

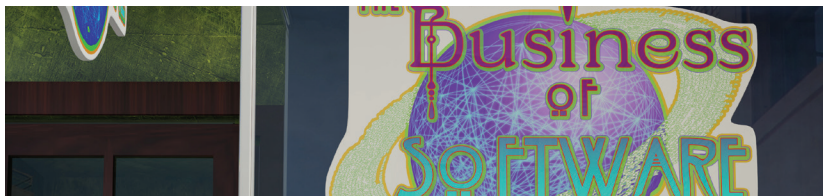
Innovation-Driven Software Development

Leveraging Small Companies' Product-Development Capabilities

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// *A proposed innovation activity model for small companies is based on the relevant literature, an ISO/IEC standard, and the experience of successful small companies. It comprises activities, outcomes, tasks, and work products and establishes interfaces with software development processes.* //



IN 2012, SMALL companies accounted for 66.5 percent of the jobs in Europe and delivered 57.6 percent of the gross value generated by the private, nonfinancial economy.¹

Many software development companies fall into this group, in some cases working as subcontractors developing components of industrial systems. Despite small companies' eco-

nommic importance, they don't have the financial capacity to undertake extensive R&D.² In addition, it's difficult to combine systematic innovation programs with the need to achieve short-term results and provide immediate answers to customer requirements.³

So, we built an innovation activity model suited to software-producing *very small enterprises* (VSEs; organizations or departments with no more than 25 workers). It's based on the pertinent literature, the ISO/IEC 29110 standard for VSEs,⁴ and the results of interviews and focus groups involving staff from successful VSEs. We identified process components that can be adopted and tailored to the needs of any VSE interested in developing its innovation capabilities.

In building our model, our main hypothesis was that the systematic planning and execution of innovation activities integrated with engineering and managerial processes will improve a VSE's ability to generate valuable innovations. The resulting model integrates the activities needed to build robust, reliable software, following recognized software engineering standards. It also integrates activities aimed at identifying and managing innovation opportunities and incorporating them into software products or software-based services. (For more on software development and innovation, see the sidebar.)

Research Method and Execution

We used grounded-theory methods⁵ to generate, collect, and analyze data and construct conclusions. Grounded theory is a qualitative-research method used in different areas, including IT research.^{6,7} This



SOFTWARE DEVELOPMENT AND INNOVATION

The ability to innovate and generate new products, services, and business models is a key factor in competitiveness. Many innovations in the current economic landscape are supported by software applications and computer technologies,¹ and, as of several years ago, software has embodied most new value-added functions² in products and services.

For example, embedded software systems—with an annual growth of 9 percent—are at the forefront of innovations in manufacturing.^{3,4} In knowledge-intensive fields such as the automotive, medical-device, or aerospace industries, the identification, prototyping, building, and delivery of innovations depend heavily on the ability to translate ideas into computer-based solutions. In addition, the continuous progress in computing technologies—for example, parallelism, Web-based services, and on-memory databases—enables known problems to be tackled using different engineering approaches.

Software impacts innovation as

- a means to prototype, build, and deploy innovative ideas and
- a source of innovation per se, providing engineers with new ways to solve problems and optimize existing solutions.

People involved in software development should be aware of this relationship between software and innovation and acknowledge their role as innovation agents.

This approach might be unfamiliar to some companies, departments, and teams involved in software development. Software engineering is understood as a set of well-defined activities aimed at building a solution using a set of transformations that start with user requirements. This approach gives software development entities little opportunity to participate in the idea generation that leads to innovation. Software engineering is like a black box. Innovation is something implicit in customer requirements and might even go unnoticed by the staff implementing the software, who focus on the engineering tasks that ensure functionality, performance, and robustness.

This approach is far from the open-innovation strategies that promote participation by various agents to figure out new solutions for business challenges. As an OECD (Organisation for Economic Co-operation and Development) report dedicated to innovation in the software sector stated, software companies' business models should rely on collaborative activities.⁵ The

diversity in software technologies is so wide that a single entity has difficulty delivering comprehensive solutions; the need exists to appeal to external resources and experience.

Companies, departments, and teams involved in software development should consider software and computer technologies' potential to generate and support innovation from different perspectives. From an internal-process viewpoint, they should analyze the competitive advantages of incorporating tools, methods, and techniques that might increase productivity, quality, or efficiency. Adopting techniques and methods for developing software has been widely discussed,^{6,7} more recently by Lutz Prechelt and Christopher Oezbek, who centered their analysis on open source communities.⁸ From an external, market-oriented viewpoint, teams should consider the potential value of sharing strategies with external partners for designing and delivering products and services.

So, organizations must systematically review their processes to incorporate rigorous innovation management practices. Our model (see the main article) aims to help small companies do just that.

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method collects data through interviews, document analysis, and so on and analyzes it through the writing of memos, data coding, and comparing the identified concepts.

The Literature

Innovation is usually defined as the transformation of ideas into new or improved products or services valued by the market. The *Oslo Manual* from the OECD (Organisation for Economic Co-operation and Development) refers to implementing technologically new products and processes and significant technological improvements in products and processes.⁸ Martin Weitzman defined innovation as the process of producing workable products, to distinguish it from invention.⁹ People must consider this difference when developing an innovation management model because it can't focus exclusively on idea generation. It must include activities aimed at conceptualizing the invention and deploying it to real customers. Innovation management processes also include launching innovations into the market. Researchers have proposed various theories regarding the rules governing the adoption of innovations. The most popular is Everett Rogers' innovation diffusion theory, which lists five attributes contributing to the acceptance of innovations: relative advantage, compatibility, complexity, trialability, and observability.¹⁰

The OECD defined software innovation as

a process that leads to: a) the development of a novel aspect, feature or application of an existing software product or process; b) the introduction of a new software product, service or process, or an improvement in the previous generation of the software product or process; and c)

*entry into an existing market or the creation of a new market.*¹¹

Tony Gorschek and his colleagues proposed the Star Search lightweight innovation process.¹² It comprises four steps: call for innovation, audition, business case preparation, and decision. The process focuses on idea generation, discussion, and refinement. Željko Obrenović's software-sketchifying technique also focuses on idea generation.¹³ It complements prototyping aimed at stimulating creation and assessment of alternative ideas and exploring the possibilities offered by innovations. It relies on nonengineers' early involvement and the disciplined, systematic exploration of ideas.

Thomas Peisl and Juergen Schmied's ICE (Innovation Capability Determination) model proposes a five-step process:¹⁴

- idea generation,
- concept evaluation,
- concept implementation,
- innovation piloting, and
- innovation diffusion.

To assess innovation capabilities, ICE incorporates 14 innovation dimensions, including product or service, brand and marketing, customer experience, balance sheet, networking, and human-resource innovation.

Henry Edison and his colleagues described three phases.¹⁵ The first is research, focusing on generating concepts and evaluating feasibility. The second is development, including project planning, design, coding, and testing. The third is use in production and commercialization.

The Study Participants

We conducted individual interviews with staff from four VSEs from

Spain and Poland dedicated to software development in knowledge-intensive sectors: healthcare and biotechnology. The main driver for selecting the VSEs was their performance in developing software-based solutions considered innovative by the market in which they operate.

The second driver for selection was the VSE's organizational model; we considered three types:

- one independent software business related to a multinational industrial group,
- two independent small companies (unrelated to bigger entities or industrial groups), and
- one internal department providing software to an entity that used it to develop biotechnology solutions.

Each VSE operated with significant independence when planning and executing its work and had the freedom to determine its methods and procedures.

Interviews and Focus Groups

We performed the interviews and then held the focus groups, with the aim of using the interview results as input to guide the focus groups. This aligns with grounded theory's *theoretical sampling* practice: data analysis leads to deciding which data to collect to clarify, confirm, or expand the original information.

The interviews aimed to provide an understanding of innovation-related practices and methods; we compared our findings with those identified in the literature review. The interviews were semistructured and employed the Critical Incident Technique, which identifies the interviewees' most memorable events and experiences.¹⁶

The interviews had these objectives:

- Objective 1. Gain contextual information about the VSE and its product development strategy.
- Objective 2. Identify the level of knowledge and awareness of innovation management theory.
- Objective 3. Identify the level of knowledge of innovation models and standards.
- Objective 4. Identify to what extent the VSE applies innovation management practices.
- Objective 5. Identify to what extent the VSE uses information sources to support innovation-related activities. This objective had four subcategories: interaction with lead users, the systematic collection of ideas, formal tradeoff analysis, and market and technology monitoring.
- Objective 6. Identify the VSE's approach to innovation exploitation.

Here are some example questions:

- Objective 1, question 1. What are the most significant milestones in the development of the product, and what's the product's relationship with the VSE's evolution?
- Objective 1, question 4. Why do you think the target users consider the product innovative? (Identify the most relevant attributes that distinguish your product from other choices in the market.)
- Objective 1, question 5. Which external agents (people or corporate entities) have contributed to the product's conceptualization and development?
- Objective 4, question 11. How often do you interact with lead

users in the different phases of product conceptualization, design, and implementation?

The focus group sessions aimed to expand, clarify, or confirm the data collected in the interviews. Each focus group had a maximum of five participants. Using the Delphi method, we asked the participants to complete a form with the five main practices, methods, and tools related to generating innovations. They then presented these items and the rationale for their selection to the rest of the team. The team rated the items and compared them with those in the draft model under discussion. The team then discussed the best way to incorporate the most valued items into the draft model.

Our Conclusions

On the basis of our analysis, we formed the following conclusions.

Objective 1. The VSEs recognized the value of strong collaborations and partnerships with external experts. They emphasized idea collection and discussion with specialists, as well as the traceability of innovations, requirements changes, and improvements in product design decisions, identified by experts.

Objective 2. The level of knowledge of innovation management wasn't uniform across the VSEs or their staff. Not all staff were familiar with terms such as cocreation or open innovation, although they recognized innovation's strategic role and the relevance of access to lead users.

Objective 3. The Spanish VSEs' staff were aware of national R&D standards. They viewed these standards' requirements as difficult for VSEs to

manage without the help of external agencies dedicated to knowledge and technology transfer.

Objective 4. Most innovation management activities at the VSEs focused on interactions with lead users and a systematic tradeoff analysis of solutions from a technical viewpoint. The systematic collection of ideas occurred in the context of a project. The ideas were recorded as candidate features that were discussed in detail with the lead users for final incorporation into the product roadmap as requirements or design decisions. The interviewees remarked on the usefulness of agile development, which aids the incremental integration of feedback from user representatives, prototyping, and product development. Agile development provides the flexibility to accommodate changes and improvements throughout the increments.

Objective 5. The VSEs collected external data through interaction with external experts and lead users. Some VSEs had access to specialized information repositories, such as IEEE Xplore, PubMed, or SciELO (Scientific Electronic Library Online), through partner institutions. However, they used these resources on an on-demand basis. No regular data monitoring occurred.

Objective 6. Product development was based on a preliminary analysis of potential market demand and estimations of product commercialization feasibility. The interviewees acknowledged the importance of patents: if copyright protects computer programs from unauthorized copying, patents are needed to protect the underlying technical ideas and principles.

Consolidating the Model

These conclusions led to the elaboration of a consolidated model, with the following characteristics.

We added four activities: *identification of innovation opportunities*, *innovation opportunity assessment*, *innovation exploitation*, and *external-environment monitoring*. We discuss these in detail in the next section.

The most valued innovation management tasks were related to identifying the “user challenge”: a clear statement of what users wanted to achieve, with a detailed description of the problem that triggers design activities. The interviewees remarked on the need to adequately assess the problem description’s validity. Software development costs are usually unknown to people not directly involved in it. Also, some factoids such as the “the software’s malleability” might lead users to propose ideas that don’t provide valid solutions to the target problem.

One of the most complex aspects of the innovation process was achieving a synthesis between the problem definition and the solution design. This synthesis requires

- analysis of the problem space from a technological perspective,
- identification of similar problems and solutions (solution patterns),
- identification of candidate technologies, and
- a feasibility analysis of the proposed solution.

Finally, our model incorporated three additional work products. The first was a project memorandum, a valuable tool for planning the product life cycle and exploring commercial opportunities. The

second was expert directories, which were extended from lists of contacts to detailed files containing data on the scientific and technical production of agents that could participate in the innovation process. The third was a database of problem–solution patterns recording the characteristics of specific problems, candidate solutions, and the tradeoff’s results.

The Innovation Activity Model

We now more closely examine our model’s four activities. Figure 1 shows these activities’ inclusion in the processes defined in ISO/IEC 29110.

Identification of Innovation Opportunities

Opportunities for innovation usually result from analyzing potential solutions to a problem. This leads to identification and specification of the problem becoming key components of any innovation strategy. The interviewees mentioned the need to obtain a problem statement validated by experts whose domain knowledge makes them representatives of the target community. These experts’ capability to further define a target scenario is important.

This activity has these outcomes:

- a record of innovative ideas that are interesting to the target community representatives,
- a written description of the problem or situation that the innovation aims to tackle,
- identification of the drawbacks of existing methods and technologies for dealing with the problem, and
- a preliminary analysis of the candidate technologies’ applicability.

Innovation Opportunity Assessment

This activity assesses the value, development, and commercialization costs and constraints associated with the innovation opportunity. The assessment must keep in mind the market value, technical feasibility, and cost. The market value assessment requires closer discussion with external domain experts. A shared understanding of the value linked to the proposal is needed before any commitment to prototyping, design, and implementation activities.

This activity has these outcomes:

- identification of potential entities interested in the proposed product,
- assessment of the benefits (quantifiable as far as possible) for the product’s target community,
- tradeoff analysis of the candidate technologies’ applicability,
- a decision on the product’s technical feasibility, and
- assessment of the risks associated with the product and candidate technologies.

Innovation Exploitation

This activity identifies commercialization opportunities for the product and protects the innovation effort. It goes beyond simply selling and commercialization. For software development companies, the results’ exploitation must satisfy additional objectives. In particular, the company might want to demonstrate competences and skills for solving a particular type of problem or applying a specific technology. The exploitation doesn’t necessarily start with a finished product; it can start during the intermediate stages.

This activity has these outcomes:

- demonstration of product

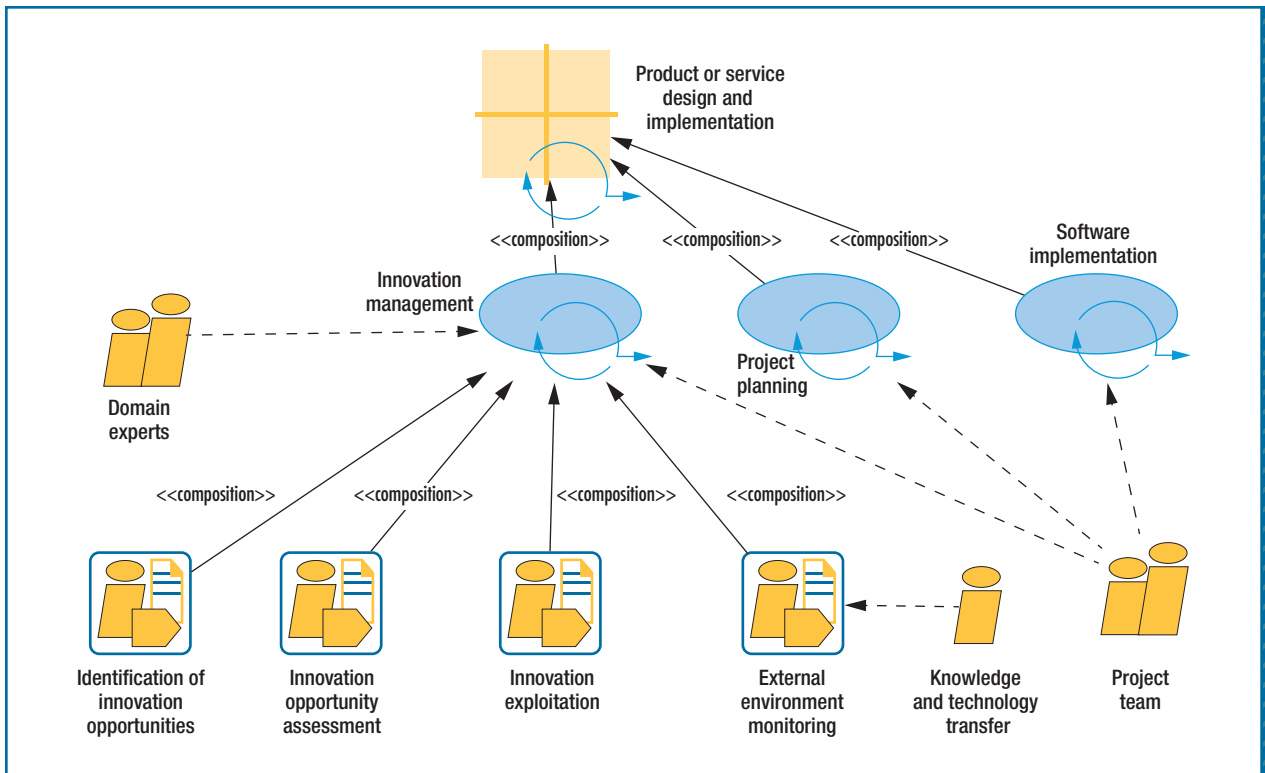


FIGURE 1. Our innovation activity model incorporated with the processes defined in the ISO/IEC 29110 standard for very small enterprises. The model comprises activities, outcomes, tasks, and work products and establishes interfaces with software development processes. The blue circles indicate reusable items.

feasibility at the intermediate stages, not only when the product is finished;

- selection of a method to protect intellectual property rights;
- identification of commercialization and distribution channels (direct sales, licensing, partnerships with system developers, open source distribution, and so on); and
- creation of information to support commercialization.

External-Environment Monitoring

This activity pinpoints contacts (people and entities), projects, technologies, experiences, and any other valuable data that could help identify

and assess innovation opportunities. Unlike traditional competitive analysis, this activity doesn't focus on competitors. In the context of open innovation, environment monitoring emphasizes identifying potential partners, technologies, and user representatives who can provide a valid problem statement and contribute to the proposed solution. This activity is supported by data sources giving access to patents, press releases, proceedings, directories of experts, and so on.

This activity has these outcomes:

- maintenance of an updated list of data sources for identifying experts, partners, and candidate technologies;

- maintenance of an updated list of contacts and related information (such as areas of knowledge and previous work);
- guaranteed access to bibliographic data; and
- information on new items on the list of monitored subjects, technologies, and entities.

The interviewees considered this activity extremely valuable for three main reasons. First, the VSE must work closely with experts to identify improvement areas and problematic situations in which software technologies can be of value. Second, discussion is necessary with experts representing the target user community to obtain a clear, agreed-upon problem

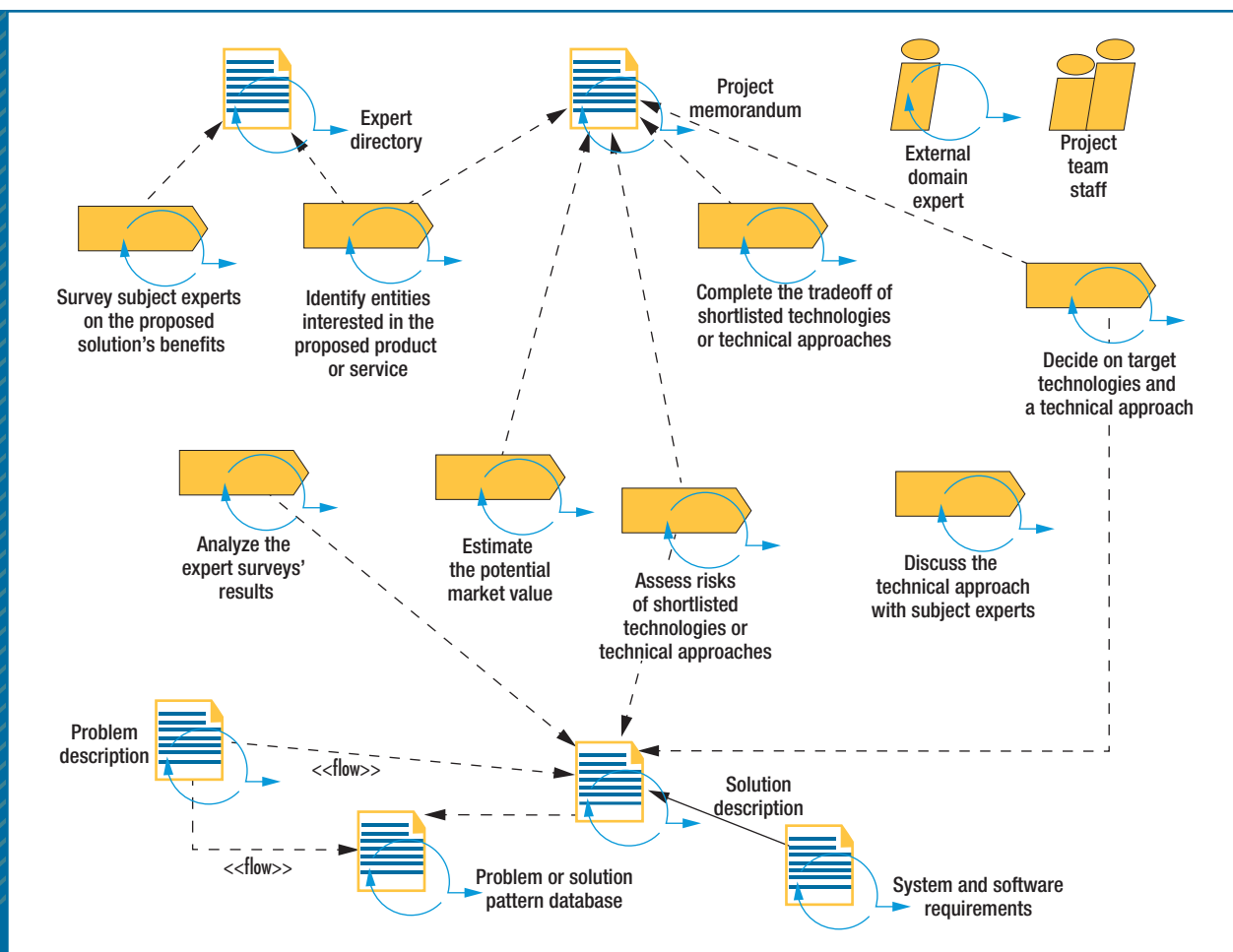


FIGURE 2. A breakdown of the innovation-opportunity-assessment activity, which assesses the value, development, and commercialization costs and constraints associated with the innovation opportunity.

statement and to assess the proposed technical solution's correctness and feasibility at its different stages (conceptualization, prototyping, implementation, and commercialization). Finally, the identified experts might become early adopters of the product and help commercialize it (by referring other parties to it).

Discussion

For each activity, the model includes a detailed list of tasks, work products, and practices derived from the literature review, ISO/IEC

29110, and the interviews and focus groups. Figure 2 shows these details for the innovation-opportunity-assessment activity.

The resulting model is aligned with approaches such as open-innovation user innovation or co-creation, in which prospects or customers contribute to product design and commercialization. Having access to a pool of outside innovators constitutes an opportunity for VSEs that can't afford internal, continuous R&D activity. However, it also implies a focused effort and should

be understood as an investment and risk reduction strategy.¹⁷

Innovation-oriented activities interface with software implementation activities, as work products generated by innovation management become the inputs to software implementation. For example, the "Collect and register opportunities" task provides input to the task "SI.2.2 Document or update the Requirements Specification" in ISO/IEC 29110. Similarly, "Assess existing approaches with target users" provides input to "PM.1.9. Identify

and document the risks ...” in ISO/IEC 29110. Likewise, a relationship exists between the “Solution description” deliverable and “PM.1.12 Include product description”

Validation

To validate the model, we implemented it at one of the participating VSEs. The context was the evolution of a software-based intraoperative-radiotherapy planner. This initiative aligned with the VSE’s certification of its R&D activities according to the national standard UNE 166001:2006 R&D. Process deployment included

- integrating activities into the VSE’s process model,
- creating a Web-based tool to manage innovation-related information (expert profiles, contacts, ideas, improvements, tradeoffs, and so on),
- training the staff, and
- planning and monitoring activities.

Although the VSE was already performing some of the practices, not all of them were systematically applied or had their results formally recorded.

Three months after implementation began, interviews with key staff and direct observation revealed the following achievements.

First, the VSE systematically captured valuable information for facilitating innovation. It set up a list of new ideas and improvements. The systematic capture of the data meant useful knowledge wasn’t missed and provided the basis for further discussion with external experts. The VSE also identified and collected data regarding external subject matter experts.

Second, the VSE began using external data sources (bibliographic

medical databases) to identify experts who could contribute to the various stages of new-product development. It asked some of these experts to participate in the product’s evolution. The organizations of two of the experts were strongly interested in becoming early adopters of the planner.

Third, the VSE instituted a metrification program. It devised metrics on the basis of the captured innovation-related information.

Fourth, the VSE formally assessed the tradeoff between the innovation opportunities’ technical complexity and potential business value. The external experts’ assessment of the complexity and value resulted in a rigorous approach to selecting the requirements driving development.

Fifth, the VSE implemented better documentation to provide evidence of new-product functionality and benefits. The external experts’ judgments provided valuable input and justified the value of the product’s new features. The interfaces between idea generation and requirements management resulted in a well-defined product roadmap and specification. This roadmap was valued by the potential adopters to whom the product’s early prototype was presented.


Finally, the VSE could show the systematic management of R&D activities to investors, prospects, potential clients, and certification bodies.

VSEs must deal with short-term constraints because they depend on the successful completion of projects, but the development of an innovation strategy is a long-term target. Putting innovation-oriented tasks and work products into the context of a standard process model suited to

VSEs’ needs helps solve this gap and reduces the initial difficulties.

Some work products our research identified are similar to software development artifacts. For example, similarities exist between the project memorandum and project management plans and between problem-solution patterns and design justification files.

But innovation-oriented work products have a different purpose. The project memorandum goes beyond supporting project implementation; it considers commercialization, dissemination, and the protection of intellectual property rights. The problem-solution patterns not only compare design solutions but also establish the basis for long-term reuse of technical approaches.

Practitioners interested in systematic innovation management can use our model to guide their activities. We recommend a staged deployment of the model, progressively incorporating the model tasks and work products into the company’s practices and interfacing them with software development activities. 

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