

A Knowledge-centric Approach to Virtual Enterprise Innovation*

Stefano De Panfilis¹, Michele Missikoff²

¹Engineering Ingegneria Informatica S.p.a., Research and Development Laboratory,
Via S. Martino della Battaglia 56, 00185 Roma, Italy
stefano.depanfilis@eng.it

²Dipartimento di Ingegneria dell'Informazione, Università Politecnica delle Marche
Via Brecce Bianche, 60131 Ancona, Italy
missikoff@dii.univpm.it

Abstract. Innovation is probably one of the most popular terms, used in different contexts, when talking about the future. From economic contexts, where it is used to indicate a key strategy to go out of the current critical economic phase, to business contexts, where it is clear that without innovation a company cannot survive. In this paper we propose an ontology-based approach to business innovation. The proposal is based on a reference framework: BIRF (Business Innovation Reference Framework) and a novel, document-centric approach. The document-centric approach starts from the idea that chasing innovation by defining specific processes will turn in imposing limitations to imagination and creativity. Conversely, the documents represents sharable traces of inspirations, ideas, and all the knowledge that is collected and produced during an innovation initiative. But documents need to be semantically enriched, therefore, the central pillar of our approach is a federation of ontologies aimed at supporting the unconstrained, imaginative adventure of innovation.

Keywords: business innovation, knowledge management, virtual enterprise, enterprise system, innovation ontology, semantic document management.

1 Introduction

Innovation is probably one of the most popular term, used in different contexts, when talking about the future. From economic contexts, where it is used to indicate a key strategy to go out of the current critical economic phase, to business contexts, where it is repeated that without innovation companies cannot survive. Indeed, innovation is required in all possible sectors, from industry to public administration, however, it is an 'easy' term often used as a sort of 'place holder', a metaphor to indicate that we need to change the existing state of play [1]. But if we try to elaborate on this term,

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we start immediately to see some problems, firstly when trying to define what we mean by innovation, then when defining objectives and concrete steps necessary to achieve them, and, last but not least, when trying to clarify related issues, possible pitfalls, key challenges, expected risks, costs and benefits, etc.

Innovation is a multi-facets notion that can be effectively addressed, no matter what is the socio-economic context, only if the innovation endeavour is based on a large amount of (relevant, high quality) knowledge. The latter, in turn, needs to be supported by effective knowledge management tools, able to integrate their service with the existing enterprise systems.

If we focus on virtual enterprises (VE), the picture gets even more complex, due to the fragmented reality, the absence of a unique coherent organization and a central authority deciding objectives to be achieved and solutions to be adopted [2].

In this paper we present a proposal for a platform aimed at supporting innovation in the context of a VE, typically composed of Small Medium Enterprises (SMEs). The proposal is based on the idea that, when establishing an innovative VE that operates in a given industry sector (typically, manufacturing) it is necessary to establish, in parallel, a virtual innovation factory (VIF) to guarantee sustained innovation. A VIF is an 'immaterial' factory, since it has no production machinery, except computers, and the products it 'fabricates' are intangible knowledge items. For a VIF, the production process consists in acquiring 'raw' knowledge from different sources (internal and external) and elaborating it to produce new, refined knowledge. In our case, since we aim at innovation on tangible products and services, the final product of a VIF consists in the knowledge necessary to intervene on the VE to innovate one or more aspects of its business to improve its value creation capability. In particular we focus on: products, processes, services, and technology.

The objective of this paper is to introduce the main lines of a new platform for enterprise and business innovation that can be easily adopted by a VE. In particular we will focus on the semantic technologies that we are developing in the context of the European project BIVEE (Business Innovation in Virtual Enterprise Environments.)

2 Open Innovation in a Virtual Enterprise Environment

Innovation requires creativity but also an important quantity of high quality knowledge. Such a knowledge cannot be fully identified at the beginning of an innovation project, it emerges as the work proceeds and it is collected from different sources and produced through the cooperation of different groups of experts. Traditionally, an innovation project starts from an idea, a problem, or an opportunity (coming from, e.g., a market, technology, etc.), then, the first step consists in building a dedicated team of experts, providing them the necessary resources. We believe that innovation needs freedom, operational flexibility, skills, expertise, and the capacity of building ad-hoc strategies, in a coordinated context. All this is difficult to achieve within a single enterprise, but it is even harder for a VE, where several independent companies are required to cooperate for a common goal. For this reason, the proposed solution

pushes the idea of a facilitation framework rather than well codified method, with rigid roles and business processes.

Another promising direction, well fitted in the BIVEE Framework, is represented by Open Innovation [3]. This is an interesting approach, able to produce important positive effects on business innovation initiatives, but not easy to implement. Innovation requires high risk, expensive activities producing results that a company wants to protect, primarily keeping them secret, at least until the innovative solution is introduced in the market and/or suitably covered by patents. But at the same time, innovation requires a continuous flow of knowledge within and outside the dedicated expert team. Such a knowledge flow needs to be somehow controlled, therefore in a VE it is necessary to define a set rules and a partners' agreement to allow a 'controlled openness' for innovation activities at different levels. In BIVEE we see a VE operating in a business ecosystem (BE), i.e., a larger circle where enterprise gather with the intent to share common resources to do business together [4]. In this frame, it is possible to adopt Open Innovation with a progression of stricter rules and higher levels of protection, according to a number of concentric circles:

- Individual enterprises may internally adopt open strategies, according to their policies and organization.
- Each VE will achieve a shared agreement for the free circulation of ideas inside the network, some restrictions will be applied when interacting with the rest of the BE, and additional ones for the external world.
- BE represents a 'protected area,' therefore, when necessary, the VE can disclose specific issues to circulate them, although properly 'packaged,' within the BE. The point is to find a balance between what needs to be communicated to get a help from BE members and what needs to be protected to avoid undesired disclosures.
- the fourth circle is represented by *associated organizations*, i.e., organizations external to the BE but, potentially useful for the business of VE (e.g., universities, customers, suppliers.) In general they have previous cooperation experiences with BE members, but they do not participate in such a membership.
- Open World represents the fifth circle, with the ocean of organizations, experts, potential customers and suppliers, that can typically be found over internet. This is the largest and most critical circle for what concerns the level of openness of innovative knowledge.

A BE is expected to provide guidelines to support its members in achieving Open Innovation at best, minimizing risks and maximizing advantages.

3 Innovation Knowledge Storage and Flow

A VIF is a sort of 'parallel immaterial factory' operating within the VE. The two factories are initially created by the same set of SMEs but with different missions: the latter to produce value while the former to produce ideas and innovative solutions (that hopefully will be adopted by the VE to improve its value production capability.) A VIF is based on the capacity of collecting, producing, organizing, and redistributing

knowledge among its players, organized in Innovation Units (IU). A key point here is that the innovation units generally belong to different SMEs and therefore tend to behave according to the internal rules and strategies, using their application systems, data formats, and business procedures, that are locally defined. Then, the organization of a VIF, and its knowledge management platform, need to be conceived respecting (as much as possible) the needs and constraints of the participating SMEs. This point has been carefully considered when we started the design of the knowledge facilities for the BIVEE platform. The proposed solution has been designed starting from two major components: knowledge storage and knowledge flow.

3.1 Innovation Knowledge Storage

Each member enterprise in the VE has its own knowledge storage (databases, document repositories, etc.) and, in general, it is not expected to open it. Therefore, we request that each SME will publish in the VE its Individual Shared Knowledge Asset (ISKA), constantly updated to guarantee its fidelity with respect to the internal knowledge assets. The data organization and format of the ISKA is agreed by all the members of the VIF and uniformly adopted (in case, requiring suitable transformations when moving knowledge in and out.)

Each ISKA provides a partial, local view of the VIF Knowledge, therefore we need a centralized structure capable of rebuilding the global picture. This facility is provided by the Production and Innovation Knowledge Repository: PIKR. The PIKR acts as a central hub for the knowledge gathering, organization, and flow across the members of the VIF.

3.2 Innovation Knowledge Flow

In the tight cooperation that the VIF requires among the partners, a key aspect is the knowledge exchange. One of the BIVEE goals is that the platform should be achieved on top of the existing enterprise systems, with a 'soft touch', i.e., minimizing the impact on the latter. One of the most common way of exchanging knowledge is by means of documents. Essentially, in BIVEE the knowledge-centric approach will appear to the end-users as a document-centric approach. Enterprises are already producing and using a large number of documents in their everyday activities, and in particular in innovation projects (e.g., idea description, feasibility study, business plan, etc.), therefore, we are moving in a familiar territory. The key point is to clearly identify what kind of knowledge is necessary along an innovation project and what are the related documents. BIVEE is therefore proposing a (non prescriptive) set of documents, precisely defined in terms of their basic structure and content, but accepting variants and customizations. Documents' structures are defined according to concepts in a document ontology (*DocOnto*) that represents one important component of the PIKR. Documents will be produced during the advancement of the innovation project, according to the BIRF.

4 The VIF and its Four Innovation Waves

One of the first steps of BIVEE has been the definition of the Business Innovation Reference Framework (BIRF.) BIRF departs from the traditional idea of basing an innovation framework on a process-oriented view. We believe that a process is prescriptive in its nature, and therefore very useful in systematizing repetitive tasks and procedures; on the contrary, innovation needs freedom in choices and behaviors. Therefore, we believe that a process-oriented approach risks to tie creativity. On the contrary, we believe that the right way to go is defining and achieving a sequence of objectives in a declarative, non prescriptive way. Innovation achievements consist in the knowledge produced by the teams of the VIF, reported in a set of well defined, structured documents. The BIVEE approach is based on an open, free innovation space, where innovators will be free to reach the objectives with the preferred strategies, according to the experience, the available resources, the addressed problem, the existing constraints (of time, budget, etc.) An innovation project evolves over time, along a trajectory, then the produced achievements are reported in a sequence of documents that follows a consistent logic, a sort of precedence scheme. The proposed innovation flow is organized in 4 (partially overlapping) parts that we refer to as *waves*. For each wave we propose 4 groups of documents and a set of dependencies among documents, meaning that, for instance, a document d_2 follows a document d_1 , since the content of the former depends or is an evolution of the latter. The proposed BIRF is therefore structured according to the following 4 waves.

W1 – Creativity: This first wave starts with an innovation idea or a problem to be solved, described by a number of preliminary documents (such as notes, emails, tweets, etc.) eventually summarized in one summary document (Innovation Proposal Summary). It requires the creation of an innovation team, establishing connections between different units, and the definition of a preliminary agenda. All this is reported in a first set of documents.

W2 – Feasibility: In this wave the scope and the intended impact need to be defined, including a first account of technical and financial feasibility. A refined planning is needed to justify the required investment, predicting the cost/benefits and the chance of success.

W3 – Prototyping: This wave features the first implementation of the initial ideas, achieving a first full scale working model. Such a model is tested and analyzed to verify the actual performance and characteristics, giving also the possibility to re-think some design.

W4 – Engineering: This final wave starts from the knowledge acquired with the prototype(s) and aims at producing the specification of the final version of the new product (essentially the Bill of Materials and manufacturing procedures), ready for the market, and the corresponding production process. This concluding wave also requires to address other issues, from the market strategy to the training of the employees.

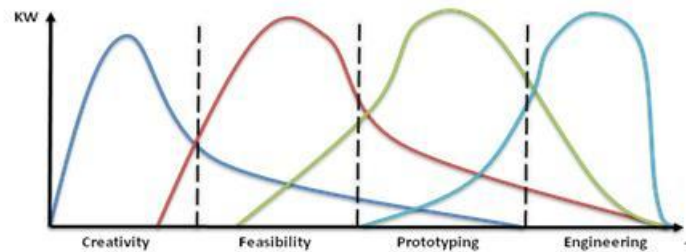


Fig. 1. The BIVEE Waves

The idea of wave, instead of phase, emerged since their starts are sequenced in the time, but they are tightly interconnected and the start of a new wave does not imply that the previous one has been accomplished. Furthermore, in the proposed document-centric approach, there will be often the need to jump back and forth to complete a document or to correct it on the bases of later findings. For instance, during the prototyping wave there can be new findings that require the revision of the previous financial feasibility study, obliging the team to rethink some parts of the innovation under elaboration. The wave approach is sketchily depicted in Fig. 1.

It is important to note that a VIF will be organized in different teams that are suitably positioned over the four waves. But the wave teams are not disjoint (i.e., there are experts who belong to more than one team) and are not strictly fixed, since the composition may vary on time depending on specific needs. For instance, a Feasibility team will have a core group of experts, but if there is the need to analyse a specific market, new experts with specific competencies will be (temporarily) co-opted in the team.

As anticipated, one of the characterising aspects of BIVEE is the push towards openness that is reflected also in the team composition. Then, the enrichment of a team may take place in a ‘pull mode’, when new experts are invited as explained above, or in ‘push mode’, when someone from outside of the team proposes a solution to a specific problem. To this end, an important knowledge resource in the BIRF is the *innovation whiteboard*.

The innovation whiteboard is an open knowledge space available to all the members of the VIF, and in some parts open. But large parts of the knowledge are also open to the VE, to the BE, and to the rest of the world. An innovation whiteboard contains questions, open issues, emerged during the innovation activities, but also hypothesis and solutions that appear potentially useful to the innovation project at hand. Then, the innovation whiteboard is widely accessible and anyone (previous registration, if not a member of the BE) can access (part of) it and contribute.

Another important knowledge structure is the *innovation diary*. This is another on-line knowledge resource where the innovation teams keep track of their activities, giving account of the addressed problems, the decisions made, the external resources consulted, the key achievements, etc. The innovation diary will be an important

source of knowledge for future activities, giving the possibility to achieve a better understanding of how the innovation activities proceeded, extracting also some lessons learned and best practices, available for future innovation projects.

5 The Virtual Enterprise Modeling Framework (VEMF)

Innovation implies significant changes in the enterprise, therefore an important section of the PIKR concerns the description of the VE with its structure, components, organization, operations and processes. Such a description avoids to cover all possible details, focussing on the parts that are in the targets of the innovation. To this end, we started from a few enterprise models available in the literature, in particular VRM [5], SCOR [6], and the operational paradigm reported in the FInES Research Roadmap 2025 [9]. Such enterprise models have been integrated and then refocused to get a simplified model, useful to our purpose: the Virtual Enterprises Modeling Framework (VEMF) adopted in BIVEE. Fig. 2 reports the ‘innovation wheel’ proposed in the deliverable D2.1, as an evolution of [7].

The evolution is represented by the fact that we added the *service spoke* to the wheel. Then, BIVEE decided to focus on the lower part of the wheel, addressing in particular innovation for: *process*, *product*, *service*, and *technology* (where the last one is carefully considered, but instrumentally with respect to the first three.)



Fig. 2. The Innovation Wheel

While the above four enterprise sectors are considered in the VEMF as the primary focus of the innovation initiatives, it is obvious to consider other enterprise sectors that will be affected when an innovation project is achieved. In particular there is the need to consider the organization dimension and the human resources, with their competences, capabilities, and skills. However, for sake of space here we will not elaborate further.

6 The Knowledge Management of VIF

We expect that the SMEs that participate in the VE and in the VIF will have different methods and tools to manage information and knowledge. The PIKR has the primary objective to act as a common hub for the relevant knowledge related to production and innovation (further information is available in [10] and the BIVÉE Deliverable D5.1 [7]). Such a knowledge will be seen in a unitary frame, structured according to a rigorous, shared vision of the reality provided by the ontologies managed within the PIKR. Here we briefly introduce the key PIKR ontologies.

DocOnto – This ontology defines in formal terms all the document templates, with their structure, organization and dependencies, that will be created during an innovation project. Each instance (the actual document) will be formally described in its key parts by a DSD (Doc Semantic Descriptors). The documents are grouped according to the 4 innovation waves. The DocOnto indicates what is the mandatory information and what is optional. Dependencies indicate that a document, to be accomplished, needs to consult (in case, including part of) the content of other documents. A dependency does not need that the preceding doc is fully achieved before releasing it for consultation, provided that its partial accomplishment level is clearly indicated. The DocOnto holds the conceptual schemes of the innovation documents, and the DSD of the instances that will be generated during a specific innovation project. A document will contain knowledge of different natures, in particular domain knowledge and business knowledge that will be defined with two other ontologies.

DomOnto – this ontology defines the classes of actors, products, entities, and processes (at a descriptive level, the operational details are given *ProcOnto*, not described for sake of space) that characterise the industrial sector in which the VIF operates. This is an important reference resource that allows the participating SMEs to achieve a uniform management of information and knowledge despite their local differences.

BusOnto – the business ontology it required to achieve an uniform understanding of the way the VE carries on business, despite the local differences. For instance, purchase orders, invoices, good delivery notes, etc., are documents largely independent from the industry sector that need to be represented at VE level in a homogenised way. There are emerging standards, such as UBL (Universal Business Language) [8], that BIVÉE intends to adopt (in case extending it as needed.)

KPIOnto – one key issue of BIVÉE is the definition of a system of performance indicators having the purpose to keep under control the innovation process. Costs, time, resources need to be constantly confronted with the defined targets, the achieved results, and the expected activities that need to be accomplished to reach a successful conclusion. KPIs are intended to keep everything (or, at least, as much as possible) under control, providing alarms in case of critical events. Furthermore, KPIs represent an essential basis for decision making.

In addition to the ontology federation, PIKR holds two important shared knowledge structures: the *Innovation Diary*, where all the innovation team report daily the essential events, including findings, problems, achievements, and the *Innovation Whiteboard*. The latter is an essential element of the Open Innovation philosophy,

since it is conceived to expose to the rest of the world (organised in concentric circles, see above) important issues that arise during the innovation project, asking for ideas, support, advice.

The Fig. 3 provides a synoptic view of the knowledge management of the BIVEE platform. We wish to recall that BIVEE addresses also production improvement, but this paper focuses only on the innovation management section of the platform, and in particular on the knowledge for innovation.

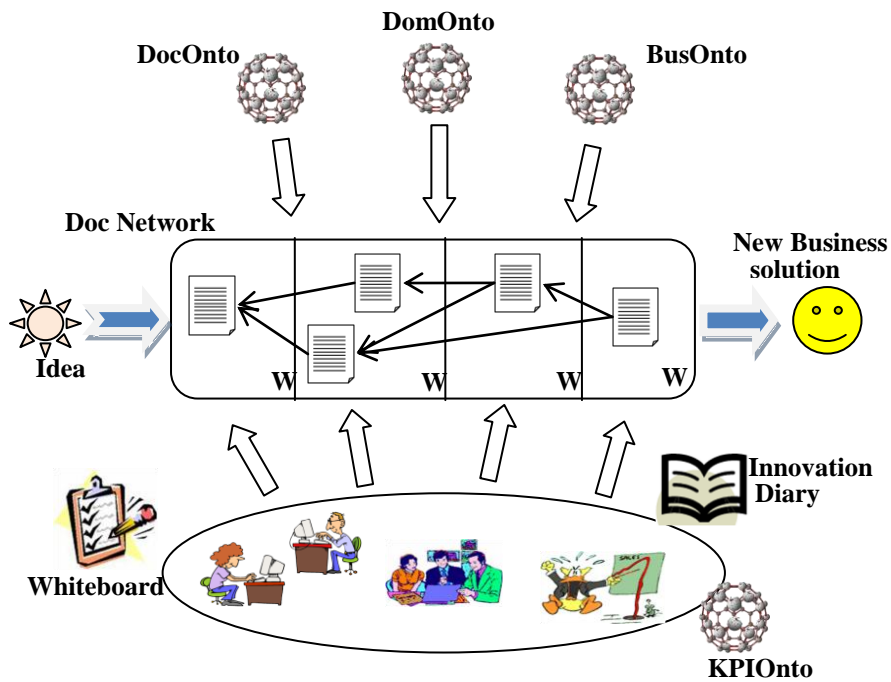


Fig. 3. Virtual Innovation Factory

7 Conclusions

This paper has briefly presented the main issues concerning the philosophy and organization of PIKR, the knowledge management solution of the BIVEE platform. PIKR concerns both the objectives of BIVEE: production improvement and innovation, but in this paper we focused on the latter. The general approach reflects the BIVEE idea that innovation cannot be tied by defining precise processes to be followed. Conversely, it is important to proceed following objectives that are sequenced in terms of knowledge structures to be completed, leaving a large freedom to innovation actors about the ways, means, partnerships necessary to achieve such knowledge structures. For the end users, the innovation knowledge structures are concretised by a

set of documents, whose organization and content is defined by a federation of ontologies. Such ontologies are developed and maintained in an open, shared context, where many different actors can intervene, exchange ideas and opinions, and contribute to the refinement and evolution of the BIVEE innovation approach. In this respect, BIVEE is also a meta-innovation environment (thus the motto ‘innovating innovation’.)

The work presented here reflects the preliminary results achieved in less than a year of BIVEE activities. The presented matter will be subject to extensive verification and test that will suggest some updates. However we believe that the approach based on knowledge and documents management, with a strong rooting in semantic technologies, will remain and will prove a valid choice.

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