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THE SHIFT TO KNOWLEDGE WORKING INTENSIVE ORGANIZATIONS AND ITS IMPACT IN THE EVOLUTION OF SOFTWARE PROCESS IMPROVEMENT

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This article presents a definition, rationality and an exemplar methodology for a proposed evolution of the current Software (and System) Process Improvement (SPI) area. This proposed evolution is a { (Process Capability Profile) Model-Driven (Process Engineering) for (Software, System and other Knowledge Work) Intensive Organization} (MDPEK). This proposal is important because the forces around the successful current successful SPI demand a revision of the current area towards a more generic area. The shift to knowledge working intense organizations, as identified by Peter Drucker, and the generalization of software and software processes to knowledge and knowledge working processes are one of these forces.

Keywords: Software Process Improvement, SPI, Model Driven Engineering, MDE, Process Engineering, Process Capability, Knowledge Working

1. Introduction

Software (and System) Process Improvement (SPI) is established as a successful area for the needed improvement of software and systems organizations. SPI "has become a driving force in the global software industry" (Card, 2004). The definition and utilization of SW-CMM (Capability Maturity Model for Software) (Paulk et al, 1994) during the 1980s established SPI. Nowadays, the models of CMMI (Capability Maturity Model Integration) (Chrissis et al, 2007), successors of SW-CMM, are the predominant models for SPI. Basically the SPI area stills the same as it was established around SW-CMM. There are, however, forces around the successful current SPI that urge for a revision and evolution of SPI area. The ISO/IEC 15504 vision for process improvement and assessment (Rout et al, 2007) (ISO/IEC 15504-1, 2004) (ISO/IEC 15504-2, 2003) (ISO/IEC 15504-3, 2004) (ISO/IEC 15504-4, 2004) (ISO/IEC 15504-5, 2006) is one of them. The generalization of software with the shift to knowledge work intense organizations as proposed by Peter Drucker is another one of these forces. This article presents a definition, rationality and an exemplar methodology for a proposed evolution of the current SPI area. This proposed evolution is a

{(Process Capability Profile)

Model-Driven (Process Capability Engineering)

for (Software, System and other Knowledge Working)

Intensive Organization} (MDPEK).

The article is organized as follows. This first section provides an introduction to the article. The second section presents the research context and methodology. The third section presents an overview about the shift to knowledge working intensive organizations. The fourth section provides a view for the consolidated current SPI and describes groups of forces for the evolution of SPI. The fifth section presents a proposal for the definition of MDPEK. The sixth section comments about an exemplar methodology for MDPEK. The seventh section comments about related, current and further work. Finally, the eighth section presents conclusions.

2. Research context and methodology

MDPEK has been conceived during many cycles of exploration, application and consolidation of already nine years research effort following the industry-as-laboratory approach proposed by Potts (1998). He argues that the traditional research-then-transfer approach has problems because it treats research and its application by industry as separate, sequential activities.

The MDPEK version presented in this article is a result of the third phase of a project in this research effort. The first phase, from 1999 to 2004, was focused in a methodology for process improvement using ISO/IEC 15504-5 continuous model, composed by a method for performing a process improvement cycle (AMP1) and a method for defining a process capability profile (MEP1) (Salviano, 2001). The second phase, from 2004 to 2007, was focused in the revision of AMP1 and MEP1 methods. It produced the initial version of an exemplar methodology for an emergent evolution of SPI (Salviano et al, 2004) (Salviano, 2006) (Salviano and Jino, 2006). During phase 2, another methodology was also produced (von Wangenheim et al, 2006). The third phase, from 2007 to 2008, is been focusing in establishing MDPEK.

The main goal of this article is to present MDPEK as a useful and convinced proposal for the evolution of SPI. Other articles have been published about previous version of MDPEK including some about experiences using MDPEK.

The articles *Experience of Process Assessment and Improvement Planning using ISO/IEC 15504 (SPICE)* (Salviano et al, 1999) and SPICE *Trials and Dissemination in Brazil: 1996-1999* (Salviano and Souza, 2000) presented the first experiences. The article *A Method for Selecting Processes for an Improvement Aligned with Business Objectives* (Salviano, 2001) presented the consolidated the first version of the methods used in those experiences. These methods were later named as AMP1 (*Abordagem para Melhoria de Processo 1* in Portuguese or Process Improvement Approach 1 in English) and MEP1 (*Método para Escolha de Processos 1* in Portuguese or Process Selection Method 1 in English).

The article *Towards an ISO/IEC 15504-Based Process Capability Profile Methodology for Process Improvement (PRO2PI)* (Salviano et al, 2004) presented for the first time the new versions of AMP1 and MEP1, renamed as PRO2PI (Process Capability Profile to Process Improvement) version 1.0. PRO2PI was then defined as an exemplar approach of a proposed evolution of the SPI area. This article was written to the ISO/IEC 15504 community. The slides *Using Continuous Modes as "Dynamic and Specific Staged Models* (Salviano and Jino, 2004) presented basically the same ideas, but to the CMMI community. The PhD Thesis *A Proposal oriented by process capability Profile for a Evolution of Software Process Improvement* (Salviano 2006) presented the complete rationality and a revised version of PRO2PI (version 1.1) and established the proposed evolution of SPI as a Model-Driven Process Capability Engineering.

The article *Towards a {(Process Capability Profile)-Driven (Process Engineering)} as an Evolution of Software Process Improvement* (Salviano and Jino 2006) presented an overview of the proposed model-driven engineering and report experiences using PRO2PI.

The articles *An Experience using ISO/IEC TR 15504 and ISO 9000:2000 for Software Process Improvement* (Nicoletti and Salviano, 2003), *An ISO/IEC 15504-Based Software Process Improvement Project in a Small Brazilian Software Organization* (Silva et al, 2003), *Experience of process assessment and the development of a software tool to support an assessment based on ISO/IEC TR 15504* (Lobo and Salviano 2004), *An experience of learning and starting a software process improvement with PRO2PI-WORK method* (de Petri et al, 2005), *A proposal for software process improvement using ISO/IEC 15504 in a small software development organization* (Duarte 2007), and *An experience of software process assessment and improvement in a very small software development organization using ISO/IEC 15504 and PRO2PI-WORK* method (Pereira, 2006), among others, report experiences using PRO2PI-WORK method.

Most of these experiences were for software working processes. At least two of them were focus in other types of knowledge working. The article *An approach with ISO/IEC 15504 (SPICE) for improving the teaching process of information technology courses in a Professional Education Center (SENAC/GO)* (Miranda 2005) presents a proposal and an experience of improving a teaching process. The article *Strategic Management in University Research Laboratories - Towards a Framework for Assessment and Improvement of R&D Management* (Silva et al, 2007) presents a proposal for a process capability model for university research laboratories processes.

The article *Model-Driven Process Capability Engineering for Knowledge Working Intensive Organization* (Salviano, 2008a) and the slides Establishing ISO/IEC 15504-Based Process Capability Profile to Process Improvement (Salviano, 2008b) present the current version of MDPEK and PRO2PI. The article introduces the current version to software process improvement community in general and to the ISO/IEC 15504 community in particular. The slides present the current version of PRO2PI-WORK methods. This article also presents the current version of MDPEK and PRO2PI. The emphasis of this article however is the impact of Peter Drucker´s knowledge working view in both MDPEK and PRO2PI as evolutions of the current Software Process Improvement. This article is target more to the information systems and technology management community.

3. The shift to knowledge working intensive organizations

Fred Nickols (2003) comments about the shift from manual work to knowledge as recognized by Peter Drucker. Since 1959, Drucker has identified this shift as relevant paradigm shift. In *Landmarks of Tomorrow*, Drucker (1959) stated that “productive work in today's society and economy is work that applies vision, knowledge and concepts -- work that is based on the mind rather than the hand." In *The Effective Executive*, Drucker (1966) emphasized that "every knowledge worker in modern organization is an ´executive` if, by virtue of his position or knowledge, he is responsible for a contribution that materially affects the capacity of the organization to perform and to obtain results." In *Management*, Drucker (1973) said that ". . . the center of gravity of the work force is shifting from the manual worker to the knowledge worker."

In *Toward the Next Economics and Other Essays*, Drucker (1981) commented about the original work of Frederick Winslow Taylor and the knowledge work. "To make knowledge work fully productive requires many things Taylor did not concern himself with. It requires objectives and goals. It requires priorities and measurements. It requires systematic abandonment of the tasks that no longer produce and of the services that are no longer needed. It also requires organization, largely along the lines of the 'matrix organization' which Taylor reached for in his ´functional foremanship` . But making knowledge work productive also requires 'task study' and 'task management.' It requires the analysis of the work itself. It requires understanding of the steps needed their sequence and their integration into an organized process. It requires systematic provision of the information needed and of the tool needed. All of these are concepts of 'scientific management.' It does not require 'creativity.' It requires the hard, systematic, analytical and synthesizing work which Taylor developed to deal with shoveling sand, lifting pig iron, running paper machines, or laying brick."

In *The New Realities*, Drucker (1989) said that "the more knowledge-based an institution becomes, the more it depends on the willingness of individuals to take responsibility for contribution to the whole, for understanding the objectives, the values, the performance of the whole, and for making themselves understood by the other professionals, the other knowledge people in the organization." In Management Challenges for the 21st Century, Drucker (1999) recognized that "the most valuable assets of a 20th-century company were its production equipment” and concluded that “the most valuable asset of a 21st-century institution, whether business or nonbusiness, will be its knowledge workers and their productivity."

Another detail in this shift to knowledge working, as described by Drucker and again emphasized by Fred Nickols (2003), is that "work and working are fundamentally different phenomena" (Drucker, 1973). As a consequence, Knowledge work and knowledge working are also fundamentally different phenomena. "Work is a process and it has a result. Both the process and the result exist apart from the worker. The work of an insurance claims examiner, for instance, consists of a set of information-processing operations that can be specified quite apart from the examiner (e.g., in the form of algorithms). The results of this adjudication process are adjudicated claims, which also exist apart from the examiner. In the case of an automated process, these adjudicated claims exist without the examiner. Working is the activity of the worker in carrying out the work process and thereby producing its results. In the case of the claims examiner, working consists of carrying out the adjudication process (i.e., adjudicating claims). The worker, of course, is the claims examiner. Work, then, is roughly the equivalent of performance and working is definitely the equivalent of behavior. Work and working, in the world of knowledge work, are very different from what they are in the world of manual work."

In *Thinking for a living*, Thomas H. Davenport (2005) gives an overview about many aspects of knowledge worker. He comments about what is a knowledge worker; how knowledge workers differ and the difference it makes; interventions, measures, and experiments in knowledge work; knowledge work processes; organizational technology for knowledge workers; developing individual knowledge worker capabilities; investing in knowledge workers' networks and learning; the physical work environment and knowledge worker performance; and managing knowledge workers.

"For example, a knowledge worker might be someone who works at any of the tasks of planning, acquiring, searching, analyzing, organizing, storing, programming, distributing, marketing, or otherwise contributing to the transformation and commerce of information and those (often the same people) who work at using the knowledge so produced" (searchCRM, 2006). The knowledge worker includes those in the information technology fields, such as programmers, system analysts, technical writers, academic professionals, researchers, and so forth. Knowledge workers include people outside of information technology, such as lawyers, doctors, diplomats, lawmakers, marketers, managers, bankers, teachers, scientists of all kinds and students of all kinds.

4. The current SPI and a group of forces to evolve it

This shift to knowledge working, as described in the previous section, offers an interesting improvement opportunity for the current Software Process Improvement area. Software working is a type of knowledge working. The technologies and approaches to software process improving have been recognized as applicable to other areas, in addition to software. This research effort proposes the generalization of software working as the domain of process improvement to knowledge working as the domain of an evolving new characterization of process improvement.

Current SPI is based on the concept of process capability as expressed by the process capability levels. ISO/IEC 15504-2 (2003) defined six process capability levels. At level 0 (Incomplete process), the process is not implemented, or fails to achieve its process purpose. At level 1 (Performed process), the implemented process achieves its process purpose. At level 2 (Managed process), the previously described Performed process is now implemented in a managed fashion (planned, monitored and adjusted) and its work products are appropriately established, controlled and maintained. At level 3 (Established process), the previously described Managed process is now implemented using a defined process is capable of achieving its process outcomes. At level 4 (Predictable process), the previously described Established process now operates within defined limits to achieve its process outcomes. At level 5 (Optimizing process), the previously described Predictable process is continuously improved to meet relevant current and projected business goals.

The main thesis on evolving current SPI from software and system processes towards a knowledge working processes is that a given knowledge working process in a given knowledge working intensive organization may be measured and improved using the six process capability levels.

This proposal is related with one of a set of seven forces to evolve the current software process improvement. In this sense, this section presents the current software process improvement area and the group of forces to evolve it.

The concept of process has been extensively used in many human intensive areas, including software and system development. A balance and a roadmap for software process research in general are presented by Fuggetta (2000). Process is about what a group of people do to achieve some objective. In order to deal with process, the community has been using its abstraction as a process description. A process description abstracts a process as a representation model about what a group of people is doing (a descriptive model) or about what a group of people is supposed to do (a specification model).

Process improvement, as a specific area, started with the work of Shewhart in the 1930´s with his principles of statistical quality control. These principles were refined by many others authors, including, Deming, Phillip and Duran (Chrissis et al, 2007, p. 5). As mention before, Software Process Improvement (SPI) was established in the 1980´s with the development and successful usage of the four cumulative fixed SW-CMM maturity levels.

There are many definitions for SPI. This research effort introduces and uses the following definition (Salviano 2008a):

Software Process Improvement (SPI) is an approach for improving a software and system intensive organization acting in some given relevant processes based on the concept of process capability aligned with the organization strategy aiming better business results using as a reference one Process Capability Model (most of the cases a CMM/CMMI maturity level or similar)

There are seven groups of forces that urge for an evolution of the current SPI (Figure 1). Each one of these forces is a combination of industry demand and improvement opportunity. Although these forces have been somehow used in practical process improvement, most of the time in an informal way, they have not been used in their full potential.

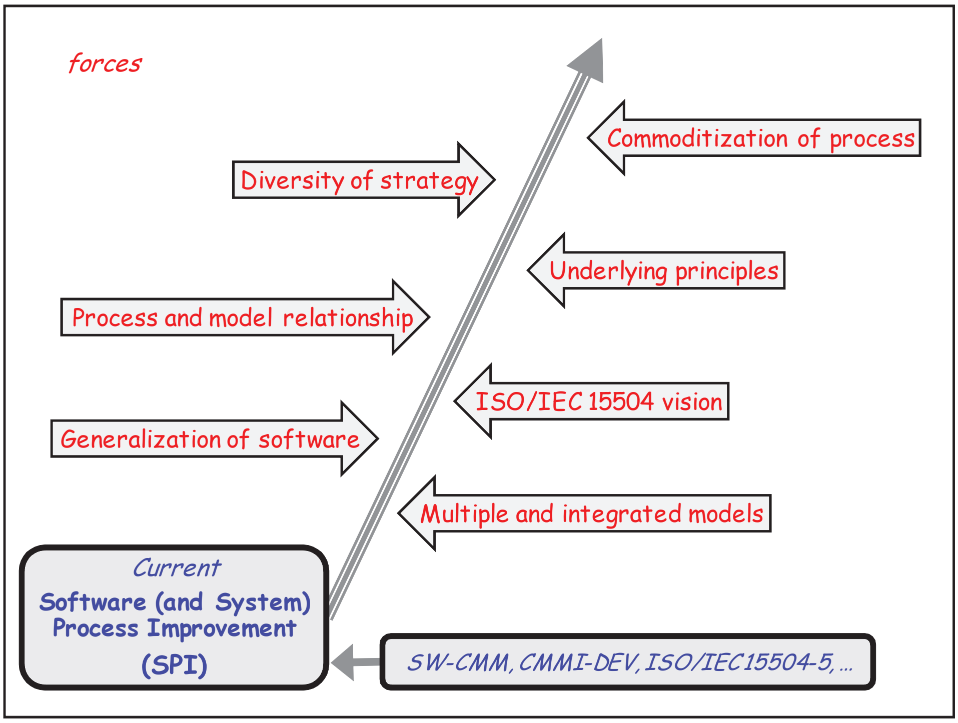

Figure 1 – Forces to evolve current SPI

4.1. Multiple and integrated models

There are many best practices models used as reference for SPI. Some of them are structured using process capability and/or maturity concepts. This research effort classifies them as Process Capability Models (PCM). A partial list of relevant PCMs includes CMMI-DEV, ISO/IEC 15504-5, iCMM (Ibrahim, 2000), eSCM-SP (Hyder et al, 2004), OPM3 (PMI 2003), COBIT (ISACA, 2007), MR-MPS (the Reference Model for the Brazilian MPS-BR Program) (Weber et al, 2007), COMPETISOFT (the Reference Model of Competisoft Ibero American Project) (Oktaba et al, 2007) and Automotive SPICE (2007). Other models are structured using different concepts. A partial list of them that have been used for SPI includes ISO 9001 (2000), PMBOK (PMI 2004), EFQM (2007), SWEBOK (Abran, 2004) and RUP.

Many organizations are using more than one model as reference for a process improvement cycle. The number of organizations using elements from, for example, CMMI-DEV, ISO 9001 and PMBOK models in a process improvement cycle is significant. Sometimes there are different teams using each model without a proper integration of them.

The current SPI provides appropriate support for using a given single model. There is a need for appropriate support for using relevant set of selected multiple models.

4.2. ISO/IEC 15504 vision

ISO/IEC 15504, also known as SPICE (Software Process Improvement and Capability Determination), is a standard for process assessment. The vision of ISO/IEC 15504, however, is beyond process assessment and also covers process capability models and process improvement. ISO/IEC 15504 introduced and consolidated many relevant concepts, including the continuous architecture, the framework of models and the generalization from software to system.

These three concepts allow more flexibility in a process improvement cycle. Although they are been used in SPI, they are not been used in their full potential. There is a need of methods to support the definition of process capability profile for process improvement from multiple models in different domains. The current SPI do not provide appropriate support for this flexibility.

4.3. Generalization of software

The term software was created as the complement of hardware. Dijkstra (1972) defined, in his ACM Turing Award speech in 1972, the humbler programmer as what is now named as software worker. SPI has generalized the software focus to system focus.

Software, however, should be generalized as explicit knowledge and therefore software process should be generalized as knowledge working process, including software and system processes. Knowledge worker and knowledge working are used in the sense defined first by Drucker (1959) ("anyone who works for a living at the tasks of developing or using knowledge"). Knowledge working is the activity of the knowledge worker. Drucker also contextualized knowledge working in a post-capitalism knowledge society (1993). Davenport (2005b) explored the Drucker´s knowledge working vision. "Knowledge workers have high degrees of expertise, education, or experience, and the primary purpose of their jobs involves the creation, distribution, or application of knowledge. Knowledge workers think for a living" (Davenport, 2005a). These views about knowledge working were described in more details in the section 3 of this article.

The vision by Armour (2003) that "probably the biggest mistake that has been consistently made since the invention of software is the view that software is some kind of a product... it is not …software is a medium in which we store knowledge. It is the fifth of such medium that has existed since the world began".

The current SPI provides appropriate support for software processes to develop products. There is a need for expanding the appropriate support to knowledge working processes.

4.4. Underlying principles

In a panel on research directions in SPI, Card pointed out that SPI "approaches have evolved or been adapted to software engineering largely without the participation of the academic research community. Does this pose a problem? My response is yes. One issue that inhibits the deployment of these approaches today is that [they] are considered competitors. In reality they are all based on very similar concepts and techniques. The packaging obscures the underlying principles. Eliciting and refining underlying principles is the role of science" (Card, 2004).

The current SPI uses different terms and definitions for similar concepts. There is a need for eliciting and refining underlying principles of SPI.

4.5. Process and model relationship

Current SPI uses a process capability model as a reference to improve processes. Although a process assessment can demonstrate that a process implements a process capability model, there is not a full model relationship between the model and the process, as the process often involves more activities than the ones abstracted by the model.

Model-Driven Engineering (MDE) is a subset of system (and knowledge) engineering in which the process heavily relies on the use of models and model engineering. Model engineering is the disciplined and rationalized production of models. Therefore MDE implies the systematic use of models as primary engineering artifacts throughout the engineering lifecycle. MDE can be applied to software, system, and knowledge engineering, and in MDE, models are considered as first class entities (Kent, 2002) (Bézivin, 2005) (Favre, 2005).

The current SPI provides appropriate support for using a maturity level or a process profile as a partial reference for improvement. There is a need for appropriate support for establishing a full relation of a process capability profile as a model for processes and process improvements, as defined by MDE.

4.6. Commoditization of process

Davenport said that "business processes are being analyzed, standardized, and quality checked. That work, as it progresses, will lead to commoditization and outsourcing on a massive scale" (Davenport, 2005b). Among the business processes, most of them are knowledge work processes. As the globalization is increasing, as pointed out by Friedman (2004), the global commoditization of process is also increasing.

The current SPI provides appropriate support for using the already consolidated generic CMMI-based maturity levels as reference for process improvement. There is a need for appropriate support for defining more specific process areas to be included in the generic maturity levels.

4.7. Diversity and importance of strategy

Strategy is very important for an organization. Strategy and business model are two complementary aspects. Porter (2000) defines that "a business model tells a logical story about who your customers are, how you deliver value to them, how you make money. A strategy explains how you'll differ from rivals: by performing different activities, or similar activities in different ways. A compelling strategy lets you sidestep "competitive convergence" — companies' tendency to become indistinguishable after copying each other's best practices."

Rifkin (2005) investigated the fit between the current CMMI-based SPI and the corporate strategy. Using the three generic strategy identified by Treacy and Wiesema (1993), Rifkin concluded that CMMI-based SPI is appropriate for organizations using operational excellence strategy, but not for the ones using product innovativeness or customer intimacy strategies. The diversity and importance of strategy definition and execution have been pointed out by Kaplan and Norton (2001) among others.

The current SPI provides appropriate support for perform a process improvement aligned with a strategy. There is a need for appropriate support for performing process improvement integrated with any strategy.

5. Proposed MDPEK

Most of the groups of forces described in the previous section have been partially identified. For some of them, partial proposals have been presented. These partial proposals are not well disseminated yet, because they cannot be satisfactorily applied in the current SPI. Actually, these forces, which are there already, demand a revision of current SPI towards a more generic area. This section presents MDPEK as a proposed evolution with a balance of the group of forces. Figure 2 presents a Concept Map for the proposed MDPEK using the ConceptMap tool. ConceptMap is a graphical tool for capturing, representing, organizing, archiving and creating knowledge (Novak and Cañ as, 2005). A Concept Map includes concepts, usually identified by a name enclosed in a box, and relationships between concepts, indicated by a connected arrow linking two concepts. In addition to the Concept Map represented in the ConceptMap tool, Figure 2 also presents three ellipses that separate the Concept Map in three parts, connected by the concept of Process Capability Profile. Figure 2 also preset the box for the concept of Process Capability Profile as it is amplified.

The key concept for MDPEK is Process Capability Profile. It provides a connection among the three sets of concepts. The next paragraphs presents a figure for each one of the three and a textual description, in which the impact of knowledge working is commented. The textual version of the MDPEK Concept Mapping definition in a box, and the comments about the definition is as normal paragraphs. Figure 3 presents the part of the Concept Map about a general definition for MDPEK. A textual description of what is represented in Figure 3 is:

{(Process Capability Profile) Model-Driven (Process Capability Engineering) for (Software, System and other Knowledge Working) Intensive Organization} (MDPEK) is a Model-Driven Engineering (MDE), using engineering body of knowledge, for improving organizations intensive in software, system and other knowledge working, integrated with business strategy aiming to better business results. MDPEK acts in relevant processes driven by Process Capability Profile.

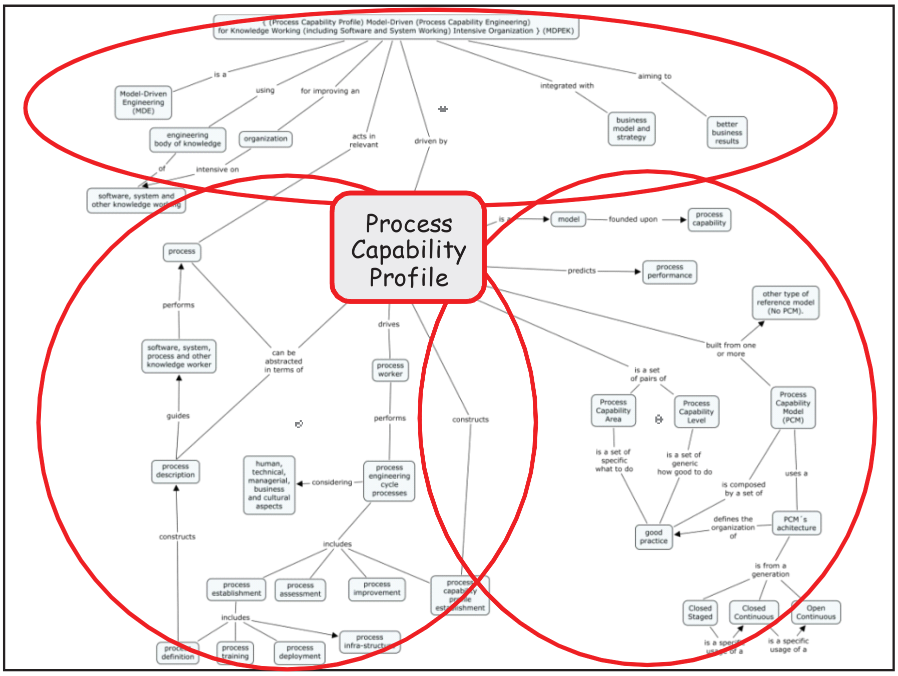

Figure 2 - Concept Map for the proposed MDPEK (Complete)

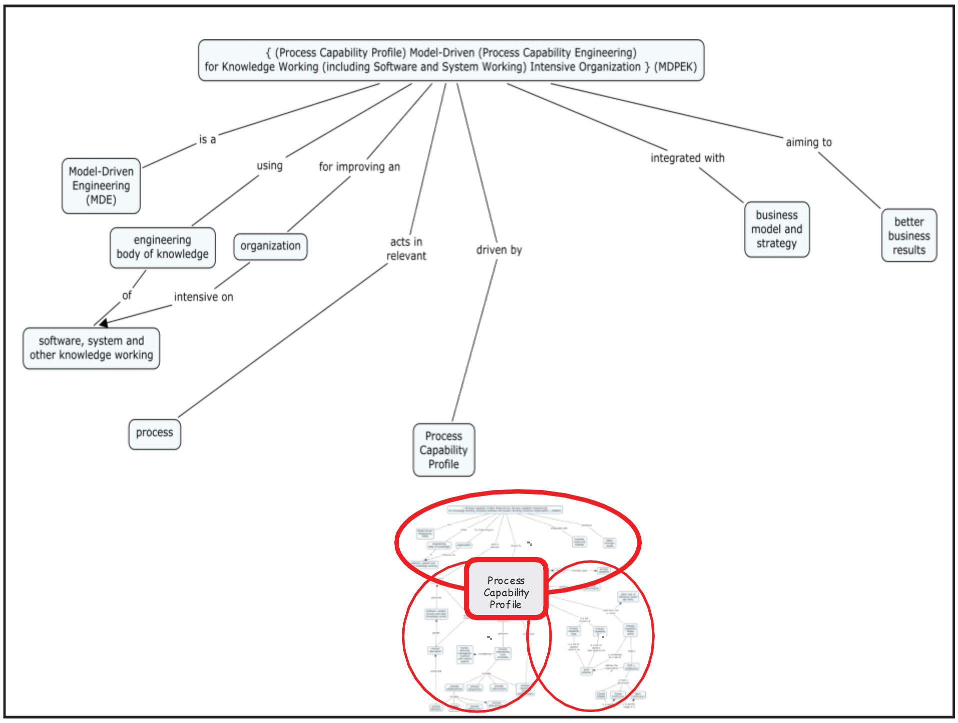

Figure 3 - Concept Map for the proposed MDPEK (part 1 of 3)

MDPEK is a specialization of MDE by the usage of Process Capability Profile model. The focus of the engineering is knowledge working processes, as defined by Drucker (1959). Table 1 repeats the definition for the current SPI and presents a definition for MDPEK in a similar structure.

Table 1 – Definitions for SPI and MDPEK

Current SPI	Proposed MDPEK
is an *approach*	is a *model driven engineering*
for improving a software and system intensive organization	for improving a *knowledge work (including* software and system*)* intensive organizations
acting in *some given* relevant processes	*identifying and* acting in *any selected* relevant processes
based on the concept of process capability	*founded upon* the concept of process capability
aligned with the organization strategy	*integrated* with the organization strategy
aiming better business results	aiming better business results
using as a reference one Process Capability Model *(most of the cases a CMM/CMMI maturity level or similar)*	*driven by a Process Capability Profile defined with elements from* one *or more* Process Capability Model*s and other types of models and references*

The current SPI does not have a precise classification; therefore the term approach is used to classify it. MDPEK, in the order hand, has a very precise classification: it is a MDE. While SPI uses as a reference one Process Capability Model, that in most cases is a fixed maturity level of SW-CMM, CMMI or similar model, MDPEK is driven (driven in the sense of MDE) by a Process Capability Profile. SPI acts in some given relevant process, the ones that implements the fixed maturity level. MDPEK allows the acting in any relevant process because any relevant and useful Process Capability Profile can be established. For the same reason a SPI is aligned with the organizational strategy while MDPEK is integrated with the organization strategy. MDPEK supports the integrated co-evolution of strategy and process improvement. The objective of SPI is to improve a software and system intensive organization while the objective of MDPEK is to improve a knowledge working intensive organization.

Figure 4 presents the part of the Concept Map about the modeling of process as process description and process capability profile.

A textual description of what is represented in Figure 4 is:

Process can be abstracted in terms of process description and Process Capability Profile.

Process Capability Profile drives process workers to perform process engineering cycle processes considering human, technical, managerial, business and cultural aspects. Process engineering cycle processes include process establishment, process assessment, process improvement and Process Capability Profile establishment. Process Capability Profile establishment constructs Process Capability Profile. Process establishment includes process definition, process training process deployment and process infra-structure. Process definition constructs process description.

Process description guides software, system, process and other knowledge worker to perform process.

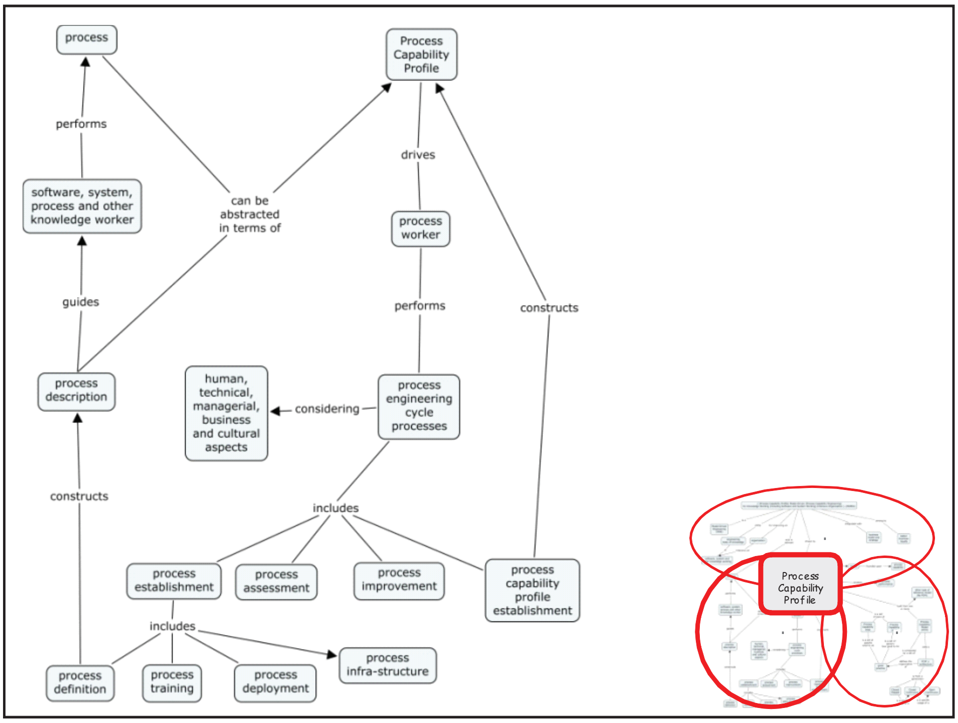

Figure 4 - Concept Map for the proposed MDPEK (part 2 of 3)

Process can be abstracted in terms of process description, using elements as, for example, role, activity and work product. Process can be also abstracted in terms of process capability, using elements as, for example, process capability area, process capability level and process capability profile. Process description is more disseminated. SPI introduced a different abstraction, under the aspect of capability. Process worker, which is another type of knowledge worker, performs process engineering cycles driven by a Process Capability Profile. Therefore, a process engineering cycle can (and should) also use MDPEK. Process engineering cycle includes all kind of activities already used by SPI with a significant addition: establishing a process capability profile. While process workers perform process engineering cycle activities, including establishing Process Capability Profile and process definition, knowledge workers perform processes.

Figure 5 presents the part of the Concept Map about a Process Capability Profile. A textual description of what is represented in Figure 5 is:

Process Capability Profile is a model in process capability. Process Capability Profile predicts process performance. Process Capability Profile is built from one or more Process Capability Model (PCM) or other type of reference model (No PCM).

Process Capability Profile is a set of pairs of Process Capability Area and Process Capability Level. Process Capability Area is a set of specific “what to do good practices”. Process Capability Level is a set of generic “how good to do good practices”.

Process Capability Model (PCM) is composed by a set of good practices. Process Capability Model (PCM) uses PCM´s architecture.

PCM´s architecture defines the organization of good practices. PCM´s architecture is from a Closed Staged, Closed Continuous and Open Continuous generation. Closed Staged is a specific usage of a Closed Continuous. Closed Continuous is a specific usage of Open Continuous.

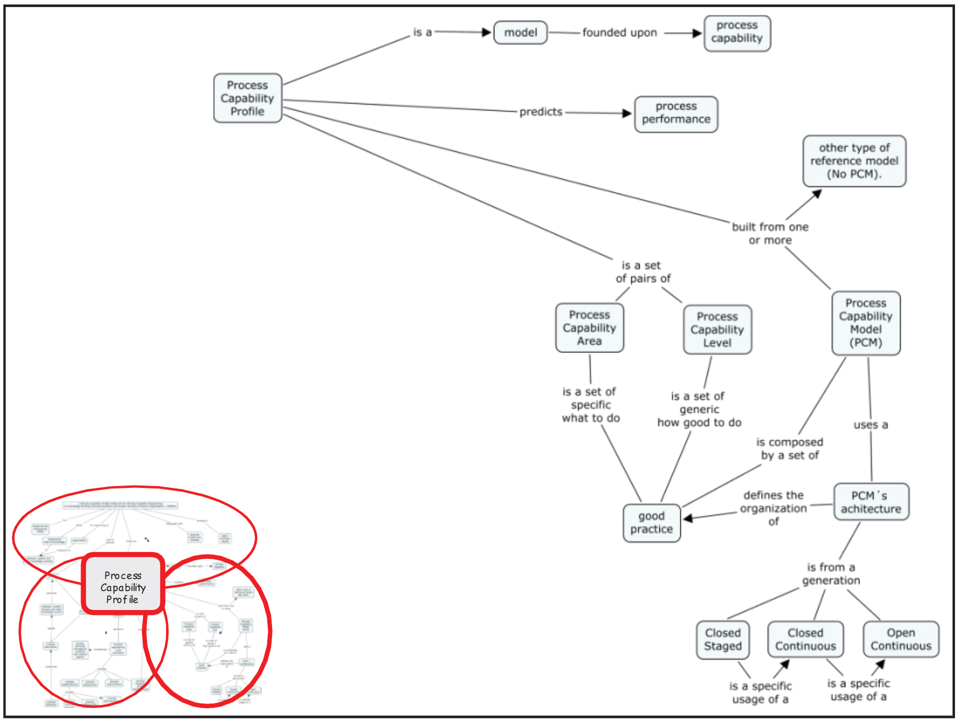

Figure 5 - Concept Map for the proposed MDPEK (part 3 of 3)

Process capability is the general conceptual reference for MDPEK. Process Capability Profile is a model of a process under the aspect of process capability. Process Capability Area is defined in this research effort as unified term for CMMI process area and ISO/IEC 15504 process. The architecture of a PCM defines how its elements are structured.

Current SPI consider two alternative architectures (or representations) for process capability models: staged and continuous. This research effort defends that they are not alternatives, but generations. There are three generations: closed staged, closed continuous and open continuous (Salviano, 2006) (Salviano et al, 2004). Closed staged is the current staged architecture. It is closed because the maturity levels are predefined and they cannot be changed, as for example, the staged representation of CMMI-DEV. Closed continuous is the current continuous architecture, when the set of process areas from which a process capability profile can be defined, are predefined, as for example the continuous representation of CMMI-DEV. Note that a maturity level is an example of a process capability profile. Therefore Closed continuous is the following generation for closed staged. Open continuous is a continuous architecture with any set of process areas, as for example, the ISO/IEC 15504-5.

This conceptual map for the proposed MDPEK expressed in the ConceptMap tool is named “Sinal Aberto” that is the Portuguese term for Green Light in the sense of traffic lights. The name “Sinal Aberto” is after the music album cover named “Sinal Aberto”. Figure 6 shows the album cover, the conceptual map and some graphical indications to support the rationality about their resemblance.

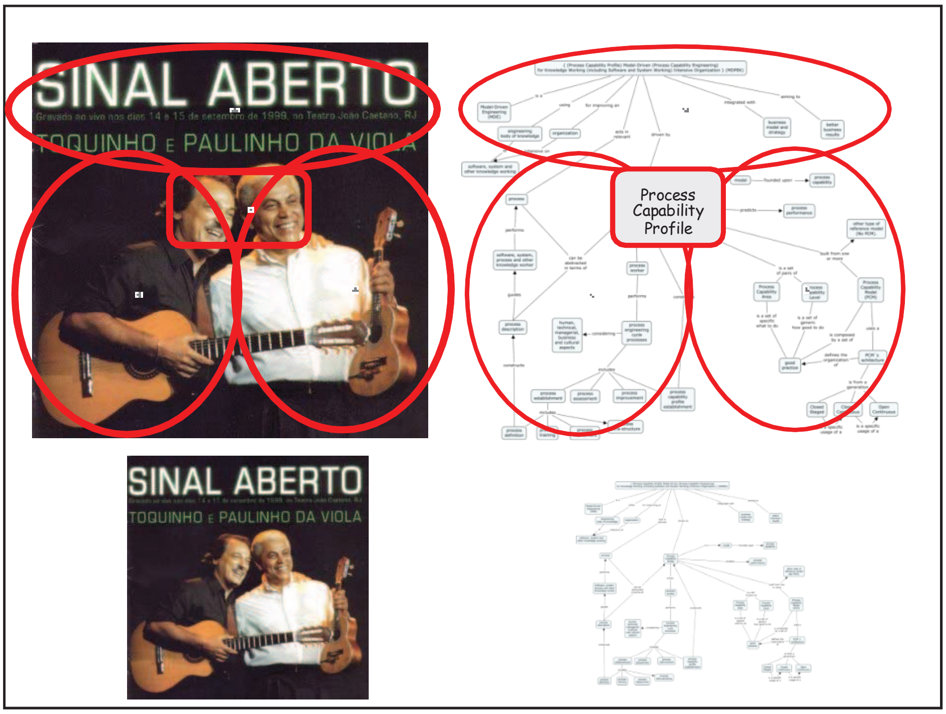

Figure 6 – Concept Map for MDPEK and “Sinal Aberto” album cover

6. Exemplar methodology for MDPEK

Following the industry-as-laboratory research approach, an exemplar methodology for MDPEK is been defined and used. This methodology is named PRO2PI (Process Capability Profile to Process Improvement). Figure 7 illustrates a first overview of PRO2PI methodology.

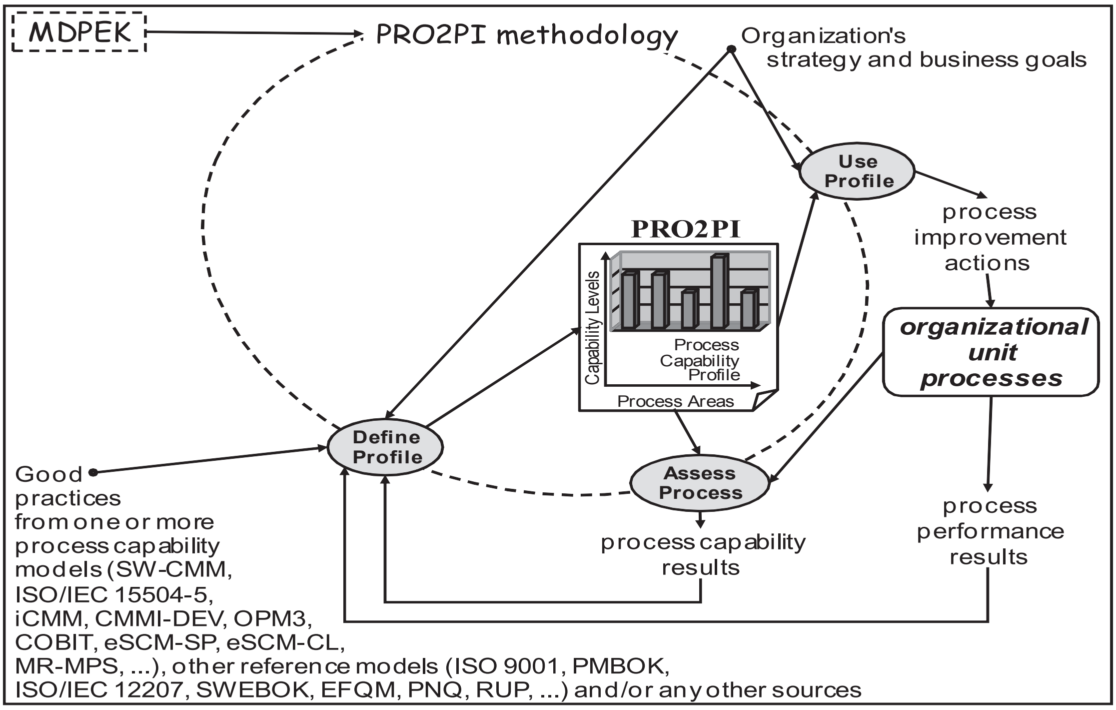

Figure 7 – First overview of PRO2PI

A PRO2PI can be defined or evolved integrated with the organization´s strategy and business goals, using selected good practices from one or more models and/or from any other source. A PRO2PI may also be defined using elements from a single model. The definition of this PRO2PI can use also analyses from the process capability results of a process assessment and from the process performance results of the current process. This definition or evolution does not need to be done at once. Rather it is better to do it in an incremental way. It is represented by the DefineProfile function in Figure 7.

A process improvement cycle uses a PRO2PI, again integrated with the organization's strategy and business goals, to plan and realize process improvement actions to change the organization unit process towards a process driven by the PRO2PI. This usage of PRO2PI is represented by the UseProfile function in Figure 7.

The organizational unit process can be examined using a process assessment oriented by a PRO2PI. This process assessment produces a process capability results. This assessment is represented by the AssessProcess function in Figure 7. These four functions represent an overview of the PRO2PI methodology.

Figure 8 illustrates a second overview of PRO2PI methodology, including the function to define model.

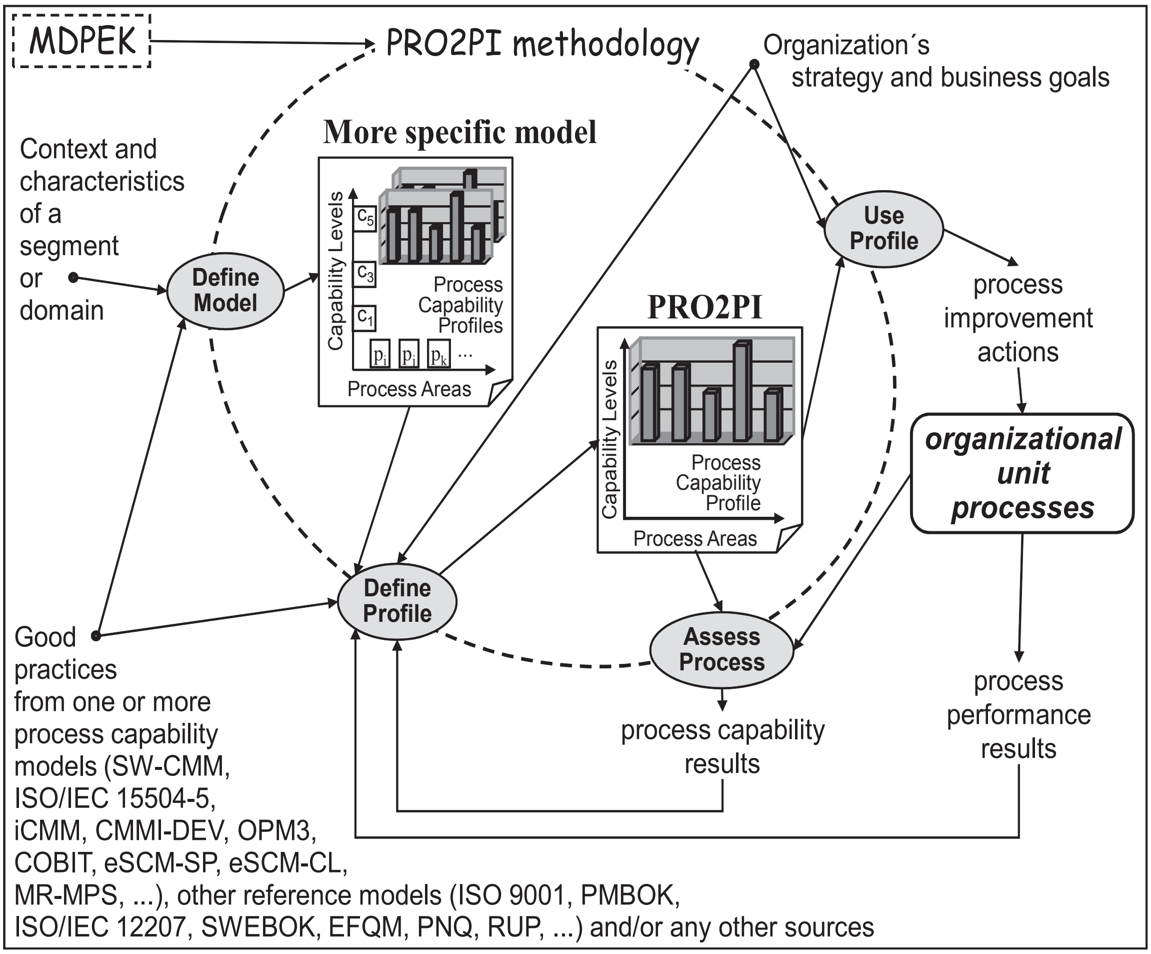

Figure 8 – PRO2PI Overview

A more specific model for a segment or domain can be defined or improved, using selected good practices from more generic models and/or from any other source. This definition or evolution is represented by the DefineModel function in Figure 8. This more specific model can be a staged model, with a hierarchy of process capability profiles, or a continuous model, with a set of process areas and process capability levels.

PRO2PI methodology has been used with the support of five elements:

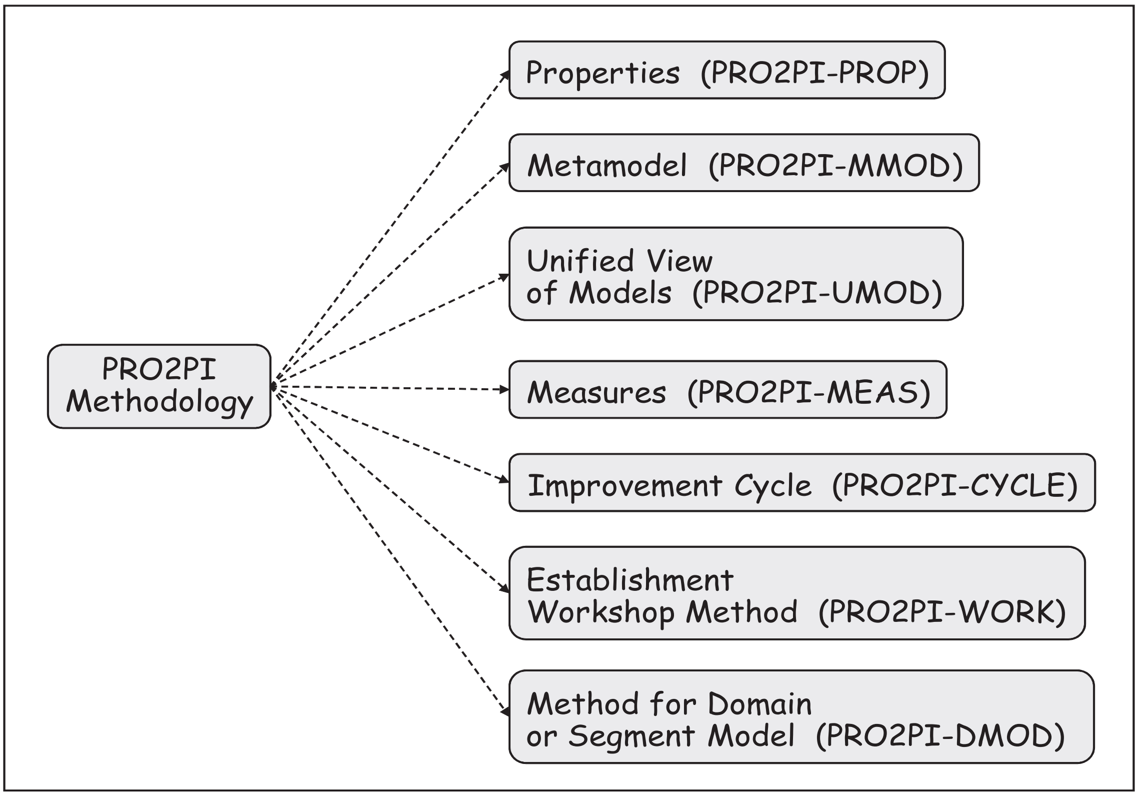

Figure 9 – PRO2PI Elements

The first element is named as PRO2PI-PROP. It is a set of eight properties for a good PRO2PI. These properties are: relevant, feasible, opportunistic, systemic, representative, traceable, specific and dynamic. A PRO2PI is an engineering model. Therefore, it should have the properties of an engineering model and some more specific properties of a process capability model. A model should follows the limited substitutability principle (Bézivin 2005): "to be able to answer some specific sets of questions in place of the system, exactly in the same way the system itself would have answered similar questions". Bran Selic (2003), for example, proposed five properties or characteristics for an engineering model: abstraction, understandability, accuracy, predictiveness and inexpensive. To be useful and effective for driving a process improvement engineering cycle, i. e., to be a PRO2PI, a process capability profile should possess, to a sufficient extend, the eight properties (relevant, feasible, opportunistic, systemic, representative, traceable, specific and dynamic) as illustrated in Figure 10.

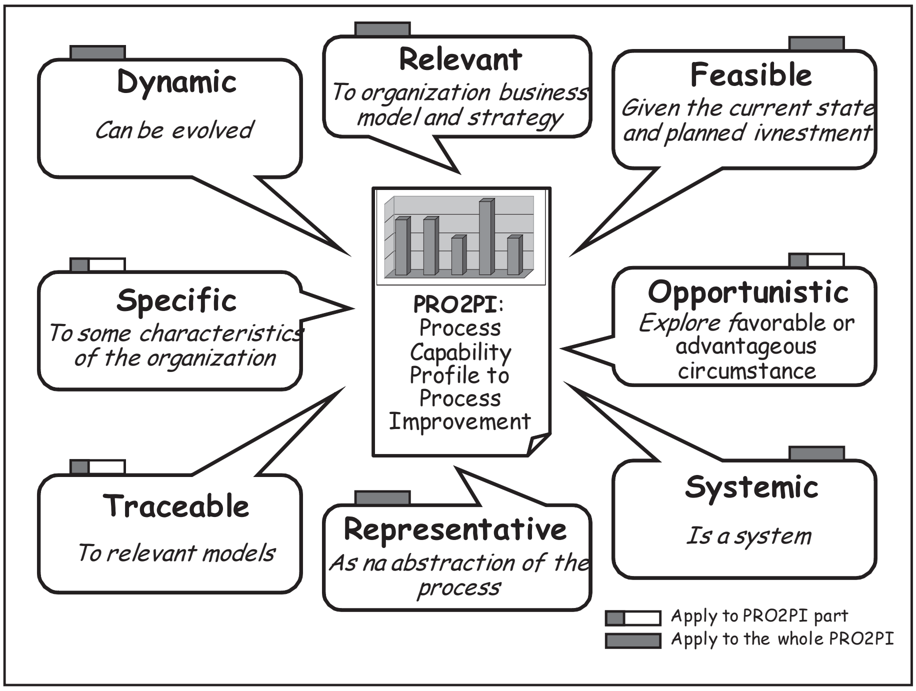

Figure 10 – PRO2PI Properties

The second element is named as PRO2PI-MMOD. It is a metamodel for process capability profile models and for process capability models. The base for this metamodel is a set of unified basic concepts. The set of unified basic concepts for process capability models is presented in (Salviano and Figueiredo, 2008). It is represented as the Geraes Class Diagram as illustrated in Figure 11 defined with the TopCased (2007), an Eclipse Modeling Framework (EMF, 2007) plugin to the definition of metamodels based on Ecore.

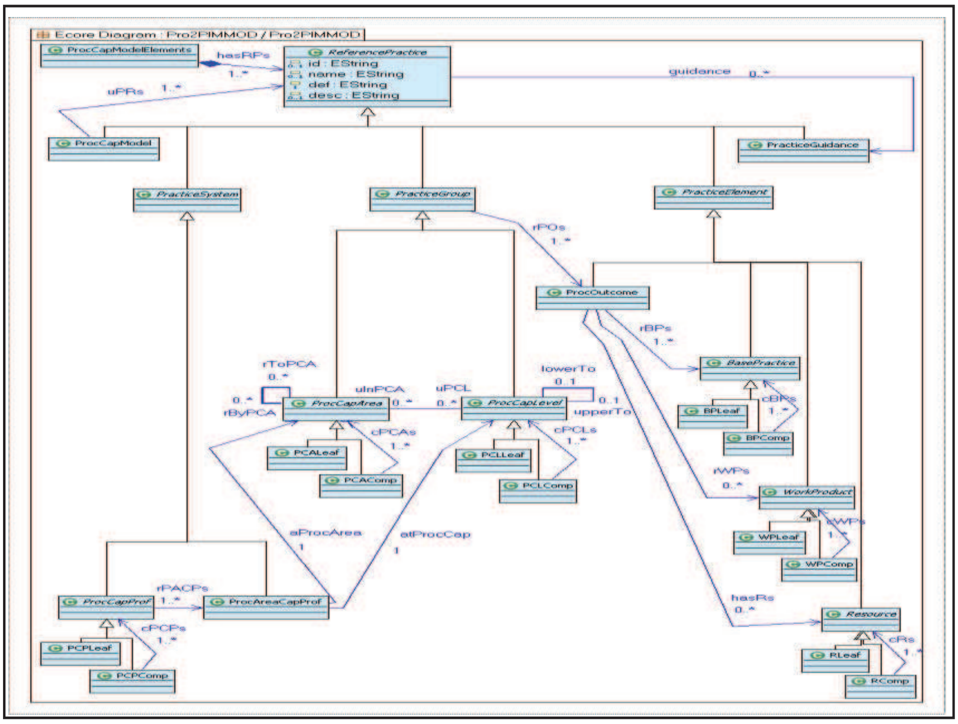

Figure 11 – Geraes Class Diagram in Eclipse Ecore

In Figure 11, for legibility's sake, the words Process, Capability and Profile are replaced by Proc, Cap and Prof.

An organization defines and uses a *ProcessCapabilityProfile* as a process capability model of its current or future process. A *ProcessCapabilityProfile* is composed by one or more *ProcessAreaCapabilityProfiles*. Each *ProcessAreaCapabilityProfile* is composed by a reference to one *ProcessCapabilityArea* at one *ProcessCapabilityLevel*. Each *ProcessCapabilityArea* and each *ProcessCapabilityLevel* is composed by one or more *ProcessOutcomes*. Each *ProcessOutcome* is composed by one or more *ProcessElements*.

A *ProcessCapabilityModel* is a collection of one or more *ReferencePractices*. *ReferencePractice* is an abstract super class for (with the exception of *ProcessCapabilityModelElement*) all classes for any element of a process capability model, including the *ProcessCapabilityModel* itself. There are four attributes for *ReferencePractice*: id (identification), name, def (definition) and desc (description). A *ProcessCapabilityModelElement* is a collection of all *ReferencePractices*. A *ReferencePractice* may refer to one or more *PracticeGuidances*. *ProcessCapabilityModel* and *PracticeGuidance* are two concrete subclasses of *ReferencePractice*. There are also three more subclasses of *ReferencePractice*: the abstract classes *PracticeElement*, *PracticeGroup* and *PracticeSystem*.

PracticeElement has four subclasses: *ProcessOutcome*, *BasePractice*, *WorkProduct* and *Resource*. *PracticeGroup* has two subclasses: *ProcessCapabilityArea* and *ProcessCapabilityLevel*. *PracticeSystem* has two subclasses: *ProcessCapabilityProfile* and *ProcessAreaCapabilityProfile*.

ProcessAreaCapabilityProfile represents a *ProcessCapabilityArea* at a *ProcessCapabilityLevel*. *ProcessCapabilityProfile* is a collection of one or more *ProcessAreaCapabilityProfiles*. A *ProcessCapabilityProfile* is a collection of one or more *ProcessAreaCapabilityProfile*. Each *ProcessAreaCapabilityProfile* is a *ProcessCapabilityArea* at a *ProcessCapabilityLevel*.

Each *ProcessCapabilityArea* and *ProcessCapabilityLevel* is a collection of one or more *PracticeElements*. A *PracticeElement* is a collection of one or more *ProcessOutcomes*. A *ProcessOutcome* is a collection of one or more *BasePractices*, zero or more *WorkProducts* and zero or more *Resources. ProcessOutcome*, *BasePractice*, *WorkProduct* and *Resource* are subclasses of *ProcessElement*.

The concrete class *ProcessAreaCapabilityProfile* makes a connection between *PracticeSystem* and *PracticeGroup*. The concrete class *ProcessOutcome* makes a connection between *PracticeGroup* and *PracticeElement*.

ProcessCapabilityArea, ProcessCapabilityLevel, ProcessOutcome, BasePractice and *ProcessCapabilityProfile* are modeled with two more subclasses each, using the Composer Design Pattern (Gamma et al, 1994). This design pattern addresses the need to compose objects into tree structures to represent part-whole hierarchies. Composite lets clients treat individual objects and compositions of objects uniformly. Each one of these classes is modeled as an abstract class with two concrete subclasses each: the first one models the composition relation (with the Comp suffix) and the second one models the leaf element (with the suffix Leaf). The composition and the leaf element use as a name the aggregation of the initials of the root element name (PCA, PCL, PO, PP, PCP and PCM) followed by the suffix Elem or Comp.

The third element is named as PRO2PI-UMOD. It is a unified view of elements and structure of relevant process capability models. PRO2PI-UMOD is represented in PRO2PI-MMOD. PRO2PI-UMOD facilitates the integrated usage of relevant process capability models selected elements.

The fourth element is named PRO2PI-MEAS. It is a set of measures about a PRO2PI. It includes measures to qualify the degree a given PRO2PI satisfy each one of the eight PRO2PI properties.

The fifth element is named PRO2PI-CYCLE. It is composed by six phases for a process improvement cycles including a function to define, update or use a PRO2PI Figure 12.

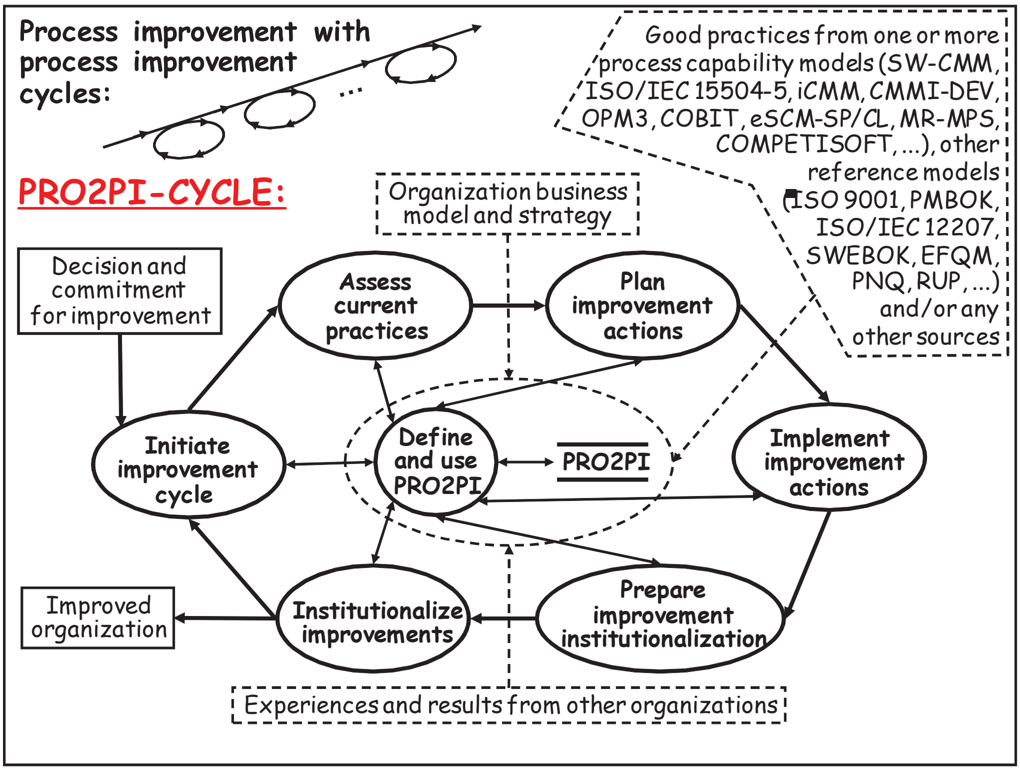

Figure 12 – PRO2PI-CYCLE

The sixth element is named PRO2PI-WORK. A method for the initial phases of this cycle for a workshop to establish a process capability profile to process improvement.

The seventh element is named PRO2PI-DMOD. PRO2PI-DMOD is an initial attempt towards a method for defining a model for a more specific domain or segment.

7. Related, current and further work

MDPEK vision includes a future with:

- a market for sets of process capability areas, where each set provides a codification of knowledge of specific "what to do good practices" for a domain;
- a metamodel for process capability models and process capability profiles;
- methodologies for establishing process capability profiles; and
- a sustainable model for defining and using process capability profiles

There are already some considerations about issues and forces for current SPI. Some of them are commented in this section as related work.

Conradi and Fuggetta (2007) reported challenging issues with existing SPI approaches and proposed thesis as initial attempts to provide directions and indications on how to address these challenging issues. The International Process Research Consortium (IPRC, 2007) identified nine forces driving the Process Research Framework: (1) value add, (2) business diversification, (3) technology change, (4) system complexity, (5) product quality, (6) product turnaround, (7) regulation, (8) security and safety, and (9) globalization. MDPEK considers most of these issues and forces.

There are already efforts to integrate models and methods for process improvement, as for example, the CMMI, ISO/IEC 15504, and iCMM themselves, the harmonization of ISO/IEC 15504 and CMMI (Rout and Tuffley, 2007), and initiatives to understand and integrate selected models and methods, as, for example, the Integrated System Framework for Excellence (Vasques, 2007), Enterprise SPICE (The SPICE User Group, 2007), the Integrated Approaches to Six Sigma and Domain Practices (Siviy, 2006), and the Unified Process Improvement Approach for Multi-Model Improvement Environments (Kirwan et al, 2006). MDPEK provides a new generic area to improve SPI and considers most aspects of these integrations efforts as examples. In 2008, the efforts described by Siviy (2006) and Kirwan et al (2006) have been combined in a project process improvement in multimodel environments (PrIME) (Siviy and Kirwan, 2008).

ISO/IEC 15504-4 (2004) and Van Loon (2007) provide guidelines to define process capability profiles. MDPEK goes beyond that and again these guidelines are examples.

There is also a proposal for Model-Driven Process Engineering by Breton and Bézevin (2001). This proposal, however, uses the term process engineering as more related with process description, while MDPEK is process engineering more related with process capability.

MDPEK is part of an ongoing research effort. Among the current activities are the development and utilization of a process capability model for university laboratory processes (Silva et al, 2007) and a proposal for unifying basic concepts (Salviano and Figueiredo, 2008).

8. Conclusion

Peter Drucker said that in the knowledge society (also named as post-capitalism society) people need to learn how to learn. Actually, the subjects to be learned may be less important than the student´s capacity to identify the subject to be learned, continuously learning and the motivation to do so. The knowledge society demands lifelong continuous learning that needs discipline (Drucker, 1993, p. 193).

MDPEK vision is that in the knowledge society, organizations need to learn how to improve their processes (which is how they learn). Actually, the processes to be improved (and the process capability areas used as reference for improvement) may be less important than the organization´s capacity for identify the processes to be improved (and identify or create process capability areas to be used as reference for improvement), continuously improving their relevant process integrated with the strategy, and the motivation to do so. The knowledge society demands lifelong continuous learning that needs discipline. MDPEK in general and the process capability levels supports such discipline.

The proposed MDPEK introduced in this article intended to be a useful attempt to address the necessary evolution of current SPI considering the set of forces, including the generalization of software with the shift to knowledge working intense organizations [Figure 13].

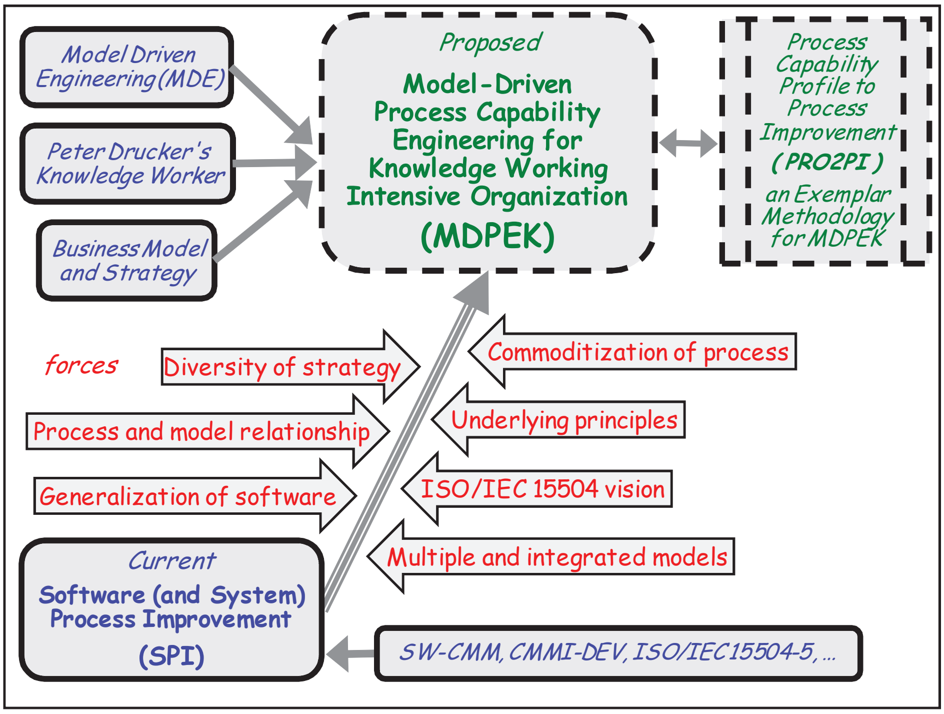

Figure 13 – Overview of current SPI, forces and MDPEK/PRO2PI

The current Software (and System) Process Improvement (SPI) has been established with success around the SW-CMM model at the first time and later around the CMMI-DEV and ISO/IEC 15504-5 models. A set of eight forces, however, urges for an evolution of current SPI. These groups of forces are: multiple and integrated models, ISO/IEC 15504 vision, generalization of software, process and model relationship, underlying principles, diversity of strategy and commoditization of process. For this evolution, three areas provide additional references: Model-Driven Engineering (MDE), Peter Drucker's Knowledge Worker, and Business Model and Strategy. The proposed evolution is defined as a Model-Driven Process Capability Engineering for Knowledge Working Intensive Organization (MDPEK). MDPEK has been conceived together with the Process Capability Profile to Process Improvement (PRO2PI). PRO2PI is an exemplar methodology for MDPEK.

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