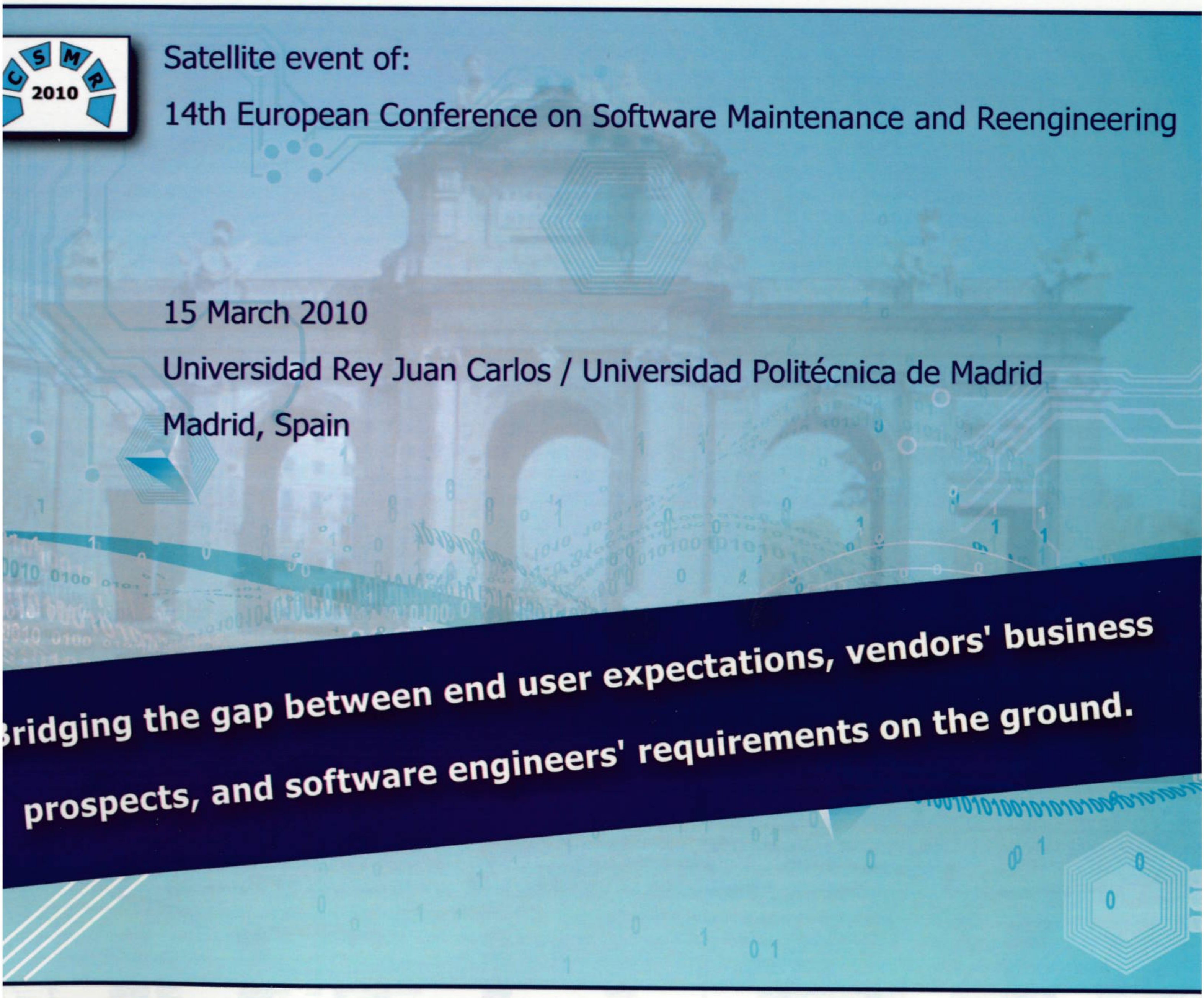
Fourth International Workshop on Software Quality and Maintainability



CSMR 2010

Satellite event of:

14th European Conference on Software Maintenance and Reengineering

15 March 2010

Universidad Rey Juan Carlos / Universidad Politécnica de Madrid

Madrid, Spain

ridging the gap between end user expectations, vendors' business prospects, and software engineers' requirements on the ground.

ditors:

udolf Ferenc

iannis Kanellopoulos

Sponsors:

FRONTENDART

SIG Software Improvement Group

Preface

The fourth international workshop on Software Quality and Maintainability (SQM 2010) offers a forum to researchers to present their original work and to practitioners to relate their experiences on issues pertaining to software quality and maintainability. Moreover, the theme of the workshop invites discussion on how to bridge the gap between end user expectations, business requirements, vendor performance, and engineering constraints regarding software quality.

SQM 2010 is a satellite event of the 14th European Conference on Software Maintenance and Reengineering (CSMR 2010). In 2009, the third SQM workshop was held as a satellite event of CSMR 2009.

In this volume, you will find the articles accepted for presentation at the workshop. Out of 13 full-paper submissions, 6 papers were selected. Additionally, a short paper submission was also accepted. Also included is the abstract of the invited talk delivered by Roger Sessions. The accepted papers address a range of topics related to software quality, including measurement, assessment, models, certificates and tool support.

Various authors discuss their ideas on the analysis of the quality of source code properties and its impact on a systems maintainability. Luijten & Visser present an empirical study of the relation between technical quality of software products and the defect resolution performance of their maintainers. Juergens & Deissenboeck present an analytical cost model to estimate the maintenance effort increase caused by code cloning.

Certification of software products and processes is a very interesting topic in this workshop. Baggen et al. provide an approach in which when a software system reaches a minimum level of maintainability then it can be certified with the TÜViT "Trusted Product Maintainability" certificate. Baldassare et al. discuss a specific process for comparing quality certifications, with specific reference to CMMI-DEV and ISO 9001 models in the direction "ISO to CMMI-DEV".

Quality analysis of complex source code bases requires sophisticated tool support. Kienle et al. are exploring the approach to utilize system-specific static analyses of code with the goal to improve software quality for specific software systems, especially targeting complex embedded systems.

Franke et al. propose the use of a Bayesian decision support model, designed to help enterprise IT systems decision makers evaluate the consequences of their decisions by analyzing various scenarios. Lagerström et al. present a methodology that uses data from 50 projects performed at one large bank in Sweden to identify factors that have an impact on software development cost.

We are grateful to all members of the Program Committee and to their sub-reviewers for helping to make SQM 2010 a success.

March 2010

Yiannis Kanellopoulos and Rudolf Ferenc
Chairs SQM 2010

Contents

Chairs

- Yiannis Kanellopoulos, Software Improvement Group, The Netherlands
- Rudolf Ferenc, University of Szeged, Hungary
- José Pedro Correia (publicity chair), Software Improvement Group, The Netherlands

Program Committee

- Danilo Caivano, Università di Bari, Italy
- Pontus Johnson, Royal Institute of Technology, Sweden
- Carl Worms, Credit Suisse, Switzerland
- Robert Baggen, TÜV Informationstechnik (TÜViT), Germany
- Florian Deissenboeck, Technische Universität München, Germany
- Christos Tjortjis, University of Ioannina, Greece
- Joost Visser, Software Improvement Group, The Netherlands
- Alexandros Chatzigeorgiou, University of Macedonia, Greece
- Jesus M. Gonzalez Barahona, Universidad Rey Juan Carlos, Madrid, Spain
- Vasile Rus, University of Memphis, USA
- Radu Marinescu, Universitatea "Politehnica" din Timişoara, Romania
- Arpad Beszedes, University of Szeged, Hungary

Subreviewers

- Johan König
- José Pedro Correia
- Ferenc Fischer
- Waldo Rocha Flores
- Per Närman
- Elmar Juergens
- Miguel Alexandre Ferreira
- Tamás Gergely
- Csaba Nagy
- Stefan Wagner

Sponsors

Software Improvement Group
Amsterdam, The Netherlands

FrontEndART
Szeged, Hungary

The IT Complexity Crisis

Roger Sessions

A number of studies have concluded that IT failures are a common occurrence. That conclusion will surprise no CIO, who has most likely experienced first hand the cost of these failures. However this talk shows that even the most pessimistic of these studies have underestimated the magnitude of the problem. There are two reasons for this. First, the studies are looking at the wrong metrics. Second, the studies ignore pertinent data. When we look at the most relevant metrics and include all of the relevant data, a problem that at first appeared to be "merely"serious turns out to be truly catastrophic, costing the world economy on the order of $6 trillion dollars annually.

While there are several factors that contribute to IT failures, complexity remains the largest. Our ability to measure complexity is key to our ability to control it. But the ability to measure IT complexity has eluded us - until now. This talk will explain how you can measure IT complexity and then test proposed solutions - before they are implemented. By measuring complexity you can rank solutions based on their capacity to reduce complexity and thereby increase your ability to deliver IT solutions that are on-budget, on schedule, on target and less costly to maintain.

Managing complexity - IT's biggest enemy - will exponentially increase your chance for building successful IT solutions. This presentation will provide a provocative case for a solution that is long overdue.

A strategy to harmonize ISO/IEC 9001:2000 and CMMI-DEV

Maria Teresa Baldassarre, Danilo Caivano, Giuseppe Visaggio
Department of Informatics
University of Bari
SER&Practices SPINOFF
Via E. Orabona 4, 70126, Bari, Italy
{baldassarre, caivano visaggio}@di.uniba.it

Francisco J. Pino
IDIS Research Group
University of Cauca.
Calle 5 # 4 – 70 Popayán, Colombia.
fjpino@unicauca.edu.co

Mario Piattini
Alarcos Research Group
University of Castilla-La Mancha.
Paseo de la Universidad, 4, 13071, Ciudad Real, Spain.
Mario.Piattini@uclm.es

Abstract—**In the past years the Software Engineering community (industry and research) has expressed a special interest in Software Process Improvement – SPI, as shown by the growing number of articles that deal with this topic. Many initiatives have focused on ISO and CMMI standards. The first is common in European countries, while the second standard is more frequent in north America, although recently companies have become interested in acquiring multi-certifications. This is due to the requirements set in calls for bids on behalf of government and public administrations. In this sense, it is interesting to investigate how a certified organization can easily shift to another one by reusing information produced for the first certification, as well as how the practices described in the CMMI-DEV and ISO 9001 models are related. As so, considering that mapping is one of the most widely used strategies for the harmonization of models, in this paper we present a specific process for comparing quality certifications, with specific reference to CMMI-DEV and ISO 9001 models in the direction "ISO to CMMI-DEV". We also illustrate, through a case study, its application to a real context related to a Small Enterprise certified ISO 9001. This work intends to support and guide a software organization to harmonize, integrate, manage, and align its quality management and software development activities using ISO 9001 and CMMI models.**

Keywords- Harmonization, Comparison, Mapping, CMMI-DEV, ISO 9001, Multi-model Process Improvement, SPI

I. INTRODUCTION

From the very beginning of the nineties onwards, the Software Engineering community (industry and researchers) has expressed a special interest in Software Process Improvement – SPI. This is evidenced by the growing number of articles that deal with the topic of SPI, as can be seen in the analysis of the trends in publications on the subject of SPI, presented in [1]. Also worthy of note is the great number of international initiatives related to SPI, such as CMMI [14, 15], ISO/IEC 15504 (SPICE) [2, 5], ISO/IEC 12207 [4, 6] and ISO 9001:2000 [3], among others.

According to the systematic review described in [13] the model from the SEI as CMMI has been used in 51% of the reported improvement efforts. The most widely-used SEI model is CMMI and CMM, with a 32 % share. The ISO models have been used in 31% of the improvement efforts carried out. The most extensively–used ISO models are the 15504 (SPICE) and the 9001, at 9% percent each. 18% of the improvement efforts reported in the studies do not use either a SEI or an ISO model. From the analysis of the models used, we noticed that 30% of the improvement efforts which used CMMI also used ISO 9001. If an ISO 9001-certified organization wishes to continuously improve its processes, the adoption of CMMI would be a good choice, since it provides more detailed practices for process improvement than ISO 9001 [17]. However, it is important to note that the compliance with ISO 9001 allows organizations to have broader beneficial effects which are beyond the scope of coverage of the CMMI. Although ISO 9001 is a generic standard for quality management (and is therefore not directly concerned with software engineering best practices), it has been relevant for the software industry as it is more feasible to adopt (in cost and time) that others standards, especially for small companies [13].

A recent study [19] 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 have become compulsory and are explicitly requested. Our work focuses on the ISO and CMMI ones. In this sense, it is reasonable for an organization, compliant to ISO 9001, to question itself on the extent to which it satisfies CMMI-DEV requirements; or on whether it should implement CMMI-DEV independently of ISO 9001, or if there are any overlapping areas that allow to reuse information and data collected in the ISO certification. Analogously, relations on the opposite situation, from CMMI to ISO are accountable as well.

Although the two constellations have been developed independently and have different purposes they have intersections and connections with each other. As so, it is interesting to investigate what effort is required for a certified organization to shift to another certification by reusing information produced for the first one, as well as investigating to what extent the practices described in the CMMI-DEV and ISO 9001 models are related.

Given the previous considerations it is important to have information on how the practices described in the models CMMI-DEV and ISO 9001 are related. Furthermore given the present need to harmonize different improvement technologies [16] we also consider it important to support organizations interested in introducing or improving their practices for quality management and software development. In this sense and considering that the mapping is one of the most widely- used specific strategies for the harmonization of models [16], in this paper we present a comparison of the CMMI-DEV and ISO 9001 models. To carry out this comparison, we have taken into account the following considerations: (i) refer to the latest versions of the models, (ii) carry out comparison at a low level of abstraction, (iii) guide the comparison through a well defined approach, (iv) apply the approach to a real case in order to validate it. The approach has been applied from two perspectives: theoretical and operational. In the first the two models have been analyzed and compared based on the documents provided by the certification institutes [3, 14]. According to the second perspective, the output of the theoretical comparison has been verified by applying it to a real case, i.e. an Italian SME that operates in the ICT sector. In this paper the comparison will be described in the direction from ISO 9001, to CMMI-DEV. The comparison has been carried out considering the *shall* statements of the ISO 9001 standard and the *specific practices* of the CMMI-DEV model.

The goal of the work can therefore be summarized as follows:

Analyze ISO 9001 standard statements
For the purpose of comparing it
With respect to the degree of fulfillment and relationship with CMMI specific practices
From the viewpoint of management
In the context of product-development organizations interested in multi-certifications

This work intends to support and guide a software organization to harmonize, integrate, manage, and align its activities of quality management and software development using the ISO 9001 and CMMI models. The aim is to investigate to what extent the ISO 9001's quality management system previously implemented in the organization meets the established requirements of the new model CMMI-DEV, that the enterprise wishes implement. We believe that the reuse of the previous work already carried out by the organization could reduce the effort and costs associated with the implementation of a new model.

The paper is structured as follows. The section 2 presents related works. In section 3 we briefly illustrate the two models ISO9001:2000 and CMMI-DEV v.1.2. In section 4 we present the theoretical comparison process, that can be used for mapping any two quality models, instantiated to map ISO 9001 and CMMI-DEV, as well as the results of the theoretical perspective. In section 5 the theoretical model is validated through an application to a real case represented by an Italian SME certified ISO 9001, by simulating its intention to become certified CMMI-DEV. Finally conclusions and future work are set out.

II. RELATED WORKS

The literature presents some works that involve comparisons and mapping between different versions of CMMI and other processes models, including ISO 9001. Among these, those related to CMMI V1.1 and ISO 9001 are:

- Different mapping between these two models is described in [8].
- In [17] a proposal that integrates the content of these two models is introduced.
- A proposal for transition from ISO 9001 to SW-CMM is defined in [7].
- In [9] a comparison and a correspondence between ISO 9001 and SW-CMM are shown.

From an analysis carried out about the works listed above we have found that:

- In none of these studies the latest versions of these models have been involved.
- None describe the specific process used to carry out the comparison and/or mapping. Consequently the approach is not replicable from others.
- In none of these studies a strategy used for defining the measurement goals with the aim of harmonizing these models has been defined.
- They are all theoretical works and none have been applied to real enterprise data.

We have carried out a comparison between the last versions of models: ISO 9001:2000 and CMMI-DEV V1.2. For the development of our comparison we have followed a well defined process, similar to the one that we have defined and used for other comparisons carried out (ISO 12207 to CMMI-ACQ [10] [11], and ISO 12207 to CMMI-DEV [12]). After formalizing and carrying out the theoretical comparison, we have applied it to a real case of an Italian SME.

III. ISO 9001 AND CMMI-DEV PILLS

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

A. *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". For this reason, suppliers refer to being "ISO 9000 certified", or having an "ISO 9000-compliant QMS", with this meaning that they claim to have a QMS meeting the requirements of ISO 9001:2000, the only standard in the ISO 9000 family that can be used for the purpose of conformity assessment. It is important to understand however, that ISO is the body that develops and publishes the standard - ISO does not "certify" organizations. 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.

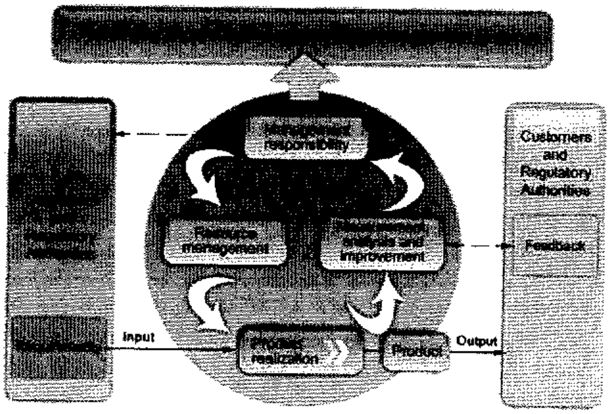


Figure 1. Model of a process based QMS

The requirements cover a wide range of topics, including your supplier's top management commitment to quality, its customer focus, adequacy of its resources, employee competence, process management (for production, service delivery and relevant administrative and support processes), 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.

B. *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 [18].

CMMI currently addresses three areas of interest:

1. Product and service development — CMMI for Development (CMMI-DEV),
2. Service establishment, management, and delivery — CMMI for Services (CMMI-SVC), and
3. Product and service acquisition — CMMI for Acquisition (CMMI-ACQ).

Although it originated in software engineering, it has been highly generalized over the years to embrace other areas of interest, such as the development of hardware products, the delivery of all kinds of services, and the acquisition of products and services. This generalization of improvement concepts makes CMMI extremely abstract. CMMI is the successor of the capability maturity model (CMM) or software CMM. The CMM was developed from 1987 until 1997. In 2002, CMMI Version 1.1 was released. Version 1.2 followed in August 2006.

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

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.

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

Figure 2. Comparison of Continuous and Staged Representation Levels

The continuous representation enables an organization to select a process area (or group of process areas) and improve processes related to it. This representation uses capability levels to characterize improvement relative to an individual process area. On the other hand, the staged representation uses predefined sets of process areas to define an improvement path for an organization. This improvement path is characterized by maturity levels. Each maturity level provides a set of process areas that characterize different organizational behaviors.

IV. ISO 9001 AND CMMI-DEV: THEORETICAL COMPARISON PROCESS

Mapping is one of the most widely used strategies for the harmonization of models. Based on previous studies carried out by the authors of this paper, and on work carried out in literature, as pointed out in the related works section, we have defined a theoretical comparison process that can be applied to map quality certifications. We refer to it as *theoretical process* in that it is general enough to be used to compare and map any quality models and because it is applied using the documents released by the certification institutes (eg. SEI for the CMMI constellation, ISO for the ISO Family, ICMB for the ITIL certification and so on.) In this section we describe the theoretical comparison process with specific reference to ISO 9001 and CMMI-DEV models in the direction "ISO to CMMI-DEV".

First, the documents (artefacts) used as input to the process must be identified. The comparison process considers the ISO 9001:2000 standard as starting point, i.e. supposing that an enterprise is certified ISO 9001, and sees CMMI v1.2 as the target one. The outcome of the theoretical 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.

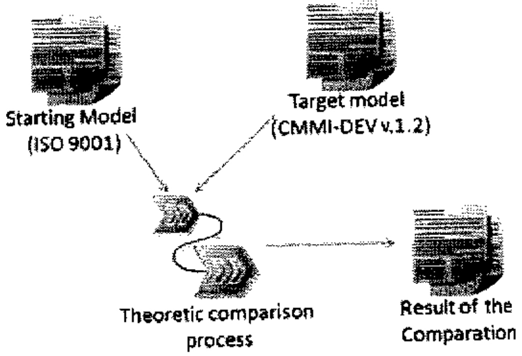


Figure 3. High Level Representation of the Comparison Process

The purpose of this process is to provide a guideline for performing a step-by-step comparison and mapping of different models, aiming to guarantee the reliability of results obtained. In order to organize and manage the people and activities involved in the comparison, two roles are assigned: the performers and the reviewers of the comparison, along with five steps (Figure 4).

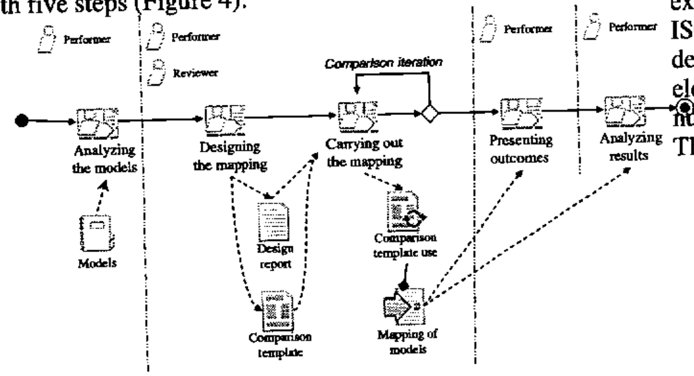


Figure 4. Detailed representation of the Comparison Process

In the next paragraphs we describe each step and comment the outcomes of the comparison referred to the two models.

A. *Analyze the models*

This task involves: (i) acquiring knowledge about the selected models (ISO 9001:2000 as starting model, CMMI-DEV v.1.2 as target one) and (ii) analyzing the structure and fixing the abstraction level to consider, based on the information provided by the documentation of each one.

In our specific case, in the ISO 9001 standard the selected level of detail was the "*shall statement*", i.e. the phrase that identifies a requirement that the QMS must fulfill. An example of "shall statement" is: "The organization shall establish, document, implement and maintain a quality management system and continually improve its effectiveness in accordance with" (cap 4.1 General Requirement). This choice is due to the fact that, in order to be certified, an organization must assure that all of the requirements are defined and applied in their QMS (and therefore documented in their quality manual).

In the CMMI the entities we refer to are specific practices or generic practices due to the fact that the definitions of the process areas, as well as the goals for each process area were too generic.

For each model we chose the entities defined in each standard that were comparable at the same level of abstraction, not too detailed, increasing the risk of loosing focus on the goal of the work, and at the same time not too general, with the risk of obtaining weak relations.

B. *Design the Mapping*

This step involves: (i) establishing the process entities to be compared, based on the research needs pointed out in the previous step, (ii) fixing the direction of the comparison, (iii) defining the comparison scale and (iv) defining a template comparison.

In our case: (i) the process entities for the comparison are the *shall* statements of the ISO 9001 standard and the *specific practices* of CMMI-DEV and (ii): the direction of the comparison is from ISO 9001 to CMMI-DEV. A discussion on the relevance of defining the direction of the comparison when a comparison involves process entities of low level abstraction is presented in [10]. (iii) In order to express the degree of relationship between a Process from ISO 9001 and a Process area from CMMI-DEV, we have defined a discrete scale (scale of comparison). 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%): there is a direct connection between the two entities, they have common aims and the application methods are the same;
- Largely related (51% to 85%): the two entities have many concepts in common and many of the have the same application methods;
- Partially related (16% to 50%): there is a relation between the two entities but there are no formal applications specified;
- Weakly related (1% to 15%): some kind of fragmented relation is perceivable between the two entities.
- Non-related (0%): no relation can be identified.

The numeric values are obtained by dividing the number of specific practices (from a Process area of CMMI) that are related to statements (in ISO 9001:2000) by the total number of specific practices defined in that Process area.

C. *Carry out the Mapping*

In this step the comparison is performed. In our case, it was done through an iterative and incremental procedure.

More precisely the process is iterative, because the execution (analysis and determination of the relationship between the ISO 9001 and CMMI-DEV process entities) of the comparison is carried out completely on one CMMI-DEV process area first, and then on the others in turn. It is also incremental, in the sense that the comparison outcome (i.e. the final product of the theoretical comparison process) grows and evolves with each iteration until it becomes the final one. Using this iterative and incremental approach has enabled us to deal with the complexity entailed in a comparison in which entities of low level abstraction are involved. The roles involved in the comparison were three people as performers of the comparison and two reviewers (all authors of the paper). At the end of each iteration, the performers carried out a peer review of the results obtained from the comparison of process area of CMMI-DEV under comparison. After that, the reviewers resolved any discrepancies between the performers and validated the results of the comparison.

The mapping is tracked on a spreadsheet having the ISO statements as rows and CMMI Process Areas with detailed Practices as columns (see Table 1). Operationally, given a "shall statement" we have taken into account the related process areas based on the *Introductory Notes* of each process area as well as the objectives that it aims to reach (*Generic Goal* and *Specific Goal*). This first selection is necessary to restrict the field for each shall statement. Next, each ISO9001 entity is compared to the Generic and Specific Practices of the selected Process Areas, keeping in mind the main goal of the ISO statement with respect to the CMMI practices. The strength of the relation is then rated according to the scale specified previously.

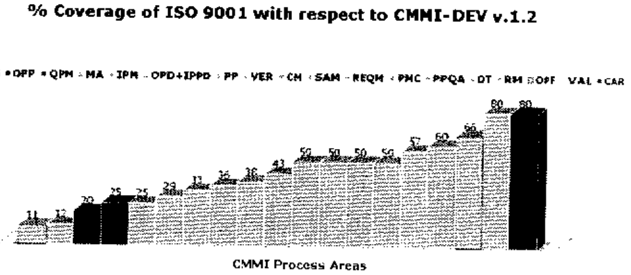
As it is intuitable, the process can be generalized to any entities of models being compared and mapped.

D. *Present the outcomes*

The outcome of the mapping is made up of two parts that specify the correlations between the two models considered according to a general and a more specific view. The first part of the results shows the intersections of the ISO 9001 statements with the CMMI process areas together with their degree of relation (Table 1); the second part shows more in detail how the ISO shall statements relate to each CMMI practice as well as specifying the degree of the relation with respect to the specific statement and to the entire process area. Of course, the non-related areas are not taken into consideration in the second part. For space reasons we have reported the results of the second part only for the CMMI Process Area "Organizational Process Definition + IPPD" (Table 2).

E. *Analyze the Results*

The tables 1 and 2 show the relations between the two compared models. Figure 5 outlines a general picture of the coverage of ISO statements with respect to each CMMI process areas for all maturity levels, expressed in percentage, based on the results of the mapping carried out.



Light Blu: Maturity Level 2; Grey: Maturity Level 3; Blue: Maturity Level 4-5

Figure 5. ISO 9001 to CMMI coverage

The results point out that the ISO 9001 standard covers most of the CMMI-DEV practices only partially, as so an organization certified ISO 9001, interested in appraising, for example, a CMMI level 2 (light blue bars in the figure) must focus its effort on: planning processes that define project activities (Project Planning); develop and enact measurement and control practices as support to information management (Measurement and Analysis); and continuously control the integrity of final or intermediate products through configuration management (Configuration Management). The other process areas needed for the appraisal have a general coverage of about 50%. Keep in mind though that this does not necessarily mean that half of the practices are covered, rather that an ISO 9001 certified organization will most likely already have enough documentation to recognize half of the practices required.

In case an organization were to choose a continuous representation, the most covered process areas are those related to planning, implementation and development of improvements in organizational processes (Organizational Process Focus), product and component requirements validation (Validation), development of abilities and knowledge (Organizational Training), management of process and product requirements and identification of inconsistencies (Requirement Management), and finally, identification of the problems and corrective actions to enact (Causal Analysis and Resolution). These are the most covered process areas by the ISO standard, in that the coverage ranges around 60%. Note that although the degree of coverage is higher than the previous areas, the nature of the comparison does not assure the actual coverage of the practices, which inevitably depends on how each organization defines and executes its activities. For this reason we have applied the results of the theoretical comparison process to a real case. More details are provided in the next section.

TABLE I. OVERVIEW OF THE COMPARISON BETWEEN ISO 9001 AND CMMI-DEV V1.2

Direction of the comparison:

From ISO 9001 to CMMI

Process entities for the comparison:

For ISO 9001: Statements shall of the standard.

For CMMI: Specific practices

Research question:

What ISO 9001's statements can offer support to specific practices of CMMI?

What ISO 9001's statements are closely related with the support to CMMI's specific practices?

Comparison goal:

To determine which statements (shall) of ISO 9001 have a close relationship with some specific practice of CMMI. The goal is know which is the degree of fulfilment of the specific practices of CMMI based on the statements described in ISO 9001.

Scale of comparison:

- *S - Strongly related (86% to 100%)*
- *L - Largely related (51% to 85%)*
- *P - Partially related (16% to 50%)*
- *W - Weakly related (1% to 15%)*
- *- Non-related (0%)*

		Process Areas of CMMI-DEV																		
		CONFIGURATION MANAGEMENT	PROJECT MONITORING AND CONTROL	SUPPLIER AGREEMENT MANAGEMENT	REQUIREMENTS MANAGEMENT	PROJECT PLANNING	PROCESS AND PRODUCT QUALITY ASSURANCE	MEASUREMENT AND ANALYSIS	INTEGRATED PROJECT MANAGEMENT +IPPD	ORGANIZATIONAL TRAINING	VALIDATION	VERIFICATION	TECHNICAL SOLUTION	REQUIREMENTS DEVELOPMENT	ORGANIZATIONAL PROCESS FOCUS	ORGANIZATIONAL PROCESS DEFINITION +IPPD	PRODUCT INTEGRATION	QUANTITATIVE PROJECT MANAGEMENT	ORGANIZATIONAL PROCESS PERFORMANCE	CAUSAL ANALYSIS AND RESOLUTION
	Level	2	2	2	2	2	2	2	3	3	3	3	3	3	3	3	3	4	4	5
	Degree of coverage	P	P	P	L	P	P	P	P	L	L	P	W	L	L	P	W	P	P	L
Statement ISO 9001:2000	4 Quality management system																			
	4.1 General requirements			W											P	P				
	4.2 Documentation requirements																			
	4.2.1 General														W	W				
	4.2.2 Quality manual														W	P				
	4.2.3 Control of documents																			
	4.2.4 Control of records																			
	5 Management responsibility																			
	5.1 Management commitment																			
	5.2 Customer focus										P			W						
	5.3 Quality policy														W	W				
	5.4 Planning																			
	5.4.1 Quality objectives																	W	P	
	5.4.2 Quality management system planning																			
	5.5 Responsibility, authority and communication																			
	5.5.1 Responsibility and authority																			
	5.5.2 Management representative																			
	5.5.3 Internal communication								W											
	5.6 Management review														P					
	5.6.1 General																			
	5.6.2 Review input																			
	5.6.3 Review output																			
	6 Resource management																			
	6.1 Provision of resources																			
	6.2 Human resources																			
	6.2.1 General																			
	6.2.2 Competence, awareness and training					W				L										
	6.3 Infrastructure								W											
	6.4 Work environment								W							W				
	7 Product realization																			
	7.1 Planning of product realization					P								W		W		W		
	7.2 Customer-related processes																			
	7.2.1 Determination of requirements related to the product													P						
	7.2.2 Review of requirements related to the product				P									W						
	7.2.3 Customer communication								W											
	7.3 Design and development																			
	7.3.1 Design and development planning					W			W		P	W								
	7.3.2 Design and development inputs													P						
	7.3.3 Design and development outputs								W				W							
	7.3.4 Design and development review		P																	
	7.3.5 Design and development verification											W								
	7.3.6 Design and development validation										P									
	7.3.7 Control of design and development changes	P																		
	7.4 Purchasing																			
	7.4.1 Purchasing process			P																
	7.4.2 Purchasing information													W						
	7.4.3 Verification of purchased product			P								W								
	7.5 Production and service provision																			
	7.5.1 Control of production and service provision																			
	7.5.2 Validation of processes for production and service provision						P				L									
	7.5.3 Identification and traceability	W																		
	7.5.4 Customer property																			
	7.5.5 Preservation of product																W			
	7.6 Control of monitoring and measuring devices																			
	8 Measurement, analysis and improvement																			
	8.1 General																			
	8.2 Monitoring and measurement																			
	8.2.1 Customer satisfaction																			
	8.2.2 Internal audit						P								P					
	8.2.3 Monitoring and measurement of processes		W															W		
	8.2.4 Monitoring and measurement of product										P	P								
	8.3 Control of nonconforming product		W		P															
	8.4 Analysis of data							P							W					
	8.5 Improvement																			
	8.5.1 Continual improvement														P					
	8.5.2 Corrective action		P																	
	8.5.3 Preventive action																			L

TABLE II. DETAILED VIEW OF THE RELATIONSHIP BETWEEN ISO 9001 STATEMENTS AND SPECIFIC PRACTICES OF THE CMMI "ORGANIZATIONA PROCESS DEFINITION + IPPD" PROCESS AREA"

	CMMI Capability Level	3		
		SP 1.1 Establish Standard Processes	SP 1.2 Establish Lifecycle Model Descriptions	SP 1.6 Establish Work Environment Standards
	Relationship degree	P(Partially) 33%		
4 Quality management system				
4.1 General requirements		P (22%)		
4.2 Documentation requirements				
	4.2.1 General		W (11%)	
	4.2.2 Quality manual	P (22%)		
5 Management responsibility				
5.3 Quality policy		W (11%)		
6 Resource management				
6.4 Work environment				W (11%)
7 Product realization				
7.1 Planning of product realization		W (11%)		

V. APPLICATION TO A REAL CASE

After mapping the quality models through the comparison process, which pointed out the "theoretical" degree of coverage of ISO towards CMMI, our interest was to validate the results by applying them to a real case. We therefore considered an Italian SME certified ISO 9001:2000 and simulated their intention to certify their processes according to CMMI levels.

The need to apply the results of the comparison to a real case is related to the fact that there is no formal model that allows the transition from one standard to another one. Indeed each implementation of the ISO standard differs from other ones since it does not standardize the structure of the processes, rather how they must be perceived. On the other hand, the CMMI-DEV gives certain degrees of freedom in terms of process implementation and choice. As so, defining a general application model is complex due to the numerous cases to take into account. Our best chance is therefore to validate the model in various cases to extract lessons learnt following to the replications. Here we present a first application.

The company involved in the application is an Italian SME that operates in the ICT sector that for privacy reasons will be referred to as SME. It operates across the national territory with technological solutions in areas related to design and development of information and telematics systems. The company is certified ISO 9001:2000, other than having other certifications of the ISO family. The company allowed us to access their entire QMS and quality manual (QM) which is structured conformingly to the chapters of the standard.

Based on the results of the theoretical comparison, and using the SME's Quality Management System we have carried out the *application process*, which has provided us some interesting results. Figure 6 represents the theoretical comparison process integrated with this other process.

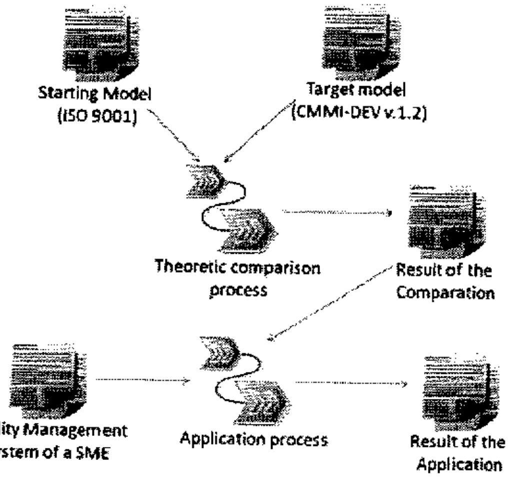


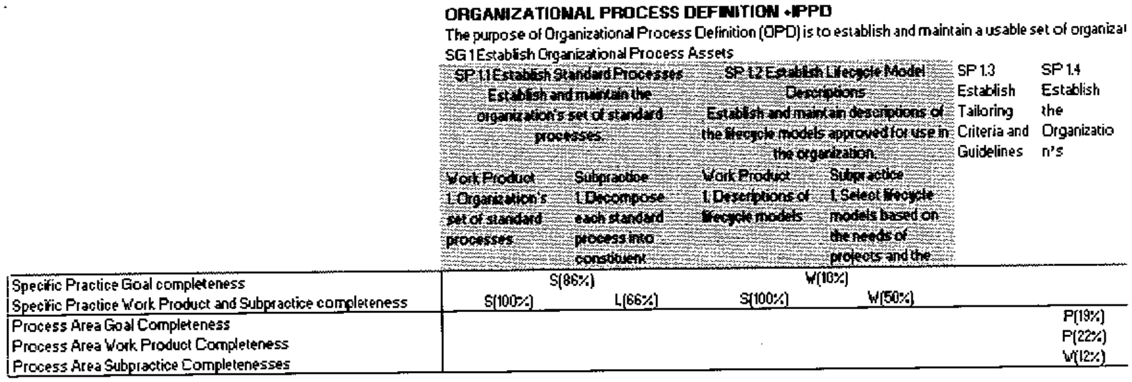
Figure 6. Comparison extended with the Application Process

Going into more detail, the application process consisted in the following steps: (i) extract the relevant documents from the QMS, according to the relations pointed out in the general comparison in order to have documents, procedures related to the quality manual, guidelines, template and operational instructions that can be used in the future CMMI-DEV quality model; (ii) analyze the documentation in depth and define a quality model, organized in measurement goals [20, 21] based on the mapped areas. The quality model quantitatively allows to measure the organization's processes with respect to the mapped CMMI-DEV areas; (iii) identify to what extent the CMMI-DEV areas are covered by the ISO statements, based on the measurement goals defined in the previous step. Once this is done, a second analysis is carried out with respect to the Work Products and Sub-practices related to the CMMI specific practice considered. Indeed, although these are defined as informational components of the CMMI model and therefore not mandatory for fulfilling the practice, they are useful for identifying the documents that an organization already has and that can be in some way reused for the CMMI appraisal. The application process is incremental and iterative, as the theoretical comparison process, in that it is applied to each process area, one at a time.

Table 3 provides an example of the result of the application process with respect to the "Organizational Process Definition +IPPD" Process Area. It specifies the degree of coverage (completeness) of the Goals, Workproducts and Sub-practices related to the Specific Practice and to the Process Area considered. The interpretation scale is the same one used for the theoretical comparison. As it can be seen, the percentages related to the Process Area (OPD+IPPD) are lower than the ones defined in the theoretical comparison (Table 2). This was predictable because the application not only considers the theoretical comparison but also how it is actually accomplished.

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 7. It highlights the differences between the results of the theoretical comparison process and the ones obtained after applying the comparison to the company's QMS.

TABLE III. RESULT OF THE APPLICATION PROCESS WITH RESPECT TO THE OPD+IPPD PROCESS AREA



ORGANIZATIONAL PROCESS DEFINITION +IPPD

The purpose of Organizational Process Definition (OPD) is to establish and maintain a usable set of organizal

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	SP 1.4 Establish the Organizatio n's
	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		
Specific Practice Goal completeness	S(86%)		W(10%)			
Specific Practice Work Product and Subpractice completeness	S(100%)	L(66%)	S(100%)	W(50%)		
Process Area Goal Completeness						P(19%)
Process Area Work Product Completeness						P(22%)
Process Area Subpractice Completenesses						W(12%)

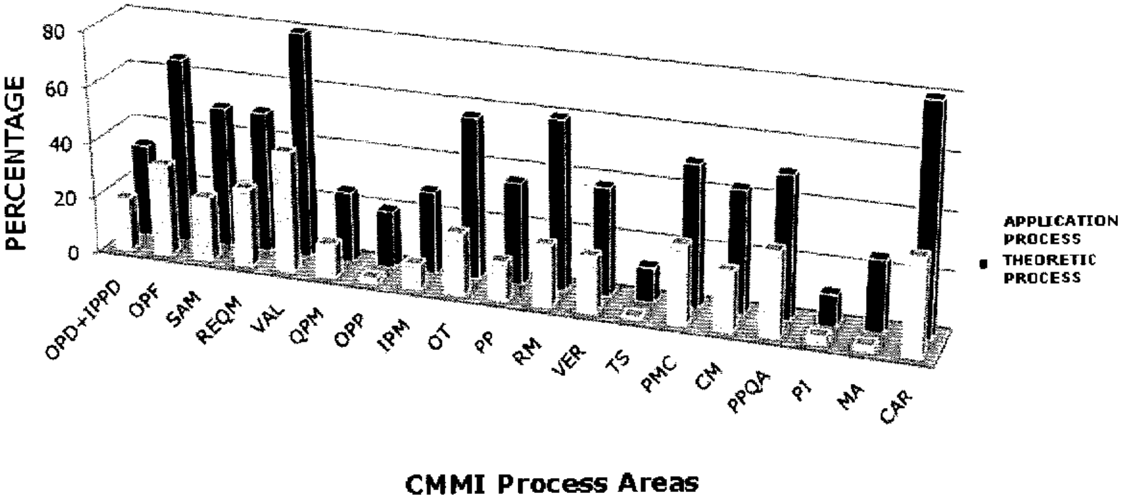


Figure 7. Application vs Theoretical Process related to all CMMI Process Areas

These results also conform to the results related to each single process area, i.e. the coverage percentages were lower in all cases. These results relate to the QMS of the Italian SME considered, and therefore represent a first application of the theoretical model.

VI. CONCLUSIONS AND FUTURE WORK

In this paper we have presented a harmonization of the quality models by establishing a relationship between ISO 9001.2000 and CMMI-DEV v1.2. In this sense, we carried out two works of harmonization: first we defined a general comparison process between statements of ISO 9001:2000 and process areas of CMMI-DEV and then we applied the results of the theoretical comparison to the QMS of a company. 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 organizational mission.

In carrying out the mapping we have taken into account the following considerations: (i) refer to the latest versions of the models, (ii) carry out the mapping at a low level of abstraction, and (iii) guide the mapping through a well defined process. Following the well defined step-by-step process has helped us to organize and manage the work performed for the mapping, with the aim of reducing the two types of error in the comparisons described by Yoo in [17]. Furthermore, following an iterative and incremental procedure to perform the mapping brought some advantages, for example:

- The performing of the mapping starts with a process area, to reduce the complexity and scope of each iteration.
- Each iteration of the mapping is short and provides feedback for the next iteration.
- There is an integration of the results of each iteration into the final report.
- With the design of the mapping the iterations can be carried out both independently and in parallel.
- The complexity of each iteration is easier to manage.

Taking into account the processes of ISO 9001:2000 and their relationship with process areas of CMMI-DEV, we can observe that there is a: (i) Strong coverage with none of the process areas; (ii) Large coverage of: CAR, VAL, OPF, RM, OT; (iii) Partial coverage of: PPQA, PMC, REQM, SAM, CM, VER, PP, OPD+IIPD, IPM, MA, QPM, OPP; and (iv) Weak coverage of: PI and TS. It is important to highlight that a strong degree of coverage (or relationship) does not mean that a process area of CMMI-DEV is satisfied. It only indicates that most of the specific practices of this process area are connected to the processes of ISO 9001:2000.

The application of the theoretical comparison process to the QMS of an ISO 9001 certified company QMS represents a first validation of the model. Indeed the relations pointed out by the mapping of the two models (theoretical comparison) are the starting point for applying the harmonization and identify the existing data of the organization that can be reused for appraising CMMI levels. Of course many other applications will be necessary with refer to various types of certified organizations of various dimensions. We expect, for example, that in a large enterprise the theoretical and application process have similar coverage percentages.

ACKNOWLEDGMENT

This work has been funded by the projects ARMONIAS (PII2109-0223-7948 of JCCM of Spain), INGENIO (PAC08-0154-9262 of JCCM of Spain), PEGASO-MAGO (TIN2009-13718-C02-01, MEC of Spain), and Harmonization of Technologies for SPI (MIUR – Italy).

REFERENCES

[1] Hall, T., A. Rainer, and N. Baddoo, Implementing Software Process Improvement: An Empirical Study. Software Process: Improvement and Practice, 2002. 7(1): p. 3-15.

[2] ISO, *ISO/IEC TR 15504:1998(E). Information Technology -Software process assessment. Parts 1-9.* 1998, International Organization for Standardization: Geneva.

[3] ISO, *ISO 9001:2000. Quality management systems -Requirements.* 2000, International Organization for Standardization: Geneva.

[4] ISO, *ISO/IEC 12207:2002/FDAM 2. Information technology - Software life cycle processes.* 2004, International Organization for Standardization: Geneva.

[5] ISO, *ISO/IEC 15504-2:2003/Cor.1:2004(E). Information technology - Process assessment - Part 2: Performing an assessment.* 2004, International Organization for Standardization: Geneva.

[6] ISO, *ISO/IEC 12207:2008 Systems and software engineering - Software life cycle processes.* 2008, International Organization for Standardization: Geneva.

[7] Jalote, P., *CMM in Practice: Processes for Executing Software Projects*, in *Infosys.* 1999, Addison-Wesley.

[8] Mutafelija, B. and H. Stromber, *ISO 9001:2000 - CMMI V1.1 Mappings.* 2003, Software Engineering Institute - SEI. p. 1-31.

[9] Paulk, M.C., *A Comparison of ISO 9001 and the capability maturity model for software (CMU/SEI-94-TR-12).* 1994, Software Engineering Institute.

[10] Pino, F., M.T. Baldassarre, M. Piattini, A. Visaggio, and D. Caivano. *Harmonizing Improvement Technologies: A comparison between CMMI-ACQ and ISO/IEC 12207:2008.* in *4th International Conference on Evaluation of Novel Approaches to Software Engineering (ENASE 2009).* 2009. Milan, Italy.: p. 177-188.

[11] Pino, F., M.T. Baldassarre, M. Piattini, and G. Visaggio, *Harmonizing maturity levels from CMMI-DEV and ISO/IEC 15504.* Software Process: Improvement and Practice, 2009. 10.1002/spip.437: pp.

[12] Pino, F., M.T. Baldassarre, M. Piattini, and G. Visaggio. *Relationship between maturity levels of ISO/IEC 15504-7 and CMMI-DEV v1.2.* in *Software Process Improvement and Capability dEtermination Conference (SPICE 2009).* 2009. Turku, Finland: p. 69-76.

[13] Pino, F., F. Garcia, and M. Piattini, *Software Process Improvement in Small and Medium Software Enterprises: A Systematic Review.* Software Quality Journal, 2008. 16(2): p. 237-261.

[14] SEI, *CMMI for Develpment, Version 1.2. Technical Report CMU/SEI-2006-TR-008.* 2006, Software Engineering Institute (SEI): Pittsburgh.

[15] SEI, *CMMI for Acquisition, Version 1.2. Technical Report CMU/SEI-2007-TR-017.* 2007, Software Engineering Institute (SEI): Pittsburgh.

[16] SEI. *Process Improvement in Multimodel Environments (PrIME Project).* 2008 [cited 2008 May]; Available from: http://www.sei.cmu.edu/prime/primedesc.html.

[17] Yoo, C., J. Yoon, B. Lee, C. Lee, J. Lee, S. Hyun, and C. Wu, *A unified model for the implementation of both ISO 9001:2000 and CMMI by ISO-certified organizations.* Journal of Systems and Software, 2006. 79(7): p. 954-961.

[18] Sally Godfrey, *What is CMMI?*. NASA presentation. Available from: http://software.gsfc.nasa.gov/docs/What%20is%20CMMI.ppt, Dec.2008

[19] Violino, Bob. *Frameworks Boost Business Efficiency.* Optimize Magazine 4, 3 March 2005, pp.68-70.

[20] P. Ardimento, M.T. Baldassarre, D.Caivano, G. Visaggio, "Multiview framework for goal oriented measurement plan design", Fifth International Conference on Product Focused Software Process Improvement—PROFES 2004, Nara, Japan, pp. 159-173

[21] P. Ardimento, M.T. Baldassarre, D.Caivano, G. Visaggio, *Assessing Multiview Framework (MF) comprehensibility and efficiency: a replicated experiment*, Information & Software Technology, Kluwer Academic Press, April 2006.