A Strategy for Painless Harmonization of Quality Standards: A Real Case

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Abstract. Globalization, is pushing companies towards continuous improvement. Quality frameworks addressing SPI practices are classifiable in ones describing: "what" should be done (ISO9001,CMMI); "how" it should be done (Six Sigma, GQM). When organizations adopt improvement initiatives, many models may be implied, each leveraging best practices for addressing improvement challenges. This may generate confusion, extra effort and cost, as well as increase the risk of inefficiencies and redundancies. So, it is important to harmonize quality frameworks, i.e. identify intersections and overlapping parts and create a multi-model improvement solution. Our aim is to propose a Harmonization Process supporting organizations interested in introducing/improving SPI practices. We present: a *what/what* combination of ISO9001 and CMMI-DEVv.1.2 models in the direction from ISO-CMMI; and detail the *what/how* perspective by showing how GQM is used to define operational goals that address ISO9001 statements, reusable in CMMI appraisals. The harmonization process has been applied to a SME certified ISO9001:2000.

Keywords: Harmonization, Mapping, SPI, Multi-model Process Improvement, GQM, CMMI-DEV, ISO9001.

1 Introduction

The increasing rate of globalization, following to the competition of international markets, is pushing companies towards continuous innovation and improvement of processes and products. This asks for methods and approaches able to manage business processes, as well as processes for measuring and controlling quality.

As so, quality management and SPI in general become of strategic importance not only as internal factor for improvement, but also as success factor once a company decides to overlook the global market and interacts with contractors, suppliers and

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customers. In this scenario, SPI efforts are motivated by the need for achieving competitiveness advantage related to aspects like customer satisfaction, business profitability, market share, product and service quality, cost reduction and so on. Furthermore, the need for standardized quality management systems is important in a market where, from a few years this way, a lot of attention is being paid to the quality of products and services offered.

Literature offers numerous reference models, standards, best practices, technologies for addressing software process improvement practices. In general we can classify the frameworks into two groups: the ones that describe *what* should be done, like for example ISO 9001 [1] and CMMI [2], and the ones that describe *how* it should be done, just to cite a few: Six Sigma, Team Software Process [3], PMBOK [4], GQM [5], [6]. All offer unique features and address particular problems. In some cases they are discipline-oriented, others relate to the enterprise as a whole. When organizations decide to adopt improvement initiatives related to different organizational functions and different hierarchical levels, many models may be implied, each leveraging the best practices provided in order to address the improvement challenges in the best of ways. However, this may at the same time generate confusion and overlapping activities as well as extra effort and cost. This risks to generate a series of inefficiencies and redundancies that end up leading to losses rather than effective process improvement. Consequently, it is important to move towards a harmonization of quality frameworks in order to identify intersections and overlapping parts and create a multi model improvement solution.

A recent study [10] has pointed out that more and more product development organizations are tending towards multi-certifications with specific attention to ISO 9001, CMM and ITIL technology standards respectively. In Europe interest in multi-certifications has increased especially because in some sectors and in calls for bids, on behalf of government institutions and public administrations, they are compulsory and are explicitly requested. Our work focuses on ISO and CMMI. Although the two constellations have been developed independently and have different purposes they have intersections and connections with each other. In this sense our contribution is twofold:

- investigate to what extent the practices described in the CMMI-DEV and ISO 9001 models are related (i.e. what/what relation);
- how a certified organization implements its quality model by using a GQM-based approach (i.e. what/how relation).

Our Harmonization Process, presented in this work analyzes both these aspects, as well as applies them to real industrial data of an enterprise certified ISO 9001:2000.

More precisely, our aim in this work is to propose a harmonization process that supports organizations interested in introducing or improving their practices for quality management and software development. In this sense and considering that mapping is one of the most widely used specific strategies for the harmonization of models [11], we present a *what/what* combination of ISO 9001 and CMMI-DEV v.1.2 models, in the direction from ISO to CMMI, as well as an application of the comparison to an Italian SME providing detail on the what/how perspective by combining ISO 9001 & GQM, i.e. how measurement goals are defined to operationally address ISO statements in order to be possibly reused in a CMMI appraisal.

The rest of the paper is organized as follows: Section 2 provides a quick overview of the frameworks considered (ISO 9001:2000, CMMI DEV v.1.2, GQM) and then presents the related works from other research works. Section 3 outlines the Harmonization Process which is described with respect to the comparison and application subprocesses. Each step of the process is described with respect to the outcomes of an application to a real case. Finally conclusions are drawn.

2 Background

In this section, we first of all outline a general view of ISO 9001:2000 and CMMI DEV v.1.2 and then we present the related works from other research.

2.1 ISO 9001:2000 and CMMI v.1.2 Overview

Next will provide some general and synthetic information to the reader on the three quality models that we have considered in our work.

ISO 9001:2000
ISO 9001:2000 is an international standard that gives requirements for an organization's Quality Management System ("QMS"). It is part of a family of standards published by the International Organisation for Standardisation ("ISO") often referred to collectively as the "ISO 9000 series". A process model based on the QMS is shown in figure 1. The objective of ISO 9001:2000 is to provide a set of requirements that, if effectively implemented, will provide the organization with confidence that they can provide goods and services that: meet needs and expectations and comply with applicable regulations. The requirements cover a wide range of topics, including supplier's top management commitment to quality, its customer focus, adequacy of its resources, employee competence, process management, quality planning, product design, review of incoming orders, purchasing, monitoring and measurement of its processes and products, calibration of measuring equipment, processes to resolve customer complaints, corrective/preventive actions and a requirement to drive continual improvement of the QMS.

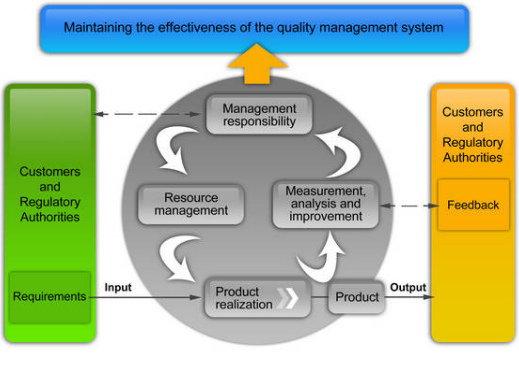

Fig. 1. Model of a process based QMS

CMMI

Capability Maturity Model Integration (CMMI) is a process improvement approach that provides organizations with the essential elements of effective processes that ultimately improve their performance. Developed by a group of experts from industry, government, and the Software Engineering Institute (SEI) at Carnegie Mellon University, CMMI models provide guidance for developing or improving processes that meet the business goals of an organization. It can be used to guide process improvement across a project, a division, or an entire organization [12]. An organization cannot be certified in CMMI; instead, an organization is appraised. Appraisals are typically conducted for one or more of the following reasons: to determine how well the organization's processes compare to CMMI best practices, and to identify areas where improvement can be made; to inform external customers and suppliers of how well the organization's processes compare to CMMI best practices; to meet the contractual requirements of one or more customers.

Level	*Continuous Representation Capability Levels*	*Staged Representation Maturity Levels*
Level 0	Incomplete	N/A
Level 1	Performed	Initial
Level 2	Managed	Managed
Level 3	Defined	Defined
Level 4	Quantitatively Managed	Quantitatively Managed
Level 5	Optimizing	Optimizing

Fig. 2. Comparison of Continuous and Staged Representation Levels

Depending on the type of appraisal, the organization can be awarded a maturity level (Staged Representation) rating (1-5) or a capability level achievement profile (Continuous Representation). Figure 2 summarizes both representations in levels.

Goal Question Metrics (GQM)

The main idea behind GQM is that measurement should be goal-oriented and based on context characterization.

According to [5], [25], the measurement model has three levels (figure 3):

- Conceptual Level (GOAL): a goal is defined for a specific purpose based on the needs of the organization, for a variety of reasons, with respect to various quality models, from various points of view, in a particular environment.
- Operational Level (QUESTION): a set of questions is used to characterize the way the achievement of a specific goal is going to be performed.
- Quantitative Level (METRIC): a set of collectable data is associated with every question in order to quantitatively answer them.

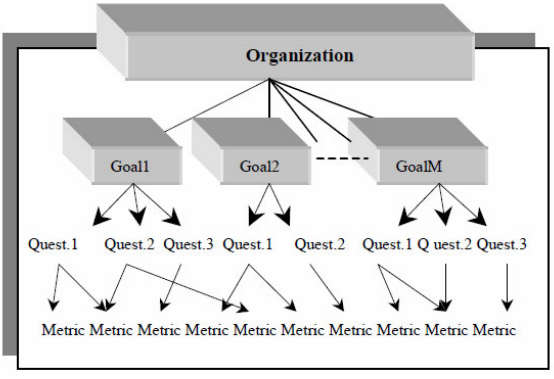

Fig. 3. Goal Question Metrics Structure

In the interpretation phase, measurements are used to answer the questions and to conclude whether or not the goal is achieved. Thus, GQM uses a top-down approach to define metrics and a bottom-up approach for analysis and interpretation of measurement data. GQM defines a dynamic quality model on which basing an effective measurement program. Quality goals reflect the business strategy and GQM is used to identify and refine goals based on the characteristics of software processes, products and quality perspectives of interest.

2.2 Related Works

Although the number of related works on the harmonization of multiple models is small, in the last 4 years there is within the software engineering community an ever-increasing interest in defining solutions for this type of environments. This is evidenced by the initiatives and projects performed or being carried out, such as: PrIME project [16], ARMONÍAS project [17], Enterprise SPICE [18]. Furthermore, some experiences reported in literature involve comparisons and mapping between different versions of CMMI and other processes models, including ISO 9001. Among these, some relate to what/what combinations such as CMMI & ISO; more precisely:

- A mapping between two models is described in [19].
- In [7] a proposal that integrates the content of these two models is introduced.
- A proposal for transiting from ISO 9001 to SW-CMM is defined in [8]
- In [9] a comparison and a correspondence between ISO 9001 and SW-CMM are shown.
- In [20] an recent comparative analysis of the CMMI DEV v.1.2 and the ISO 9000 family is discussed.
- An ontology for the integration of these quality standards for collaborative projects is show in [21].
- Some works that involve relationships, comparisons and mapping between different versions of CMM(I) and SPICE (ISO/IEC 15504) can be found in [15], [22], [23], [24].

However, in all these comparisons none of the studies refer to the latest versions of these models (with the exception of the work presented in [20]); none describe the specific process used to carry out the comparison and/or mapping. Consequently the approach is not replicable from others. They are all theoretical works and none have been applied to real enterprise data. Furthermore, no insight is given on the what/how perspective. None of the studies adopt or indicate a strategy used for defining the measurement goals with the aim of harmonizing the models. The contribution of the proposal described in this paper consists in taking into account and addressing the issues above in order to provide organizations a specific stepwise strategy for harmonizing quality standards.

3 Harmonization Process

Any organization that have a software process improvement (SPI) strategy follow it as a means for assessing and assuring quality. They will most likely have their business, organizational and production processes formalized in some way. The processes can be formally defined and conform to some kind of SPI framework (CMMI; ISO, TQM, SPIQ, etc.) [13], or can be informally defined based on the previous history and experience of the organization. Independently of the framework adopted, the description of the processes contain details on the: activities, procedures, products produced, relations with other activities, tools and technologies used to execute them; the quality model (i.e. goals, metrics and interpretations) defined to assess the achievement of desired quality levels. In this sense, the quality model must be structured so that its goals (G_i) relate to specific process model grains (P_j) specified by the SPI framework referred to (eg. Process areas for CMMI, statements for ISO 9001, etc.), forming a matrix [GxP] (Table 1) where each crossing (G_i, P_j) means that the goal G_i measures that process grain P_j.[5].

Table 1. Goal x Process Model matrix

GOALS	Process Grain				
	P_1	P_2	P_j	...	P_n
G_1	X				
G_2		X			
G_i			X		X
...					
G_k	X		X		

In this scenario it is reasonable that an organization with an organized SPI strategy may to want to or have to conform to other frameworks due to explicit requests on behalf of contractors, public administrations or restrictions in bids. For simplicity, let us define the process model of the current SPI framework $P_{Current}$, and the process model of the new SPI framework the organization wants to conform to as P_{Target}. An interesting question is therefore: How can an organization painlessly shift from $P_{Current}$ to P_{Target} and reuse as much possible of the information produced in $P_{Current}$? Given an SPI framework (eg. ISO or CMMI), how can an organization operationally define a quality model (i.e. measurement goals and interpretation models) for it?

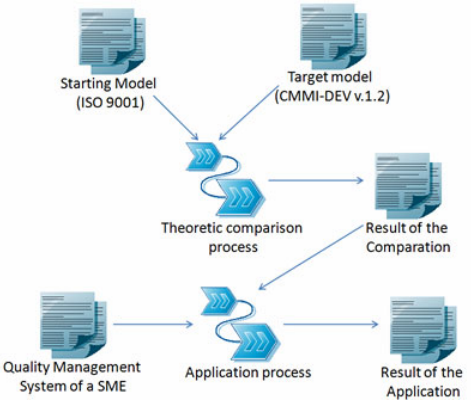

Fig. 4. Harmonization Process

To answer these two questions we have defined a Harmonization Process made up of two sub-processes: a comparison process and an application process. The process is general and can be instantiated to any couple of SPI frameworks ($P_{Current,}$ P_{Target}). In this specific work, we have considered $P_{Current}$: ISO 9001:2000 and P_{Target}: CMMI-Dev A general representation is given in Figure 4. This section will primarily focus on the application sub-process, as the comparison one has been described more in detail in a previous work [14]. In the next two sections we will provide a description of the two processes, with more detail on the application process.

3.1 Comparison Sub-Process

The Comparison Sub-Process is the first part of the harmonization of any two SPI frameworks. This activity followed the process for mapping described in [15]. In this specific case, the comparison process considers the ISO 9001:2000 standard as starting point, i.e. supposing that an enterprise is currently certified ISO 9001, and sees CMMI v1.2 as the target one. The outcome of this sub-process is a document that maps the two models and points out the relations between them, i.e. in this specific case, the extent to which ISO satisfies CMMI requirements and whether there are any overlapping areas that possibly allow to reuse information and data collected in the ISO certification to assess any of the CMMI levels, allowing for a quantitative analysis (*what/what* comparison). The mapping is tracked on a spreadsheet having the ISO statements as rows and CMMI Process Areas with detailed Practices as columns. The overlapping areas are filled with colour. An extract related to the ISO statement "4. Quality Management System" and CMMI process area "Organizational Process Definition + IPPD" is shown in Figure 5. The mapping criteria was iterated for each statement, one at a time, with respect to every process area.

This sub-process steps have been completely described in more detail in a previous work by the authors [14]. For completeness sake we have however provided a brief description to give the reader a general picture of the approach and better understand the application sub-process. The approach is general and stepwise. So if the SPI standards change, the instantiations change, but the approach remains the same.

The outcome of the mapping is a document (Result of Comparison) that specifies the correlations between the two models traced on the spreadsheet, i.e. the intersections of the ISO 9001 statements with the specific practices of CMMI process areas together with their degree of relation. . The degree of relationship indicates the extent to which an ISO 9001 statement supports, or has any connection with, a Process area of CMMI. This expresses a one-to-one relationship. In order to express the degree of relationship between an ISO 9001 statement and a CMMI Process area, we have defined a discrete scale (scale of comparison) when each of the elements of the scale has been associated with a set of numeric values which are described in terms of percentage. This scale is made up of the following elements: Strongly related (86% to 100%), Largely related (51% to 85%), Partially related (16% to 50%), Weakly related (1% to 15%) and Non-related (0%). The numeric values can be found by dividing the number of specific practices (from a Process area of CMMI) that are related to shall statements (from ISO 9001) by the total number of specific practices defined in that Process area. For this work, it is important to highlight that this numeric value is only indicative of the extent to which a process area of CMMI is addressed by means of the statements of ISO 9001. The degree of relationship is hence expressed only through the discrete scale. So, the blue indicate correlations/intersections between the areas. For each area, a degree of relation is quantified.

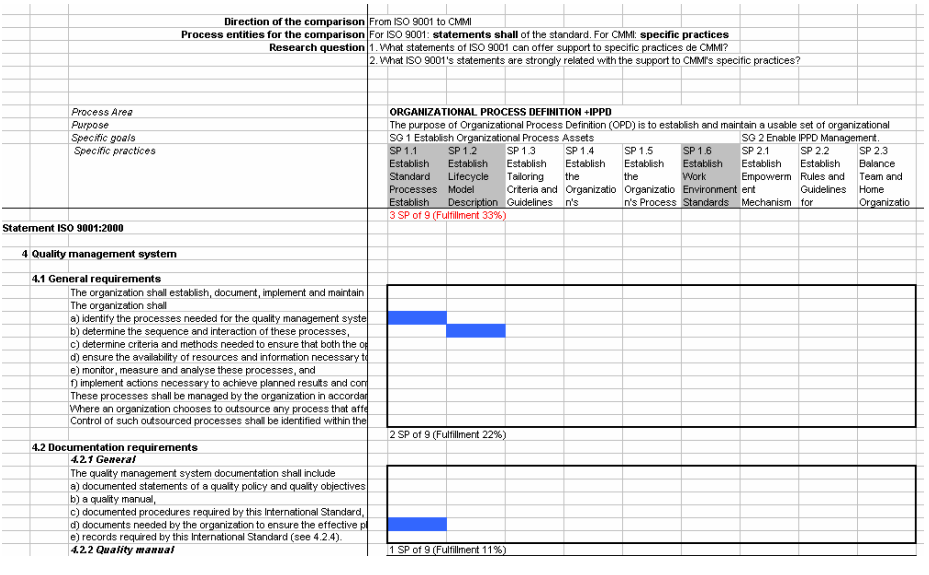

Fig. 5. Extract of results for the comparison sub-process

3.2 Application Sub-Process

If the comparison sub-process points out the overlapping common areas between the two SPI frameworks, and therefore provides a what/what perspective, instantiated in this case on ISO 9001 and CMMI, the application sub-process applies the comparison results to a specific organization's Quality Management System (QMS).

Indeed, if an organization certified, lets say ISO 9001 intends addressing CMMI, it would be worth investigating what part of the data and information collected with the ISO standard could be reused for a CMMI appraisal. This is done by formalizing a GQM-based quality model and then, according to the overlapping areas, reusing the data/information related to the intersections. More precisely, this part of the process defines how to structure a quality model, through operational goals, based on the mapping results and in accordance to the organization's QMS, and provides a what/how perspective by tracing ISO 9001:2000 with GQM.

The steps of the application sub-process are represented in figure 6.

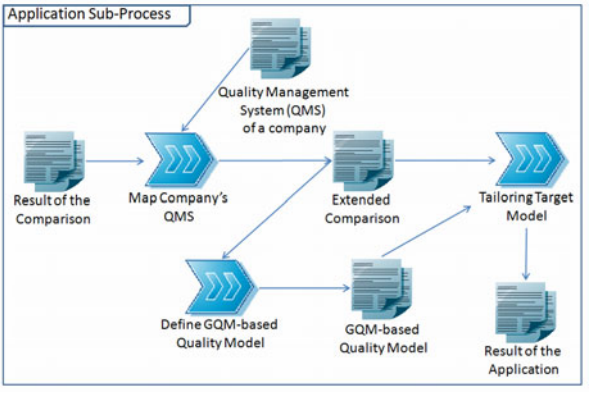

Fig. 6. Application Sub-Process

In the following, we will describe each of the three steps that make up the sub-process and provide evidence on their application to the data of an Italian SME. The company involved in the application operates in the ICT sector that for privacy reasons will be referred to as SME. It is certified ISO 9001:2000, other than having other certifications of the ISO family. The company allowed us to access their entire QMS which is structured conformingly to the chapters of the standard. For the case study, we simulated their intention to certify their processes according to CMMI levels.

Map Company's QMS

This step starts from the outcome of the comparison sub-process, i.e. the theoretical mapping of the two frameworks. Moreover, it consists in extracting the relevant documents from the QMS, based on the relations pointed out in the general comparison, in order to identify the specific documents, procedures, guidelines, templates and operational instructions that can be used in the future CMMI-DEV quality model.

The result of this step is an extension of the comparison (Extended Comparison), which not only contains the mapping of the two SPI frameworks, ISO 9001 and CMMI, but with respect to each relation identified, it also explicitly specifies the documents of the QMS. An example is shown in figure 7.

The two columns added are: *SME's QMS*, which contains the references to the paragraphs of the QMS, and *SME's Procedures*, which refers to the procedures, through links. This was done for each ISO statement having relations with a CMMI process

area. This step is important because the references can be reused when the SME decides to shift to the target SPI framework, i.e. CMMI, and must define the target quality model. The question this step answers is: "How are the ISO 9001 statements, which are mapped with CMMI specific practices, traced in the SME's Quality Manual and other procedures?"

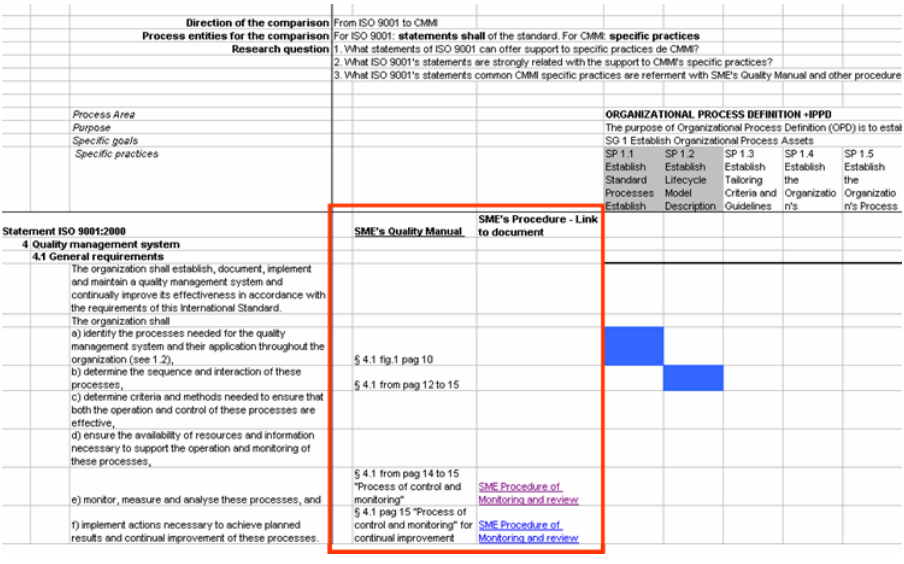

Fig. 7. Extended Comparison

Define GQM-Based Quality Model

The second step of the sub-process consists in defining a quality model. This is done by adopting a GQM-based approach [5], [25], according to the output of the previous step. Moreover, analyze the QMS documentation traced in the extended comparison, in depth, and define measurement goals based on the mapped areas. As so, the quality model produced allows to quantitatively measure the organization's processes with respect to the mapped areas.

This step provides insight on the what/how perspective mentioned in the previous sections, in that it shows how to operatively produce a quality model by instantiating ISO 9001 statements (what to do) through measurement goals (how to do it).

The result of this step is a matrix like the one in table 1, where the process $P_{Current}$ is ISO 9001, and the process grains are the ISO statements, while the Goals are the GQM measurement goals related to each statement. In Table 2 we show an example of a measurement goal, with questions and metrics defined for the ISO Shall Statement n.4.1. In our real case study, the procedure was iterated for each statement of the framework to obtain a complete quality model for all the ISO statements. The question this step answers is: "Given an ISO Statement, how can the related SME's QMS and Procedures be measured through operational GQM goals?"

This information is then used to evaluate the degree of coverage of the CMMI practices with respect to each "shall statement".

Table 2. Goal for ISO Shall Statement 4.1

Statement ISO 9000:2001		4.1 General requirements a) identify the processes needed for the quality management system and their application throughout the organization
		Goal 1
Object of study		Management Manual (Quality management system)
Purpose		Evaluate
Quality Focus		defined processes' correctness
Point of view		Management
Context		Italian SME
Question	*Metric*	*Description*
Q1.1	M1.1.1	List of processes expected for the quality management system
Q1.2	M1.2.1	List of processes for the quality management system really runned
Q1.3	M1.3.1	Level of adhesion of defined processes to the standard normative
Q1.4	M1.4.1	Level of completeness of defined processes for the quality management system
Q1.5	M1.5.1	Level expected of adhesion of defined processes to the standard normative
Q1.6	M1.6.1	Level expected of defined processes for quality management system

Tailoring Towards the Target Model

The last step of the sub-process collects the results of the previous steps and organizes them according to the practices of CMMI-DEV. It consists in identifying to what extent the CMMI-DEV process areas are covered by the ISO statements, based on the measurement goals (GQM-Based QM) defined in the previous step and the mapping applied to the SME (Extended Comparison). Given a Process Area (eg. Organizational Process Definition + IPPD), the goals that relate to that process area are identified. These goals are extracted from the previous step based on the mapping results with the ISO Statements. Next, a similar activity is done with respect to the work products and sub-practices of the process area considered. In other words, for each work product and sub-practice, we evaluate their degree of coverage with respect to the SME's QMS. Figure 8 reports the result of the step with respect to the Organizational Process Definition + IPPD process area. For each Specific Practice, the goals of the ISO quality model that can be reused in CMMI assessment are specified; for each work product and sub-practice the coverage is highlighted in color, together with a specification of the document in the SME's QMS.

In this way, we assure that the migration towards the target model (P_{target}), CMMI, reuses as much as possible of what is already defined in the current model ($P_{current}$). This time the step produces a matrix like the one in table 1, where the process grains are the specific practices of the CMMI Process Areas and the goals are the GQM-based measurement goals reused from the quality model defined in the previous step. The matrix of the target model is obtained as follows: $[G \times P_{target}] = [G \times P_{current}] \times [P_{current} \times P_{target}]$, where $[G \times P_{current}]$ is the set of goals for each ISO statement, and $[P_{current} \times P_{target}]$ is the mapping between ISO and CMMI. In our application, the completeness of the target model matrix indicates the degree of coverage of the CMMI-DEV with respect to ISO. Although, the matrix is not complete for the areas that are not mapped and for those that are not related, it assures that the existing quality model is reused as much as possible.

	ORGANIZATIONAL PROCESS DEFINITION +IPPD				
	The purpose of Organizational Process Definition (OPD) is to establish and maintain a usable se				
	SG 1 Establish Organizational Process Assets				
	SP 1.1 Establish Standard Processes Establish and maintain the organization's set of standard processes.		SP 1.2 Establish Lifecycle Model Descriptions Establish and maintain descriptions of the lifecycle models approved for use in the organization.		SP 1.3 Establish Tailoring Criteria and Guidelines
	Work Product 1. Organization's set of standard processes	Subpractice 1. Decompose each standard process into constituent	Work Product 1. Descriptions of lifecycle models	Subpractice 1. Select lifecycle models based on the needs of projects and the	
Statement	4.1 a) Goal 1 4.2.1 d) Goal 7 4.2.2 b) Goal 8 5.3 a) Goal 2 5.3 e) Goal 4 7.1 the Goal 1 7.1 Planning Goal 2		4.1 b) Goal 2		
Work Product	1. Organization's	§ 4.1 fig 1pag 10	1. Descriptions of lif	CASQPRG	
Subpractice	1. Decompose each	§ 4.2.1 fig. 2 pag. 16	1. Select lifecycle mo		
	2. Specify the critica		2. Document the de	CASQPRG	
	3. Specify the relatic	§4.1 fig.1 pag 10	3. Conduct peer rev		
	4. Ensure that the or	§4.1 fig.1 pag 10	4. Revise the descri	CASQPRG	
	5. Ensure that the or				
	6. Ensure that there				
	7. Document the or	§4.1 fig.1 pag 10			
	8. Conduct peer rev	CASQMQR			
	9. Revise the organi	CASQMQR			

Fig. 8. Coverage of CMMI Process Area from ISO Statements

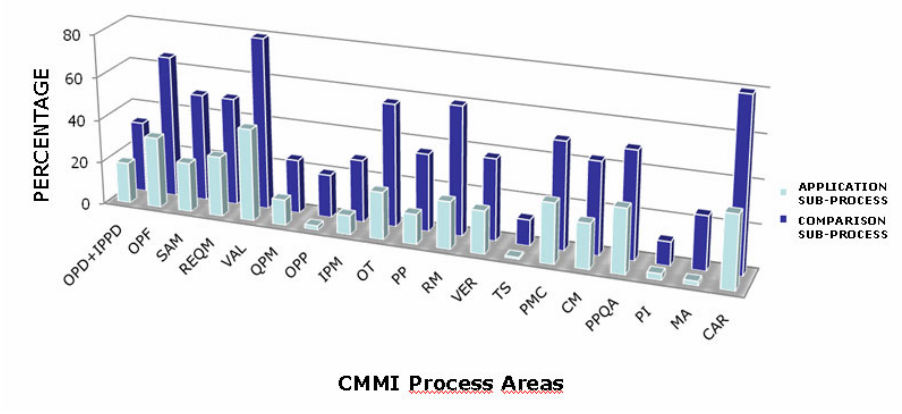

Fig. 9. Degree of Coverage of CMMI Process Areas

For space reasons we are not able to show the results of every single process area. We have provided a general picture, i.e. the overall results of the application process to the Italian SME, shown in Figure 9. The results are shown with respect to the comparison sub-process, which represents the theoretical mapping of the two SPI frameworks; and the application sub-process, where the comparison was applied to the QMS of a real enterprise.

As it can be seen, the percentages related to the Process Areas in the application sub-process are lower than the ones defined in the comparison one. This was predictable because the application not only considers the theoretic comparison but also how

it is actually accomplished within the enterprise. These results relate to the QMS of the Italian SME considered, and therefore represent a first application of the harmonization process in the direction from ISO to CMMI.

4 Conclusions

In this paper we have presented a harmonization process of two SPI frameworks: ISO 9001:2000 and CMMI-DEV v1.2, by mapping the models and identifying overlapping areas in the direction from ISO to CMMI. Furthermore the general results of the mapping have been applied and instantiated to a real case, i.e. a QMS of an enterprise. This has also provided some insight on the differences between the theoretical comparison, carried out based on the documentation available from the SPI institutions, and the application sub-process in which the instantiated documentation to the real QMS has been considered.

Such harmonization can help an organization to: (i) understand both the differentiating and the overlapping features of the improvement models, and (ii) determine and understand which of these improvement models can support the organization's mission. Carry out cost/benefit analysis before transiting to a new quality standard.

The application of the harmonization process to the QMS of an ISO 9001 certified company QMS represents a first validation. Indeed, the relations pointed out by the mapping of the two frameworks are the starting point for applying the harmonization and identify the existing data of the organization that can be reused for appraising CMMI levels.

For what concerns the theoretical comparison, this work is limited to the viewpoint from ISO to CMMI, and therefore represents only half of the complete picture. Moreover, the application process data relates to a small enterprise so, this may also be the reason for such differences for the degree of coverage between the application and theoretical sub processes. As so, other applications will be necessary with refer to various types of certified organizations of various dimensions.

Currently we have applied the application process to a large enterprise, we are analyzing the data. We expect, for example, that in the large enterprise the comparison and application sub-processes have similar coverage percentages.

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