

A SYSTEMATIC REVIEW ON THE HARMONIZATION OF REFERENCE MODELS

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Abstract: At present, there are wide ranges of reference models that are available to improve the way to develop and manage the software development in an organization, e.g. there are models to improve quality management, such as ISO 9001, for Software Quality Management there is ISO 90003, to improve the capacity of models there are CMMI and ISO 12207, for the IT Governance, there are ITIL, PMBOK and COBIT, Information Security Management Systems such as 27000 and Bodies of Knowledge such as SWEBOK, amongst others. However, the heterogeneity of the models available, together with the need to solve problems from many dimensions and organizational hierarchies, means that organizations face problems in improvement process projects which have to deal with different models at the same time. In this article, a systematic review is presented of works, initiatives and projects published and carried out on the harmonization of multi-model environments. Another objective stemming from the above is to discuss the significant issues related to this area of knowledge, providing an up-to-date state of the art and identifying possible related research streams.

1 INTRODUCTION

There is currently a wide range of models that can be taken as references for the improvement of an organization's processes, e.g. models to improve quality management such as ISO 9001, models for software quality management such as CMMI, ISO 12207 and ISO 90003, models for IT governance such as ITIL, PMBOK and COBIT, models for security management systems such as 27000, models for IT Service Management such as ISO 20000 and Bodies of Knowledge such as SWEBOK, amongst others. According to (Piattini et al., 2007), it would be imprudent to think that any of the models defined at present provides a total solution for process management in the context of: Information Security

Management System (ISMS), Information Technology Governance Processes (IT Governance), or processes of development, software maintenance and operation.

The great diversity and heterogeneity of available reference models, together with the need to solve problems from many dimensions and organizational hierarchies, provides organizations with a positive environment which enables them to choose different solutions to various problems and needs (Pardo et al., 2009). However, each of these approaches defines its own structure of process entities, definitions and quality systems, which increases the complexity in the implementation of multi-models in a single organization. Organizations must, therefore, define the most appropriate means of choosing and implementing multi-models in the

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face of this huge quantity. Harmonization may be one solution towards working simultaneously with multiple models (Pardo et al., 2009). The multi-model environments in software process improvement are present when an organization decides or needs to integrate into its processes different practices or characteristics that are present not in one, but in several models (Siviy et al., 2008b).

At present, 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: the PrIME project of the SEI (SEI, 2010), ARMONÍAS project of the research group ALARCOS (ARMONÍAS, 2009), Enterprise SPICE (SPICE, 2008), among other publications and works analyzed in this paper.

In this article, we present a systematic review of the literature which deals with the proposals that exist to support the harmonization of reference models for process improvement. In accordance with the general goals of systematic reviews, our aim is to provide an up-to-date state of the art which synthesizes the work in this area of knowledge and which can be used to identify gaps from which to formulate innovative research activities. The works found are classified and analyzed taking into account the trends of publication, the models used and the methods and techniques proposed. Some factors that influence the work with multiple models, as identified from the studies analyzed, are set out.

The paper proceeds as follows. In Section 2 the systematic review itself is presented. Section 3 presents the results obtained and a discussion of these. Finally, the conclusions and future work are outlined.

2 SYSTEMATIC REVIEW ON THE HARMONIZATION OF REFERENCE MODELS

To carry out the systematic review on the harmonization of reference models we followed the guidelines presented in (Kitchenham et al., 2007), the protocol template defined in (Biolchini et al., 2005) and the field procedure proposed in (Pino et al., 2008).

The research question is: *What works and initiatives related to the harmonization and*

integration of reference models have been carried out? The list of keywords used to find an answer to the research question is shown in the basic search string presented in Table 1.

Table 1: Basic search strings.

(integration OR integrating OR integrated OR unification OR unifying OR unified OR combination OR combining OR combined OR mapping OR mapped OR harmonization OR harmonizing OR harmonized OR) AND (standards OR models OR frameworks OR technologies) AND ("process improvement" OR "software process")

The planned list of sources with which the systematic review was carried out is:

- Science@Direct, on the subject of Computer Science,
- Wiley InterScience, on the subject of Computer Science,
- IEEE Digital Library,
- ACM Digital Library, and
- As grey literature, the reports of the PRIME project from the SEI were reviewed. In addition, some papers and works delivered by experts were reviewed.

The inclusion criterion of the primary studies obtained focused on the analysis of the title, abstract and keywords. This allowed us to determine whether the articles found were related to software process improvement, and moreover whether they perform or propose a strategy for carrying out the harmonization of multiple-models.

The exclusion criterion focused on the reading and detailed analysis of the abstract and conclusions. In certain cases where this was not enough, it was necessary to extend the analysis to other parts of the document.

The selection of studies followed an iterative and incremental procedure. This procedure was implemented by searching, extracting and visualizing results from each search source iteratively. In this way the revision report grew and evolved more and more until it was complete, thereby obtaining the final revision report.

3 RESULTS AND DISCUSSION

On the basis of information extracted from the studies found, a statistical analysis to show relevant findings of the systematic review was performed. Below are the results from different points of view.

3.1 Trends of the publications Multi-model environments in Software Process Improvement

As shown in Figure 1, we may note that there has been increasing interest in recent years on the part of the software engineering community with regard to process improvement environments where multiple models are involved.

Figure 1 shows an increase of the publications found in the last years. From the analysis of the 32 studies found (see all references of the studies selected in references section), it is possible to classify them into six categories. Figure 2 illustrates a summary of the categorized studies.

A brief summary of the studies categorized is presented below:

a. *Studies where only Two Process Reference Models are Harmonized.* These models can be from the same organization, or different. It is possible to see that 38% (12) of the works found harmonize only two models. In these proposals models are harmonized based on internationally recognized standards, e.g. ISO 9001 and CMM (Paulk, 1993; Paulk, 1994; Paulk, 1995), and ISO 9001 and CMMI (Mutafelija et al., 2003; Yoo et al., 2004; Yoo et al., 2006a; Kitson et al., 2009). These proposals seek to integrate the processes of the models from ones that have been previously institutionalized. Other studies attempt to integrate CMM or CMMI with other models different and apart from ISO 9001. These are: CMM and Cleanroom model (Oshana et al., 1999), CMMI and SWEBOK model (Mutafelija et al., 2006), CMMI and Six-Sigma model (Lin et al., 2009), CMMI and ITIL (CITIL, 2010) and CMMI and ISO 12207 (Pino et al., 2009).

b. *Studies that Harmonize more than Two Process Reference Models.* 9% (3) of the works found harmonize more than two models, e.g. the high-level comparison between EIA IS 731, the CMMISM and SECM (Minnich, 2002), the analysis performed to identify the problems of interoperability and harmonization of the models ISO/IEC 15288, EIA 632, IEEE 1220 and other related ISO standards (Croll, 2002), and the aligning of Cobit 4.1, ITIL V3 and ISO/IEC 27002 for Business Benefit (ITGI, 2008).

c. *Studies that Harmonize Two or more Process Reference Models and Assessment Models.* 22% (7) of the studies analyze the integration of the assessment models and their implementation in different process reference models. Some of the related studies include: analysis of compatibility

between SPICE and CMM (Rout, 1998), analysis of the compatibility of CMMI as Process Assessment Model, ISO 12207 as Process Reference Model and ISO 15504-2 as Measurement Framework (Rout et al., 2007; Pino et al., 2009), integration of ISO/IEC 15504 and CMMI-SE/SW (Wangenheim et al., 2005; Rout et al., 2007), defining support structures and comparison between CMMI and SPICE (Lepasaar et al., 2002; Foegen et al., 2003), among others.

d. *Studies that Propose unique and/or Universal Models.* 3% (1) of the works found correspond to a study that proposes a unique and/or universal model, but which does not describe the solutions used, e.g. steps, activities or process performed carried out. The study found presents the lessons learnt from the definition of the Capability Maturity Model (iCMM), as a new approach that integrates multiple approaches, including: ISO 9001, Malcolm Baldrige National Quality Award criteria, International lifecycle and assessment standards and processes, and several CMMs (Ibrahim et al., 2004a).

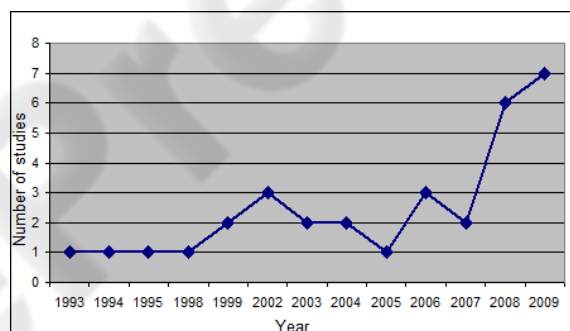


Figure 1: Trends of the publications on Multi-Model environments in Software Process Improvement.

e. *Studies that Provide a Solution for Supporting Multi-model Harmonization.* 25% (8) of the works proposed provide solutions (methodology, process, framework, activities, tasks, steps, amongst other elements) for supporting the harmonization of multiple models, these being the following: the VM XT project, which is applied as the standard in harmonizing the different approaches and projects of Information technology (IT) under a specific model (Biffel et al., 2006), an ontology for the integration of quality standards in ISO 9001:2000 and CMMI is taken for collaborative projects (Ferchichi et al., 2008). The PRIME project presents the value of harmonization process improvement in organizations when different models are in use

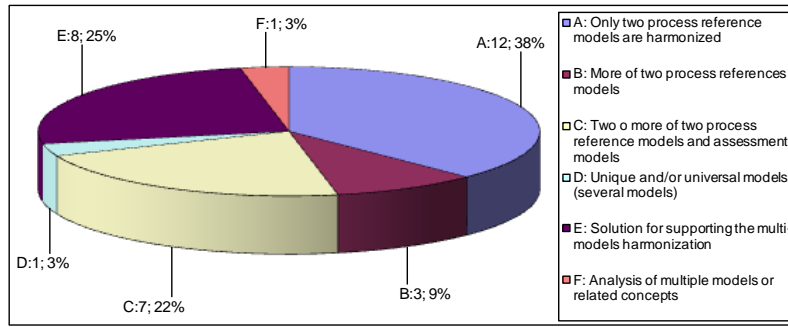


Figure 2: Trends of the publications on Multi-Model environments in Software Process Improvement.

(Siviy et al., 2008a; Siviy et al., 2008b; Siviy et al., 2008c) and Infosys Project defines a path for the transition from ISO 9001 to SW-CMM level 4, based on the experience of an organization (Jalote, 1999). Enterprise SPICE is an initiative to establish an Enterprise Integrated Standards-Based model for use with international standard ISO/IEC 15504 (SPICE) (SPICE, 2008). In (Ferreira et al., 2009) a work is presented that identifies principles and process characteristics for designing a system of processes at the architectural level and in (Kelemen, 2009) we can discover research that defines a method for process-based unification of different approaches to multiple process-oriented software quality.

f. *Studies that Provide Analysis of Multiple Models or Related Concepts.* 3% (1) of the works found correspond to a study that recognizes the value of having processes that are drawn from widely accepted and proven quality models e.g. CMMI-DEV, ISO 9000, ISO 20000, eSCMSP, ITIL, Lean Six Sigma and ISO 27001 (Heston et al., 2009).

3.2 Models used

On the basis of the analysis and classification performed above, it is significant to highlight that in the harmonization of models, different types of models are involved. In Table 2 the process reference models and reference models for assessment used in the studies are shown in alphabetical order. As can be seen in the Table, the models for assessment that are most frequently used in the integration with other models are the ISO/IEC 15504 or SPICE, at 11%. Likewise, it can be seen that the process reference models which are most frequently used are CMM (13%), CMMI (25%) and ISO 9001 (18%). On the other hand, models such as ITIL and ISO 27000 (Part 1 or 2) are used in a lesser percentage; 5% each one, respectively. The ISO

12207 and Sigma and Lean Six-Sigma have 4% usage compared to other models such as CSE, COBIT, EIA IS 731, eSCMSP, ISO 20000, SECM, SWEBOK, V-Modell XT, Six- and other ISO standards have a 2% usage each.

Table 2: Models used.

Models	Total	%
Cleanroom Software Engineering (CSE)	1	2
CMM	7	13
CMMI	14	25
COBIT	1	2
EIA IS 731	1	2
eSCMSP	1	2
ISO 12207	2	4
SPICE or ISO 15504	6	11
ISO 20000	1	2
ISO 9001	10	18
ISO/IEC 15288, EIA 632, EEE 1220 and other related ISO standards	1	2
ISO 27000 Part 1 and Part 2	3	5
ITIL	3	5
SECM	1	2
Six-Sigma or Lean Six-Sigma	2	4
SWEBOK	1	2
V-Modell XT	1	2
TOTAL	56	100%

With regard to process reference models, those which are most widely used are the ISO models at 41%, of which ISO 9001 is the most frequently used, at 18%, and the SEI models at 39%, of the which the CMMI is the most frequently used at 25%. Other models are used in smaller percentage (20%); see Figure 3(a). Likewise, we can observe that in most of the studies that involve these models, the way of achieving CMM or CMMI is analyzed starting from ISO 9001. Although the major aim is to reuse parts of the ISO standards in a CMM or CMMI environment, it is difficult for an ISO-certified organization to implement CMMI easily because of the differences in the language, structure, and details of the two sets of documents; see (Yoo et al., 2006a).

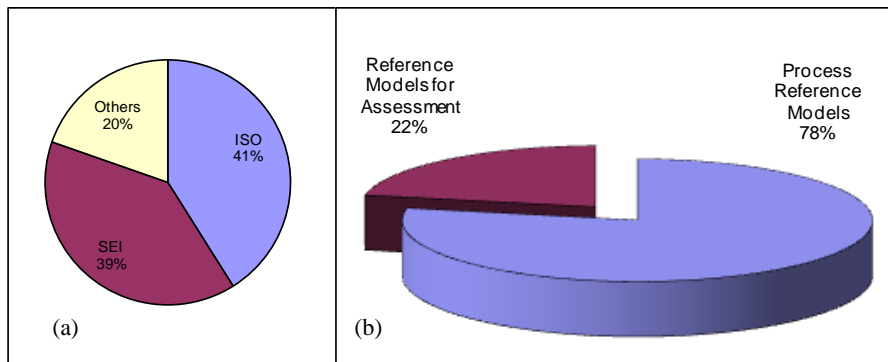


Figure 3: Reference model for the assessment and process reference models involved.

With regard to process reference models and reference model for assessment, Figure 3(b) shows that: (i) 22% of the studies involve the harmonization of reference models for assessment and process reference models and (ii) 78% only involve the study of process reference models. This suggests that there is a special interest in analyzing the compatibility and the relationships between two approaches, e.g. the relationships established between CMMI, as a candidate conformant Process Assessment Model, relative to the Measurement Framework defined in ISO/IEC 15504-2, and the Process Reference Model described in ISO/IEC 12207, e.g. (Rout et al., 2007).

3.3 Methods and Techniques Proposed

With regard to the analyses carried out above, this section provides a brief summary of some of the methods and techniques used in works found. Table 3 shows those techniques used.

The above table shows that several attempts have been made to define solutions for the harmonization of multi-models. These works propose various techniques with solutions to support harmonization. The techniques used are classified in different ways, e.g. the activity used to discover related elements in several models may be called *comparison* or *mapping*. Other works use terms such as *synergy* or *compatibility* to identify the level of relationship between models. However, most related comparison techniques do not use a *comparison scale* that allows a range for the relations identified among the models compared to be established. This would allow the subjectivity in the comparison to be minimized. Similarly, *combining* and *merger* are used to refer to several *integrated* or *unified* models, but with the difference that the steps followed for their integration are not shown. Some works use the term *single model* or *universal model*.

Table 3: Methods and Techniques proposed.

Technique, term or concept used	Studies	Number of studies	%
Integration, Unification	(Siviy et al., 2008a; Siviy et al., 2008b; Siviy et al., 2008c), (SPICE, 2008), (Yoo et al., 2004; Yoo et al., 2006b), (Jalote, 1999), (Biffl et al., 2006), (Ferchichi et al., 2008)	10	31
Comparison, Mapping, Align	(Biffl et al., 2006), (Paulk, 1993; Paulk, 1994; Paulk, 1995), (Mutafelija et al., 2003; Mutafelija et al., 2006), (Rout, 1998; Rout et al., 2007), (Minnich, 2002), (ITGI, 2008), (Oshana et al., 1999), (Kitson et al., 2009), (Pino et al., 2009), (Minnich, 2002), (Wangenheim et al., 2005), (Lepasaar et al., 2002)	17	50
Combine, Combination, Merger, Single model, Universal model	(Lin et al., 2009), (CITIL, 2010), (Ibrahim et al., 2004b)	3	9
Harmonization	(Croll, 2002),	1	3
Neither	(Ferreira et al., 2009), (Kelemen, 2009)	2	6

Likewise, *complementarily* is used to refer to models that take elements of other models to maximize their qualities.

It may be seen that of the techniques used in 50% of the studies analyzed, some kind of comparison, alignment or mapping is used as a technique leading to the harmonization of multiple models. Only some of the studies propose different harmonization techniques. However, we believe that the techniques or terms used in the other studies correspond to general or related concepts. In that sense, we believe that the terms found can be classified into *methods* and *techniques*. The *methods* are general procedures and the *techniques* are

specific procedures applied to the definition or framework of a method. That is, a *method* is a procedure which is generally oriented towards a specific purpose, while the *techniques* are different ways of applying the method. Based on the techniques found, in Table 3 we have ordered the techniques, terms or concepts used in the studies analyzed into a general concept called harmonization, along with methods, techniques and the possible objective or result.

Table 4: Methods and Techniques.

	Methods	Techniques	Objective
Harmonization	Comparison	Align, Mapping (Pino et al., 2009), (Mutafelija et al., 2003; Mutafelija et al., 2006), (Biffl et al., 2006),	Complement Homogenization Single model, Universal model
	Integration or Unification	Combine, Merger (Jalote, 1999), (Yoo et al., 2004; Yoo et al., 2006b), (Biffl et al., 2006),	

3.4 Factors that Influence the Work with Multiple Models

The primary studies were also used to search for and extract the information that reported the factors that may influence an organization in needing to work with more than one assessment or process reference model. The following can be highlighted as some of these:

- *Market Niches with Specific Models.* It is possible that in some market niches the groups of organizations prefer certain models or fact standards, e.g. according to the literature analyzed, CMMI or ISO 9001, respectively.
- *Improvement of Practices from Legacy Process Models.* It is possible that is necessary to carry out the complementarily of the process and practices which have been institutionalized from specialized models or more detailed ones, e.g. to obtain a certification in CMMI from an ISO certification obtained previously, see (Yoo et al., 2006a).
- *Business Positioning.* Although certification on a specific model does not entail an increase in sales for an organization, at a commercial level

it increases confidence among its customers, allowing a better business positioning.

- *Leveraged or Merger Corporate.* It is possible that in a corporate merger the organizations do not use the same model. Taking into account that in a merger an organization can be absorbed by other, it is necessary to identify and define rules to lead the merger adequately.
- *Systematic Search of the Capability of the Processes.* For the organizations interested in performing a continual and ever-more-complete improvement of their processes, it is possible that the harmonization of multiple models may allow them to carry out substantial growth in the capacity of their processes from other models.
- *Business Growth.* Business growth involves more mature and complex processes. At any specific time in their business growth, organizations can require integration of models and practices that support the performing of activities and the process of management and/or development.

4 CONCLUSIONS

Undoubtedly, the effort required in systematic reviews is considerably greater than for a conventional review of the literature. The way systematic reviews are performed allows us to summarize the evidence found on a specific topic. In this article a systematic review of the literature on the harmonization of multi-models for software process improvement has been presented, which has allowed us to obtain a view of the initiatives and related works.

From the results obtained in the current review, the first observation from the study that was carried out is that in the last 4 years there has been an ever-increasing interest on the part of the software engineering community in harmonizing multiple models. Currently, software development organizations may need more than one model to support and achieve the organization’s strategic goals. Nevertheless, there is a lack of proposals, so for the organizations it is no easy task to carry out the implementation and management of the different events to be taken into account to harmonize more than two approaches or models as references for software process improvement.

With regard to the most frequently used models, it can be seen that the CMMI as process reference model is the one most used by the SEI. We note that

the models defined by the ISO are the ISO 9001 as reference model and the ISO 15504 as process assessment method, while a smaller percentage of studies involve other models.

Another relevant fact is that the systematic review carried out has allowed us to identify that, depending on an organization's needs, the multi-model environments are characterized by the implementation of different approaches and techniques to support their harmonization. These techniques are identified using different terms to bring into consonance two or more models. There is no single glossary to identify the multiple techniques used.

Another fact to highlight is that there are significant differences between the structures, terminology and approaches; these hinder the harmonization of multiple models. Likewise, it has been possible to identify several factors which influence the work with multi-model environments. These factors or needs we have identified can influence the approach to implementation or selection of the models when carrying out a multi-model project.

Bearing in mind the shortcomings found in this current research stream, we are implementing some proposals towards the definition of a Framework for the harmonization of multiple models, see (Pardo et al., 2010). As of this moment, we have defined some harmonization techniques which make it easier to harmonize models, e.g. the homogenization technique and comparison, see (Pardo et al., 2009) and (Pino et al., 2009) respectively. We are also working on the definition of an ontology of terms and relationships that integrate the most frequently concepts used in this type of environments.

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