CATEGORIZING USER PAINS, USAGE SITUATIONS AND EXISTING SOLUTIONS IN FRONT END OF INNOVATION: THE CASE OF SMART LIGHTING PROJECT

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Abstract

Companies make substantial R&D investments in early design stages to develop radically innovative products. However, despite abundant research work in the field of human-centered design, the front end of innovation is the least well-structured part of the innovation process. Radical Innovation Design (RID) methodology has put forward a structured process aiming at exploring, organizing and categorizing required knowledge to design a useful problem in the form of value buckets (i.e. overlooked problems of users) to be evaluated. In this paper, we aim at reinforcing the knowledge acquirement process in parallel with the problem design process to fine-tune the firm's R&D strategies, and to increase the likelihood of successfully reaching the mainstream markets.The contributions of this paper are twofold: i) to provide a set of knowledge acquisition rules in front end of innovation; and ii) to specify a set of problem design guidelines mainly by introducing a tool called Dependency Structure Modeling (DSM)-Value bucket algorithm, which enables a systematic identification of value creation opportunities. The example of a smart lighting project is analyzed in this paper as a case study.

Keywords: Innovation, Design methods, Early design phases, Knowledge exploration, Radical Innovation Design

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Please cite this paper as:
Surnames, Initials: *Title of paper*. In: Proceedings of the 21st International Conference on Engineering Design (ICED17), Vol. 4: Design Methods and Tools, Vancouver, Canada, 21.-25.08.2017.

1 INTRODUCTION

Companies make substantial R&D investments to develop more disruptive innovations rather than incremental ones. In their recent report, Booz and Company (Jaruzelski et al., 2014) prove through an extensive survey that companies adopting a *need seeker* innovation strategy are inherently "*effective at both the ideation and conversion stages of innovation*". Need seeker-oriented companies "*make a point of engaging customers directly to generate new ideas. They develop new products and services based on superior end-user understanding. Their goal: to seek out both articulated and unarticulated needs, and then to try to get their new products to market first.*" In addition, the study reveals that in average these companies financially outperform other companies ruled by *market reader* and *technology driver* strategies. Need seekers seem to be more disruptive in terms of innovation since they develop customer-led ideas by investigating overlooked usage segments from early design stages or front end of innovation. Being need seeker thus requires leadership and also an organized problem identification process that must be managed in terms of cost and time of R&D. In this context, one may wonder how to establish, from early design stages, a set of principles and tools that make companies more effective in the identification of a relevant problem to be solved?

Despite abundant research works in human and users-centered design emphasizing the importance of problem exploration in early design stages, the front end of innovation is the least well-structured part of the innovation process (Herstatt and Verworn, 2004). It is therefore necessary to forge a *language* capable of systematically scanning users' unsolved problems and providing convincing evidences on the problems' relevance. To this end, Radical Innovation Design (RID) methodology provides a structured process that allows identifying subsets of value buckets i.e. unsolved or poorly solved problems with the existing solutions (Yannou et al., 2016a). The quality of the identified value buckets depends on acquiring significant knowledge about the problems of users and the specific perimeters of their issues. The latter remains a non-trivial task insofar as the knowledge, which is necessary to design a value creating solution, is very often low and with little certainty in front end of innovation.

In this paper, we aim at reinforcing the knowledge acquisition process of an innovative project in parallel with its problem design process to fine-tune the firm's R&D strategies as well as the creativity sessions. Therefore, the contributions of this research are twofold: i) to provide a set of knowledge acquisition rules in front end of innovation; and ii) to specify a set of problem design guidelines mainly by introducing a tool called Dependency Structure Modeling (DSM)-Value bucket algorithm (Yannou et al., 2015), which enables a systematic identification of value creation opportunities. The case of a smart lighting innovation project is studied here. It should be noted that the creativity and problem solving phases of the innovation process exceed the scope of the current research. Indeed, this research focuses mainly on how to acquire the needed knowledge to design a useful problem in an industrial context, while previous publications on the RID methodology concentrate on problem and solution design phases.

In the next section, we review the literature on the existing tools and methods aiming at exploring front end of innovation. The section 3 is devoted to the presentation of the RID methodology and its problem identification process. In section 4, we take the example of a smart lighting project to illustrate the fact that the knowledge acquisition can be structured in innovation projects. Section 5 presents some of the benefits of adopting a structured knowledge exploration approach to robustify a company's R&D strategies. Finally, the last section puts forward a set of guidelines to consolidate the knowledge acquisition and problem design processes.

2 TOOLS AND METHODS TO EXPLORE FRONT END OF INNOVATION

Literature on tools and methods to explore early stage of the innovation process is affiliated with a multidisciplinary literature on the following domains of technology management, design engineering, and marketing of innovation.

In technology management field, several research works (see for instance (Schweitzer, 2014; Thomke, 2003)) emphasize that an innovation opportunity must be identified mainly by involving lead-users in front end of innovation since the costs of developments are low and the degree of freedom in design and the influence on project outcomes are high. Nevertheless, proper decisions cannot be made in this stage unless the necessary information is collected. More often, generic guidelines are suggested to determine the degree of newness of an innovation project (Herstatt and Verworn, 2004). However, these guidelines do not allow systematically investigating end-user contexts and their unsolved problems.

Customer focused approaches such as Quality Function Deployment (QFD) and axiomatic design (Suh, 2001) analyze the transformation of customers' expectations to quantitative parameters. Although these approaches put forward planning tools, they do not necessarily improve the innovation potential of a company as these tools enable to roughly model users without taking into account their needs. Companies may therefore lack creativity because of their simplistic perception of users' problems. TRIZ methodology proposes a set of tools and principles for creative problem solving by analyzing patterns of problems and solutions to suggest an inventive solution based on previous experiences. TRIZ has been widely used in lean management methods since the experience can allow saving time and cost instead of starting from scratch. Despite of the advantages of adopting TRIZ tools, the market aspects (existing solutions on the market) as well as user contexts are not systematically integrated into those tools.

In order to gain a better understanding of user contexts and also to identify unsolved or poorly solved problems of users, "job-based" approaches (Christensen and Raynor, 2003; Ulwick, 2005) point out the importance of characterizing functional, emotional and social jobs. According to Clayton Christensen, "[customers] *often buy things because they find themselves with a problem that they need to solve*." Exploring customer profile - composed of *jobs-to-be-done, pains and gains* (Osterwalder et al., 2015) - has significantly helped executives to identify disruptive innovation opportunities.

In the context of Radical Innovation Design (RID) methodology (Yannou et al., 2016b), pains and substantial usages of customers are the core source of a radical innovation. RID methodology provides tools to meticulously investigate a worthy problem in front end of Innovation by quantifying value buckets (i.e. unsolved or poorly solved problems by the existing solutions).

3 RID METHODOLOGY: CAPTURING USERS' RELEVANT PROBLEMS

Following a set-based thinking and a need seeker approach, the Radical Innovation Design methodology emphasizes that collecting a maximum amount of information in front end of innovation can considerably improve the design of a successful product or service. RID introduces a structured process composed of 4 sub-processes as depicted in Figure 1. The "Knowledge Design" and "Problem Design" sub-processes start from an initial idea that must be reframed to specify an ideal goal. This ultimate idealistic goal is generally formulated following investigations on the various "fields of activity". Subsequently, pains, usage situations and existing solutions are characterized and the coverage (or effectiveness) of existing solutions regarding "pains occurring in usage situations" is quantified. At the end of the problem design process, a tool called Dependency Structure Modelling (DSM)-Value Bucket (VB) identifies the painful usage situations where the existing solutions are not at all or not enough effective or satisfactory.

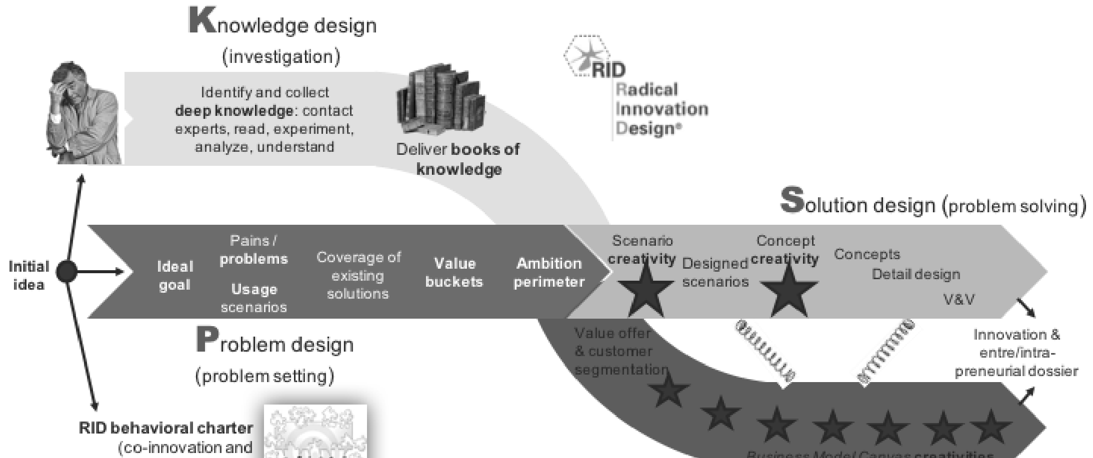


Figure 1. Radical Innovation Design process made of 4 sub-processes

The DSM-VB tool is an algorithm that combines three dimensions: pains, usage situations (characterized by scenarios) and existing solutions (see Figure 2) in interdependent matrices. As shown in Figure 2 the matrix "A" characterizes the ideal performances (i.e. there is no pain or suffering). This matrix indicates the frequency of occurrence of a problem (here, a pain) in usage situations. The difference between the ideal performances and the existing solutions' performances (represented by C * B) produces intrinsic value buckets that are weighted afterwards by undertaking the relative weight of pains and usage situations. In other words, this outcome determines a set of unfilled gaps between an ideal goal and the averaged performances of the existing solutions. This gap represents an ambition perimeter or the potential of value creation in the light of fields of activity explored at the beginning of the RID process. The quality of this ambition perimeter depends on data that feeds the matrices of DSM-VB tool. This data is extracted and verified following a rigorous knowledge exploration task.

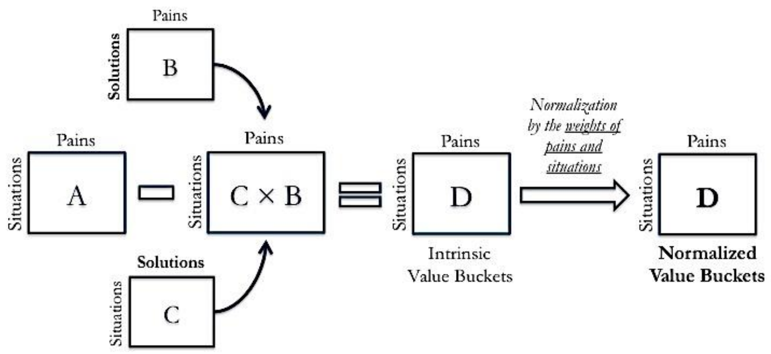


Figure 2. DSM Value bucket algorithm, adapted from (Yannou et al., 2016b)

As the design teams move forward on the RID process, they intend to identify a relevant problem to innovate on. However, it is not trivial to access the relevant needed knowledge insofar as intensive investigations are necessary. The "Knowledge Design" sub-process consists in systematically extracting, structuring and organizing required knowledge to better understand the problem for which a solution should be designed. This sub-process involves directly the R&D teams who must identify the most relevant knowledge acquisition techniques leading to generate useful books of knowledge. It should be noted that what is designed here is not the Knowledge *per se*, but more the way of setting and organizing teams and resources to identify and collect the needed knowledge.
The solution and business design sub-processes begin once a sound ambition perimeter is identified. In the following, we will describe the Knowledge and Problem Design sub-processes for the case of a smart lighting project.

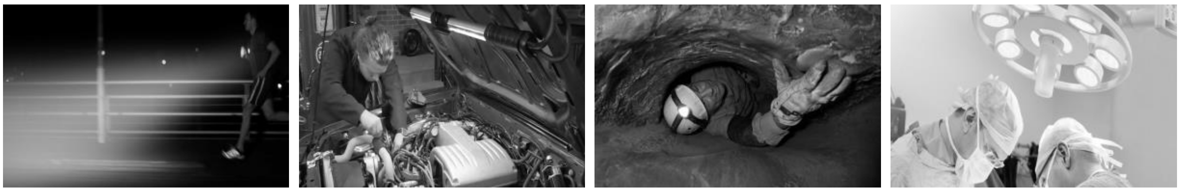
4 KNOWLEDGE EXPLORATION AND PROBLEM DESIGN IN THE CASE OF SMART LIGHTING PROJECT

RID methodology has so far been applied to different industrial cases (see for instance (Yannou et al., 2016b)). It serves also to coach entrepreneurs as well as innovation management consultants. Besides, this methodology has been taught for several years in an engineering school in France. Each year, multidisciplinary students from engineering, industrial design and technology management fields are asked to carry out a project based on an initial idea provided by companies. A team of 5 students has worked on a smart lighting project brought by an industrial company producing DIY tools and household hardware.
The initial idea was stated by the company as: "*how to make lighting more intelligent at work since having no light or an unsatisfactory lighting is a painful situation mainly because of casted shadows and occupied hands while operating a given task."*
The most common practice in companies consists in organizing problem solving sessions around an initial idea expressed as such. At best, designers empathize a minimum with workers needing light, before generating prototypes and iterating. However, this approach is related to high degree of uncertainties because it will trigger a set of trial-and-error tests to probably reach an acceptable solution. To reduce these uncertainties, the RID methodology provides enough hindsight to set a worthy problem to innovate on. In what follows, we first describe how the knowledge is explored in the case of smart lighting project. Then, we detail the problem design sub-process.

4.1 Knowledge Exploration

In order to deepen the understanding of the problem, user contexts must be analyzed from a number of perspectives. These are mainly: fields of activity, existing solutions, users' behaviours and experiences, usage situations, pains and problems as well as their consequences and causes. In other words, deep knowledge must be explored to provide a holistic vision of the problem and consequently to improve the process of setting a relevant design problem. In RID terminology, Knowledge design implies an organization as well as deliverables, called books of knowledge, which represent valuable design intermediate objects.

In the case of smart lighting project, a first book of knowledge is an extensive list of lighting fields of activity (see Figure 3 for some examples). To do so, students working on the project have screened an important amount of research publications and lighting standards (see for instance (INRS, 2016)) that pertain to the case. Then, 12 mains categories of fields of activities are identified (in an alphabetical order: *dentist, do-it-yourselfer, electricians, fireman, mechanic, plasterer, plumbers, security agent, sewer inspector and caver*, *sport activities*, *surgeon* and *truck driver*).



Nocturnal sport | Mechanical reparation | Caving | Surgical operation

Figure 3. Examples of activities and professions with the need of lighting

Based on the identified categories, they have investigated among 25 professionals and end-users following 15 to 20 minutes' interviews. Besides, 2 field-related experts from industry and 1 expert specialized in safety and security at workplace are interviewed. The techniques employed in interviews were mainly "ethnographical research" and "customer visit teams". Ethnography is ranked as the most effective in generating new ideas (Cooper and Dreher, 2010) and it consists in observing real-life situations with users using existing products and services. Customer-visit teams have been utilized as a complementary technique to gain more deep knowledge regarding the users' uncovered problems and unalleviated pains. Students have carefully prepared interview guides where tasks, usage situations, pains and problems are thoroughly investigated among users and activity-related experts. Moreover, photos and short films are recorded when end-users perform a given task in poorly illuminated places. A second book of knowledge is thus an extensive document containing observation forms (see Figure 4).

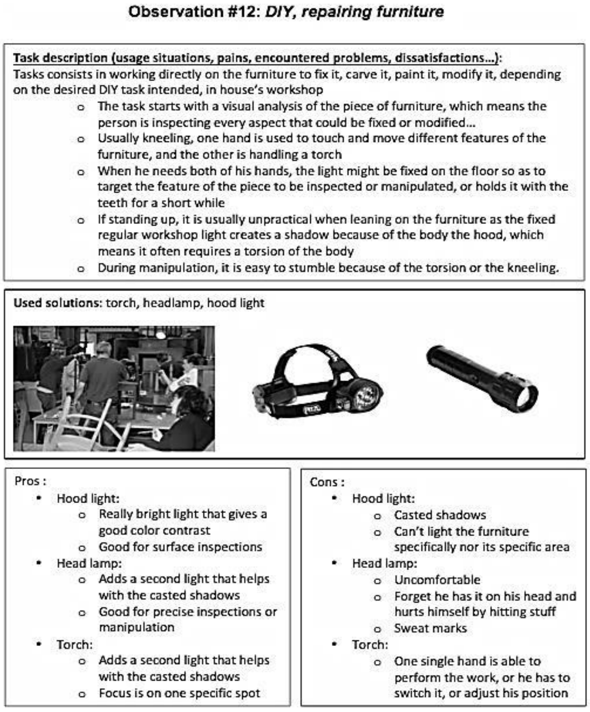


Figure 4. Example of an observation executive summary

Analyses on first generated books of knowledge have allowed defining patterns of problems, usage situations and the existing solution families. Even though in most cases a same problem or usage is frequent among end-users of different categories (e.g. surgeon and mechanic), the functional causes are the same. For instance, a frequent problem or pain is the lack of freedom in movements while doing a precise action in a dark or poorly-illuminated place. This problem is visible both for electricians working on complex electric switchboards as well as for dentists who have to change regularly the position of dental exam light.

A sequence of root-cause analyses on the patterns of problems encountered in 12 fields of activity has been done by diagnosing the causes and consequences of problems. As a result, another book of knowledge contains 4 sets of pains (see Figure 5).

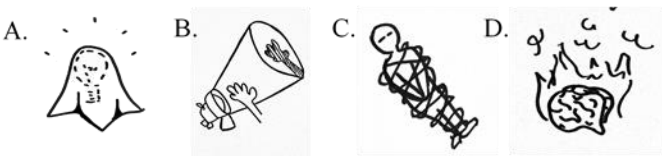


Figure 5 Characteristic pains: A) Inappropriate lighting; B) Casted shadow by parts of the body; C) Movements restriction and physical pain (musculoskeletal disorders) and D) Cognitive overload (psychological pain)

Usage situations are categorized following the analyses of the patterns of tasks retrieved from interviews and visual documentations (photos and short films). Real-life *stories* told by users and experts occur in given contexts and following a usage scenario. In general, a usage situation is characterized by an environment (e.g. poorly illuminated corridors); a specific action (e.g. inspection or reparation) as well as user-related factors (e.g. socio-demographic and behavioural factors). Following these characteristics, 4 frequent usage situations (see Figure 6) are identified in a book of knowledge on usage situations.

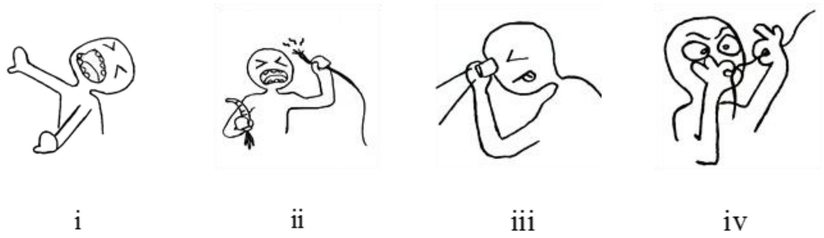


Figure 6. Frequent usage situations: i) Moving in dark places; ii) Manipulating an object in a dark place; iii) Precise inspection of an object and iv) Precise manipulation of an object

As regards existing solutions, market researches and legal watches (by reviewing related patents) have resulted in identifying a large set of uncategorized solutions. Students have also studied the existing solutions and their advantages and drawbacks. For this part of the study, they have not only screened several market studies, but also consulted patent databases and 30 online crowdfunding projects in the field of lighting. In general, to categorize lighting solutions and to define distinct families of solutions there are several techniques, for instance by undertaking the price, the used technology and the luminous intensity. However, these categorizations are not satisfactory when one wants to assess the effectiveness of a family of solutions in a usage situation or in terms of alleviating a given pain. Therefore, functional analyses provide an appropriate framework to determine the abilities of a solution by systematically answering the questions of why, how and where a solution is effective. Two general dimensions (light coverage and special mobility) have been proposed and then have been validated by industrials. The light coverage can be either diffuse (e.g. spotlights or light belts for running) or directional; and the spatial mobility can be either fixed or mobile. As illustrated in Figure 7 a last book of knowledge contains 4 families of lighting products.

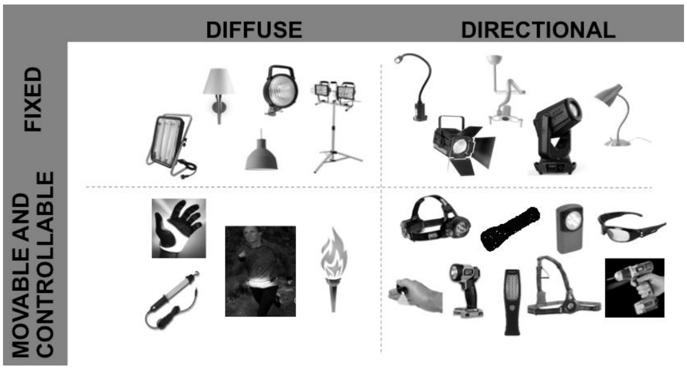


Figure 7. Categorization of existing lighting solutions

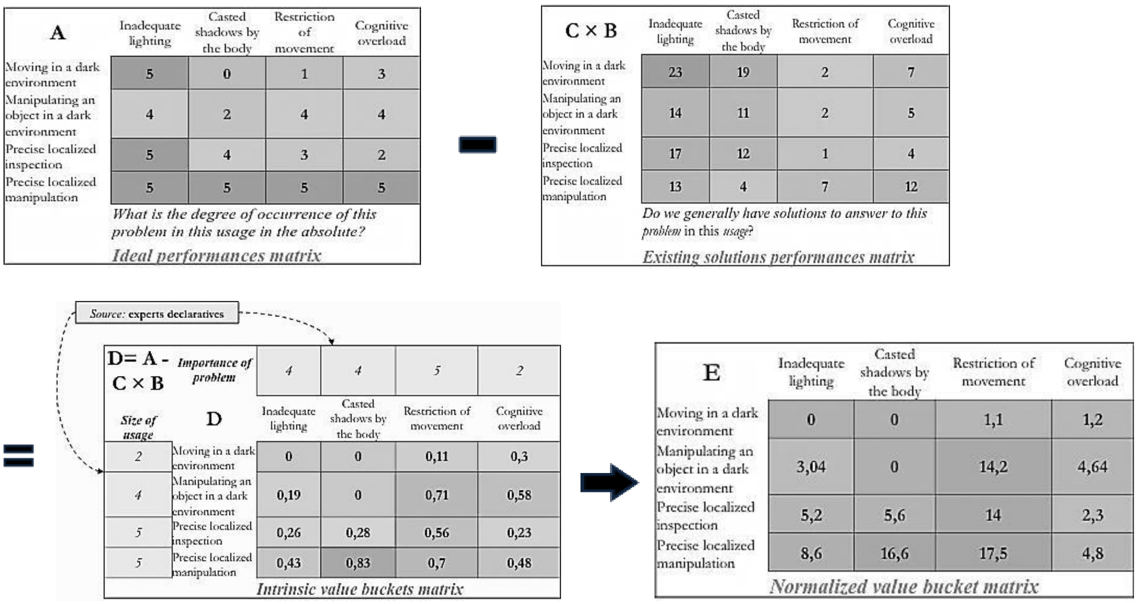
Once pains, usage situations and existing solutions are identified, the ideal goal as well as the value buckets can be identified. In the following, we only focus on the beginning and the end of problem design sub-process.

4.2 Problem Design

Unlike most industries that generally seek to increase lighting during a given activity with inexpensive solutions, students working on this project have focused on the users' pains and usage situations rather than merely the lighting's techno-economic feasibility. The identified ideal goal thus embraces a transformation from an existing painful state to a world without pain.

The ideal goal of the project is identified as: "*improving the comfort and security of end-users to help them better accomplish a given task in dark or poorly-illuminated spaces without restraining their movements.*"

The DSM-Value bucket tool has been used here to highlight worthy value buckets to be exploited later in creativity sessions. The generated books of knowledge have enabled feeding the matrices of the DSM-VB tool (see Figure 8). The values indicated in matrices A, B and C are between 0 to 5 (5 as the most important). For instance, *casted shadows by the body* occur very often in *precise localized manipulation* and it is obviously not important at all when *users move in a dark environment*. The data is collected from different sources: interviews with users and experts; field observations and also the accidentology databases related to the lack of lighting. The Matrix E is computed by integrating 2 weights i.e. the *importance of problem* and the *size of usage situation* (again by using a 0 to 5 intensity scale). These weights are retrieved from experts' declaratives in lighting. The final matrix (E) represents the normalized value buckets. The highest values in this matrix refers to the worthiest value buckets.



A	Inadequate lighting	Casted shadows by the body	Restriction of movement	Cognitive overload
Moving in a dark environment	5	0	1	3
Manipulating an object in a dark environment	4	2	4	4
Precise localized inspection	5	4	3	2
Precise localized manipulation	5	5	5	5

What is the degree of occurrence of this problem in this usage in the absolute?
Ideal performances matrix

C × B	Inadequate lighting	Casted shadows by the body	Restriction of movement	Cognitive overload
Moving in a dark environment	23	19	2	7
Manipulating an object in a dark environment	14	11	2	5
Precise localized inspection	17	12	1	4
Precise localized manipulation	13	4	7	12

Do we generally have solutions to answer to this problem in this usage?
Existing solutions performances matrix

Source: experts declaratives

D= A - C × B	Importance of problem	4	4	5	2
Size of usage	D	Inadequate lighting	Casted shadows by the body	Restriction of movement	Cognitive overload
2	Moving in a dark environment	0	0	0,11	0,3
4	Manipulating an object in a dark environment	0,19	0	0,71	0,58
5	Precise localized inspection	0,26	0,28	0,56	0,23
5	Precise localized manipulation	0,43	0,83	0,7	0,48

Intrinsic value buckets matrix

E	Inadequate lighting	Casted shadows by the body	Restriction of movement	Cognitive overload
Moving in a dark environment	0	0	1,1	1,2
Manipulating an object in a dark environment	3,04	0	14,2	4,64
Precise localized inspection	5,2	5,6	14	2,3
Precise localized manipulation	8,6	16,6	17,5	4,8

Normalized value bucket matrix

Figure 8. Data streaming in DSM-Value bucket tool: the case of smart lighting project

The outcome of the DSM-VB algorithm is 5 value buckets under the form of "pain × usage" situation:

- The movement restriction while manipulating an object in a dark environment;
- The movement restriction while manipulating precisely an object in a specific area;
- The movement restriction while inspecting an object precisely in a specific area;
- The casted shadows by the body while manipulating an object precisely in a specific area;
- The inadequate lighting while manipulating an object precisely in a specific area.

5 RID GENERATED INSIGHTS TO FINE-TUNE R&D STRATEGIES

The innovation process is often considered to be nonlinear and iterative insofar as in many projects, there is no linear sequence of activities to lead an innovation project. This vision is shared by most creativity approaches such as Design Thinking, which consists in an "Express-Test-Cycle" problem-solving process containing interrelated "Empathize, Define, Ideate, Prototype and Test" steps. These approaches are taught and instilled in most industrial design courses and in the context of innovative companies. Although such creativity approaches are considered as human-centric, they generally fail to provide relevant tools to the front end of innovation. Indeed, various creativity models focus merely on "*designer's sensibility and methods [that] match people's needs"* (Brown, 2008) rather than on how, through empathy step, the people's needs and pains are identified and evaluated. Recent human-centered approaches attempt to fill this gap by putting forward a more scientific way of perceiving the innovative design process by systematically identifying and quantifying users' pains and usage situations from the early design stages (Yannou et al., 2013). Spending more time on grasping end-users' pains and usages turned out to generate more convincing results later for the problem-solving stages. In other words, innovating in a set based manner (i.e. progressively reducing uncertainties in the innovation process) leads to more robust and useful innovations.

Our study has followed such set based thinking through RID methodology. Problem design phase in RID methodology allowed having a global view of lighting activities as well as the frequent pains with limited or any existing solution. The identified value buckets have represented an important source of creativity for industrial partners of the project enabling them to optimize their R&D activities.

6 PROPOSITION OF GUIDELINES TO ROBUSTIFY KNOWLEDGE EXPLORATION AND PROBLEM DESIGN SUB-PROCESS

The relevance of the results of problem design sub-process is closely linked to the quality and of the acquired knowledge. Fields of activity, users' pains, usage situations and existing solutions must be carefully identified and categorized to obtain consistent spaces that are used in the DSM-Value Bucket tool. Our experience in the smart lighting project and also other industrial projects using RID methodology has allowed to propose 4 sets of rules to better define these spaces.

6.1 Fields of activity

Fields of activity are outlined following an extensive investigation around the main need stated in the initial idea. A legitimate problem perimeter (compared to a "box perimeter") must be defined based on the initial idea. In the RID methodology, being creative does not necessarily mean thinking outside a box that no one knows its perimeter. A sufficiently well-defined box perimeter is indeed more relevant for creativity. Here, a set of pieces of advice are suggested to define a legitimate box containing the main fields of activity:

- Detect the most important purpose stated in the initial idea of the project;
- Study the ultimate goal where the well-being of humans is undertaken;
- Mind map or make lists of main related actions, professions, usage contexts/places and value beneficiaries (end-users and other stakeholders).
- Ask regularly the questions of: Where? Why? For what purpose? And also, what could be the eventual evolution of the need?

The abovementioned non-exhaustive rules can help initiate an innovation project in an organized way rather than thinking outside an uncertain box.

6.2 Users' pains

The second set of rules refers to users' pains. Pain categories must be coherent scopes with the following main properties. These properties are not exhaustive, but they aim at providing a general framework to pain identification and categorization. Indeed, pains are:

- social, economic, physical and/or psychological problems or counter-performances to be reduced;
- observable in the large majority of activities and professions;
- not specific to a given activity or profession;
- implicitly expressed in the definition of the ideal goal (the ideal goal must intend to alleviate pains); and
- investigated following a root-cause analyses to detect their causes and consequences.

6.3 Usage situations

The third set of rules addresses the identification of usage situations by proposing the following properties of a relevant usage situation category. Indeed, usage situations are:

- not merely based on qualitative personas or random stories told by lead-users or imagined by designers;
- listed, quantified and observed over the identified fields of activities; and
- common in most activities and professions regardless the nature of the activity or profession.

6.4 Existing solutions

The fourth set of rules is related to the characterization of existing products and services aiming at alleviating users' pain in representative usage situations. Here, there are some insights to achieve a better mapping of solutions. It should be noted that we also advocate the analyses on the technological and marketing roadmaps by exploring patent databases, annual techno-market watch reports as well as crowdfunding platforms. Indeed, existing solutions are:

- not analysed following their marketing features or their only technical capacities;
- described functionally (where they function? why? and to do what?); and
- characterized and categorized through the identification and combination of their main functional attributes.

7 CONCLUSION

The Radical Innovation Design (RID) methodology is a pain and usage-driven approach consistent with human-centered methods. In RID, being knowledgeable about customers' frequent pains rather than their mere expectations can reasonably increase the chances of success of an innovation on the market. This methodology is an inciter of knowledge exploration, which is essential to design a relevant problem and thus to robustify the R&D of an innovative firm. The case of smart lighting project in the context of a DIY large company has been studied in this paper. The knowledge exploration and problem design aspects of this project are particularly challenging as the lighting is used in multiple situations, professions and places. Moreover, it is not trivial to identify representative pains, usage situations and the families of existing lighting solutions. The use of DSM-Value Bucket tool has allowed presenting insightful and relevant innovation opportunities according to the company's representatives. Our study has also resulted in the proposition of guidelines to reinforce the process of identifying and characterizing fields of activity, usages, pains and existing solutions. The smart lighting project has been selected as the most sense-making innovation project by an innovation jury (composed of industrial, academics and innovation experts). Our future research work will focus on experimenting and validating the identified value buckets for launching disruptive products by the company.

REFERENCES

Brown, T. (2008), Design Thinking. *Harvard Business Review,* 86**,** 84-92.

Christensen, C. M. & Raynor, M. E. (2003), *The Innovator's Solution: Creating and Sustaining Successful Growth*, Harvard Business School Press.

Cooper, G. R. & Dreher, A. (2010), Voice of Customer Methods: What is the best source of new-product ideas? *Marketing Management Magazine,* 19**,** 38-43.

Herstatt, C. & Verworn, B. (2004), The 'Fuzzy Front End' of Innovation. *Bringing Technology and Innovation into the Boardroom: Strategy, Innovation and Competences for Business Value.* London: Palgrave Macmillan UK.

INRS. (2016), *French National Institute of Research and Security* [Online]. Available: http://en.inrs.fr/ [Accessed 2016].

Jaruzelski, B., Staack, V. & Goehle, B. (2014), Global Innovation 1000, Proven Paths to Innovation Success, Ten years of research reveal the best R&D strategies for the decade ahead. *In:* STRATEGY&, P. A. (ed.).

Osterwalder, A., Pigneur, Y., Bernarda, G., Smith, A. & Papadakos, T. (2015), *Value Proposition Design: How to Create Products and Services Customers Want*, Wiley.

Schweitzer, F. (2014), Integrating Customers at the Front End of Innovation. *In:* GASSMANN, O. & SCHWEITZER, F. (eds.) *Management of the Fuzzy Front End of Innovation.* Cham: Springer International Publishing.

Suh, N. P. (2001), *Axiomatic Design: Advances and Applications*, Oxford University Press.

Thomke, S. (2003), *Experimentation Matters*, Harvard Business School Publishing Corporation.

Ulwick, A. (2005), *What Customers Want: Using Outcome-Driven Innovation to Create Breakthrough Products and Services: Using Outcome-Driven Innovation to Create Breakthrough Products and Services*, McGraw-Hill Education.

Yannou, B., Chen, W., Yvars, P.-A. & Hoyle, C. (2013), Set-based design by simulation of usage scenario coverage. *Journal of Engineering Design,* 24.

Yannou, B., Cluzel, F. & Farel, R. (2016a), Capturing the relevant problems leading to pain- and usage-driven innovations: The Dependency Structure Modeling Value Bucket algorithm. *Concurrent Engineering,* 0**,** 1063293X16666311

Yannou, B., Farel, R. & Cluzel, F. (2015), The DSM value bucket tool. *ICoRD'15, International Conference on Research into Design* Banglore, India.

Yannou, B., Farel, R., Cluzel, F., Bekhradi, A. & Zimmer, B. (2016b), The UNPC innovativeness set of indicators for idea or project selection and maturation in healthcare. *International Journal of Design Creativity and Innovation***,** 1-17.

ACKNOWLEDGEMENT

The authors would like to acknowledge students Nikolina Gendre, Terry Huang, Nicolas Klaeylé, Andrea Schirato, Ismaïl Tahri and Quentin Warcollier for their hard and serious work on the smart lighting project. A special thanks to Terry Huang for his drawing talent.