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## **Integration of technology management, prospective and innovation strategy: the case of a luminaire manufacturer**

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### **Abstract:**

In this research and in line with authors like Yanez and Kahlil (2010) technology is considered as a complex system of knowledge and know-how supported by equipment. To update methodologies aiming at the identification of scenario about the company's profession and knowledge of tomorrow and the corresponding tomorrow business ecosystem outside the company, the following concepts are studied and combined:

- The notion of innovation.
- The theory of evaluation applied to the field of knowledge and know-how and the concept of Value.
- The notion of prospective scenario.

As one objective consists also to elaborate a decision-making aid methodology, a data collection and treatment approach is suggested. This includes a census and evaluation of the core competencies of the company, a list of new candidate technologies and decision aided tools to select the most valuable ones.

Finally a first experiment of the approach is described within a small and medium company manufacturing luminaires

**Key words:** technology system, knowledge, evaluation, newness degree, innovation, prospective.

### **Introduction**

Technology management is a major concern for IAMOT research community, it deals among other with observing company strategies and developing management approaches to help top managers in the definition and valorisation of technologies allowing the development of the company. Hence, technology is one of the major variables taken in account by top managers when defining the company strategy. Beside decisions about marketing, finance, supply chain and quality management, the definition of the core technologies allowing the development of the company is a key success factor. In line with authors like Yanez and Kahlil (2010)

technology is considered as a complex system of knowledge and know-how supported by equipment. This includes scientific and technical knowledge as well as business abilities, these latter correspond to any knowledge mobilized for the economical exploitation of technic: customers need, sales technics, purchasing, production planning among others. Thus, technology represents mainly a dynamic combination of individual and collective knowledge and skills that evolves as a result of (Gnepke and Coeurderoy, 2017):

- Human resources changes: hiring people or departures influence the company set of knowledge,
- Activities like: research (knowledge generation), internal education, outsourcing may extend the scope of inner competencies,
- Modification on the borders of the company: this includes company acquisition.

Taking this theoretical background in consideration, technology is then specific to a company and the result of an internal collaborative and continuous process of elaboration. Consequently, the management of the technology has to be personalized. Moreover all knowledges are interconnected so that innovation induces changes in the previous technology system of the companies. As a result defining the best valuable technology to be mastered by the company is a top management major concern. Literature attests of some decision aided approaches proposed by authors to strengthen the elaboration of the technological strategy of companies (Cooper, 2000; Kaplan and Jarzabkowski, 2006; Kim and Mauborgne, 2010). These approaches are always evolving as the context of companies is changing (Shu-Hsien, 2005). Moreover as the knowledge landscape globally evolves too, technology management attests of a temporal dimension, meaning the need to define present and future strategies. Consequently, in order to elaborate decision making aided tools, three main concepts have to be integrated:

- Innovation as a process of launching new product valorising new knowledge,
- Value as an innovation performance evaluation criteria,
- Foresight as a methodology to define future scenarios.

In this research and to contribute to the scientific production about technology identification and evaluation in a context of innovation, the previous concepts are studied and their combination is analysed thanks a literature review. As one objective consists also to elaborate a decision-making aid methodology, a data collection and treatment approach is suggested.

The remainder of this paper is organized as followed: the first chapter is concerned with the scientific background. Then the methodology elaborated is explained and in chapter three an experimentation is described within an innovative manufacturing SME. Results are discussed in the last chapter.

## **Scientific background**

### *Innovation*

In this research the aim is to put in coherence an innovation strategy with the decisions about technology. As innovation often emerges thanks new acquired knowledge and more particularly combinations of scientific knowledge from several disciplinary domains (Fong,

2003), innovation is directly linked with decisions about knowledge and consequently technology.

Innovation is characterized by four main aspects: a process with meta-activities (design, adoption, implementation and diffusion), novelty, value creation (Marquis and Meyers., 1969), and finally particular outcomes (new product, service, and business model among others). Innovation is a multilevel process. Boly at al. (2016) describe the “company level” where permanent tasks are organized for idea generation, knowledge management, networking and strategy, “ a project level” where teams assume temporary tasks about product design, “a product level” consisting in the new product characteristics and finally a “cognitive level” based on individual and collective creative and learning processes. Novelty is associated to the concept of discontinuity. Garcia and Calantone (2002) distinguish the internal technology and marketing discontinuities (gaps between present and innovation required knowledge of the company) and the external technology and marketing discontinuities (changes in the environment before and after innovation). Combining these discontinuities allows the definition of a newness degree: from incremental, to really new and radical.

Thus, the methodology proposed to enhance technology strategy decision will focus on the “enterprise level” and integrate an evaluation of the novelty degree.

#### *Value evaluation.*

Innovation is a value creation process (Stroh, 2016) (Kumar and Reinartz, 2016). Then, the evaluation of Value is a major concern when choosing the technology to adopt in the company (Train and Dain, 2008). Value can be considered as multi-criterial with the integration of financial (margin), marketing (market share and catchment area), reputational (notoriety degree), sustainable (environmental, social and health impact) and strategic criteria (competitive pressure and differentiation degree) (Boly, 2016). It is a quantitative and qualitative variable. To define the best technology to master and/or to acquire, value is then the key concept used to evaluate the candidates technologies. One problem is the temporal dimension: Value is unstable if considering short or long term, then, a prospective approach is required to assess the future potential value of a given technology.

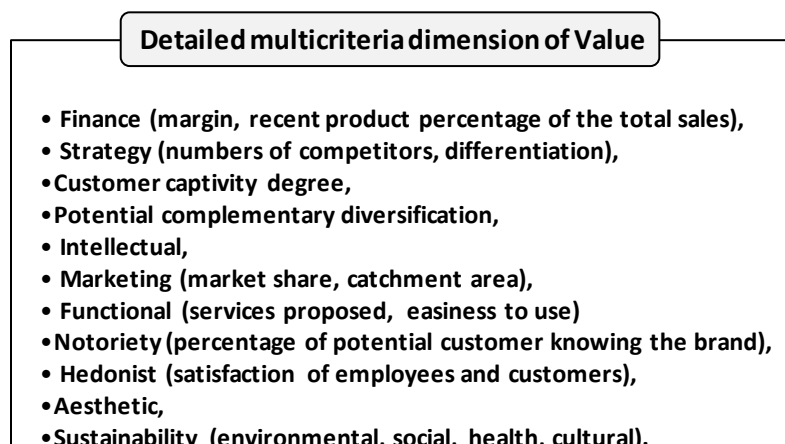


Figure one: Value as a multi criteria innovation assessment variable

### *Foresight*

Technology is moving, hence some authors consider digitalization as a world revolution (Lindstone, 2011). Then, uncertainty remains high on the future context of companies and consequently the elaboration of different scenarios modelling different potential future environments of the company is required. Moreover, technology may require heavy investments and then a long term exploitation, as consequence the long term impact of a technologic choice has to be studied (Coates et al., 2001). Foresight consists in considering that the future is plural and that some events called ruptures may change historical tendencies. Then authors propose different methods to elaborate possible scenarios about the future, this includes Delphi, Cross-impact matrix (Micmac) and Political, Economic, Social, and Technological (PEST) analysis (Alizadeh, 2016). Scenarios describe strong trends (present evolutions that will be continuous in the future), weak signals (present events that may move to strong trends), future constraints (new rules the stakeholders will have to follow) and contrasted visions of the future (global characteristics about the environment). Thus the proposed methodology integrates a prospective step to elaborate scenarios about future valid technologies.

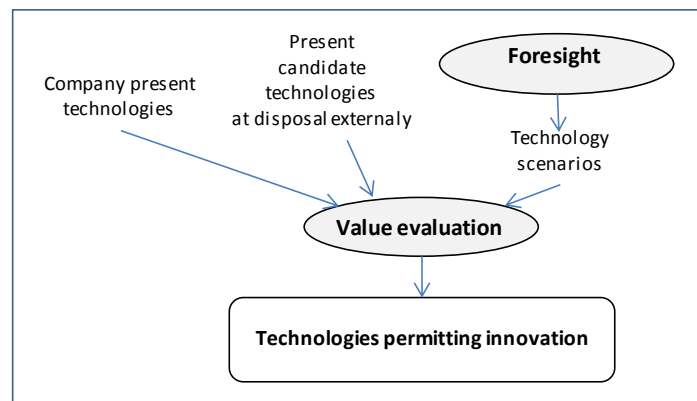


Figure two: technology strategy elaboration

The definition of the technology strategy of a company is then based on the collection and treatment of information about the core competencies of the company and candidate technologies identify through technology survey. Moreover foresight activities extend the set of potential technologies. Finally the outcomes of the approach are competencies:

- to save inside the company (compagnonnage, teaching),
- to protect (intellectual property),
- to acquire internally (research),
- to acquire externally (hiring and all form of outsourcing),
- to acquire collectively (open innovation),
- to scrap (restructuration).

Note the dynamic aspect of this approach that represents a continuous task in the company, as new information from outside the company and new opportunities about the future required to renew the strategy.

## **Methodological proposition**

In order to elaborate technology management guide lines for practitioners the following five steps are proposed:

- An internal census of the core competencies associated to the value chain of the company,
- The definition of criteria and observable phenomena to assess the present knowledge and know-how of the company,
- The collection of data about the environment and the elaboration of a list of candidate technologies linked with the innovation objectives of the company,
- Foresight approaches to elaborate scenarios about the emergence of some technologies but also about use,
- The elaboration of a global technology strategy (represented with a roadmapping model) and based on multi-criteria value analysis. And the identification of a plan of progress including the in-house process of development of the technology or out-sourcing scenarios.

In this method, attention is directed toward the data collection and treatment approaches required considering different theoretical problems: the existence or not of standards, the influence of the evaluator on the system to be evaluated, the importance of the scale and context (does a particular knowledge have the same interest and value within a team and the related company and according to the targeted markets?). Moreover the dynamic aspect of knowledge has to be taken in account considering employees mobility and the effects of experience among others. Hence some procedures are stated to strengthen the approach. Firstly, in accordance with the theory of evaluation (Hadji and Meirieux, 1989), each of the competencies to be assessed is associated to one or several observable phenomena defined beforehand. More precisely, each skill is linked with a fact, a document or a material artefact proving the presence of the competence. Thus subjectivity of the evaluator is reduced. Secondly, each of the qualitative criteria used for the Value evaluation is assessed by a comparative approach. This is the case for “easiness to use” where comparative tests are achieved between the product of the company and those of its competitors.

Thirdly, data processed during the foresight step are confronted to the literature and experts

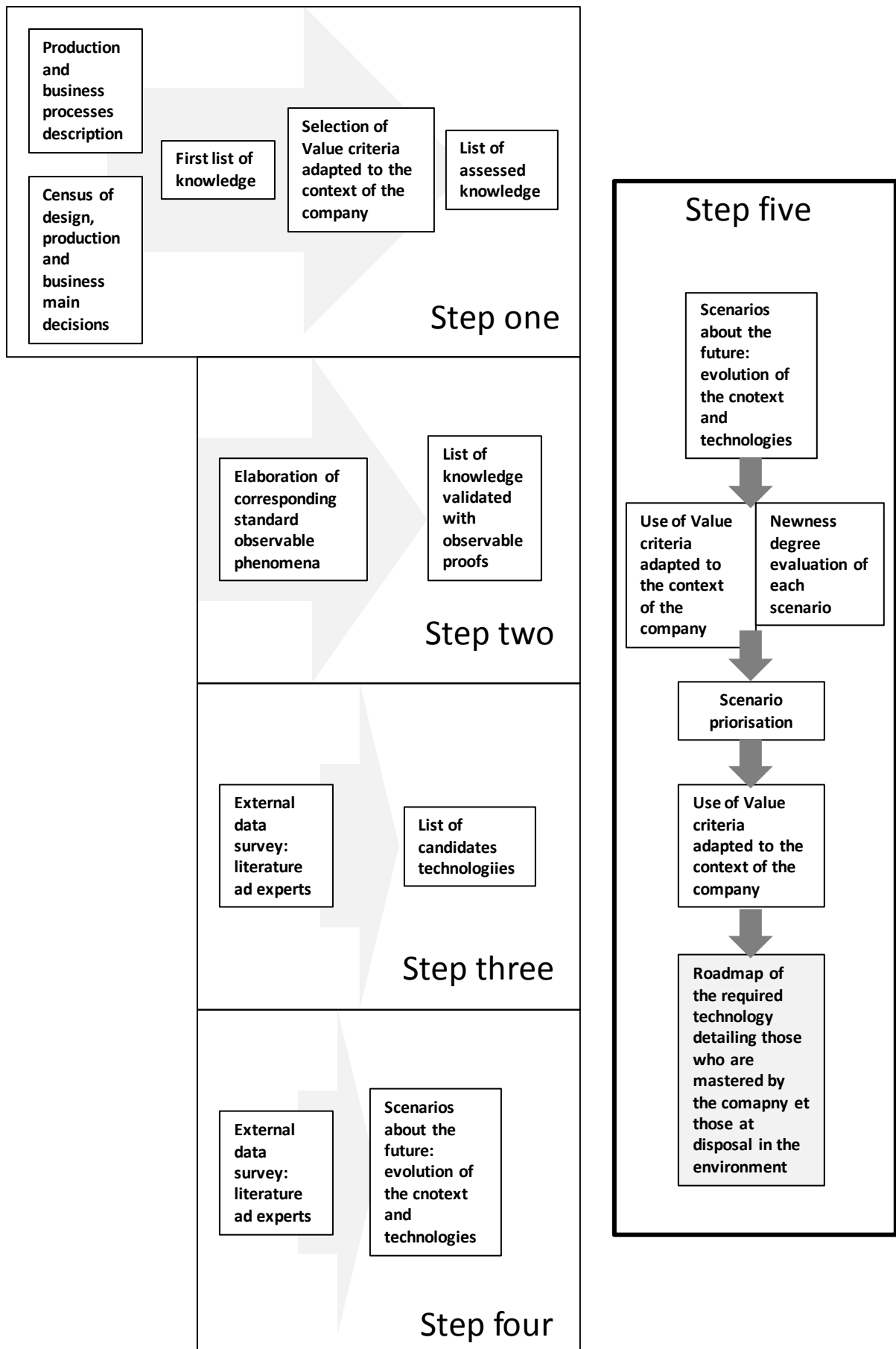


Figure three: global approach

## **Experiment: methodology implementation in a manufacturing SME**

Through a first constructivist approach, the aim consists to test the pertinence of the proposed approach: adaptability to the case, adoptability by managers and production of information used to take decisions. The experiment is efficiency-oriented and also it consists in a first implementation in order to get a genuine return on experience for latter improvement.

One company, who asks for anonymity, is selected because of its experience in the field of innovation, the data at disposal, the agreement of the top management to integrate researchers to the strategy reflection and to some innovative projects and the geographical proximity allowing close contacts. The grids elaborated to treat data are given and the final roadmap is detailed. Operational aspects are also described and discussed. The experiment duration is eight months and authors are on-site about half a day per week.

The original company founded in 1896 operated in the field of carpentry. Initially, its activity was the repairing of furniture and the production of frames and floors. In 1937, following its acquisition by one of the employees, the company changed its name. During the 1950s and 1960s, the CEO has massively invested in woodworking machines and specialized in woodturning to become a reference in its domain. At this time, the company has twenty-two employees. In 1998, following the arrival of a new CEO, the company develops a totally new activity in luminaries. This new strategy directly affects the turnover of the company that was growing rapidly. Its products are now distributed in the different large stores and among interior designers. Luminaries represent 54% of the turnover, the rest being covered by the carpentry business. In recent years, the turnover of the carpentry activity stagnates while the turnover of the luminaries' activity increases. Indeed, pieces turned in wood from the carpentry sector are "cash cow" products, they generate profits and they require little investment to the company. Top management strategy is then to keep expertise in wood turning that can be valorised in two ways, either by maintaining sales of turned parts, or by producing parts of electrical installation for luminaries. The integration of woodturning parts in several models has been successful but as these products are moving to a maturity stage, innovation is required. Note that over time the evolution of the activities induced strong changes in the technology system of the company, this includes: assembly of wood and electric parts in a clean environment, knowledge about electric items regulation, advertising skills and negotiation with central purchasing companies. Moreover, as new varieties of products are launched every year, this company is considered as innovative in a low tech sector.

*Step one: internal census of the core competencies and associated to the value chain of the company*

Data are collected through interviews of employees, bibliography in the technical literature, analysis of company documents (production planning, after sales results among others) and in



situ observation campaigns. The present knowledge is identified after the description of the production and decision processes of the company. Figure four details one part of the production process corresponding to the luminary assembly phase.

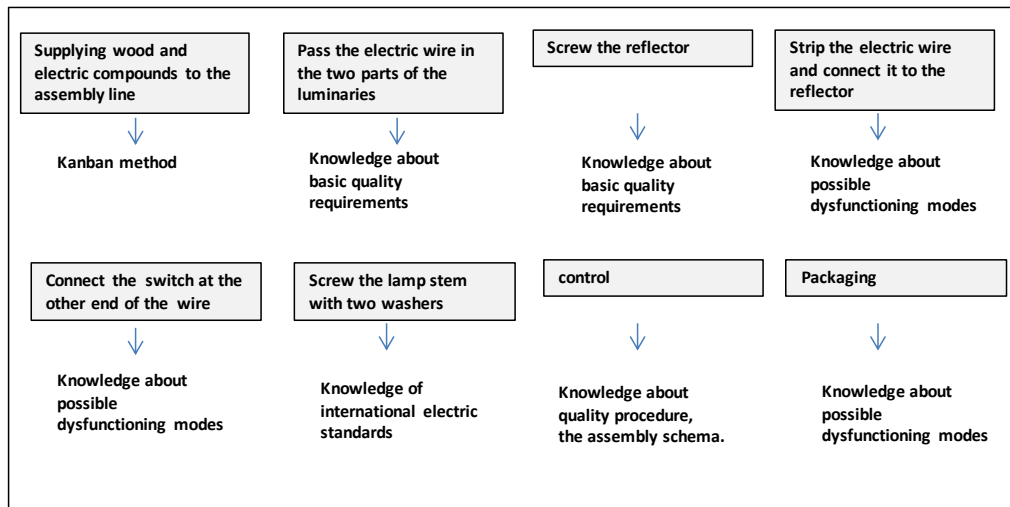


Figure four: process of assembly of the company and related required knowledge

The table one gives then a partial but more global list of the technology (sum of knowledge) of the company (the real list is too long to be integrated here).

Market	Product	Technical knowledge	Connected knowledge
Carpentry	Woodturning parts sell to furniture producers	<b>Production knowledge</b> Wood turning Wood drying Wood control Specific machine set-up Specific machine maintenance Ram material consumption optimisation <b>Design knowledge</b> Drawing <b>Quality knowledge</b> Visual control, statistics	<b>Management of short term orders</b> <b>Wood purchasing and storage</b> <b>Logistics of large volumes</b>
Luminary	lampshade Chandeliers Spots	<b>Production knowledge</b> Internal handling Kanban method Varnishing Assembly procedures Possible dangerous defects Packaging <b>Design knowledge</b> Drawing Fashion trends Design technics Prototyping Usage tests <b>Quality knowledge</b> TQM	<b>Management of time lag between commitments and payments</b> <b>Purchasing of electric parts</b> <b>Logistics of small volumes</b> <b>Promotion, marketing in the field of interior decoration</b>

Table one: major knowledge constituting the technology system of the company

Part of the knowledge is common in the sector: people having the related competencies are easy to find on the local labour market or learning of new people is fast. This is the case of “knowing how to package luminaries avoiding chocks between wood parts”. Other knowledges are more specific to the company as “purchasing raw material adapted to the case of luminaries”.

Then during meetings with top managers of the company and some operators the evaluation of the knowledge is achieved by detailing the contribution of each of them to the Value criteria:

- **Financial criteria:** net margin.
- **Marketing Criteria:** annual percentage of market increased volume.
- **Strategy criteria:** number of competitors.
- **Functional criteria:**
  - *Adaptability of luminaries to different places:* The various possible uses of luminaires create opportunities on the market. Lighting can vary depending on location in one considered house and according to the use chosen by the consumer,
  - *Individual control of the performance of luminaires:* The development of digital technology and electronics in the luminaires market encourages consumers to have new requirements and to contribute in their environment. Objects control (with a smartphone or other interface) is a tendency not to be ignored.
- **Sustainable criteria:**
  - Minimum consumption of electric power:* The various policies implemented to reduce consumption must not affect the quality of the produced light. From this perspective, the “energy consumed VS light produced” ratio must be optimized and efficient.
  - Lifetime of luminaires:* While trends show that the renewal of luminaires is more frequent than in the past, it is necessary to find the right balance in terms of life cycle,
  - Ecological traceability of product:* To fully meet the political requirements and offer “green” products, knowing the characteristics of products and raw materials is important.
  - Recyclability of product:* In a strong ecological context, offer of recyclable product is relevant.

Note that sustainability is one priority in term of added value and that the company seek some “blue ocean” spaces to develop its activity (Kim and Mauborgne, 2004).

knowledge	Financial value	Marketing value	Functional value	Sustainable value
<b>Production knowledge</b>				
Wood turning	+	0	0	0
Wood drying	0	0	0	0
Wood control	0	0	0	0
Specific machine set-up	0	0	0	0
Specific machine maintenance	+	0	0	0
Raw material consumption optimisation	+	0	0	0
<b>Design knowledge</b>				
Drawing	0	0	0	0
<b>Quality knowledge</b>				
Visual control, statistics	+	0	0	0
<b>Management of short term orders</b>	+	0	0	0
<b>Wood purchasing and storage</b>	0	0	0	0
<b>Logistics of large volumes</b>	0	0	0	0
<b>Production knowledge</b>				
Internal handling	0	0	0	0
Kanban method	+	0	0	0
Varnishing	0	0	0	0
Assembly procedures	0	0	0	+
Possible dangerous defects	0	0	0	+
Packaging				
<b>Design knowledge</b>				
Drawing	++	++	++	0
Fashion trends	++	++	0	0
Design technics	++	++	++	++
Prototyping	+	+	++	++
Usage tests	+	+	++	++
<b>Quality knowledge</b>				
TQM	0	0	0	+
<b>Management of time lag between commitments and payments</b>	+	+	0	+
<b>Purchasing of electric parts</b>	0	0	0	++
<b>Logistics of small volumes</b>	0	0	0	0
<b>Promotion, marketing in the field of interior decoration</b>	++	++	0	++

Table two: value evaluation of the competencies

Globally, a degradation of the global value is observed. Five years ago as the first wood halogen spots were launched, the company was the only one to produce this specific product (high strategic value) and purchaser made efforts to stimulate this innovative niche. But now competitors exist all over the world. Moreover the use of functional and sustainable criteria is new for the company. Thus some of them are not significant: people in the company consider that their products are “recyclable” because they are made up with wood, a natural material. But in fact varnish used as surface treatment limit the effective recyclability.

*Step two: The definition of criteria and observable phenomena to assess the present knowledge and know-how of the company*

To attest of the real presence of the knowledge, list of observable phenomena are elaborated with top management and then validated by experts (table two). An observable phenomenon is mostly a document (e.g. a written procedure) or an artefact (e.g. a prototype). In this case three experts have been mobilized in the field of marketing, wood industry and supply chain management to validate the list. Observable phenomena concern all services of the company: production, sales, administration, design, logistics and management. A selection is done in order to have a small number of observable references to treat with the employees. This constitutes obviously a limitation of the approach.

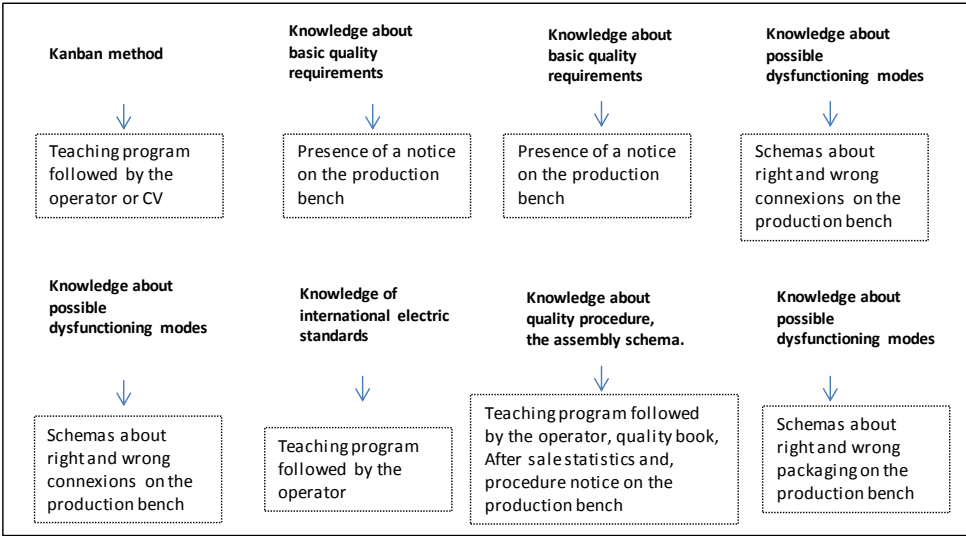


Table three: list of some observable phenomena relating to the knowledge of people in charge of the assembly.

*Step three: The collection of data about the environment and the elaboration of a list of candidate technologies linked with the innovation objectives of the company*

The survey is conducted in the field of lightning and others sectors are targeted with top management. Priority is given to electronic items and automotive industry. Data from these domains are considered useful because of the attractiveness of the products to the consumers and their strong standards. Three technologies are the pointed out:

- The use of composite to replace partly or totally the wood,
- The technologies developed to connect the luminaries (smart spots). This include telecommunication items and software development,
- New electronic sensors to adapt the light and to minimize the energy consumption.

*Step four: Foresight approaches to elaborate scenarios about the emergence of some technologies but also about use*

This step is based on a Politic, Economic, Social, and Technologic (PEST) analysis because it required less time than other methodologies. And this aspect is very important as the experimental SME resources are weak. This foresight approach is based on a literature review and interviews of the same experts mobilized during step two. The main outcomes are described in figure five.

<p><b><u>strong trends</u></b>            Phototherapy in urban areas -S-            Price as purchasing criteria number one -E-            Large variety of lightning sources -T-            No interest for refined material -S-            Surface housing reduction -E-            Connected product -T-</p>	<p><b><u>contrasted visions of the future</u></b>            National subsidiaries for the wood industry continue or stop -P-            Lightning product life cycle shorter or longer -S-E-</p>
<p><b><u>weak signals</u></b>            Furniture integrating directly lamps -T-            Renting product or services instead of buying them -S-E-            Revolutionary shop fitting to fight against internet purchasing -E-</p>	<p><b><u>future constraints</u></b>            Eco-taxes -P-            Luminaries safe guarantee -P-            Wireless luminaries -T-S-</p>

Figure five: main prospective trends about the company (P relates to Political trends, E to Economical, S to Social and T to Technology)

Some conclusions are deduced with top management in term of scenarios of evolution. Lightning would have different functions and representations for the consumer, a relation between well-being and lightning may be more and more important. New technologies will impact the producers with knowledge far from their present core competencies: computing, electronic and telecommunication among others. A threat is that new entrants may target the market. Then the evolution of housing and especially the reduction of the surface per people may induce an integration of the lightning items into the furniture.

*Step five: Elaboration of a global technology strategy (represented with a roadmapping model) and based on multi-criteria value analysis. And the identification of a plan of progress including the in-house process of development of the technology or out-sourcing scenarios.*

Different strategic scenarios are elaborated to establish technology priorities. In fact two reasoning modes are developed:

- One is based on external prospective trends: what technology will add value in a particular context?
- One is based on the candidate technologies: if two or three potential new technologies are applied what will be the potential flows of added value?

The value criteria used at this stage are the same as the one of step two. To model the scenarios roadmap models are used detailing five elements: the competences, the global name of the technology, the function (services) deliver to the customers, the targeted market and the product (or service) offer (Rohrbeck et al., 2008).

Top managers elaborate two roadmaps (figures six and seven).

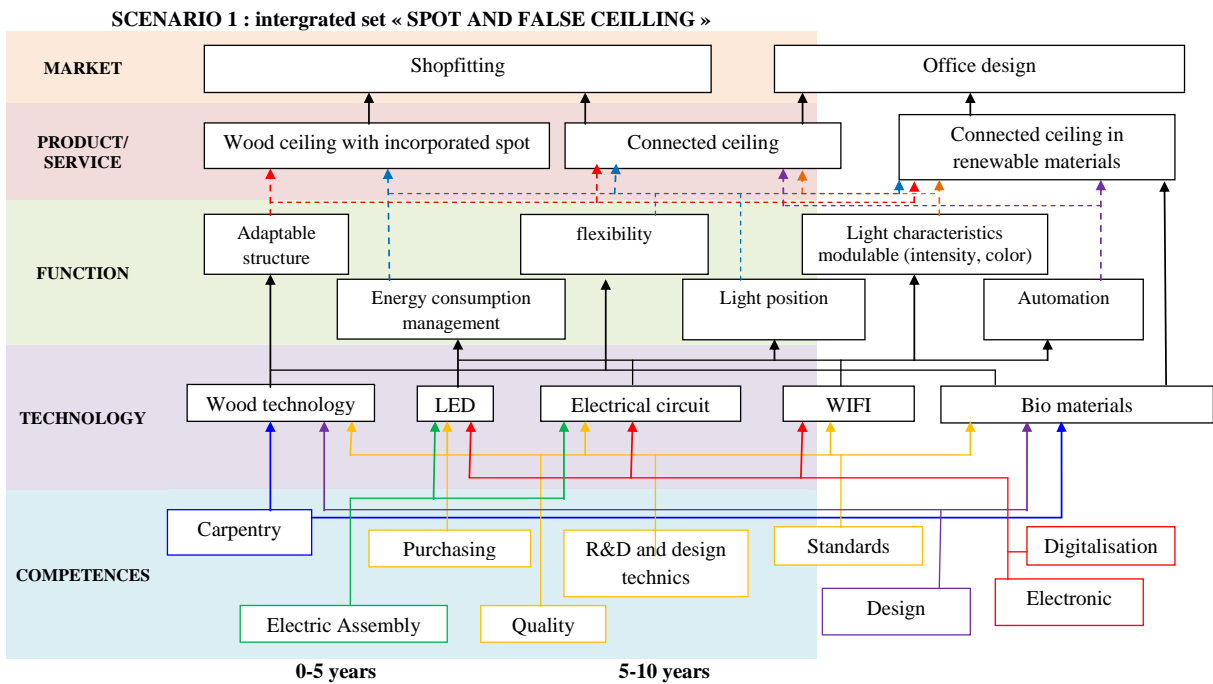


Figure six: roadmap corresponding to a new market

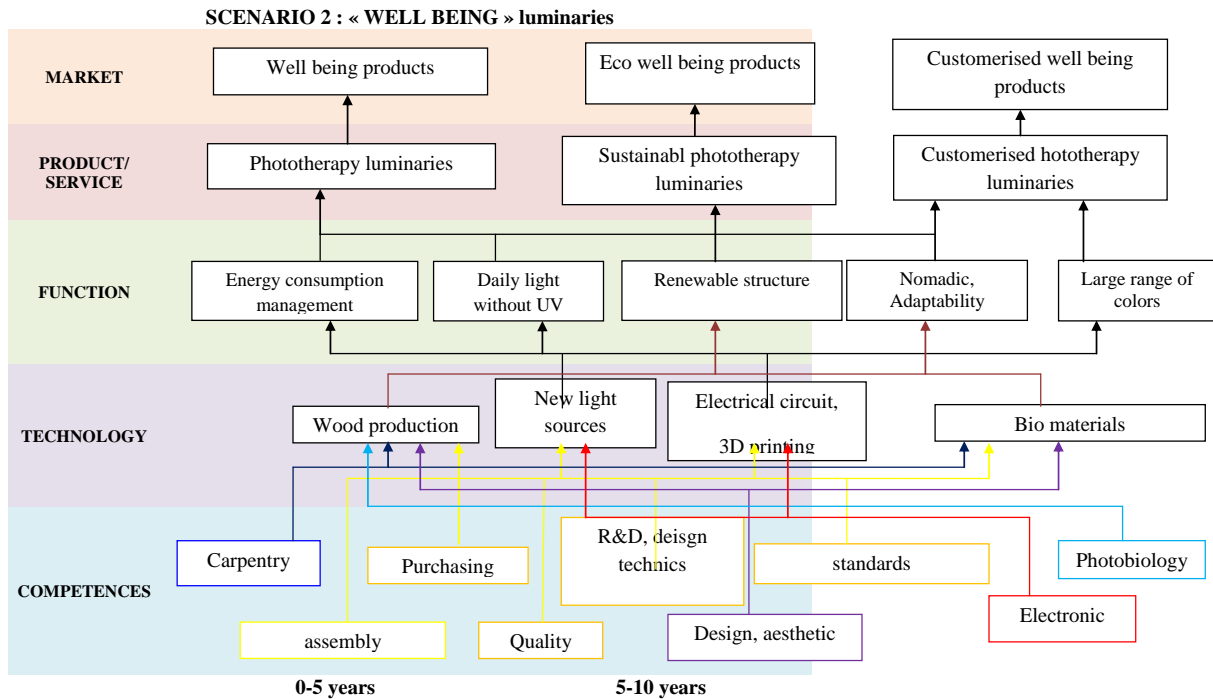


Figure seven: Figure six: roadmap corresponding to a new social trend

The value creation of the technologies required for the roadmap one relates mainly to financial and marketing criteria, when the one of roadmap two is more strategic and sustainable. Experts and employees agree to state that the newness degree (discontinuity) of products relating to roadmap one is higher than roadmap two, as phototherapy is already developed in some European countries. The final analysis of the technology system shows that the evolution may be the following if these scenarios are applied:

- to save inside the company: wood turning (scenario one), design (all scenarios),
- to protect: branding (all scenarios),
- to acquire internally: specific design technics (all scenarios), photobiology (scenario two),
- to acquire externally: electronic (all scenarios), digitalisation (scenario one),
- to acquire collectively (open innovation): none at this stage,
- to scrap: wood turning (scenario two).

## Discussion and conclusion

The contribution of this research is mainly based on the integration of newness, innovation and the multi-temporal analysis of the value creation within a technology management approach. Note that the final aim of the program is the development of a website or a software to assist practitioners. Moreover the objective is to elaborate a methodology adapted to the case of SME, meaning low human resources and financial capacity.

The experiment attests partly of the pertinence of the methodology. The proposed approach is considered as efficient: top managers have gathered new data and they took decision

concerning the future investment of the company. Hence, the approach helps taking decision in an uncertain and complex environment. The figures and tables elaborated allow team working and foster the contact with external experts, this aspect is important in the case of small enterprises. Operators have been involved easily. One limitation remaining is the duration of the study and then two complementary perspectives exist: the simplification of the approach and the necessary involvement of a method expert. With one experiment at this stage, the question of the autonomy of managers remains accurate.

The main obstacle faced during the test is the access to information. It is difficult for people with high experience to investigate technology fields far from their own expertise.

Considering the literature, the contribution may be described according two aspects:

- The methodological dimension: if the Blue Ocean approach is considered, the proposed methodology helps to transform the description of market spaces or more generally spaces with low competition pressure into a census of required technology skills. It means that one contribution is to close the gap between business and engineering vision. If the Value Chain model is considered, the contribution consists in a more robustness in the competencies identification thanks the observable phenomena definition step. Moreover by adding internal audit, external technology survey and foresight top managers are confronted to the coherence between short and long term decisions. The temporal dimension of technology management is assumed with operational results.
- The theoretical dimension. A technology system is specific to a company, it constitutes one of these characteristics. Moreover the context of companies is highly heterogeneous. So it is important that technology management methodologies are configurable according to the context and the basic intentions of company policy makers. The multi-criteria aspect of Value suggested in the research helps top managers to put more objectivity in the assessment of each possible scenario and to adapt the strategy evaluation process to the constraints.

In perspective other experiments are planned in SME, the research is still exploratory and some digital mock-up are under development to support the approach. Moreover a link as to be done with the main strategy schemes based on other variable: finance among others.

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