions. They cover 80% of desired eco-design space (Ves(innovation) = 19 %, Ves(lifetime optimization) = 40 %, Ves(end-of-life optimization) = 21 %).

Only 14 % of ideas are concerned by means of incubation. None of the groups could investigate all possible interactions between stakeholders and explore their exhaustive potential roles. Thus, different strategies of stimulation emerged from the animator of each group: G2-PN and G4-PF ordered stakeholder items according to the numbers of post-it generated during the part 1; G3-SN let members of the group choose and intuitively introduce some stakeholders in case of blanks; G5-SF followed the initial apparition order of different single stakeholder focus canvas. In the third part, group produced business models with a lot of similarities. More redundant terms were *"renting, fashionable, proximity, after sales services, natural &bio, network, reparable, upgrading*". They frequently differ according to customer segmentations, modalities of distribution and revenue. The diversity of potential partnerships identified in business models is illustrated in *Figure 3*.

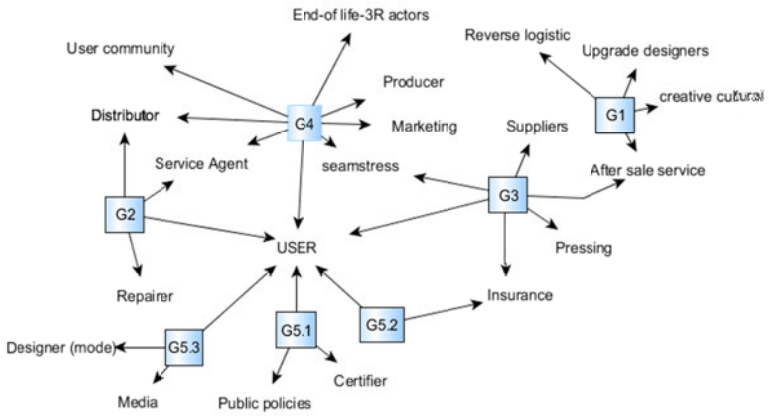

Figure 3. Diversity of stakeholders in Business Model concepts

3.2 Presence of stakeholder-centred tools (V1):

3.2.1 V1 X DV1: Ideation effectiveness

Quantity rate is lower for G1-referent than other groups. No particular differences are observed for novelty, variety indicators.

In the conceptual view of maturity graph, more ideas, more detail level changes, more variety in solution space are observed for V1-yes groups. In general, the pathway of V1-yes group is quite chaotic, illustrating a high capacity to make transitions between different detail levels. Even if the same quantity of ideas discussed in P2 are present in the final business model for both groups, the part of relevant idea is higher in G1-referent (V1-no).

3.2.2 V1 X DV2 and V1 X DV3: stakeholder network & incubation focus

All stakeholder indicators are higher in groups stimulated by stakeholder items *(Figure 4a)*. The stakeholder view of maturity graph shows poorer frequency (Fs = 5/12) and diversity (Ds = 1/13) of stakeholders in G1-reference ideas.

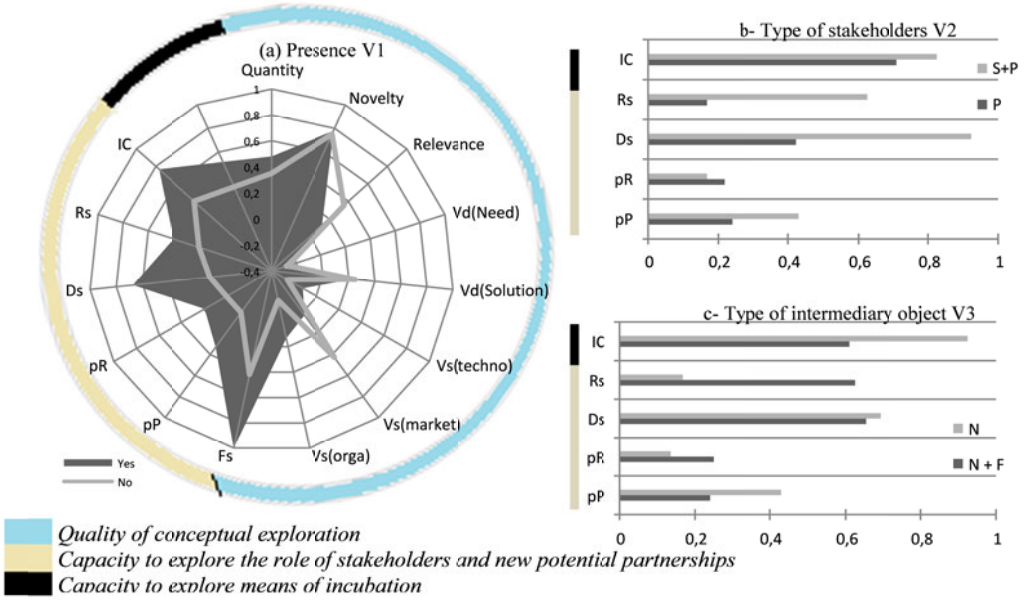

Figure 4. Differents indicators according to (a) the presence of stakeholder-centred environments, (b) the type of stakeholders, (c) the type of intermediate objects

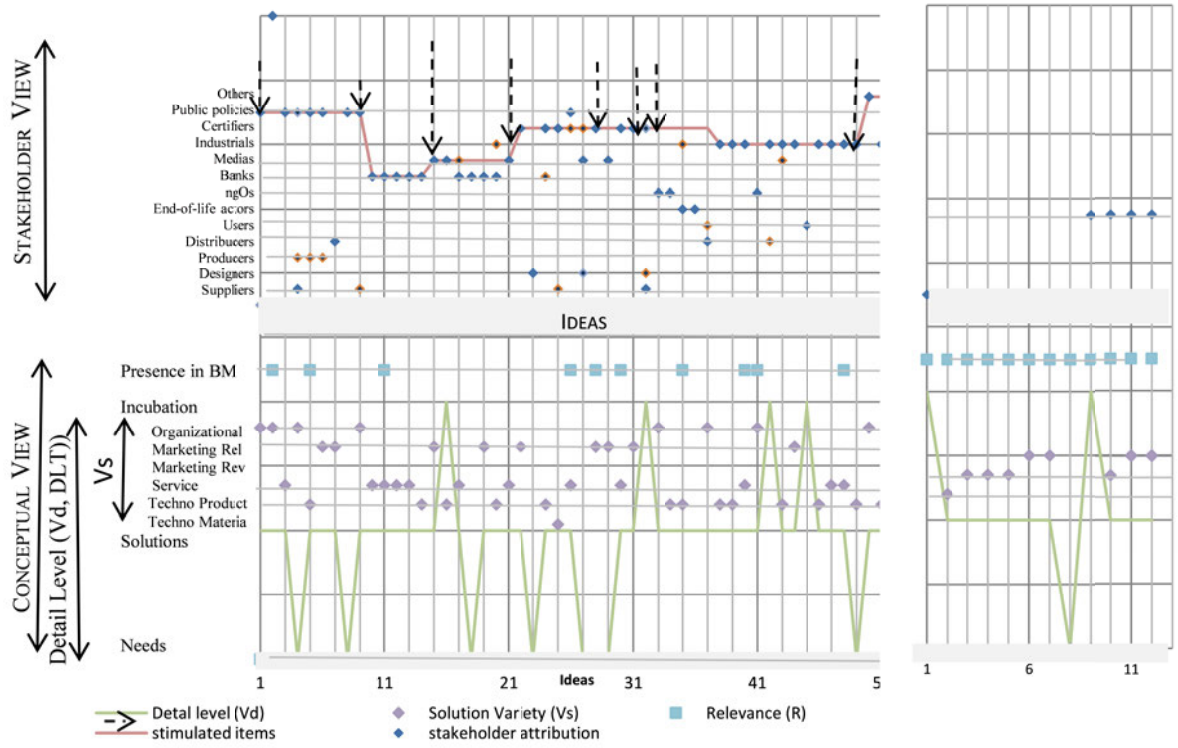

Figure 5. Examples of maturity graphs: (a) G5-SF; (b) G1-Referent

The part of incubation concepts is quite the same between both conditions. However, G1-referent is the only one which did not generate ideas of new partnerships.

3.3 Characterizing stakeholder-centred environments (V2 & V3)

Type of stakeholder items (V2)

S+P-groups tend to explore the stakeholder space in a deeper way (higher stakeholder diversity, relevance, more identified potential partnerships) while the ideation effectiveness is higher for P-groups.The maturity graph permits to see how many ideas were generated for each stakeholder stimulated items. Some stakeholder items were more utilized (designers, users, distributors, industrials, certifiers) than others (banks, NGos). According to some participant feedbacks, "*the cognitive effort to play with secondary stakeholders is quite important but is promising: even though first connexions took a lot of time to be made, then, surprising ideas overcame rapidly"*. Some other feedbacks highlight the importance to segment *users according to their ways of living*.

Type of intermediate objects (V3)

Some differences are observed in the exploration of potential roles and partnerships, the quality and novelty of ideas. Whereas N+F-groups have a propensity to generate a more important number of new ideas and a higher capacity to explore new potential roles (pR-N+F-group = 11 vs pR-N = 3), N-groups were exploring more potential partnerships (pP-N+F-group = 24 % vs pP-N =43 %).

4. Conclusion

A real complexity appeared to evaluate and support the maturity of eco-innovations due to the diversity of variables able to influence its development (economic context, involvement of people, company's process & eco-innovation culture). This paper proposes a double contribution: (1) recommendations to design stakeholder-centred tools; (2) a framework for analyzing the maturation of

FEEI process. An experimental study was carried out to give first feedbacks and working path-ways to guide us towards future researches.
This experiment shows that the presence of stakeholder-centred tools during an intermediate step of the company-Y FEEI process helped the maturation of ideas by producing higher ideation effectiveness (H1), and by facilitating the exploration of some stakeholder mutations (H2). Groups using both primary and secondary stakeholder items went towards more qualitative ideas, and more varied combination of stakeholder items. The two types of intermediate objects complemented one another: the network view facilitated the identification of potential partnerships while single stakeholder focus views went deeper in detecting potential stakeholder roles. However, a large gap still exists from the resulting ideas of this session until their incubations (H3).

4.1 Designing adapted stakeholder-centred environment during FEEI

Introducing stakeholder-centred environment in the divergent steps of FEEI, as in this experiment, can help to explore new part of solution spaces as the organizational one but it stays hard to go deeper in the identification of stakeholder mutations and to think about their future implementation. To do so, concepts need to be chosen and sketched. Selecting concepts with a high degree of rupture is an important risk taking for companies. A possible way to reduce the risk-taking is to improve the perceived feasibility of concepts. It involves forcing companies to change how they deal with uncertainty and to explore unusual scenario. Storytelling and scenario-based tools could be introduced in stakeholder-centred environment during more mature projects, based on particular concepts.
In this study, the exploration of FEEI dimensions was limited to create unidirectional connexions from concept to other concepts, stakeholders or incubation means (C->C; C->S and C->I) and from stakeholder to concepts (S->C). Other type of methodologies could be considered to evaluate stakeholder network mutations focus on stakeholders (S->S and S->I), characterizing interactions between them: affinity, influence, distance in eco-design practices and ethical principles...
In future works, several experimentations will complete this study in order to design a kit of stakeholder-centred tools adapted to the context of session (ideation, evaluation).

4.2 Consolidating the framework to analyze the maturation of the FEEI process

Data analysis can be completed by multiple coding and other types of measures. For instance, the relevance of ideas was few analyzed for this study. Different level of relevance (economic, social, and environmental) can be discussed by experts and evaluated in a participative way. Unlike ideation effectiveness indicators, few authors have worked on stakeholder mutations and means of incubation metrics. Measures proposed in this study need to be discussed.
This framework can be used for both theoretical and operational works. For operational objectives, measures are too complex. A simplified version could be built to facilitate the management of the FEEI process. An example could be to design an interactive interface which co-explores concepts, stakeholder network changes and means of incubation all along the development of eco-innovations.
Combining such a management tool and a stakeholder-centred toolkit will help designers and managers to improve the maturation of FEEI process. This will be the subject of future works.

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