SUPPORTING TECHNOLOGY INNOVATION PROCESSES IN MANUFACTURING SMALL AND MEDIUM ENTERPRISES

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ABSTRACT: Manufacturing SMEs need to innovate to keep their competitiveness on the market. In spite of this widely recognised need, few tools and methodologies are available to support SMEs in the innovation process, in particular during the definition of the concept idea. This paper describes how the technology innovation needs of SMEs could be supported by external consultants making use of structured methodologies, the Open Innovation approach and IT tools. A use case validating the proposed process is then reported.

1. INTRODUCTION

It is widely recognized that research and innovation are key competitiveness factors for European SMEs[1]. In spite of this recognised need, SMEs lack a systematic approach that supports them in the overall innovation process. The so called "Innovation Management Techniques", considered by the European Commission as an useful driver to improve competitiveness, are still underutilized by SMEs; in particular, among such techniques (which include knowledge management, market intelligence, creativity development, innovation project management, business creation, etc.) the Creativity Development Techniques are the less used among SMEs[2]. Several studies [3] showed that the process of generating ideas for innovative products could achieve better results if supported through methodology and tools. In recent years, mechanisms have emerged to add further structure and effectiveness to systematize new product and service concept generation. These approaches range from very formal techniques such as QFD (Quality Function Development), value chain analysis, Business Process Reengineering (BPR), TRIZ (Theory of Inventive Problem Solving), to techniques based on market dimensioning, behavioral research and lateral thinking techniques [4].

Moreover, in the current scenario the web provides SMEs with the possibility to access worldwide knowledge to perform their innovation processes; in such context the Open Innovation (OI) paradigm has been growing in recent years. It is believed that the usage of Open Innovation can improve competitiveness and market leadership [5]. The need to collaborate while innovating is felt both by SMEs working in traditional sectors (such as the manufacturing sector) as well as by hi-tech SMEs that need to connect with stakeholders to propose and implement their technologies. This is in line with the consideration that OI is the use of purposive inflows and outflows of knowledge to accelerate internal innovation, and expand the markets for external use of innovation, respectively.

While structured methodologies have been recently studied to support a systematic approach to innovation, and semantic web technologies allow to search, retrieve and use external knowledge relevant for innovation processes, information solutions integrating and supporting the usage of structured innovation methodologies and optimizing the search and usage of internal and external knowledge for innovation processes is still an untapped field.

The way providers of technology / expertise, and seekers of technology/expertise are able to connect is still driven by classical communication channels (such as word of mouth, brokerage events, etc.) and few very simple internet services. At the same time, few tools are available to support SMEs in the usage of structured methodologies such as TRIZ, and they often are unusable by users that do not have a proper knowledge of the methodologies, meaning that they fail in supporting SMEs with limited resources and without capacity to learn and use methodologies such as TRIZ. As a result, possible innovation and/or technology transfer actions are missed by the lack of specific tools to support "intelligent" and proactive connections. The recent development of semantic web technologies and the offering of IT tools as services are creating the conditions to facilitate innovation processes of SMEs through the usage of IT tools and methodologies with a continuous interaction by external experts (consultants) that could support and train SMEs while optimizing their innovation processes.

2. THE SMES INNOVATION PROCESS

In SMEs the innovation process is usually performed through the following steps:

1. ***Idea Generation:*** the stimulus to innovate might come up from a set of possible sources, and specific information is used to make the correct choices:

- Specific engineering needs (example: a manufacturing process that is frequently stopped due to break of a specific mechanical part). No external information is used in this case.
- Specific market needs due to lowering of competitiveness, request of advanced functionalities or mature market. In this case, a set of external information is necessary to plan any innovation: a) competitors behaviour and products; b) market trends; c) new or hidden needs of customers (which new functionality will delight the customer?).
- A "concept idea" born in brainstorming sessions, or through internal talks among engineers and/or through specific "intuition" of some bright professional in the company. In this case, the source of knowledge may derive by external information such as R&D results, publication, and technology trends.

2. ***Innovation concept definition***: depending on where the innovation request has been generated, different needs emerge, that could be faced by the responsible person of production, and/or R&D, and/or of marketing:

- Solving the engineering needs: the engineering problem needs to be defined, and internal sessions are held among engineers to search for a solution. Usually, knowledge outside of the company is searched by engineers, to search for technological systems present in the market (worldwide) performing the requested functionality, searching for patents as well as relevant R&D projects;
- Market needs: the request coming for the market is very demanding for SMEs. In this case, the marketing responsible of the company is asked to search for "what the customers wants", or for the "hidden needs of customers". Specific market analysis should be performed, with detailed evaluation on market potentialities, competitors, regulation, market positioning, etc.
- Technology push: the idea coming from engineers could be the one that address hidden customers' needs, with the potentiality to delight customers with unexpected functionalities. In this case, both a technological feasibility and a market analysis should be performed.

3. ***Innovation Design:*** each single step of the innovation process is already quite unstructured within SMEs. Moreover, the different steps should be merged at a certain point to support the SME managers in defining the innovation concept. During this step, the information requested to support the responsible person are:

- Technology knowledge: which are the available systems currently used to perform the same function, which are the available skills and needed competences outside of the company to perform the innovation, etc.
- Market knowledge and financial feasibility: detailed overview of most wanted features from customers; evaluation of costs, financial engineering to finance the innovation.

As the process above described shows, different kind of information (internal and external to the company) is used by different personnel within the company, without a specific methodology and neither tool to support the innovation process activity. The information used during a technological innovation is mainly related to three domains: market, engineering (available solution for specific engineering needs), and R&D. Several sources of information are used by SMEs to address the above mentioned domain knowledge: customer's inputs, participation to trade shows, events, but mostly the Web.

In the innovation process, the only activity that almost all SMEs perform is to search for external information, in different sources such as the web, patent databases, in trade fairs or discussing with clients and partners. The main source of information for SMEs is the Internet [6], which is an activity realised by more than 90% of SMEs when dealing with innovation. During INSEARCH project (funded by the European Commission – project INSEARCH – www.insearch-project.eu), the authors performed an analysis involving 90 SMEs to understand the process of searching and using information during the innovation process of SMEs. Most of the SMEs (92% of 90 interviewed SMEs) declared to make use of market and/or technology information when planning a technological innovation. Such information are used to sought information for innovative ideas, performing prior art investigation, acquiring knowledge for technical planning or just gather inspiration and ideas. The mostly sought information are about product and processes, performed on scientific Web Sites and Competitors web site. Papers and scientific publications are in fact usually sought while performing innovation processes by SMEs of all dimensions and sectors, while Patent analysis is mostly of interest of manufacturing SMEs. Patent analysis is mostly realised through Espacenet, using patent classification as the most used feature during patent search. The function of the product, and functions of components / subcomponents are the most used keywords by SMEs in performing patent search.

91% of the interviewed SMEs stated that they make use of Google or similar general search engine (such as Yahoo). While performing searches for information related to innovation processes, they use keywords related to product types and functions of the products. Search is mostly performed through iterative searches, evaluating search results through the very first lines of documents/web sites In realising the searches, most of SMEs use bookmarks in their browsers as main way to check/monitor interesting web sites during innovation/market analysis processes. Information is therefore searched in the web in an unstructured way, mainly using general search engines (ex. Google) and intuitive keywords to search the web, and then apply human cognitive filters to select relevant information from the retrieved results, and focus further researches. Moreover, the filtered information is usually stored in unstructured databases and not used (or analyzed) in a structured way by SMEs, which usually tend to read the information, and "store" such information in the mind of the person carrying out the research. The overall process is quite time-consuming, it certainly shows to the user only a very minor part of relevant knowledge available on the web, and is not make usage of any techniques allowed by current IT systems to analyse the retrieved information.

3. THE CHALLANGES WITHIN THE INNOVATION PROCESS

The different tools already existing to support SMEs during their innovation processes are often based on well known methodologies such as TRIZ and QFD.

Particularly the TRIZ methods [7,8] allows to SMEs to structuring and improving knowledge about their production processes, in order to solve specific engineering problems encountered in an innovative process and identify possible evolutions of existing systems.

The QFD (Quality Function Deployment) [9] helps SMEs to collect the clients' requests traducing them in formal specifications and features of the products and considering all their aspects: quality, costs, features, performances, etc.

The usage of this kind of tools as the one developed during the European funded project TECH IT EASY, lead to the following observations:

1. Tools users need to have a strong knowledge of the laws on which the methodology is based. It seems that only in this way is possible to take full advantage from the tool capabilities. It is also clear users are not generally interested in learning a complex methodology but they

prefer to have a simple tool able to support them in an easy and practical way.

2. Another important route SMEs could follow to realize their innovations and to be more competitive on the market consist in sharing knowledge with stakeholders of both the same and different sectors. This is in line with the Open Innovation paradigm for which tools are not available. But clearly the SMEs need to be supported in exchanging information related to projects and researches already conducted that could help to reach new innovations. The SMEs are not able, without any support, to keep alive a large network of enterprises, in order to transfer knowledge and to make faster the innovation processes.
3. Also the web is a wide and update source of information about everything could be of interest for the SMEs during their innovation processes. Nevertheless, finding the right information is difficult and depends strictly on the skills of single person in getting more results as possible. And also in that case platform able to support SMEs in structuring their research in the world-wide-web are not yet available.

In all the possible mentioned methods, the role of intermediaries as facilitators and in many cases catalyst of the innovation process is crucial. This kind of broker, for example, could have enough competences to guide SMEs in the right usage of appropriate tools such as the TECH IT EASY one. And also to support them maximize the potentiality of the information coming from the web, or to link SMEs working in different sectors but having similar interests.

4. THE PROPOSED METHODOLOGY

As individuated in the previous section the innovation processes are performed with better results if they are realized taking into account:

- outcomes of researches conducted through the web
- gained knowledge of other SMEs
- to systematize processes by using tools based on specific structured methodologies.

Due to these observations the proposed approach consist in creating a strong interaction between expert consultants, external to the SMEs involved in an innovation process, the usage of IT Tools and the SME itself.

The achievable benefits arising from this kind of interaction are:

1. The SMEs are guided in structuring their problems in TRIZ terms in a non invasive and affordable manner; the SMEs are supported in adopting the TRIZ theory in the best way;
2. The SMEs are getting behind the researches of new information conducted into the web and in their own knowledge base. The support consist in structuring the researches with the usage of OAT patterns (the specific relationship among the product mechanisms and functions can be represented through the TRIZ logical schema OAT, means Object Action Tool) and with advanced textual search tool;
3. Thanks to the consultant's large network, the SMEs have more chances to get in touch with other organisations, also of different sectors, and share their knowledge with them. Moreover, the experts guide the SMEs using existing Open Innovation platforms.
4. The consultants in specific case are also able to suggest to the SMEs funding opportunities useful to realized innovations.

5. A USE CASE

The presented methodology was tested in a real case: the innovation management consultancy company, CIAOTECH (CTECH) supported the SME, TACORE (TAC), during some of its innovation processes.

TACORE's core business sector is machinery for the canning, which includes the construction of complete tuna processing plants using leading edge technology in cutting, cooking, cleaning steaks, etc., with on-going control of yield and production with the help of applied computing systems.

TAC doesn't have a structured way and dedicated professional figures to carry out market analysis and technology innovation processes. TACORE calculates designs and assemblies its machines according to customer needs, limiting outsourcing to manufacture processes. Information exchanged with partners or suppliers are basically on technical, performance and economic issues. Its main needs are generally: continuous innovation of technology systems, increase of competitiveness at both economic and technological levels and reduction of costs.

The technological solution that TACORE wanted to innovate is a machine for selecting, sizing and allocating pelagic fish (anchovies, sardines, mackerel, etc.). The main function of the apparatus was to provide an accurate selection of fresh or frozen fish from a large and casual quantity to a distributed homogeneous flow according to the fish species and sizes.

The degree of the selection accuracy was very small (about 20%), because during the separation process fish can't be properly positioned. The wrong localization of fish made impossible the capacity to detect and track the processed fish by the vision system and the selecting nozzles for classification, so the target was to solve the problems of handling and positioning pelagic fish within the modular belts. In conclusion **the two main functional problems** of the TACORE machine were *overlapping of fish* and *collocating the fish in a transverse position*.

It was clear the need of technology innovation and improvements in some specific machine components. The company estimated a big potential market because of the absence of similar apparatus and the expressed interest for the machine from many TACORE clients.

To solve this problem CTECH supported TAC in using an IT Tool guiding users in TRIZ and QFD methodologies (developed during the TECH IT EASY funded project) as described in the following step:

1. The first step of the problem analysis consisted in decomposing the whole system in sub-mechanisms and each component was associated to one or more functions, in order to model the machine in an analytical and detailed way.
2. The TAC machine was identified by Quality Characteristic (QC), which represent specific physical and measurable properties related to the performance of the technology system.
3. The most relevant Customer Requirements (CR) of the TAC machine was individuated, underlying the needs of

the customers (industries for fish packaging or related products) and producer (TAC or competitors) of the technology system.

4. The next phase of analysis consisted of a comparison among the Quality Characteristics (QC), the Customer Requirements (CR) and the Mechanisms in a numerical framework, which is called in literature House of Quality (HOQ). The QC weights and the degree of importance of each mechanism calculated automatically with a mathematical formula showed the importance of each QC and Mechanism from a market prospective.
5. Two different OATs have been created, one for each problem of the TAC machine in order to have a formal formulation of the individuated problems and apply the TRIZ laws to get two concepts of technological innovations.
6. The OATs helped in researching through the web to find patents and scientific papers. In fact, the structured formulation of the OAT is relevant for keywords definition, being OAT usually composed by a triple of Noun – Verb – Noun.
7. The TRIZ tools to stimulate innovation (such as contradiction matrix, laws of evolution, etc.) were also used to stimulate innovative ideas to solve the problem.

The support of the external consultants and the interaction with the SME brought to the identification of a set of possible new concepts, namely:

- NEW BRUSHES: The fish are transported with a modular belt under separator to reduce the number of overlapped fish. With the usage of this kind of separator a large number of fish are still attached to each other. The solution consists in including an intermediary tool, substituting the big flaps of the separator with smaller and thinner flaps like a brush. The solution is under study as only a very minor pressure could be applied on fish otherwise the fish gets damaged. The concept idea was identified following the TRIZ indication of applying "separation in space and time" to solve physical conflicts, as well as the principle of going from "macro" to "micro".

- NEW SLOTS: The fish are transported under the video with a modular belt composed by slots. The solution consists in changing the inclination of that slots to ensure all fish collocated in a transverse position. In particular, the innovation concept is to make slots that are not flat, thus allowing the fish to lie slightly inclined, and one wall limiting the slots higher than the other. In this way, the fish thanks to gravity should always be positioned in a transverse way which should allow the vision system to recognise the fish itself. The concept idea was identified following information gathered from the web (similar situations in different sectors) as well as TRIZ indication of making usage of environment resources (in this case the force of gravity).

The company is now evaluating the technical and economical feasibility of such innovation concepts.

6. MARKET-IT, AN INTEGRATED APPROACH

The usage of a software tool to support SMEs innovation with strong interaction with external consultants, is the objective of the demonstration project financed by the European Commission called "MARKET IT".

In MARKET IT a different approach of the usage of semantic methodology in SMEs' innovation processes will be demonstrated.

The approach consists in developing an integrated tool capable both to structure information about SMEs' products in a formal manner and managing relevant market and technology knowledge, improving their knowledge about SMEs' own processes.

The software tool is based on three main pillars:

1. a collaborative environment, allowing different people form the SMEs to interact among each other and with external professionals
2. high usable features to support the usage of methodologies such as TRIZ and QFD.
3. A knowledge search and extraction tool able to find relevant knowledge in the web or in the internal knowledge base related to the innovation process.

The pursued idea is to create a tool ready-to-install, to allow an external expert (a consultant) to systematize the use of innovation methodologies as well as the "search" for information through a unique and complete tool, where external consultants could support SMEs in the usage of TRIZ and QFD methodologies.

The advanced search and extracting knowledge tool will be based on the results of the funded project INSEARCH, which consist of a powerful tool to search and extract information about products and processes both inside and outside SMEs' systems.

MARKET-IT will provide a usable Web interface for the innovation process (a wizard-based "roadmap manager" is offered for guiding the users in the problem solving and in the innovation discovery processes) and on the possibility to use the platform with a SaaS [10] (Software as a Service) approach. Therefore a completely Web-based and remote consultant service aid is offered inside the platform, through an integrated help and training center.

This approach has been further detailed by employing the product-service system (PSS) concept [11], which is a great support for business sustainability and for providing added value to the customer [12]. MARKET-IT was sketched as a product-service system by using the methodology in [13], considering five market needs as a starting point:

- RQ_1 - training on innovation (importance: 0.7),
- RQ_2 - systematizing organizational processes (importance: 2.1),
- RQ_3 - identifying product or process problems (importance: 2.3),
- RQ_4 - improving products or processes (importance: 3.9),
- RQ_5 - systematizing the company knowledge (importance: 1.0).

The importance for each market need was determined with the AHP tool.

Based on the above market needs, five target functions were identified (weights within brackets were determined using the AHP method):

- TF1 - increased quality (2.3)
- TF2 - increased learnability (1.4)
- TF3 - increased ergonomy (0.6)
- TF4 - effective information identification (1.8)
- TF5 - effective innovation projects (3.9)

Following a concurrent approach, each of the target functions was developed into a local PSS solution; afterwards, an aggregation algorithm produced the *functional perspective* of MARKET-IT as a product-service system. This functional perspective comprises the high-level functionalities of MARKET-IT, which further help sketching the architecture.

The functional perspective of MARKET-IT consists of:

$PSS_{f.1}$ - an installation and customization module, suited for the customer's environment:

- different languages and environments should be supported; locale selector, feature to allow translation, by the user, in a different language [product]
- the SaaS approach could be used for the product part of Market-IT; alternatively, a 100% configured & ready-to-use virtual machine with the server part should be provided [product] [service]
- specific ontologies (for structuring domains & the knowledge base) might be provided or current ontologies extended / updated / assessed [service]

$PSS_{f.2}$ - an integrated help & training centre (covering system usage, innovation, business processes etc.)

- traditional help system [product]
- "runtime" training centre, offered by Market-IT experts (e.g. CIAOTECH) directly through the platform and in the specific context / project requested by the user [service]

$PSS_{f.3}$ - a roadmap manager

- roadmap generator through templates; projects should start with the specific problem to be solved; the roadmap within a project should be a set of specific information to be gathered (like "define competitors", "define distinctive features the product should have", "identify stakeholders", "describe CTQs and bottlenecks", "formulate conflicts", "get innovation directions" - these should be activities doable each by one or more tools; an activity should be "describing some information, either by search, direct input, link to existing data or by data generated by some tool") [product]
- (optional) roadmap assessment (+ recommendations) by experts (external, e.g. CIAOTECH, or internal to the customer company) [service]
- roadmap browser - like a forum thread, but with a "social media" flavour in order to make it appealing to the users [product]

$PSS_{f.4}$ - an innovation project management module, to choose the adequate innovation roadmap, project description and goal, corresponding business processes, user access rights [product]

$PSS_{f.5}$ - an innovation toolbox (implementation of tools like AHP, House of Quality, TRIZ contradiction matrix, Nine Window Analysis, Laws of Evolution, etc.) [product]

$PSS_{f.6}$ - (optional) a customer-specific "challenge" repository, structured by marketing and technical (electromechanical) concepts, where each piece of information is a [problem - solution] pair, built over a document management system and searchable by module $PSS_{f.8}$ [product]

$PSS_{f.7}$ - an open innovation module, based on $PSS_{f.6}$, which allows problem solving by (external) experts; problem solving means addressing challenges above; could be done by external experts or by internal experts [service]

$PSS_{f.8}$ - a search module, to extend the information repository (search should be carried out in the "outside" world - on the web and in dedicated databases such as patent repositories) [product]

$PSS_{f.9}$ - a trend monitoring centre, to estimate future changes in customer behavior or competitor strategies

- might be built over the search module and the market centre; user defines watches and gets updates in his dashboard [product]
- a crawler to monitor information sources [product]

$PSS_{f.10}$ - a dashboard specific to each user [product]

$PSS_{f.11}$ - a sample repository

- 3-4 complete sample projects to be provided with MARKET-IT [product]
- extra project sample repository to be accessed online (maintained by MARKET-IT experts); accessible through the search feature ($PSS_{f.8}$); sample repository should be accessed through MARKET-IT and should look like incorporated here, even though its data is remote [service]

The architecture is described in Figure 1, where the following main packages are shown:

- A service hub, that allows centralized definitions of the services offered by the platform and supports the definition of security levels on each service (based on Apache CXF, an open source services framework [14]).
- An auditing module that registers all the user activities on the services, so that is possible to prepare activity reports on the service usage to submit to the billing system (external module/service).
- An abstraction layer on top of the semantic repository to store and retrieve concepts, relations and ontologies related to the project (a set of general ones and the possibility to define and load new ones, specific for the company or the business sector). The semantic layer will be based on Apache Clerezza, a service platform based on OSGi (Open Services Gateway initiative) which provides a set of functionality for management of semantically linked data accessible through RESTful Web Services [15].

- A search engine module, based on the INSEARCH tool, to extend the information repository with additional information from the Web and from external open information sources, such as the European Patents repository.
- An installation and customization module, that allows a step by step installation of the platform on SMEs' own service centers and offers customization of the language settings and other options.
- An integrated help & training center that provides contextual help and training sessions offered by Market-IT experts, directly through the platform, covering system usage, innovation, business processes, etc.
- An innovation toolbox, that contains all the implementations of TRIZ innovation tools (AHP, House of Quality, TRIZ contradiction matrix, Nine Window Analysis, S-Curve, SuField, Ideal Final Result, Laws of Evolution), to have a Swiss army knife always available.
- A Document Management System module, that is capable to support advanced full-text searches and gives the possibility to organize the documents in folders and subfolders.
- A roadmap manager, that guides the user to add or collect a set of specific information to solve specific problems, and capable to suggest a solution or to address a specific innovation path.
- Additional modules like a configurable dashboard, a customer-specific "challenge" repository, a trend monitoring center, a sample repository with a set of classical innovation solutions already available as examples to follow.

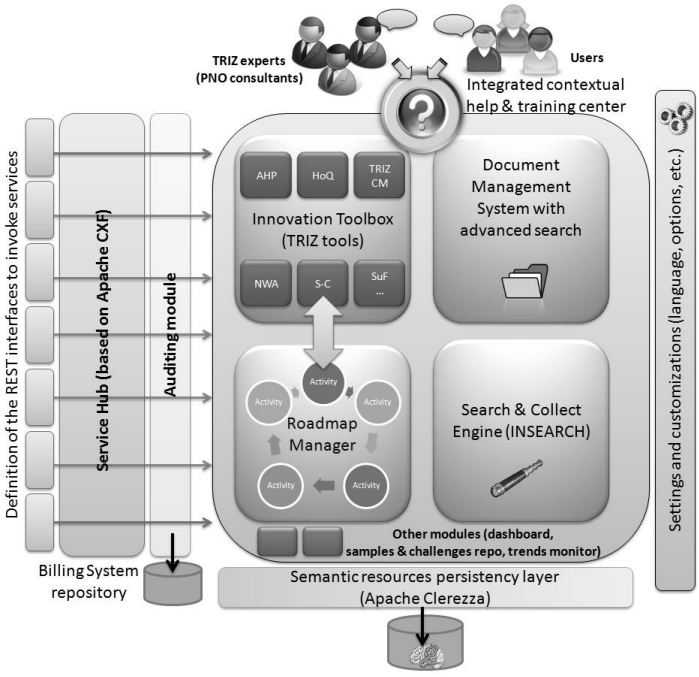

Figure 1. MARKET IT architecture.

7. CONCLUSIONS

On one side, MARKET-IT is a software tool thought to be used easily and projected to be ready-to-install. It is not strictly necessary to have a deep knowledge of the complex methodologies used, such as TRIZ and QFD, to use the software; in this way, SMEs can quickly get results through using it.

On the other side, it is likely that these tools, even if their usage is enormously simplified, can support SMEs more efficiently if they are handled by external experts (consultants) in these methodologies. In fact, external experts can not only improve the results obtained by using the tools and better exploit all its functionalities and methodologies, but they can observe and study the processes from an external, more objective point of view, without psychological inertia that internal experts might be driven when examining the same processes.

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