Monitoring Innovation in Virtual Enterprises: an Agile Semantic Approach*

Claudia Diamantini[1], Benjamin Knoke[2] and Michele Missikoff[1]

[1] Dipartimento di Ingegneria dell'Informazione,
Università Politecnica delle Marche - via Brecce Bianche, 60131 Ancona, Italy
{diamantini,missikoff}@dii.univpm.it
[2] BIBA – Bremer Institut für Produktion und Logistik GmbH
Hochschulring 20 · D-28359 Bremen / Germany
kno@biba.uni-bremen.de

Abstract. In this paper, the key ideas adopted in the BIVEE project to monitor and support an innovation venture are illustrated, and developed in the context of a virtual enterprise (VE). The proposed approach is based on two pillars: a novel framework, further split into three parts, and the support of a semantic platform. In particular, the novel framework is split into the Virtual Enterprise Modelling Framework (VEMF), the Business Innovation Reference Framework (BIRF) and the Innovation Monitoring Framework (IMF). VEMF is aimed at providing a unique approach to the modelling of a VE, overcoming the divergences that the different real enterprises forming the VE may exhibit. The BIRF is aimed at providing guidelines for carrying out effective innovations in a VE. Finally, the IMF provides a set of methods, including Key Performance Indicators (KPIs), to monitor performances of activities and the achievement of planned goals. The second pillar is represented by a semantic platform relying on a federation of ontologies that allow the business context to be semantically enriched in a formal way.

1 Introduction

This paper addresses the problem of monitoring innovation in the context of a virtual enterprise (VE). A VE is essentially a network of cooperating enterprises getting together to achieve a production (of goods and/or services) that could not be achieved if separated [1, 7]. Today, an enterprise is required, in parallel to the value production, to be able to constantly innovate. While the structure and organization of a VE is (supposedly) conceived to be optimal for the value production activities, innovation projects are difficult to manage in a distributed, loosely coordinated (beyond production) context. For this reason, the idea is introduced that in parallel to a value production organization there should be an innovation oriented organization that is referred to as Virtual Innovation Factory (VIF). A VIF is a production factory aimed at manufacturing an immaterial good: innovation, where its nature is essentially

* This work has been partially funded by the European Commission through the Project BIVEE: Business Innovation and Virtual Enterprise Environment , Grant No. 285746

knowledge. Therefore, a VIF is conceived to take pre-existing 'raw knowledge', manipulate and enrich it to achieve the sought innovation, seen as a complex body of knowledge (in case, partially materialised in the form of running prototypes). This paper describes the key ideas behind the organization and operations of a VIF, with a focus on the monitoring of the innovation activities.

Innovation is about change. However, when starting an innovation venture a fuzzy, intuitive, rather incomplete idea is the start of the undertaking. Therefore, the innovation venture is mainly about a progressive collection and organization of knowledge to refine the initial idea (**innovation objective**) and to identify the **transformations** that are needed for the enterprise to achieve at best the innovation objective. The enterprise is a complex world and in principle innovation can focus on any single aspect of it. However, in accordance with a number of studies [8] it is intended to carry out a focused study, with four innovation targets. The first two concern product innovation, i.e., *goods* and *services* offered to customers. Then the focus is on *production processes*, where innovation can bring important advantages to the enterprise and, as effect, to price and quality for the customers. Finally, *technology* is considered as one of the major enabler used both in the production processes and in the final products. Despite a clear focus of intention, an enterprise has to be considered a complex organism where all its parts are connected and interdependent. Therefore, even in case of a focused innovation project, addressing one specific innovation target, all the rest of the enterprise will be impacted.

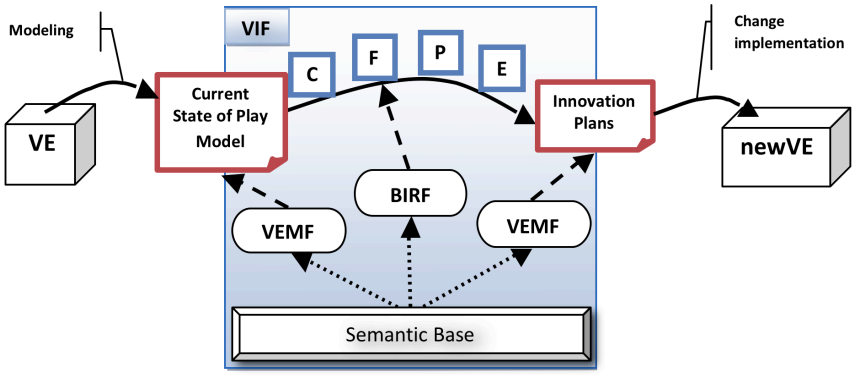

Figure 1 - An overview of the VIF approach

The proposal is based on two key pillars: a novel framework and the support of a semantic platform. The framework is further split into three parts: the Virtual Enterprise Modelling Framework (VEMF), the Business Innovation Reference Framework (BIRF) and the Innovation Monitoring Framework (IMF). The VEMF allows for a unified approach in modelling the different enterprises forming the VE, the BIRF provides a coherent strategy for achieving the innovation objective in the context of a VE, IMF provides the methods and metrics for the measurement of the performances of activities and the achievement of planned goals. The second pillar, the Semantic Base (based on a federation of ontologies) guarantees a precise,

rigorous, unambiguous approach to the three above frameworks. It is also the base of the semantic platform aimed at providing a number of semantic services.
In the next sections the methodological pillars of the BIVEE approach are illustrated. Because of the lack of space, the focus of the discussion will be on innovation in the perspective of innovation monitoring. Hence, the BIRF and IMF parts of the framework will be detailed, together with the Semantic Base.

2 BIRF: Business Innovation Reference Framework

As anticipated, it is intended to address Innovation with an industrial approach, seeing innovation as a manufactured product (largely immaterial.) It is essentially a refined knowledge product that starts from an asset of base knowledge (representing the current VE and the innovation options) and then is refined and enriched until the 'innovation product' is released. With this in mind, the Virtual Innovation Factory (VIF) can be described as a parallel production factory that coexists with the 'value production' enterprise. Today, the innovation ventures are generally carried out by a specific department of the enterprise (e.g., the R&D Department). The BIVEE project is aiming to move from this traditional approach, opening the innovation activities to the whole enterprise beyond the dedicated department, and to external actors and stakeholders (customers, suppliers, universities); all of them will participate in the VIF. It is important to underline that it has been decided to move in the direction of an Open Innovation (as described by [3]) perspective where the VIF staff is not 'a priory' defined and the actors may change from a moment to another, within the same innovation venture.
A VIF operates according to a paradigm and guidelines defined by the BIRF (Business Innovation Reference Framework). The latter, that is not tightly prescriptive, to allow the maximum freedom to the innovation teams, it is suggested to organise the activities according to four 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 rethink 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 addressing other issues, from the market strategy to the training of the employees.

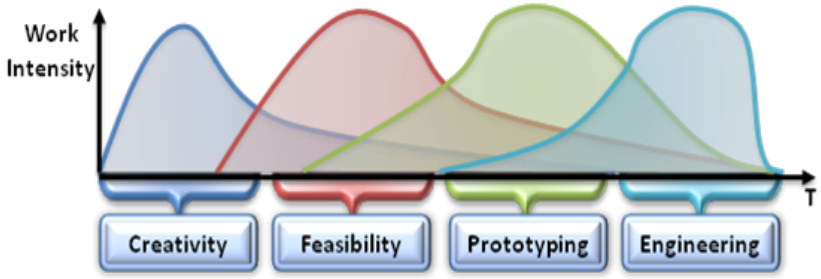

Figure 2. The innovation waves

The idea of waves, instead of phases, 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 in order to complete a document or to correct it on basis 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 marketing strategy. The wave approach is sketchily depicted in Fig. 2.
During the innovation venture, the knowledge production is related to the creation of a number of documents, according to pre-defined templates. One of the key contributions of BIRF is the definition of what kind of information is needed in each wave and a set of document templates, distributed along the four innovation waves, conceives to gather and organise such information, guiding the innovation activities and recording the achieved results. The description of information and document templates falls outside of the scope of the present paper.

3 IMF: Innovation Monitoring Framework

The key objective of the BIVEE project concerns the methodological and technological solutions to systematically support innovation in VEs. To this end, from a methodological point of view, the following elements are in development:

- A systematic approach, with guidelines and business innovation document templates, to be adopted in carrying out innovation. This is represented by the BIRF.
- A dedicated modelling approach for the key aspects of the VE, relevant for enterprise innovation. This is represented by the VEMF framework.
- A systematic approach, available to the innovation team, to monitor the innovation going on in the VE, concerning both the quality of the innovation target and the effectiveness of the innovation activities, providing a continue

assessment and an early discovery of unexpected deviations, with information useful to correct them. This is represented by the Innovation Monitoring Framework (IMF) that includes a system of KPIs and methods to derive them.

KPIs as tool to measure process performance have gained massive attention during the last decade, also for networked environments (see e.g. [2, 5, 6]). However, very little work focuses on innovation. In the IMF a set of key performance indicators (KPIs) is introduced that aims at supporting the assessment of the innovation to check if the venture is proceeding in the right direction, with the right pace. These KPIs are associated to specific activities, to monitor their progress, and their outcomes, to monitor the quality and the achieved business objective. The business objectives are prioritized according to the innovation and business strategy of the VE. The IMF organises the business objectives in eight groups:

- **Reliability** describes the ability of the network to constantly achieve its innovation goals. It has a reversed relationship with the error rate of the outcome of the measured activities.
- **Velocity** aims at pushing a low duration of the measured activities. The cycle time of each activity is a typical KPI that can always be measured and describes the time needed between the start and the end of an activity.
- **Adaptability** is the ability of the VIF to react to obstacles and varying demands that arise from external or internal reasons. This can be for instance an increased demand for a higher product quality or reduced costs of some components (see how contradictory business objectives can be).
- **Cost Orientation** comprises the KPIs that measure the negative financial dimension of expenses. A lower cost in carrying out innovation grants a higher profit and leads to a higher business success.
- **Asset Orientation** contains KPIs that measure the positive financial dimension of resources that cycle within an activity. In the innovation context, resources are mainly intangible (knowledge) and assets mainly relates to the knowledge power of knowledge workers. KPIs measuring the money spent on employee training/development, or the amount of investment devoted to new products belong to this class.
- **Innovative Potential** is the ability of a VEE to create ideas and to successfully lead them into the market. This includes a certain level of creativity as well as successful innovation management to reach for the market.
- **Customer Orientation** groups all measurements that are connected to the fact that the sought innovation is geared towards the satisfaction of the customers. Typical KPIs are the rating of customers' focus groups or the target value proposition.
- **Network Orientation** describes the objective of an optimal collaboration within the VIF that is inherently a distributed, networked organism. The expected number of new partnership made during idea development is an example of KPI in this class.

These Business Objectives are are based on the Value Reference Model, created by the Value Chain Group[1], the performance measurement of [5] and the agility aspect

[1] The Value Reference Model as it is part of the Value Chain Business Process Transformation Framework (http://www.value-chain.org/en/cms/?1960)

described by [4] that has been adopted with the network orientation. The mentioned literature is mainly focused on a value production evironment, the contribution of the BIVEE project focused on its revisiting in the perspective of business and enteprise innovation. In fact, the KPIs differ between Innnovation and Production. The KPIs on produition (P-KPIs) address the Production Space and are aimed at optimising the value production of a VE, conversely the KPIs on innovation (I-KPIs) apply for the activities withing the Innovation Space and aim at optimising the innovation capabilities of the VIF. Within the innovation space, the I-KPIs are aligned to the activities to develop innovations. Each KPI is assigned a wave, activity, business objective, name, unit of measurement and is provided a brief description about its content. For instance, the amount of investment devoted to new products is aligned to the activity *Idea Generation* within the *Creativity Wave* and it is connected to the business objective *Asset Orientation,* as already said. The unit of measurement (UOM) is %, since it is calculated as the ratio between R&D investment devoted to new products and the toal of R&D investments.

4 The Semantic Platform

In order to provide a formal grounding for the three frameworks, BIRF, IMF and VEMF, a method based on the semantic annotation of model elements is used. Semantic annotation consists in the linking of model elements to one or more ontological resources (e.g., concepts). To this end, the problem space of VIF has been partitioned and conceived as a federation of ontologies that will provide the required semantic base. Then, the VE models, the innovation venture, the KPIs, etc., will be suitably annotated by using one or more of the following ontologies.

- **Domain ontology (DomOnto)** that models the business domain in which the VE operates, including the manufactured products and services.
- **Process Ontology (ProcOnto)** that models the activities performed by the VE, organized in two main sub-classes: production activities that will be affected by the innovation, and innovation activities.
- **Actor&Role Ontology (AROnto)** that models the active entities operating in the VE, and beyond, when relevant (including competencies and skills.)
- **Resources Ontology (ResOnto).** The production innovation means, including technology and locations, except the HR.
- **KPI Ontology (KPIOnto)** that models the entities (referred to in the DomOnto and ProcOnto) and related phenomena that are intended to keep under control. In particular, here all the dimensions that characterize each selected KPIs are defined along with the measures they are based on the formulas and algorithms to calculate actual KPI values. The description is outlined according to the W5H method (see below.)
- **Business Ontology (BusOnto)** represents the relevant business entities / info, such as order, invoice, with the carried information.
- **Document Ontolgy (DocOnto).** Since all the info / knowledge need to be documented, this onto describes all of the VE docs that are relevant in the innovation venture.

The semantically enriched VIF resources can be managed by using a number of advanced services, such as consistency checking and semantic search and retrieval.
Within the KPI Ontology, each KPI will be characterized according to the W5H Method, detailed according to the following 6 dimensions: *What (WT), Why (WY), Who (WO), When (WN), Where (WR), How (HW)*. Therefore, a KPI is formally represented by a 6-tuple:

KPI = (WT, WY, WO, WN, WR, HW)

When instantiating the above tuple for a specific KPI the 6 components need to be specified, according to the ontologies presented below. In particular:

- **What** – this is about the business entity (activity) that is intended to be measured (or assessed). Depending on the nature and target of the innovation, different ontologies will support this. E.g., DomOnto in case of manufacture product innovation, ProcOnto in case of process and/or service innovation, ResOnto in case of technology innovation (considered as a production resource2).
- **Why** – this is a complex dimension and allows explaining the goals and expected benefits aimed with the innovation venture. Potentially all the ontologies are involved. Goal decomposition will be extensively adopted. In BIVEE, the innovation goals are categorise according to the eight business objectives.
- **Who** – this dimension reports different actors and roles, from stakeholders to partners to actual executors. AROnto is the reference ontology that reports also the capabilities and responsibilities of each role. This is particularly important in a VE, where it is necessary to know who is responsible of what and what are the activities currently assigned.
- **When** – the time dimension is important to identify a point of time interval. Formally, it can be considered a resource and therefore represented within the ResOnto ontology.
- **Where** – this is the location, intended also as an administrative location (legal site) or geographical location. In a networked enterprise it is particularly relevant. In particular, when dealing with the monitoring of innovation in a distributed, networked environment (i.e., the VIF), this information becomes crucial since it concerns the information on the place where the measurements takes place. (The formal aspects of the 'Where' are represented in the ResOnto, to avoid the proliferation of Onto.)
- **How** – this dimension has a double meaning: behavioural and instrumental. At first, it is essential to specify how to perform the measure / assessment, what methods will be adopted, including algorithms and formulas (if any) that will be hosted in the KPIOnto. Here, also the underlying KPMs will be clarified. Since a given KPI can be obtained in different fashions by different end users, here the key issue is to provide a clear semantics. Besides a description and a few (non mandatory) examples a formal representation of formulas is given. The formal representation enables reasoning mechanisms for KPIs reconciliation, rewriting, and consistency checking of the whole system of indicators in the Semantic Base. Then, the end users will have the option of adopting one of the provided

[2] Please note that we avoid the building and maintenance of a Technology Ontology that would exceed our scope

formulas / method or define a proprietary3 one, as long as its nature (i.e., semantics) is preserved. The second parameter required is specified if specific instruments, including software tools, online forms, etc. (as specified in the ResOnto) are needed to achieve the assessment.

5 Conclusions and Future Work

This paper presented a synthesis of part of the work conducted in the BIVEE project to monitor and support innovation in a Virtual Enterprise Environment. In particular the modeling effort has been discussed, with a description of the framework that serves as a reference for classifying the key entities involved in an innovation endeavor, and a description of the Semantic Base guarantying a precise, rigorous, unambiguous approach to the representation of the above framework. Initial feedbacks by the end-users participating in the projects allow pushing on this model-based, semantically rich approach, refining the framework and developing semantic-based services. This is the matter of future work.

Bibliography

1. Barnett, W., A. Presley, M. Johnson and D. Liles (1994) "An Architecture for the Virtual Enterprise". IEEE International Conference on Systems, Man, and Cybernetics, San Antonio.
2. Bongsug, K.C. (2009) "Developing Key Performance Indicators for Supply Chain: An Industry Perspective". Supply Chain Management: An International Journal, Vol. 14, No. 6, pp. 422 -428.
3. Chesbrough, H. (2003) Open Innovation: The new Imperative for Creating and Profiting from Technology. Boston, Massachussetts: Harvard Business School Press.
4. Cusumano, M. A. (2010) "Staying Power - Six enduring principles for managing strategy and innovation in an uncertain world". Oxford University Press, New York.
5. Hieber, R. (2002) Supply Chain Management – A Collaborative Performance Measurement Approach. vdf Hochschulverlag AG, ETH Zürich.
6. Kaplan, R. S., Norton, D. P. (2001) "Transforming the Balanced Scorecard From Performance Measurement to Strategic Management: Part 1". Accounting Horizons, Vol. 15 No. 1., pp. 87-104.
7. Nikitas A. Assimakopoulos and Aggeliki D. Theodosi (2003) "A Systemic Approach for Modeling Virtual Enterprise's Management Features". Tamkang Journal of Science and Engineering, Vol. 6, No. 2, pp. 87-101 (2003)
8. OECD Oslo manual on GUIDELINES FOR COLLECTING AND INTERPRETING INNOVATION DATA. Third edition. http://epp.eurostat.ec.europa.eu/cache/ITY_PUBLIC/OSLO/EN/OSLO-EN.PDF

[3] We are considering a formal language that, suitably edulcorated, can be adopted by end users