# Towards an Open and Scientific Approach to Innovation Processes

Claudia Diamantini, Domenico Potena and Emanuele Storti

Dipartimento di Ingegneria dell'Informazione,
Università Politecnica delle Marche - via Brecce Bianche, 60131 Ancona, Italy
{c.diamantini,d.potena,e.storti}@univpm.it

**Abstract.** Being the modern economy constantly changing and evolving, organizations are asked to develop a more flexible, open and collaborative mindset. In particular, an attitude towards continuous product/process innovation is seen as one of the potential solutions capable to effectively address the dynamism of the market. However, Business Innovation (BI) still lacks methodologies and best practices capable to effectively drive business users from an innovative idea to its realization and evaluation. This work investigates the possibility to adopt a pragmatic and systematic approach to support business users in the management of an innovation process, with the aim to increase the control over the process and reduce the risks of failure [1].

## 1 Introduction

Profound changes in economy, society and technology are nowadays dramatically reshaping the environment in which companies, nations and people are used to live. Moreover, in last years a more open society and economy is contributing to tear down commercial barriers, allowing more highly competitive businesses to join the global market. Being the modern economy continuously changing and evolving, organizations are asked to develop a more flexible, open and collaborative mindset. In particular, innovation is seen as one of the potential solutions capable to effectively address such challenges. Anyway, it is widely recognized that Business Innovation (BI) is also a risky process whose outcomes are often unpredictable, affected by multiple internal and external variable conditions, many of which are non-observable and therefore cannot be properly kept under control. For such reasons, design and management of innovation processes, especially in highly collaborative Virtual Enterprises (VE) environments, are challenging tasks. This is the main reason why, in fact, there is still a lack of methodologies capable to provide directions and best practices to innovation, as well as a theoretical systematization of the notions related to BI, often considered more an art than a science. In last years several tools and heuristics have

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been proposed as solutions to support an innovation process, even though they are mainly based on suggestions and "10-best-rules" lists derived by personal experience of business experts or innovation guru. Such attempts, although not always particularly effective, share the idea that business have to master the variables behind the innovation process.

This work is a contribution to investigate the adoption of a pragmatic and systematic approach to support business users in the management of an innovation process, with the aim to drive business innovation from the "art" towards the "science" side, by also indicating solutions that are already available for specific scientific fields, especially in e-Science. In more details, Section 2 discusses the main similarities and differences between a scientific process and an innovation process, comparing the formulation of a hypothesis to the definition of an innovative idea, and proposing a scientific approach to estimate the effectiveness of the latter; an open innovation perspective is introduced in the context of Virtual Enterprises. In Section 3 we recognize some functional and non-functional requirements for an ideal BI framework, together with some basic technologies and tools that can be able to support it, while in Section 4 we make reference to some specific existing platforms supporting experimentations in e-Science, whose functionalities can be reused or adapted to provide more advanced support for BI. Finally, Section 5 contains some final remarks.

## 2 Scientific and open approach to Business Innovation

A rigorous and methodical approach distinguishes science from other forms of explanation because of its requirement of systematic experimentation and reproducibility. The scientific method is recognized as the basic research paradigm for understanding the validity of a hypothesis. Given the phenomenon to be studied, this includes the following macro-activities, with possible iterations, overlapping and parallelization:

- Observation: the activity of gathering facts and data about the phenomenon under study, often driven by the recognition of an open problem or the draft of a hypothesis.
- Analysis: the activity of understanding, by means of manual or automatic tools, the gathered data, in order to gain insights, and possibly new knowledge capable to better explain the phenomenon.
- Formation of a hypothesis or a conjecture capable to explain the phenomenon, and the formulation of a testable prediction. Note that the process often starts with a draft of such a conjecture.
- Evaluation, which includes the planning of an experiment able to assess whether the prediction occurs or not.

Several fields of study and research, although not directly definable as scientific disciplines, find in the scientific method an approach to consistently systematize and formalize their method of inquiry, in order to develop more useful,

accurate and comprehensive models and methods. In this broader sense, a scientific approach, based on methodical management and analysis of data, could provide a valuable improvement for innovation processes in the evaluation of an innovation idea [1].

Nowadays, such a perspective can be effectively put in practice [2]. In fact, massive volumes of data are produced by organizations daily: every product, task, activity and process that is planned or realized can be potentially traced and logged, and this constitutes the preconditions on which an observation can be performed. Moreover, effective and mature techniques are available to analyse data and to extract knowledge from them.

It is to be noted that innovation processes, however, are in general much less structured than scientific experimentations, and often characterized by non-controllable or non-observable variables that could strongly affect the final result. Moreover, while scientific investigation is aimed to discover the static rules underlying some phenomenon in the physical world, innovation processes has a focus on the market, which is dynamic and subject to continuous and frequent changes. For such a reason, the re-execution of a BI process, in general, may not produce identical outcomes. The scientific method relies on a set of practices and formalizations which constitutes a common background for scientists. This includes, among others, methods and protocols for evaluation and analysis, units of measurements, standards and theories that represent a theoretical framework for planning and execution of a scientific process. Conversely, Business Innovation is a less mature discipline, which still lacks enough background knowledge and theoretical analysis to depict a specific methodology.

Besides such differences, the two types of processes share some similarities. The starting point of the investigation is represented by an idea, or a hypothesis, which often arises from previous knowledge and the recognition of an open problem. Both processes has a dynamic and risky nature, because the output is not known in advance, and could either contradict or validate the idea (hypothesis). Successive iterations allows, in both cases, to make use of the current and previous outcomes in order to come out with a better explained or defined idea (hypothesis).

According to such a perspective, a general "meta-process" can be devised for innovation processes, including the following activities:

- Observation, which is driven by prior knowledge or the draft of the idea, and includes data trails about previous related innovation processes, business processes, logs about internal products and tasks, together with related external data from the market, clients, and suppliers. Data about competitors and background knowledge could be considered as well.
- Analysis of data in order to clearly recognize open problems and opportunities. In fact, the proper definition of an idea requires, at first, to identify the cause-effect relations between the open issues to solve and the structural elements of the product/service or process at hand. Such a systematic approach could help to point out which internal variables can be adjusted or what part of the internal process should be modified.

- Formulation of an innovation idea, starting from the consideration provided by the previous step.
- Planning of an implementation and experimentation process, which is followed by an evaluation phase aimed at assessing the validity of the idea in terms of a set of indicators and measures.

Despite its rigorous approach, the scientific process is far from being an automatable pre-defined procedure to follow, because it strongly relies also on imagination and creativity, especially for what concerns data understanding, hypothesis generation and experiment planning. Similarly, an innovation process requires a deep interaction with business users. As a matter of fact, the role of creativity and human evaluation in the context of business innovation is even more important than in science, because the process is more strongly affected by human decision-making, and the collaborative dimension (even within the same company) is much more prominent.

Conventionally, the achievement of innovation is based on the skills available within the boundaries of the company, and every improvement and idea is considered a competitive advantage.Such a perspective, known as closed innovation, ultimately refers to companies as closed systems, and strongly relies on the control and ownership of intellectual property. Recently, also thanks to the improvement of IT technologies for communication and information/knowledge sharing, a new paradigm of open innovation is emerging [3]. Open innovation is based on the usage of both internal and external resources and ideas capable to create opportunities for generating significant value. It is based on the notion that knowledge cannot be constrained within a single company, team, and university: as a matter of fact, the availability of pre-competitive knowledge proved to be capable to create a more dynamic market.Open innovation practices include the exploitation of new collaborative business models and strategies like co-production and co-creation, crowd-sourcing, peer production, as well as the usage of social technologies to support and coordinate collaboration.

Companies could greatly benefit from exploiting both a scientific approach in the innovation process and a more open attitude towards collaboration. In fact, collaborative environments, like Virtual Enterprises, where information and ideas can be cooperatively collected and organized, are both a source and a driver for innovation. Then, the usage of proper tools and shared methodologies within the VE, together with a scientific approach to experimentation, can enhance the success rate of innovation ideas and provide a basis useful as a reference for future processes in the VE.

## 3 Requirements for a BI support framework

According to the data-driven/open perspective introduced in the previous section, for each of the macro-activity of an innovation process we identify the main functional requirements of an ideal BI framework, together with the available technologies useful to provide the needed support:

- Observation: the system should provide tools to support data gathering and storage from (possibly) multiple sources, which allow to have evidences and facts at disposal about the product or process under study. Useful technologies include, besides databases and data warehouses, Customer Relationship Management systems (CRM), Workflow Management Systems, Enterprise Resource Planning, market analysis.
- Data analysis and definition of an innovation idea: the framework should include support tools to analyse the collected observations, in order to obtain both a summarized view of them and to extract possible relevant hidden relations, patterns or regularities, useful to gain new or clearer knowledge about the domain and its open issues or flaws. Data Mining and Knowledge Discovery in Databases (KDD) algorithms, together with statistical methods are effective solutions for such a purpose. Systems for collaborative discussions and knowledge sharing, then, allow new ideas and suggestions to emerge.
- Experimentation and evaluation, which require tools useful to support business users in planning the innovation process, including suggestions about which steps ought to be taken in given circumstances, and which Key Performance Indicators (KPI) should be used to gain insights about the process status. Moreover, during and after the execution, tools can be used to collect intermediate and output results, for instance tracing and logging systems, CRM or surveys for information about customer satisfaction and feedback, systems to analyse data in order to evaluate previously defined KPIs, capable to catch and show the impact or the success of the innovation idea.

Given that in this work we refer especially to environments like Virtual Enterprise's, we envisage in the following the most challenging problems that arise from the peculiarities of such an open, collaborative and distributed scenario. On such a basis we contextually define non-functional requirements for a framework capable to support a data-driven innovation process:

**Integration** A distinctive feature of the scientific community is the existence of a shared corpus of standards, norms, rules, aimed at producing comparable, measurable and reliable results. Integration of knowledge from different scientific fields is feasible thanks to the usage (and the sharing) of the same communication language, the same measurements units and common practices and methodologies. Conversely, standards and practices for BI have not been identified yet. Apart common background knowledge like logics or statistics, specific business domains may require specific solutions. For such a reason, a framework should provide means to identify and describe resources within the Virtual Enterprise by referring to the same terminology, to overcome the heterogeneities among the partners.

**Complexity** The lack of standard procedures and best practices affects also the planning and execution of an innovation process. The framework should allow to codify the dependencies among the innovation process' activities, provide

suggestions about which specific resource to use in a given context, and in the choice of the best output indicators. Complexity management also involves to keep track of the status of an innovation process, its variables and outputs. Common IT technologies include data management systems, optimization algorithms and planning techniques.

**Distribution** Given the data-intensive dimension of modern science, especially in certain fields, a recent trend is the constitution of virtual laboratories, in which computation of massive datasets can be performed in a distributed manner. Also an innovation process could be potentially based on several distributed resources, which are to be managed through specific technologies, especially in environments like Virtual Enterprise's. Besides traditional communication infrastructures like internet and the Web, specific instruments are needed whenever the enterprise follows a more open approach towards innovation, for instance in sharing of knowledge/data, of distributed tools and even of computation, especially when innovation is highly data-driven or requires simulation.

**Collaboration and coordination** Since the cooperative planning and execution of a complex process typically require several skills, both technical and managerial, collaboration can easily become a source of complexity if not supported by any kind of coordination. In last years the scientific community is showing a continuously growing interest in technologies for data, model and workflow sharing (e.g., [4]), which constitute the backbone of a more networked and collaborative way to science. Similarly, Virtual Enterprises could greatly benefit of systems to share information, data and ideas among the distributed partners, and to support a virtual team by putting together diverse competencies and capabilities, and providing means to manage coordination and to co-operatively perform tasks and activities.

## 4 Technologies for a BI framework

In this section more specific solutions for a BI framework are introduced, taking into account previously identified requirements to sketch up the general approach of such a system, aimed at supporting business innovation processes.

Aspects of this proposal involve not only the adoption of certain technologies, but also several organizational changes. This often requires the organization to reshape itself, and adopt a more flexible attitude towards revision and improvement of internal processes and procedures, and the concepts around which the enterprise is organized. In this sense, one of the emerging solutions is the application of "service" approach to enterprises [5].

Service orientation, in which single tasks and activities may be considered as modular and (possible) distributed services, is capable to improve flexibility and efficiency. In order to further maximize modularity and interoperability, like in traditional SO architectures, services can be described by using the same

format, in order to provide a syntactically homogeneous representation of their capabilities and functionalities. Such an approach allows to reuse some of the methodologies and tools currently implemented in SO frameworks, which can be fruitfully exploited to respond to some requirements. One of the distinctive aspects of SOA is related to the distinction among service publisher (e.g., internal or external suppliers), service consumer and service registry, where services holding certain characteristics or aimed at certain functionalities can be retrieved through searching mechanisms. Within the business domain, such a repository could enable the discovery of business services useful in a given stage of the innovation process or for supporting certain business tasks, like the evaluation of a KPI, or the optimization of a business process.

Advanced functionalities can rely both on service and process repositories (1) to understand which services are usually applied after a given one, or (2) to provide suggestions about which (typology of) service is recommended in a certain stage of the innovation process, and (3) to discovery the most common practices of usage of certain services. Moreover, the description of such services by using semantic technologies to define a common terminology (at least, shared among the members of an organization or among the partners of a VE) allows to address integration problems.

Some general-purpose technologies to support each of the phases of an innovation processes have been introduced in the previous section. Anyway, especially in last years, several solutions have been investigated in the scientific community to solve similar tasks. In particular we refer to those scientific fields that are mostly concerned either with data-intensive computation or collaborative issues, and that have at disposal advanced tools that could be adapted or reused in the context of BI. Among them: biology and bioinformatics frameworks, e.g. Taverna [6] and Kepler [7], support users in the design of processes and workflows. Also the Data Mining/KDD domains are particularly active in providing support for users with diverse competencies in designing and executing a data analysis/manipulation process for knowledge extraction. Some of the frameworks, like NeXT [8] or KDDVM [9] provide advanced support for process semi-automatic planning and algorithm/service matchmaking, given that each applicative brick of the process is described through some specific language. KDDVM platform, moreover, includes a process repository, useful for keeping track of all the processes developed in the past, together with all their temporary versions. Such a repository is used both as a reference for next projects, in order to retrieve information and details about past executions, and also to understand which algorithm/service's sequences performed better over certain data. For what concerns collaborative platforms, while $^{my}$Experiment project [4] is aimed at process sharing within a community, KDDVM provides team building functionalities with functionalities for retrieving users with a specific set of competencies or that were involved in a certain past project. Some of such solutions can be reused or adapted for this purpose, in particular the support for process design, composition and execution.

## 5 Conclusion

The discussion provided in this work is aimed at analysing at what extent a scientific and methodical approach can be adopted in the context of innovation processes to estimate the effectiveness of an innovative idea, increasing the control over the process and reducing the risks of failure. Currently, the lack of methodologies for BI represents the major hindrance against the actual application of such principles. To this aim, we proposed a set requirements and technological solutions that can constitute the basis of a future framework, aimed both to provide support to BI processes design and management, and a means to devise and test theoretical and practical models and methods for BI. Ultimately, a BI framework could significantly help in better discriminating the best from the worst practices in business innovation processes, which can be considered as the first step towards the definition of methodologies for BI. Although it could be useful to make innovation processes more efficient/effective within a single organization, this is especially true in collaborative environments, where shared methodologies could be identified starting from the information/processes that are shared among the partners. As future work we would like both to deepen the theoretical analysis and to propose an architecture of such a BI framework.

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