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INTEGRACJA PRAKTYK ZARZĄDZANIA INNOWACJAMI W INFRASTRUKTURZE ORGANIZACYJNEJ IT: RAMY METODOLOGICZNE

[słowa kluczowe: zarządzanie innowacjami, SPEM, inżynieria oprogramowania, modele procesów**]**

Streszczenie

Badania nad zarządzaniem innowacjami często koncentrują się na dużych firmach i organizacjach. Z drugiej strony małe i mikro-przedsiębiorstwa stanowią istotną część krajobrazu przedsiębiorczości i w znacznym stopniu przyczyniają się do rozwoju gospodarczego społeczeństwa i tworzenia miejsc pracy. Dotyczy to także obszarów biznesowych systemów i oprogramowania. Większe systemy budowane i wdrażane w całej Europie są zazwyczaj budowane z udziałem małych przedsiębiorstw lub ośrodków badawczych, których wkład wnosi kluczowe znaczenie dla tworzonych systemów. Chociaż te firmy są bardzo ważne dla systematycznych innowacji, większość modeli innowacji jest skierowana do dużych i średnich przedsiębiorstw i nie uwzględnia specyfiki systemu i przemysłu inżynierii oprogramowania. W tym szczególnym obszarze działalności innowacje muszą brać pod uwagę dwa odrębne wymiary: a) możliwości innowacji wewnątrz tego systemu i co firmy zajmujące się rozwojem oprogramowania mogą oferować swoim obecnym klientom i potencjalnym klientom, b) stosowanie technik innowacji w procesach tworzenia oprogramowania, aby osiągnąć lepszą wydajność oraz wykorzystać możliwości firmy i jej wydajność. Oba wymiary wymagają systematycznej integracji procesów zarządzania innowacjami z procesami zarządzania i inżynierii organizacji. Niniejszy artykuł proponuje rozszerzenie modelu procesu opisanego w normie ISO / IEC 29110, tak aby umożliwić procesy zarządzania innowacjami i działania skierowane do małych i mikro przedsiębiorstw. Działania innowacyjne i narzędzia włączone do powstałego modelu opierają się na istniejących modelach innowacji i zostały wybrane przez wywiady i ankiety przeprowadzone w różnych firmach zajmujących się tworzeniem oprogramowa-

nia. SPEM (metamodel inżynierii procesów i systemów) został wykorzystany jako podejście do projektowania procesów do kodowania powstałego modelu. Model ten formalnie integruje procesy innowacyjne, zarządzania inżynieryjnego dla małych i mikro przedsiębiorstw.

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THE INTEGRATION OF INNOVATION MANAGEMENT IN IT ORGANIZATIONAL INFRASTRUCTURE: A METHODOLOGICAL FRAMEWORK

[keywords: Innovation Management; SPEM; Software Engineering; Process models]

Abstract

Studies on Innovation management are often focused on large companies and organizations. On the other side, small companies or VSE (Very Small Entities), constitute a significant part of the entrepreneurial landscape, and contribute – in a great extent – to the economic outputs of society and to the creation of employment. This is also valid for the system and software engineering business areas. Larger systems being built and deployed across Europe are usually built with the participation of small enterprises or research centers whose contributions have a key role in the resulting systems. Although these companies are sensitive to the importance of systematic innovation, most of the innovation models are targeted to large or medium enterprises and do not consider the specific characteristics of the system and software engineering industries. In this particular business area, innovation must consider two separate dimensions: a) the opportunities to innovate that system and software development companies may offer to their customers and prospects, and b) the application of techniques to innovate in the software development processes, to achieve better performance and leverage process capabilities and company productivity. Both dimensions require a systematic integration of the innovation management processes with the managerial and engineering processes of the organizations.

This paper proposes an extension of the process model described in the ISO/IEC 29110 standard to enable innovation management processes and activities

addressed to VSE. The innovation activities and tools incorporated into the resulting model are based on existing innovation models and have been selected through interviews and surveys completed on different software development companies. SPEM (System and Software Process Engineering Metamodel) has been used as a process design framework to encode the resulting model and formally integrate innovation, managerial and engineering processes for VSE.

1. Introduction

The capability to innovate and improve existing products, services and business models is recognized as a key factor for competitiveness. A great percentage of innovations in the current economic landscape is supported by software applications and computer-based systems. In knowledge intensive domains like automotive, aerospace or biomedicine, the identification, prototyping, building and delivery of innovation heavily depend on the capability of translating new ideas into working software applications. Software and computer technologies affect innovation from a double perspective: they are the tools that enable the prototyping, building and deploying innovative ideas, and they also provide engineers with new approaches to solve problems and optimize existing solutions.

Companies involved in software development should be aware of this tight relationship between software and innovation, and acknowledge their role as agents of innovation. A new approach is needed: an approach that may sound unfamiliar to most of the companies involved in software development, whose activities have traditionally been focused on the construction of business solutions that fulfil a set of requirements specified by their customers. In these cases, software development processes are understood as a set of sequential or iterative activities that generate a running solution through a set of transformations that start with the client requirements. This model offers software development companies little opportunities to participate in the ideas' generation process. Software engineering is similar to a black box, and innovation is implicit in the requirements proposed by the customer. Teams working on these projects dedicate their efforts on pure engineering activities aimed to ensure functionality, performance and robustness: this is far from the collaboration models proposed by Open Innovation strategies, which promote the participation of different agents to figure out potential solutions to business challenges.

To overcome the constraints implicit in these strategies, software development teams should consider the need of incorporating into their processes sys-

tematic innovation management practices. This paper proposes a framework to incorporate these practices into their process portfolio. The systematic planning, execution and control of innovation activities fully integrated with engineering and managerial processes shall improve the companies' capability to generate innovations and new business opportunities. Software development should no longer be viewed as the implementation of requirements stated by a third party, but as a dynamic, iterative process that interacts with stakeholders to figure out how software and computer technologies may re-define products, processes and business models. Software and computer technologies may help business recombine existing models and technologies into innovative value-added proposals.

This research focuses on innovation at SMEs (Small-Medium Enterprises). Although SMEs do not have at their disposal all the resources and the financial capability needed to complete complex R&D, production and marketing activities, they can be much more innovative than larger firms (Gay, 2014). In the case of SMEs involved in software development, just a few studies have been completed. Capaldo (2003) proposed a methodology to assess their innovation capabilities based on the available resources (resource-based competition approach), including financial and human resources and the involvement of the entrepreneurs and their personal know-how on both technical and managerial aspects. His study included – among the pull of available resources -, the deployment of software engineering methodologies as a means to increase technical know-how.

2. Reference framework

System and software development companies need to incorporate innovation management practices as part of their process map and corporate procedures. Procedures and organizational routines are in fact the result of the knowledge accumulated after years of self-experience and captured from accepted industrial practices throughout a continuous improvement cycle. The strategic management of innovation (planning, deployment and monitoring), requires a similar approach to improve the probability of success in the design of new products and their delivery to the market.

The need of combining innovation management practices within corporate procedures has been discussed by Laperche (2013) and Hage (2013), among others. Laperche (2013) analysed the opportunities that Open innovation strategies offer to SMEs to increase their knowledge capital. Hage's idea innovation

network theory proposes a framework for assessing innovation capabilities of companies in knowledge-intensive sectors – that remarked the need of keeping a tight connection between the different activities involved in R&D: basic and applied research, product development and production, commercialization, marketing and quality control. According to this author, the lack of interaction between these areas is one of the factors that slow down innovation. Idea innovation network theory does not restrict quality control to the identification and correction of defects: this activity is seen as a means to reduce operating costs and "negative properties" of the products, an understanding that is aligned with the product assurance approach that is found on several system and software engineering standards.

This research proposes the combined use of innovation management activities and engineering and managerial practices for VSEs. The resulting approach integrates two models: the first one for guiding software development activities, and the second one for innovation management practices. Their combined deployment offers a global framework that puts together: a) activities needed to build robust, reliable software following recognized software engineering practices, and b) activities aimed to identify innovation opportunities, promote them and disseminate their results. To achieve this objective, the ISO/IEC 29110 – a software process model designed to meet the needs of VSEs involved in software development – has been extended with additional activities and work products identified in a set of innovation and R&D standards: UNE 16600X, Spanish national standard closely related to CEN/TS 16555-1.

3. The engineering and managerial referential: ISO/IEC 29110

The recently published ISO/IEC 29110 "Software engineering – Lifecycle profiles for Very Small Entities (VSEs)" is expected to become one of the most relevant standards for guiding system and software development activities. Software process models provide practitioners with descriptions of activities or groups of activities and product flows, that is to say, inputs and outputs for the activities, the control flow between processes and the relationships between activities, techniques, methods, tools and roles (Münch, 2013: 11). Software process models are oriented toward the resolution of recurrent problems when building software, and they reflect the accumulated know-how regarding software development practices. In the case of an international standard like

ISO/IEC 29110, this know-how also represents the consensus reached between different national standardization bodies participated by a wide spectrum of organizations of different types.

ISO/IEC 29110 is a prescriptive process model, as it provides organizations with instructions on how to develop software to achieve business objectives and improvement goals. The standard defines software development processes tailored to VSE (Very Small Entities): organizations, departments or project teams with no more than twenty five workers. Even in the case of bigger companies, the teams in charge of developing particular software applications fail within those dimensions. ISO/IEC 29110 was elaborated to solve one of the classical problems in process improvement at small software companies: organizations within this group do not have at their disposal the time and resources needed to deploy complex improvement models like CMMI or SPiCE (O'Connor, 2012; Laporte, 2013). These software process improvement models were developed to monitor the performance of big contractors for governmental projects, and imply complex and costly requirements different to fulfil for SMEs. This is a problem for both small and large organizations: a) for small companies, it is difficult to demonstrate their capability to develop reliable software following standard life cycle processes and best practices (Ribaud, 2010); b) for large organizations subcontracting software development activities to SMEs, the lack of process models tailored to the characteristics of SMEs hinders the assessment of their capabilities as subcontractors. ISO/IEC 29110 explicitly states its value for both contractors and acquirers of software. Having this standard as a reference, small companies and groups may adopt a sound process model to complete engineering activities, demonstrate their processes' capability to third parties and guide improvement efforts (Boucher, 2012).

The ISO/IEC 29110 standard focuses on the definition of standard profiles, defined as "pre-tailored packages of related software engineering standards" (ISO/IEC 29110-2 sec. 2.2.1). Profiles are created by combining relevant elements from existing standards referred to as base standards. These elements may be processes, processes outcomes and objectives, activities, tasks and work products. One standard profile may be the result of merging elements defined in different base standards: for example, the Basic standard profile – the only one defined at the moment of writing this paper -, is built with process elements taken from ISO 12207:2008 and work products defined in ISO 15289:2008. The creation of profiles must follow a set of rules that are also defined in one of the normative parts of ISO/IEC 29110: ISO/IEC 29110-2:2011 "Framework and Taxonomy". Profiles are put together within groups. Up to this moment just

one profile group has been released: the Generic Profile Group defined in the normative part ISO/IEC 29110-4-1. It is aimed at VSEs that develop or maintain non-critical software, regardless the application domain. The definition of an additional profile group for system engineering activities is in progress with the collaboration of INCOSE (Laporte 2012).

The definition of profiles is completed with other non-normative parts known as management and engineering guides. Two guides have been published for the profiles in the Generic group corresponding to the Entry level (ISO/IEC TR 29110-5-1-1) and the Basic level (ISO/IEC TR 29110-5-1-2), being the latter the only one that is certifiable. The elaboration of a guide for an intermediate level containing additional processes is in course. These guides are aimed to organizations interested in implementing the standard, and they provide the specific activities, tasks and work products that should be enacted when developing a software project.

The selection of ISO/IEC 29110 for conducting this research is due to several reasons. Firstly, the rationale behind the standard supports a modular architecture that combines elements from existing standards. This feature is necessary to leverage software development processes with innovation management practices. Secondly, the adoption of innovation management by SMEs deals with a problem similar to the one they faced when adopting software process models: existing innovation management frameworks are too complex for this type of companies.

4. The innovation referential

The selection of a reference model for identifying innovation management activities suited to SMEs is more complex. In this case, there is no international standard similar to ISO/IEC 29110 for innovation practices. Existing innovation management models present some difficulties and limitations for this type of companies. Models like Innospace®, an excellent tool for assessing innovation capabilities, do not provide a detailed activity model to support SMEs in the identification and sequencing of activities and work products. Other models proposed in the literature (Eversheim, 2009; Pikkarainen, 2011) are targeted to large companies or networks with the capability of deploying complex innovation programs with a strategic, long-term view. In the case of VSEs, a more restrictive view needs to be applied, due to their resource constraints and short-term strategies: innovation management needs to be tightly integrated and

coupled with the work completed as part of projects' execution. As stated in ISO/IEC 29110, VSEs focus on the successful completion of projects to ensure their continuity in the market. Similarly, innovation efforts need to be incorporated as part of the work completed in the context of projects.

This rationale guided the selection of the second component of the referential model toward the national standard UNE 166001:2006 "R&D&I management: Requirements for R&D&I projects". This standard developed by the Spanish standardization body – AENOR -, establishes requirements for the management of R&D projects. It is part of a family of standards grouped under the name UNE 16600X. The 16600X family includes parts focused on different aspects of innovation, like the requirements for a corporate R&D system, market intelligence and technology monitoring activities, innovation capability assessments, etc. The objective of this set of standards include: a) establishing a framework to demonstrate to third parties the managed execution of R&D, b) improve the visibility of the investments on R&D made by companies and c) communicate the outcomes and results. These objectives respond to the need of providing guarantees to decision-making agencies that evaluate opportunities and manage funding. The standard provides agencies and innovation agents with a framework for assessing the actual capabilities of companies and research groups involved on innovation. This is another similarity between UNE 166001 and ISO/IEC 29110, as both models serve as tools to demonstrate capability to third parties. There is another similarity between UNE 166001 and ISO/IEC 29110: the adoption of UNE 166001 is considered as a first step toward the adoption of more complex requirements stated in other standards of the 16600X family (those related to the R&D system characteristics). In a similar way, the adoption of ISO/IEC 29110 is considered as an entry point to the latter adoption of more complex standards like ISO/IEC 12207.

5. Model analysis and merging

This section describes the mapping and merging between the elements defined in ISO/IEC 29110 Basic profile for SW development, and the innovation management activities defined in UNE 166001. The ISO/IEC 29110 Basic profile establishes two mandatory processes: a) Project management (PM) and b) Software implementation (SI). For each process, the standard establishes their definitions, objectives, outcomes, activities, tasks, roles and work products, all

of them traced to those defined in the base standards. The importance given to the Project management process is due to the fact that most VSEs need to focus on the successful completion of projects on time and budget.

The focus on project management is also a major feature of UNE 166001. This standard establishes a set of requirements for the systematic management and execution of R&D and innovation projects whose main characteristic is the fact that the final results may differ substantially from those initially stated. Chapter 4 of the standard establishes the requirements for managing R&D projects. A detailed comparison – completed as part of this research – of these requirements with those established by the ISO/IEC 29110 PM process results in no significant gaps. Other management requirements stated in UNE 166001 for the control of documents and records generated during the project life cycle, their identification and archival for at least 3 years may be traced to ISO/IEC 29110 activities for the control of configuration items.

Although project management is at the core of UNE 166001, this standard incorporates additional requirements that need to be incorporated into the VSE working processes. These requirements are described in chapter 4.3 of the standard, and they refer to the diffusion of the innovation results. In particular, chapter 4.3 requests an additional work product, the "Project Memorandum" and prescribes their content and structure. Project Memorandum contents include: objectives of the R&D project and the plan to achieve them, impact and opportunities, state of the art regarding the knowledge, products, processes and technologies, proposed scientific and technical advances, planned activities for protecting the results, regulations that affect the project, authorizations, collaboration agreements and licensing model.

The exploitation of results is the core of chapter 5 of UNE 166001. A second work product – the exploitation plan – is requested. It should contain the planned actions to exploit, protect and disseminate the results, and the elaboration of information explaining the characteristics, applications and expected use of the new product or process. This work product must identify the innovation's potential market and clients, an economic forecasting and the planned participation of the involved companies in the exploitation of results. An analysis of the contribution of the project results on the company mid-term competitiveness is also requested.

The elaboration of these two work products requested by UNE 166001 as part of the project planning and execution, implies the need of incorporating additional tasks as part of the team activities: identify and describe the state

of the art, environmental constraints, value added by the proposed innovation, etc. These activities are incorporated into the resulting model based on the ISO/IEC 29110 Basic profile.

But UNE 166001 just offers a partial coverage to the range of base practices needed to ensure the successful deployment of an innovation management program. Strategic aspects like the generation of ideas through creative and innovative thinking, the management and participation on collaboration networks and task to monitor the external environment are not explicitly mentioned in the standard. These points are covered in UNE 166002:2006 that establishes the requirements for a R&D and innovation management system. Similar to other certifiable standards like ISO 9000, ISO 9100 or ISO 14000, UNE 166002 requests the definition of a corporate policy with planned objectives that are regularly reviewed by Management, setting up of a separate R&D unit provisioned with the necessary resources to execute R&D projects, and a designated responsible in charge of managing the system. This approach clearly exceeds the capabilities of most SMEs interested in the systematic planning and management of innovation. But UNE 166002 defines innovation-oriented activities and tools that cover the hole identified in UNE 166001. These activities and tools include, among others:

- Systematic monitoring of the technological landscape to capture, analyse, disseminate and use scientific and technical information,
- Management of alerts on scientific and technical innovations that may result on opportunities or threats to the organization,
- Identification of innovation needs, searching and assessment of external information,
- Capture, analysis and selection of ideas on the evolution of products, services and processes,
- Promotion of creativity to solve problems,
- Internal and external analysis of competitors, skills and competences,
- Identification and assessment of alliances,
- Commercialization of the resulting project.

UNE 166002 includes other requirements that may be difficult to fulfil in the context of VSEs, like those related to procurement, the execution of internal audits or the measurement and assessment of the R&D system.

The combination of the basic set of requirements stated in UNE 166001 with some of the activities defined in UNE 166002 provides an adequate coverage to the innovation management needs of a VSE. It must be considered that VSEs

innovation efforts may be supported by innovation management agencies. Candidate activities to be done with external support are the monitoring of the technical environment, the use of external information sources or the search of partners for establishing alliances. The role of these innovation support agencies and the success factors related to their use has been widely discussed in the literature (Tödtling, 2002; Arvanitis, 2008; Markovich, 2011). In this research, these activities have been incorporated into the resulting process model attending to their value to generate innovation, regardless the possibility of outsourcing or making them in cooperation with external agents.

6. Process model design and integration through SPEM

The synthesis of the software process model defined by ISO/IEC 29110 with the identified subset of innovation activities extracted from UNE 16600X requires a conceptual, sound basis. A metamodel for process definition is needed to ensure the consistency of the resulting model. The SPEM (Software & Systems Process Engineering Meta-Model) modelling framework has been selected to model the integration. SPEM is a MOF-based metamodel and conceptual framework published by the Object Management Group (OMG) that provides process architects with the concepts and notations to represent, exchange, publish and enact different processes. Although it is usually applied for modelling software development activities, SPEM has a general scope and can be applied in a variety of scenarios.

SPEM does not specify a specific set of activities, tasks, roles or work products. It just provides the concepts used for building process definitions and their reusable elements, referred to as "method content". The main sources of method content are companies' experience and industry best practices, standards, and professional and academic literature. SPEM is not linked to a particular life cycle or development methodology, and consist of "the minimal elements needed to define any process and accommodate a large range of development methods and processes of different styles, cultural backgrounds, levels of formalism, life cycle models and communities." (SPEM, p. 2). SPEM's philosophy roots on the definition of reusable elements. This is also the basis of the Unified Process framework and its RUP (Rational Unified Process) and OpenUP variants. Methods content act as building blocks that may be combined to define the organizational processes. They correspond to tasks definitions, work product definitions, role definitions and categories. Tasks, work products and role

definitions are related: roles participate in tasks that generate or consume work products. Categories are used to classify method content items according to different criteria. Sample categories include: a) disciplines, used to group tasks, b) domains and c) work product kinds, both used to group work products, d) role sets and e) tools, to group roles and tools respectively. Process architects can add custom categories to classify method content following other criteria: maturity levels, criticality, etc.

One of the advantages of using for modelling the integration of ISO/IEC 29110 with the innovation model is the possibility of defining activities, tasks and work products independently. These items can be later combined in process definitions tailored to different life cycles or project needs. This SPEM feature leverages reuse opportunities and avoids the risks derived of early decisions. SPEM supports an additional level of tailoring by breaking down tasks into steps. Steps do not represent a requested sequence or order, but a set of subtasks that may also be combined when enacting a task in a particular context. The selection of the steps that are needed to execute a defined task is part of the SPEM customization capabilities. Additional elements provided by SPEM are guidance items, which provide additional details on how to execute tasks, play a role or create a work product. Checklists, list of concepts, estimates, examples, guidelines, tool mentors, etc., are examples of guidance items.

The rules to combine method content items to create activities and processes are other components of the SPEM metamodel (in SPEM, both activities and processes represent two different levels of aggregation of method content items). Activity diagrams or Gantt breakdown structures are used to do that. The terms “Task use”, “Role use” and “Work Product use” refer to the occurrences of task, roles and work product definitions in the definition of activities and processes. Two types of processes are distinguished: delivery processes and capability patterns, being the first one end-to-end process templates, and the latter sub-processes or process fragments that may be assembled to build delivery processes. Capability patterns are useful to group activities that are enacted in different projects and may be reused as a consistent set. SPEM also introduces the concept of phases, iterations and milestones.

7. Conclusions

SMEs constitute a significant part of the entrepreneurial landscape, and contribute – in a great extent – to the economic outputs of society and to the creation of innovation. Innovation management studies have traditionally focused on large corporations and networks, and the systematic management of innovation has been considered as something unaffordable for VSEs.

The recent publication of ISO/IEC 29110 for system and software development process model is the answer to the needs of SMEs. This standard not only provides companies with clear guidelines to do their process and support improvement programs. It also ensures the capability of demonstrating to third parties the maturity of their engineering and managerial processes. This promising set of standards and guidelines is called to demonstrate the weakness of the perception that promulgates the difficulties of VSEs to follow sound, well-established engineering and project management practices to develop reliable software.

The analysis completed as part of this research discusses the feasibility of a similar approach for the systematic management of innovation. R&D practices and activities must be carefully selected to avoid unaffordable costs for SMEs. In the software development sector, SMEs focus on short term results and their main stream of revenue depends on the completion of projects on time and within budget. These constraints constitute obstacles to the systematic management of R&D efforts understood as long-term initiatives that require complex investment on financial resources or human capital. A model supporting the needs of SMEs must integrate innovation practices in the context of the project management practices. The tailoring or extension of ISO/IEC 29110 with the addition of innovation practices is a promising area, as SMEs can leverage the effort required by the adoption of ISO/IEC 29110 to deploy valuable innovation practices and demonstrate compliance with other R&D standards like UNE 166001 (it is remarked that both ISO/IEC 29110 and UNE 166001 share core requirements for project management).

The integration of these models has been implemented using SPEM as a configuration tailored to the needs of SMEs. Configurations are a SPEM tailoring mechanism that allows the reuse and customization of method content without modifying the definitions of the reused items. The elements of ISO/IEC 29110 have been modeled using SPEM and grouped together in a reusable plug-in, taking as a reference the process description in ISO/IEC 29110-5-1-2. A separate plug-in has been created for the activities, tasks and work prod-

ucts identified in UNE 16600X. Another customization mechanism provided by SPEM, variability, has been applied to extend existing items using different rules: contribute, extends or replace. Innovation management activities have been either integrated within the PM or SI engineering processes, or grouped into a reusable capability pattern that may be enacted in a recurrent way in innovation or R&D projects. Activities related to the generation and assessment of ideas and the preparation of work products like the project memorandum or the exploitation plan have been integrated by extension within the PM and SI processes. On the other hand, activities related to the monitoring and surveillance of technologies and the external environment have been modelled as capability patterns. The process model has been implemented with the support of the SPEM 2.0 Eclipse Process Framework (EPF) open source tool.

The resulting framework extends ISO/IEC 29110 Basic profile with new deliverables, tasks and activities taken from UNE 166001. Companies adopting this configuration may easily demonstrate the compliance of their projects to the requirements established in these standards. The verification of the model is being conducted as part of an action research project conducted with a SMEs building medical software. This practical work is aimed to validate the feasibility of the proposed model, assess the practical value of the tasks and deliverables incorporated into the process model and identify gaps and activities that should be integrated into the final framework.

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