The Journal of Systems and Software xxx (2012) xxx–xxx

Contents lists available at SciVerse ScienceDirect

The Journal of Systems and Software

journal homepage: www.elsevier.com/locate/jss

From chaos to the systematic harmonization of multiple reference models: A harmonization framework applied in two case studies

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ARTICLE INFO

Article history:
Received 14 December 2011
Received in revised form 3 May 2012
Accepted 14 July 2012
Available online xxx

Keywords:
Harmonization process
Harmonization of multiple models
Multi-model
Harmonization
Improvement process
SPI
Case study

ABSTRACT

At the present time, we can observe that in an effort to deal with the issue of quality, a variety of models, standards and methodologies have been developed to give support in different domains of the IT industry. This wide range of heterogeneous models makes it possible to resolve multiple needs. In recent years, as the integration of different models has increased, organizations have started to note that their business and technical processes can be aligned with more than one model. Currently, however, we are not aware of any other attempts to provide an explicit and systematic solution that would allow us to address the issue of harmonization of multiple reference models in such a way as to satisfy the needs of the companies. In the quest to help support the work of harmonization of multiple models, this paper presents (i) a framework that defines elements needed to support the harmonization of multiple reference models, (ii) a process, which is the backbone and way of integrating all the elements defined in the framework thus allowing the implementation of a harmonization project to be guided systematically, harmonizing multiple models through the configuration of a harmonization strategy, and (iii) a set of methods, which allows us to know "what to do", as well as "how to put" two or more models in consonance with each other. The experience of the application of our proposal is illustrated in two case studies. The findings obtained show that the harmonization process has enabled us to harmonize and put the models involved in consonance with each other.

1. Introduction

At the present time, we can observe that a variety of models, industry-specific standards and methodologies of quality 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 ISO 27001, models for IT Service Management such as ISO 20000 and Bodies of Knowledge, such as SWEBOK, amongst others. These are available to provide a guideline in multiple instances of IT organizations, e.g. Information Security Management System (ISMS), Information Technology Governance Processes (IT governance), amongst others. Some models are widely used in the industry to improve the competitiveness of organizations; others are required as mandatory standards, becoming a regulation method in certain market niches. Independently of the model to be used, the implementation of any model requires specific experience and knowledge and resources, along with a high degree of effort and investment, as key factors for it to be successful. All this means that the task is by no means easy and that there is a significant risk of failure (Aaen, 2003).

However, taking into account that there is no one single model that meets all requirements that an organization needs to satisfy, organizations can today demand the implementation of the best practices of more than one model as support to multiple requirements (given, perhaps, by the organization or business domain) when these are aligned with multiple reference models (Heston and Phifer, 2011), e.g. models required both from their customer

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http://dx.doi.org/10.1016/j.jss.2012.07.072

contracts and business domains (which can involve models to support their business processes and technical processes). Given that some of these models address similar approaches, they can share similar practices and therefore similar quality objectives (Ferreira et al., 2010a). It is thus possible to come to the conclusion that implementing multi-models process from shared quality goals reduces the costs of the adoption of multiple models. However, selection of the most suitable model is not an easy task. It is true that the heterogeneity of models provides a wide range of options, with the possibility of choosing different models that allow us to meet multiple needs of the organizations. We must take into account, nevertheless, that each model defines its own structure, terminology, scope, approach and level of abstraction or detail, domain and size of the organization (Biffl et al., 2006). It is often the case that the organizations do not use a clear and systematic harmonization proposal that allows them to reconcile multiple models suitably. That can lead to inefficient harmonization, which in turn may lead to a drastic increase in the operational risk, as well as in the cost associated with the implementation of different models. Productivity is thereby decreased and this brings about some problems related to the redundancy of the practices defined (Heston and Phifer, 2011). Consequently, it is important for organizations to have a proposal that assists them in harmonizing multiple models, identifying and resolving their differences and similarities. When this occurs, an integrated solution is obtained, which takes advantage of the qualities of each model and maximizes them. This should make a positive impact on the entire organization, mainly on (i) the interoperability of the processes defined from multiple models, (ii) the cost and effort used to implement integrated models, and (iii) the work of each person that makes up the work team in charge of carrying out the harmonization of the models.

Bearing in mind the aspects described above, the goal of this paper is to give an overview of a harmonization framework (HFramework) which allows the harmonization of models which can be taken as reference model to be supported, e.g. generic standards which describe their requirements at a high level, such as ISO 9001, process maturity models such as CMMI-DEV, SPICE, and process models like Extreme Programming, amongst others. We provide extensive discussion of its harmonization process (HProcess), which is the backbone of HFramework. In addition, the paper presents the application of HFramework in two case studies where multiple models such as ISO 27001 and ISO 20000-2, as well as Basel II, Risk IT, Val IT, Cobit 4.1, ISO 27002 and ITIL V3 are integrated. This work therefore intends to support and guide organizations toward the harmonization of multiple models through a harmonization framework and its elements, i.e. harmonization process, a set of methods, roles and work products presented in this paper.

The rest of the paper is structured as follows. Section 2 provides an analysis of the related work. After this analysis, Section 3 sets out in detail the HProcess, the harmonization process used for Driving Multi-models Harmonization. The application of HProcess in two case studies is described in Section 4. Section 5 presents a perspective and comparative analysis of the work related to our proposal. Finally, the conclusions drawn are presented, and future work is outlined.

2. Related work

There are a number of proposals which have been defined and that are in current existence, related to the harmonization of multiple models. On that subject, we are going to highlight the most important aspects of some related works and the differences between them and our proposal. In doing this, we place our work within the reference literature on harmonization, pointing out exactly what our contribution is.

As the systematic review performed in Pardo et al. (2011a) affirms, it is quite clear that there has been a growing interest in recent years on the part of the software engineering community with regard to process improvement environments where multiple models are involved. Some examples of this are: the harmonization of internationally recognized standards such as ISO 9001 and CMM (Paulk, 1993), or ISO 9001 and CMMI (Mutafelija and Stromber, 2003a), proposals which have sought to integrate the CMMI with other models, such as SWEBOK (Mutafelija and Stromber, 2006), Six-Sigma (Lin et al., 2009), ITIL (CITIL, 2010) and ISO 12207 (Pino et al., 2010). There are studies which attempt to align Cobit 4.1, ITIL V3 and ISO/IEC 27002 for Business Benefit (ITGI, 2008a), as well as proposals such as the Capability Maturity Model (iCMM), which defines a unique and/or universal model from the integration of the best practices of multiple models like ISO 9001, Malcolm Baldridge National Quality Award criteria, International lifecycle and assessment standards and processes, and several CMMs (Ibrahim and Pyster, 2004), amongst others. For more information about studies related to the harmonization models, please consult (Pardo et al., 2011a).

From the analysis of the 32 studies found, and with respect to their characteristics, it has been possible to classify them into six categories:

(i) Studies where only two process reference models are harmonized.
(ii) Studies that harmonize more than two process reference models.
(iii) Studies that harmonize two or more process reference models and assessment models.
(iv) Studies that propose single and/or universal models.
(v) Studies that provide a solution for supporting multi-model harmonization.
(vi) Studies that provide analysis of multiple models or related concepts.

Taking into account that in this research work we proposed a solution to support multi-model harmonization.

Some studies which tackle the fifth category are: Process Improvement in Multimodel Environments, or the PrIME Project (Siviy et al., 2008a,b,c), Ferchichi, who proposes an ontology for the integration of quality standards in ISO 9001:2000; CMMI is taken for collaborative projects (Ferchichi et al., 2008), as well as the V-Modell XT Project (Biffl et al., 2006) (hereafter known as VM XT). Kelemen proposes a process-based unification of process-oriented software quality approaches (Kelemen, 2009), and Ferreira carries out the mapping and/or comparison of some models, describing a framework for auditing and assessing the software of multi-model environments (Ferreira et al., 2011).

From the results obtained in the review presented here, the first observation from the study that was carried out is that in the last 5 years the software engineering community has shown an ever-increasing interest in harmonizing multiple models. Organizations may currently need more than one model to support and achieve the organization's strategic goals. Nevertheless, although there are some pieces of work and projects where different reference models have been mapped and integrated, these have addressed only a specific set of models, e.g. CMMI, ITIL and ISO 9001. Likewise, there is a lack of proposals, and it is therefore no easy task for organizations to carry out the implementation and management of the different events that must be considered in order to harmonize more than two approaches or models as references for software process improvement. On the other hand, it is necessary to define more elements and tools which make it possible to address different needs which have not been taken into account within a multi-model viewpoint. An example of this would be the need to reconcile the

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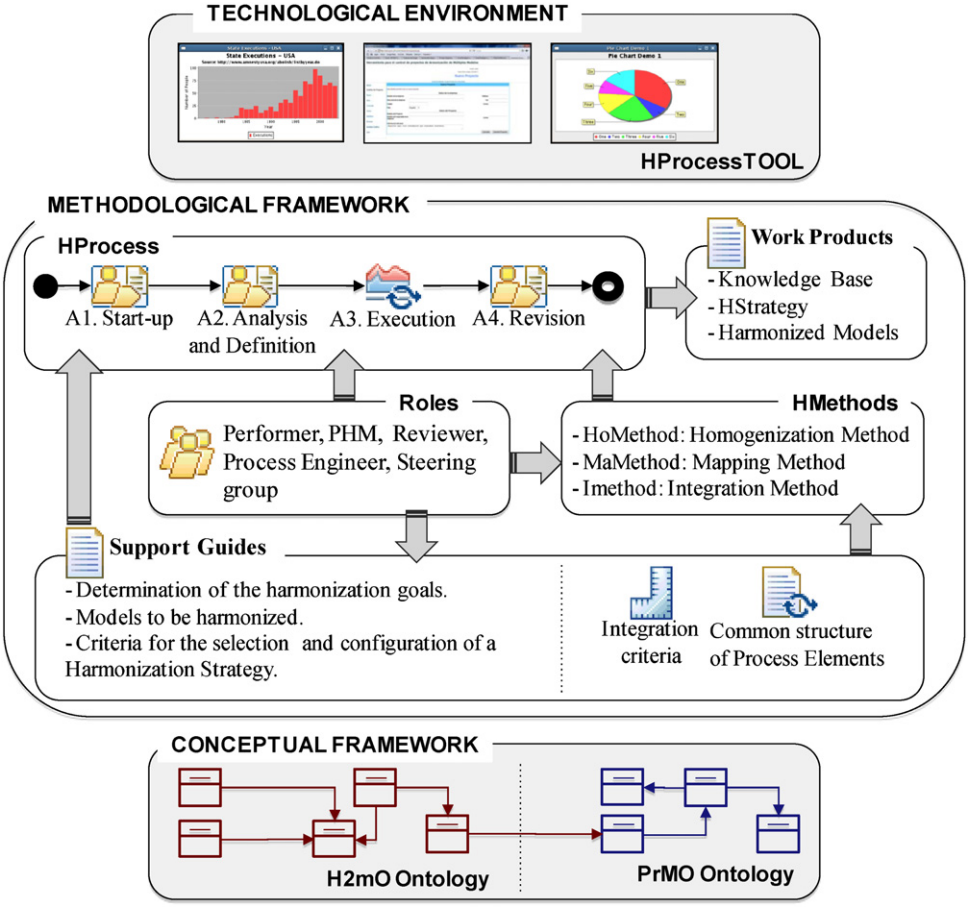

Fig. 1. Framework for supporting harmonization of multiple reference models.

structural differences found between models first, before carrying out their comparison and/or integration. There should be integration criteria to support the definition of multi-model processes and a definition of harmonization solutions from the business needs of organizations.

Bearing all the above in mind, this article presents HFramework, which defines a set of elements to support these issues; its application in two case studies is also discussed. A detailed comparison of HFramework and the related work is presented in Section 6.

3. HFramework: a framework for the harmonization of multiple-models

From the analysis of a systematic review performed, we have found some proposals which define solutions to support the harmonization of multiple models. Most of these only provide solutions to specific issues, however, and do not provide a detailed methodology for supporting the complexity related to the harmonization of models. In an effort to provide the conceptual, methodological and technological support needed to facilitate the harmonization of multiple models, this section presents HFramework, a methodological framework of the ARMONÍAS project defined. A general description of the harmonization framework and its elements is given below.

Fig. 1 shows an overview of the elements which constitute HFramework. As can be observed this figure, HFramework defines a set of elements which are organized in three frameworks, as follows:

- Conceptual framework. This defines two ontologies for the representation and management of knowledge related to the harmonization of multiple models. The conceptual framework provides the means needed to understand the complexities involved in aligning multiple models. To this end, the conceptual framework consists of the following elements:
  - H2mO, an ontology for the harmonization of multiple reference models, which defines the main concepts that could be used in a harmonization work. H2mO provides a formal and clear support of the most widely used methods, techniques and concepts in the harmonization of multiple models, as well as the relationships and related terms. A detailed description of H2mO ontology and its application in a real context has been presented in Pardo et al. (2012).
  - PrMO, a Process-reference Models Ontology which establishes the key elements used to express process-based approaches. From PrMO, a common structure of process elements has been defined. This is applied along with a homogenization method, to put different models under the same process structure and facilitate their harmonization. A brief summary of the CSPE, the homogenization method and PrMO is presented in Pardo et al. (2009).
- Methodological framework, which permits the systematic driving and leading of the activities, tasks and roles required to support the efforts related to the management and configuration of a suitable harmonization strategy (HStrategy) that in turn enables the harmonization of multiple models to be carried out. To this end, the methodological framework consists of the following elements:
  - A guide for determining the harmonization goals, which allows the harmonization objectives to be clearly identified and defined. This guide uses the strategic plan and the

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organization's objectives from its mission. Our objective is to make it possible to identify the most suitable harmonization strategy to follow when different models need to be harmonized.
  - The criteria for the selection and configuration of the harmonization strategy, which are based on a general harmonization strategy that provides support for the configuration of HStrategies and for the identification of the methods to use.
  - Harmonization process (HProcess), the process used to manage and drive a suitable strategy, which allows multiple models to be harmonized step-by-step and through of set of elements defined in HFramework. HProcess is therefore the backbone and means of integrating all the elements defined in HFramework. HProcess is also used to define and implement an HStrategy according to the strategic business objectives of an organization. HStrategy is the main work product resulting from the implementation of HProcess.
  - Harmonization methods (HMethods), a set of methods, techniques and elements which provide information on "how to put" two or more models in consonance with each other. HMethods complements HProcess and supports the configuration of HStrategy. HMethods describes the following elements:
- Homogenization method (HoMethod), which provides a set of activities for setting in harmony the structural differences between multiple models. It uses a template defined from the CSPE structure specified in PrMO to put the models in the same structure and make it easier to compare them.
- Mapping method (MaMethod), which allows the identification of differences and similarities between multiple models to be carried out; see Pino et al. (2010).
- Integration method (IMethod), which is responsible for offering support in combining and unifying best practices of multiple models. It is currently being updated from the findings obtained in this paper. A first Spanish version of this method, along with a set of criteria to support decision-making during combination and/or unification of practices, is presented in Pardo et al. (2011b).
- Technological environment, which is composed of a harmonization process TOOL (HProcessTOOL), a WEB tool that allows a harmonization project to be supported, managed, controlled and monitored. HProcessTOOL has been designed from the elements defined in HFramework.

The guide for determining the harmonization goals, the criteria for the selection and configuration of the harmonization strategy, the H2mO and PrMO ontologies and the methods defined in HMethods have been presented in detail in other pieces of work and so are beyond the scope of this paper, which has focused only on the description of HProcess.

Fig. 2 shows an overview of the elements and relationships that are defined in the HProcess. The approach of the framework application is determined by the objectives of the harmonization, which are identified and defined from the plan and goals specified in the organization's mission and by a guide for the determination of the harmonization goals. The objectives will establish the particular approach for tackling the work of harmonization, which may involve the harmonization of product and/or process models. With the approach and the objectives of harmonization that have been identified, HProcess will guide the organization during the harmonization of multiple models, through the definition and configuration of a suitable harmonization strategy (HStrategy), see Fig. 2. HProcess is supported by: H2mO ontology, PrMO ontology, and HMethods. Given that each organization has its own different organizational needs, configuring a strategy is very important. Doing so makes it easier to harmonize multiple models and allow support to be offered to a strategic objective of the organizations. The HStrategy obtained thus determines the strategy implementation process to be followed for the harmonization of the models that have been analyzed.

4. HProcess for driving the harmonization of multiple models

This section presents HProcess in detail, by means of the description of the considerations and principles involved in its creation, a detailed description of HProcess, i.e. purpose, objectives, activities (diagram and descriptions), work products, roles and a description of the Tool developed to support the harmonization process – HProcessTOOL.

4.1. The harmonization process – HProcess

HProcess has been defined according to the notation SPEM 2.0; it includes activities, tasks, roles and some main work products (see Fig. 2).

4.1.1. Principles

The harmonization process is based on the following principles:

- Promotion of harmonization of models incrementally and iteratively.
- Provision of a technical and management infrastructure that is suitable for supporting a harmonization project of multi-models.
- Fostering of the effective formation of the groups proposed by the work infrastructure, based on capabilities of individuals.

4.1.2. Purpose

HProcess is a detailed process for managing harmonization of multi-models and it has been developed with the purpose of: (i) providing the IT organizations with the elements needed to carry out the harmonization of multiple models and (ii) making it possible to reduce the complexity of harmonization of multiple models in organizations; it includes new and/or legacy models.

4.1.3. Objectives

HProcess defines the following objectives:

- To achieve model harmonization in a disciplined and systematic way, by means of the compliance of the activities, responsibilities and generation of the work products defined in HProcess.
- To define the objectives and scope for the harmonization of multiple models, based on the objectives described in the plan and mission of the organization.
- To support the harmonization of multiple models in organizations through an HStrategy configured from their strategic needs.

4.1.4. Activity diagram

Given the complexity of harmonization of multi-models, it is a significant contribution to provide a process which gives support to this activity. Fig. 2 shows how, by means of the activities presented by HProcess, harmonization of multi-models can be tackled by defining a HStrategy as a result of the execution process.

HProcess, its activities, tasks, roles, work products, templates and other elements have also been edited with the EPF composer (Eclipse, 2011); this ensured that documentation was generated in a standard format which can be updated and which is available through the Web (see Fig. 3 and detailed process in ARMONÍAS (2009)).

4.1.5. Activities description

HProcess is made up of four activities: Start-up, Analysis and Definition, Execution and Revision. The activities of analysis and

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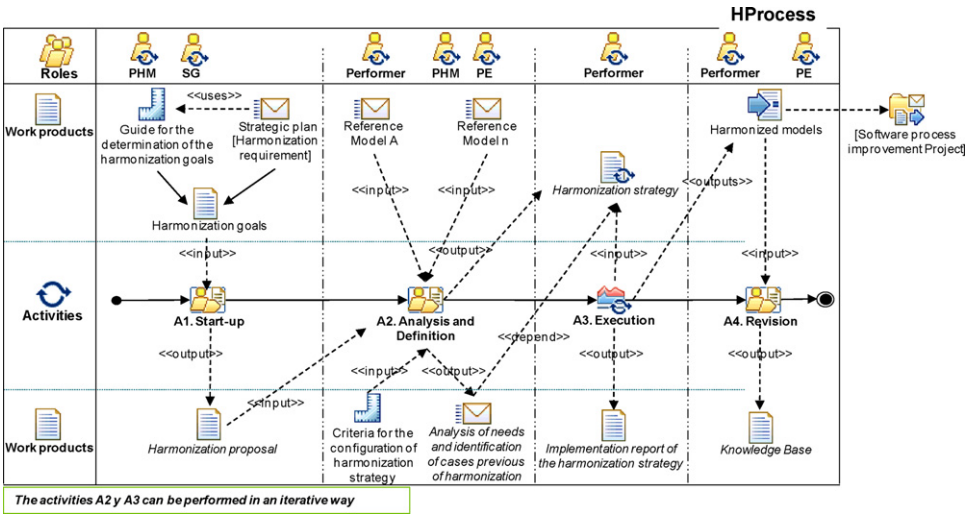

Fig. 2. Process for driving harmonization of multiple models.

definition and execution can be performed iteratively. They are presented below:

- (A1) *Start-up*: In this activity the *Process Harmonization Manager* (PHM) identifies the harmonization requirements, which are aligned with the organization's strategic planning as laid out in the strategic plan. The PHM defines a harmonization proposal in which the goals, person responsible, schedule, work structure and other elements needed to guide the organization through each of the following harmonization activities are described. The proposal must be approved by the *Steering group*.
- (A2) *Analysis and definition*: In this activity the PHM and the *Performer* carry out the prioritization of the harmonization requirements identified. The *Performer* identifies the processes of the models that support the solution of the harmonization requirements. Similarly, the *Performer* and *Process Engineer* (PE) identify which harmonization methods to use. To minimize harmonization efforts, the PE should carry out a search process to identify previous cases where harmonization methods of the models involved have been applied, such as mappings, comparisons, integrations, complements, amongst others. The findings discovered could update the harmonization requirements. With the information found and the changes performed, the PE defines an HStrategy. The HStrategy describes the prioritized requirements of harmonization, the models and processes that provide a solution to the requirements, directionality of the harmonization between models, the harmonization methods, the previous harmonization cases and updated requirements.
- (A3) *Execution*: In this activity, the *Performer* manages and executes the HStrategy. As mentioned above, the HStrategy defines the methods and activities that will be performed to harmonize multiple models, e.g. a strategy that is made up of two activities; analysis and comparison. These activities are detailed by the methods of homogenization and comparison described in Pardo et al. (2009) and Pino et al. (2010) respectively. The *Performer* must write up the lessons learned during the execution of the HStrategy. The information related to this activity is registered in the implementation report of the harmonization strategy. This report describes the relevant information about activities, goals, iterations, incidents, solutions and suggestions which have

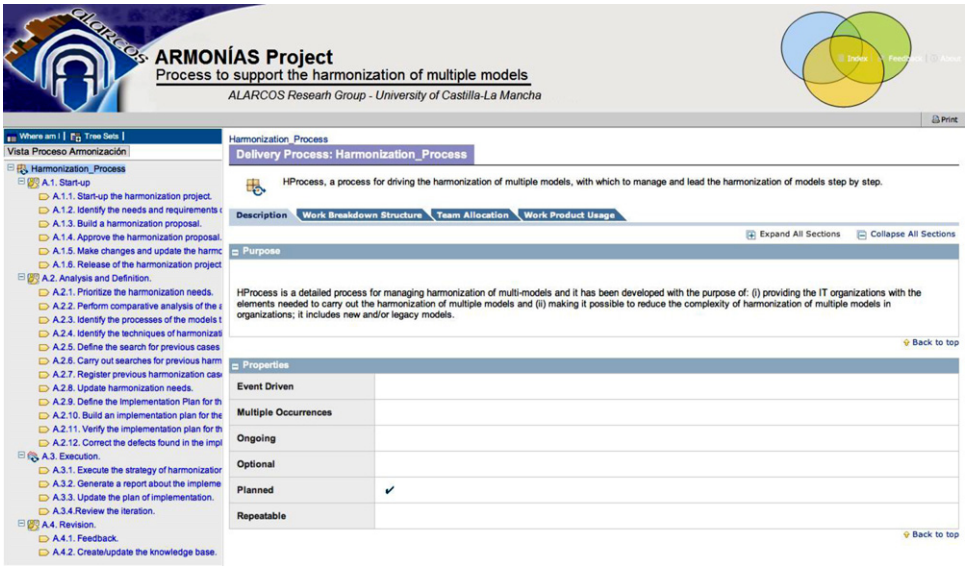

Fig. 3. HProcess described with EPF composer.

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occurred. Both the Analysis and Definition activity and Execution activity follow an iterative and incremental approach.
- (A4) *Revision*: In this activity, all the elements related to the execution of the harmonization project are analyzed, discussed and documented. The *Performer*, PHM and PE get feedback about the lessons learned, the models harmonized, methods used and so forth. All related elements are registered in the Knowledge Base of the harmonization cases. This report can be used as a basis for future harmonization projects.

4.1.6. Work products

A self-contained template has been developed by each work product defined in the harmonization process, in order to make its construction easier. This allows the effort associated with the activities related to each work product to be registered on the template. The main work products (of input and output and their abbreviations) related to the activities of HProcess are:

- (WP01_A1_HP) Harmonization proposal. This proposal defines a general perspective and focus of the harmonization project. It is a document that allows us to describe and record the scope of the harmonization project, along with the objectives and needs of the organization that motivate the project. The proposal also registers the reference models, as well as inclusion and exclusion criteria for selecting the practices of the models liable to be used in harmonization. In addition, it describes general or global planning of the project. An excerpt of the template of the harmonization proposal for a case study can be seen in Table 1.
- (WP01_A2_ANICPH) Analysis of needs and identification of cases prior to harmonization. This collects previous cases of harmonization that will be used as a baseline to reduce the effort foreseen in the initial planning of the iterations that describe the execution of the HStrategy. In addition, this document specifies the updated and prioritized harmonization needs, the results obtained from comparative analysis of the attributes of the models to be harmonized, the processes that support the solution to the needs identified, the directionality of harmonization, along with methods that support the realization of the harmonization objectives and goals.
- (WP01_A2_HS) Harmonization strategy. This document is one of the main work products resulting from the HProcess with which it carries out the harmonization of the models. As well as all this, it sets out the objectives of harmonization to be developed in each one of the methods configured in HStrategy (that depends on each situation; hence it can be different in each instance, see case studies in Section 4). It is also comprised of the methods to be used in addressing each harmonization objective, a detailed description of the process to implement the harmonization strategy, along with an activity diagram, strategies to address the development of the methods, the measurement plan, the training plan, the risk-management plan and the schedule for the different iterations of the harmonization cycle.
- (WP02_2_IRHS) Implementation report of the harmonization strategy. This collects the information about the strategy that has been executed, the state of harmonized processes and the information about the execution of all iterations with regard to the results, incidents, issues, effort, decisions, suggestions and other significant information. There is a report template for each iteration, but this document or final report is a summary of the state of the execution of all iterations defined in HStrategy.
- (WP02_2_KB) Knowledge base. This collects the problems and solutions adopted in each of the activities performed. Besides this, the goals achieved and lessons learned should be incorporated in a knowledge base for decision-making in future harmonization projects.

4.1.7. Roles

There are four roles involved in HProcess; they are presented in Table 2.

The associations between tasks, activities, roles, work products used and produced in HProcess are presented in Fig. 2.

4.2. Tool for supporting the harmonization process – HProcessTOOL

To make it possible to apply HFramework in the case study organizations, it is important to provide them with software tools which enable HProcess to be carried out. This kind of tool allows us to support repetitive actions and reduces the cognitive load of the individuals involved in the harmonization activity, as well as any administrative load associated with the manual application of this activity. Given the above, a flexible environment to support the process and defining strategies for driving the harmonization of multiple models has been developed; it is called HProcessTOOL. This tool is a WEB environment that facilitates the control and monitoring of multi-model project harmonization. To support this characteristic, HProcessTOOL uses as its basis the harmonization process presented in this paper and described above.

HProcessTOOL provides five functionalities: (i) management of the harmonization project, which allows the control and monitoring of the harmonization projects, (ii) management of the harmonization strategy, which allows the definition and systematic configuration of a harmonization strategy to be carried out, (iii) management of models, which allows new models to be added through the homogenization method and the CSPE template, (iv) graphical analysis, which allows the data stored in HProcessTOOL to be deployed through a graphical analysis such as Gantt diagrams, activity, task and role diagrams and (v) help. HProcessTOOL is presented in detail in Pardo et al. (2011c).

5. Case studies

We have used the case-study method to carry out the application of our proposed methodology in two harmonization projects of multiple reference models. They take place in a Spanish organization (in the first case) and a research project in the banking sector (the second case). We should point out that we have conducted these case studies following the protocol template for case studies presented in Brereton et al. (2008) and the guidelines proposed in Runeson and Höst (2009). The following subsection describes these studies in terms of background, design, subjects and analysis units, field procedure and data collection, intervention in each case study, harmonization strategies followed by each case study, together with an analysis of results and lessons learned.

5.1. Background

The previous research on harmonization of multiple models was obtained during the application period of this work. A more detailed analysis about the research topic identified is presented, along with a systematic review in Pardo et al. (2011a). Based on the knowledge obtained, we have defined the main research question (MRQ) tackled by these case studies. We also identified three additional research questions (ARQ) to be addressed. By means of these questions we seek to find out whether HProcess has a useful function, if it is of practical use and whether it conforms to the reality of the harmonization projects. The research questions are presented in Table 3 .

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Table 1
Excerpt of the harmonization proposal template.

Template: Harmonization project proposal																	
Objective: The Harmonization proposal lets us define a general, well-focused perspective of the Harmonization Project. Similarly, it lets us track and monitor, amongst other things, the scope, objectives, and organizational needs, as well as some typical features of management, models to harmonize, or inclusion and exclusion criteria for selected models.																	
The ARMONIAS project (Junta de Comunidades de Castilla-La Mancha, PII2I09-0223-7948), aims to foster the improvement and management of processes in software firms, using a multi-framework approach, incorporating models, processes, methods and tools which work in favor of harmonization and integration of reference frameworks for software process quality and security.																	
Harmonization project																	
Firm name	Superintendency of Banks in Guatemala – SIB-																
Name of the harmonization project	Model for Government assessment of the ITS in the banking sector																
Name of person in charge of the case study	Sandra MaríaLemus																
Name of person representing ARMONÍAS	César Jesús Pardo																
Objectives and scope of the harmonization project																	
Business needs	To have available a generally applicable reference framework which blends the best practices and models that are being used for ITS Governance with the principles of operational risk set out by BASEL II. That framework should also be able to be used to assess the technological profile in the SIB.																
General harmonization objectives	Integrate a reference model for evaluating ITS Governance in the banking sector, taking the principles of operational risk set out by BASEL II as a basis and incorporating into these the COBIT principles that they support in their treatment. That in turn is the foundation on which to harmonize further models, namely VAL IT, RISK IT, ITIL, ISO 27002 and ISO 13569.																
Scope of harmonization project	Harmonize the principles established by BASEL II with COBIT, integrating a starting model, which will subsequently be harmonized with the following models: VAL IT, RISK IT, ITIL, ISO 27002 and ISO 13569.																
Harmonization process	The harmonization process to be followed is the one described in the ARMONÍAS Harmonization Process (as described in the appendix called Harmonization Process).																
Models to analyse and Area or Process that is the object of study																	
Model A Base model for carrying out harmonization with respect to other models	BASEL II COBIT 4.1	Principles that may be applied for the management of operational risk in the financial sector. (10 principles). Processes which are directly related to the fulfillment of the requirements of operational risk established by BASEL II.															
Model B	VAL IT	Processes which are directly related to the processes of COBIT described in Model A															
Model C	RISK IT	Processes which are directly related to the processes of COBIT described in Model A.															
Model D	ITIL	Processes which are directly related to the processes of COBIT chosen in Model A.															
Model E	ISO 27002	Processes which are directly related to the processes of COBIT in Model A.															
Model F	ISO 13569	Requirements which are directly related to the processes of COBIT in Model A.															
Resources and infrastructure of the work																	
ARMONÍAS Project Adviser (APA)	2 people																
	1 person																
Process Engineer (PE)	1 person																
Performer (P)	1 person																
Steering Manager (SG)	1 person																
Overview of the harmonization project planning																	

CHRONOGRAM: The overview of the general plan for harmonization in the organization is set out.

Months and weeks / **Activities**	**Month 1**				**Month 2**				**Month 3**				**Month n**			
	1	**2**	**3**	**4**	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**
Start																
Analysis and definition																
Execution (iterations)																
Check																

The number of iterations to be carried out is planned on the basis of the number of recommendations or practices that are expected to be harmonized from Model A.

Comparison iterations of model processes

Iteration	**Model**	**Process, practice, recommendation**	**Length of time**	**Starting from**	**Month**
1	A	10 Requirements of BASEL II 17 Processes of COBIT	Day 2	Week 4	Month 1
2	B	22 Processes of VAL IT	4	4	1
3	C	9 Processes of RISK IT	6	1	2
4	D	37 Processes of ITIL	7	1	2
5	E	41 Processes of ISO 27002	11	2	2
6	F	10 Requirements of ISO 13569	16	3	2

Estimate of effort					
Date	Activity	Role	Timetable	Adviser time	Case study
28/Nov/2009	Preparation of the harmonization plan (preliminary)	P	9:00–18:00		540
30/Nov/2009	Meeting with the management group to define the harmonization proposal.	SG	10:00–10:30	30 × 2	
		APA			
		P			
03/Dec/2009	Meeting with the management group to adapt the harmonization proposal.	APA	17:30–20:00	150 × 2	
		P			150
		RMHP			
05/Dec/2009	Preparation of the document.	P	9:00–18:00		540
				Sub-total	360	2130
				Overall total	1590	

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Table 2
Description of roles in harmonization process.

Abbrev.	Role	Competences
P	Performer	This is the person responsible for the analysis of models, who implements the harmonization methods. This person must have the capacity for abstraction, as well as for model analysis, and must be able to relate and compare models
PE	Process Engineer	This is the person responsible for carrying out activities related to the definition of strategies, including: identification and configuration of the harmonization strategy, as well as definition, documentation and guidance of the harmonization process for driving the strategy. This role should be performed by a person who is knowledgeable in the definition and modeling of processes
PHM	Process Harmonization Manager	This person is responsible for guiding the implementation of the activities of the harmonization process. This individual must also possess qualities of leadership and management so that they can: understand the organization's requirements and needs, establishing priorities in these and: seek approval for resources and elements needed for the normal execution of activities
SG	Steering group	This group is comprised of senior management, or at least one representative of this body. It is responsible for proposals to approve resources and/or changes in the organization. The PHM is part of this group but it does not have a decision-making vote

Table 3
Stages of the assessment process of the assessment proposals.

Research questions (main and additional)	
MRQ	Is HProcess suitable for carrying out the harmonization of multiple reference models?
ARQ_1	Is the effort of applying the proposed process suitable for leading a harmonization project?
ARQ_2	Does the proposed process enable IT organizations to find out how they conduct the harmonization of multiple models, as well as how to enable its integration?
ARQ_3	Does HProcess allow us to identify, define and configure a suitable strategy that is useful for harmonizing?

5.2. Design

Taking the approach presented by Yin (2003), the design type of the case study undertaken in this work is multiple cases – holistic, since HProcess has been applied in the context of two different cases in which multiple models are harmonized. The object of study is a new process through which to carry out the harmonization of multiple reference models. The measures used to investigate the research questions from each case study are:

- The effort of carrying out the tasks associated with each HProcess activity.
- The harmonization of models with the execution of HProcess in each case study.
- Furthermore, we have also taken into account the benefits, limitations and lessons learned described by the case studies involved in this work.

The effort was evaluated by means of two variables: the time (hours), and the amount of people involved in each activity of HProcess. As for the harmonization of the models, a qualitative analysis of the templates defined by HProcess was carried out, which allowed us to observe whether the models involved have been integrated and/or they had something in common.

5.3. Subjects and analysis units

The participating case study subjects are part of the ARMONÍAS project and each one executed a harmonization project with the support of an adviser in harmonization of models and with the aid of an expert in the use of the Framework's components and of the elements defined. The analysis units in the case studies are (i) the HProcess activities, as well as the (ii) harmonization strategy and (iii) the harmonization of the models. There are two case studies on which HProcess was executed; these are detailed below.

5.3.1. Case study one

The first case was carried out in a small-size organization in Spain; its name is Audisec, which has 10 employees and three years of experience. Its market focus is consultancy and support for the certification of standards such as IT Service Management Standard ISO 20000-1 (ISO, 2011) and the Information Security Management System (ISMS) ISO 27001 (ISO, 2005a). The framework was applied by the organization, with the main goal of establishing a harmonization strategy to harmonize the reference models ISO 27001 and ISO 20000 to use them during consulting activities with their customers. The needs identified by the organization were: (i) to compare and identify differences and similarities between the models ISO 27001 and ISO 20000, (ii) to identify the level of complementarities of ISO 27001 and ISO 20000, and (iii), to carry out a consultancy in the certification of organizations in ISO 20000, taking into account the efforts and institutionalized practices in certification and knowledge of ISO 27001.

5.3.2. Case study two

The second case is a research project which sought to define a model for Information Technology Governance applicable to the Superintendence of Banks of Guatemala and the banking sector in general. The main goal of this project was to establish a model that takes into account the multiple regulations that the banking sector is subject to. In that sense, the main needs identified by the major researchers were to define a model to harmonize different practices, standards and/or management models and IT security, which could be applied in managing the operational risks which the banking organizations have to deal with. Taking into account all the above, the main researchers decided that the models to be involved should provide support to: IT governance and the banking sector. Thereby, researchers decided to harmonize: COBIT 4.1 (ITGI, 2007), Basel II (BIS, 2006), Val IT (ITGI, 2008b), Risk IT (ITGI, 2009), ISO 27002 (ISO, 2005b) and ITIL V3 (ITIL, 2010).

5.4. Field procedure and data collection

The field procedure and data collection of the case studies is closely related to the HProcess activities (Start-up, Analysis and Definition, Execution and Revision), roles and work products presented in Fig. 2 and described in detail in Section 3. The data collection was directly related to the elements defined in each of the work products (in italics) described by HProcess. From Fig. 2 it is possible to see that the work products are harmonization proposal, analysis of needs and identification of cases prior to harmonization, harmonization strategy, harmonized models, implementation report of the harmonization strategy and knowledge base. The data collected were stored using the self-contained template of the work products and by employing HProcessTOOL.

5.5. Intervention in each case study

A brief description of the most important aspects in the execution of the field procedure described previously is presented in the

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following subsections, along with the data collected in the two case studies carried out.

5.5.1. Start-up

A formal assignment of the roles defined by HProcess was carried out. Both in the first case and in the second, the roles were applied to the process as follows: for both of the roles of PHM and PE, two people were assigned to each one; these were researchers and authors of HFramework. The *Performer* role was assigned to a person from the organization (for case one) and an investigator came from the research project (for case two). The SG role was performed by a person from the top management of the organization and the director from the research project.

Each case study took the process that it was particularly interested in to harmonize its own set of models; these were identified from its needs and business objectives as described in the harmonization proposal. Although each case study set as harmonization objective the harmonization of several models, the scope of each one was different. For example, the scope of the first case was to determine the support that ISO 27001 offers on the fulfillment of the processes described in ISO 20000-2 (ISO, 2012). In the second case, however, the scope was to define a model from the integration of the related practices of several models.

The control and monitoring of the activities and tasks followed in both case studies was included in the HProcessTOOL.

5.5.2. Analysis and definition

With the harmonization needs identified, goals of harmonization defined, roles assigned and the harmonization proposal approved in the start-up activity, the case studies performed the activity of analysis and definition. In this activity the prioritization of the harmonization needs (see Section 5.3.1 for case one and Section 5.3.2 for case two) took place and a high-level comparative analysis of the attributes and approach of the models was carried out. The processes of the models that provided a solution to the needs that had been marked out were identified, as were the harmonization methods. A search process to discover previous harmonization cases was set up. The search process enables the identification of harmonization efforts related to the harmonization objective, which have previously been performed and that can be taken as basis for carrying out our harmonization project. This allows the organization to reduce the effort needed to carry out their harmonization projects. In the case studies conducted, no previous harmonization case was found. More information related to the search process can be seen in ARMONÍAS (2009).

The ultimate end of HProcess was to guide the case studies in the design (definition and configuration) of the harmonization strategy. In both case studies, the strategy was described by the person known as PE in the work product for the implementation of the harmonization strategy. The harmonization strategy consisted in describing the implementation of activities related to the homogenization of process elements under a CSPE, followed by a low-level comparison of the process elements identified. In that sense, the harmonization methods followed by the person with the role of *Performer* were homogenization and comparison (with some adaptations in each case). Moreover, the second case involved a third additional method that supported the integration of the practices that were part of the models analyzed. A detailed description of the harmonization strategies configured for each case study is presented in Section 5.6.

5.5.3. Execution

The activities performed to harmonize the models were given by the different methods configured in the HStrategies of each case study. Those in charge of managing the execution of the

Table 4
Effort involved in the case studies.

	Harmonization process				Roles				Total	HStrategy	Harmonized models
	A1. Start-up	A2. Analysis and definition	A3. Execution	A4. Revision	P	PE	PHM	SG			
Case study one	1870 min	740 min	4720 min	595 min	6690 min	230 min	110 min	30 min	7060 min	Yes Homogenization and comparison	Yes 2 models
Case study two	1900 min	765 min	9880 min	680 min	11,620 min	1185 min	400 min	20 min	13,225 min	Yes Homogenization and comparison and integration	Yes 6 models

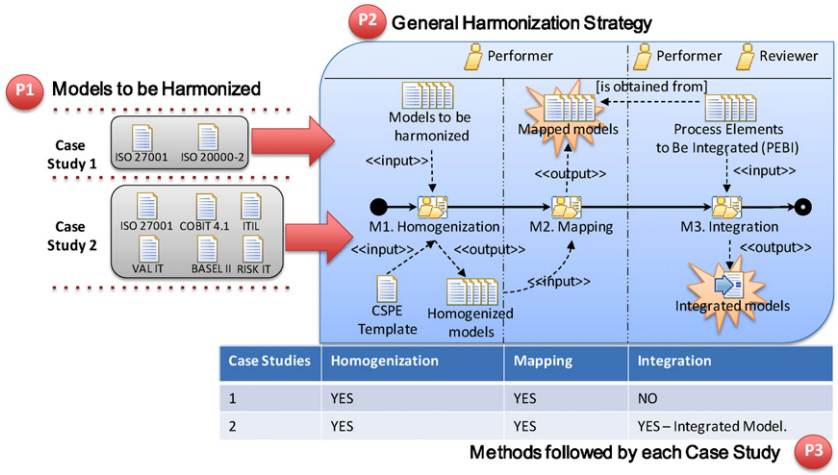

Fig. 4. Harmonization strategy used in the case studies.

strategy were the person who had the role of PHM, and the PE. The *Performer* was in charge of executing the activities defined in the methods that made up the harmonization strategy. The PE had an active part to play in the execution of the strategy, being in charge of verifying and validating the results obtained in the harmonization, comparison and integration conducted by *Performer*. The information relating to executing the HStrategy was registered in the implementation report of the harmonization strategy. To support the monitoring and control of the harmonization strategies, these were included in the HProcessTOOL. A detailed description of the execution of harmonization strategies for each case study is presented in Section 5.6.

5.5.4. Revision

In the organization, as well as in the research project, a post-mortem analysis was performed of the work which took place throughout the harmonization project. The object of this check was to obtain a knowledge base for future harmonization projects. At the end of the harmonization project we established how much effort had been used to carry out the application of HProcess in each activity (see Table 4). This information was obtained by means of the synthesis of the data recorded in the templates of each activity performed in the procedure field. A graphical analysis of the time and effort across the HProcessTOOL was performed. Similarly, the comments and other relevant information that emerged in each activity were analyzed.

5.6. Harmonization strategies

We should remember at this point that the main purpose of HProcess is to offer a process to make it easier to manage the activities related to the harmonization of multiple models. In that sense, we should also stress the importance of the identification, definition and configuration of a suitable harmonization strategy that allows us to harmonize multi-models on the basis of the harmonization needs that had been identified. That being the case, this section presents the HStrategy configured to support the case studies. Fig. 4 summarizes the strategy used in each case. In order to organize and manage the people in the activities and tasks defined, the harmonization strategy established two roles, performer and reviewer, which were applied in each case study.

From the needs and scope defined in each case and based on the widespread strategy presented in Fig. 4, e.g. case study one starts with the homogenization of models and it ends after finishing the comparison of them, whereas case study two takes into account the same activities shown in Fig. 4, along with an additional activity, the integration. Fig. 5 shows the activity diagram of the integration method. Harmonization, comparison and integration methods are part of HFramework. A summary of the execution of the harmonization strategies is presented as follows.

5.6.1. Homogenizing the models

In the execution of the strategy designed, the CSPE for homogenizing the process element structures of each model in each case

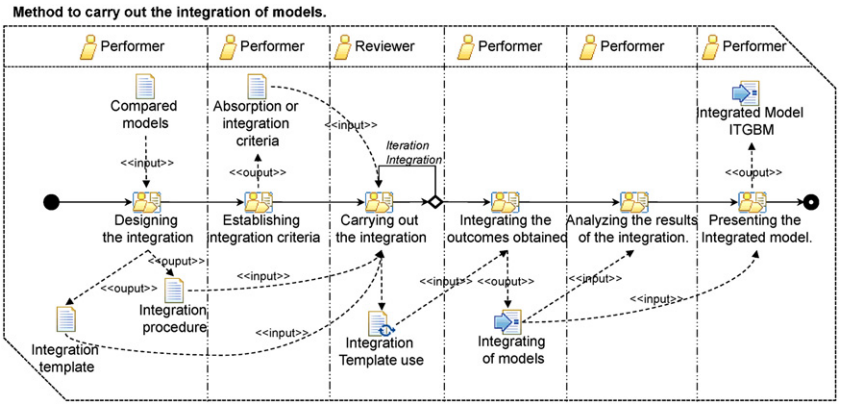

Fig. 5. Integration method used in case study two.

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Table 5
Correspondence and coverage found between the processes of the ISO 27001 and ISO 20000-2.

Processes group of ISO/IEC 20000-2	Processes of ISO/IEC 20000-2	Processes ISO/IEC 27001	% of Coverage by Processes group
PG1 3. Requirements for a management system	P1: 3 Requirements for a management system	P1 4.2 Establishing and Monitoring the ISMS P2 4.3 Documentation requirement P2 5.2 Resource management P1 6. Internal ISMS audits P1 8. ISMS improvements	71%
GP2 4. Planning and implementing service management	P1: 4.1 Plan service management (Plan)	P1 4.2 Establishing and Monitoring the ISMS	32%
	P2: 4.2 Implement service management and provide the services (Do)	P1 4.2 Establishing and Monitoring the ISMS	
	P3: 4.3 Monitoring, measuring and reviewing (Check)	P1 4.2 Establishing and Monitoring the ISMS P1 5.1 Management commitment P2 5.2 Resource management P1 7. Management Review of the ISMS P1 8. ISMS improvements	
	P4: 4.4 Continuous improvement (Act)	P1 4.2 Establishing and Monitoring the ISMS P1 8. ISMS improvements	
GP3 5. Planning and implementing new or changed services	P1: 5 Planning and implementing new or changed services	P2 5.2 Resource management P1 5.1 Management commitment	29%
GP4 6. Service delivery process	P1: 6.1 Service level management	P1 4.2 Establishing and Monitoring the ISMS	24%
	P2: 6.2 Service reporting	P2 4.3 Documentation requirement	
	P3: 6.3 Availability and service continuity management	P1 4.2 Establishing and Monitoring the ISMS	
	P4: 6.4 Budgeting and accounting for IT services	P1 4.2 Establishing and monitoring the ISMS	
	P5: 6.5 Capacity management	Within relationship	
	P6: 6.6 Information security management	P1 4.2 Establishing and Monitoring the ISMS P2 4.3 Documentation requirement P1 6. Internal ISMS audits P2 5.2 Resource management P1 5.1 Management commitment	
GP5 7. Relationship processes	P1: 7.2 Business relationship management	P1 4.2 Establishing and monitoring the ISMS P2 4.3 Documentation requirement P2 5.2 Resource management	36%
	P2: 7.3 Supplier management	P2 5.2 Resource management	
GP6 8. Resolution processes	P2: 8.2 Incident management	P1 4.2 Establishing and Monitoring the ISMS P2 5.2 Resource management	36%
	P3: 8.3 Problem Management	P1 4.2 Establishing and Monitoring the ISMS P2 4.3 Documentation requirement P2 5.2 Resource management	
GP7 9. Control processes	P1: 9.1 Configuration management	P1 4.2 Establishing and monitoring the ISMS P2 4.3 Documentation requirement P1 6. Internal ISMS audits P1 8. ISMS improvements	64%
	P2: 9.2 Change management	P1 4.2 Establishing and Monitoring the ISMS P2 4.3 Documentation requirement P2 5.2 Resource management P1 7. Management Review of the ISMS P1 8. ISMS improvements	
GP8 10. Release process	P1: 10.1 Release Management	P1 4.2 Establishing and Monitoring the ISMS P2 4.3 Documentation requirement P2 5.2 Resource management	43%

The percentage of coverage is found by dividing the number of related activities between ISO 27001 and ISO 20000-2 by the total number of possible relationships with respect to the process group of the ISO 20000-2.

study was used (see Pardo et al., 2009). To carry out the homogenization of these, a homogenization method was employed to identify the process elements that made up the models and to know which of these were common to both. With the homogenized models, it was possible to carry out an analysis of complexity of models; it consisted of a first mapping 1 to 1 with regard to the homogenous process elements in each model. This method allowed us to carry out an in-depth analysis of the constituent elements of models involved, e.g. in case study one ISO 27001 and ISO 20000-2 were homogenized, letting us see that both were closely related to the level of their terminology and the structure of process elements, and in case study two BASEL II, COBIT, ITIL, Risk IT, Val IT and ISO 27002 were homogenized.

5.6.2. Comparing the models

After identifying the processes, activities and tasks in the models involved in both cases, the *Performer* carried out a low-level comparison with regard to the information described in the tasks defined in the comparison method (see Fig. 4). The comparison supported comparative analysis of descriptions from the point of view of all the relations of the elements classified as tasks. In that sense, the directionality of the comparison in each case study was:

- Case study one, comparing the ISO 27001 with regard to ISO 20000-2, the choice of the directionality took into account the services offered by the company.

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- Case study two, first, carrying out the comparison of the principles of BASEL II and the COBIT processes, and finding out the principles that support these processes. This comparison was the basis for the definition of the integrated model. The following comparisons were performed taking into account the first comparison between Basel II and COBIT 4.1. In total, 5 comparisons were carried out, as follows: BASEL II with COBIT 4.1, Val IT with COBIT 4.1, Risk IT with COBIT 4.1, ISO 27002 with COBIT 4.1 and ITIL V.3 with COBIT 4.1. In the first comparison, 44 relationships (processes) were found; these have been reinforced from the comparisons with other models, that is Val IT, Risk IT, ISO 27002 and ITIL. The definition of ITGSM is based on the integration of the set of comparisons of the models involved (a detailed description of models obtained; see Lemus et al. (2010) and the HStrategy defined to obtained it; see Pardo et al. (2011d).

As can be seen in Fig. 4, both cases used the iterative and incremental approach to make it easier to manage the complexity in comparing the entities concerned at a low level of abstraction. Based on the harmonization objective defined and on the directionality of comparison, the comparisons result was a ratio of one to many in each case study. Table 5 shows an example of the correspondence and coverage found in case study one, between the related clauses of ISO 27001 and ISO 20000-2.

5.6.3. Integrating the models

The third one is a method, which was only applied on case study two, which needed to define an integrated model. It enabled there to be integrated collaboration between models, taking as a starting point the combination and merger of the recommendations created from the models analyzed. The integration method allows an integrated model to be reached, based on analysis of descriptions of each of the associated process elements, e.g. activities to activities or tasks to tasks. This can be carried out thanks to the fact that the process structures were homogenized previously. A set of rules and integration criteria were applied, to make the merger of process elements easier (for more details about criteria, see Pardo et al. (2011b, 2012). The implementation of the harmonization strategy defined has allowed consolidation of the governance framework called ITGSM, which consists initially of 22 processes defined at the level of five groups of activities proposed from the perspectives of: (i) maintaining IT governance, (ii) managing the investment of IT, (iii) IT risks, (iv) managing information security and (v) the life cycle of services. An extract of the structure of the unified model is presented in Table 6. A detailed description of ITGSM and the HStrategy defined to support its definition is present in Lemus et al. (2010) and Pardo et al. (2011d) respectively. Based on the results obtained in each case study, it has been possible to harmonize BASEL II, COBIT, ITIL, Risk IT, Val IT and ISO 27002, thus achieving the harmonization objectives defined.

5.7. Analysis of results and lessons learned from the case studies

In this section the most outstanding aspects in the application of HProcess in the two case studies are highlighted.

5.7.1. Tutorship by the ARMONÍAS consultant

In the harmonization projects, both for the first case and the second one, there was a tutorship in each case study provided by the ARMONÍAS project Adviser. This allowed us to acquire training in HProcess and do the job properly.

In the first activity of HProcess, the work infrastructure to support the execution of the tasks defined in each activity with its own staff was installed; this infrastructure consisted of roles described in Section 3.1.7. To offer suitable consultantship to the staff, a weekly meeting was established. This meeting took place between the *Performer*, the PE and the PHM, who dealt with topics and issues related to the harmonization of the multiple models. These people attended in person but when they needed to resolve any doubt between meeting and meeting, they used e-mail. This communication strategy made it possible to establish continuous communication and feedback from the application of HProcess in the two case studies.

5.7.2. Effort

In Fig. 6 it is possible to see that if we compare both case studies, the effort of the *Performer* is higher in case Two. This additional effort is due to the fact that the harmonization project in this case study involved more models, 6 in total, which means 4 models more than case study one. We believe that the experience and previous

Table 6
Structure of the unified model ITGSM.

PR	Processes	Activities				
		IT governance	Management the IT investment	Specific risk management IT	Management of information security	Management the service lifecycle
PR4	P11	PO9.3, PO9.4, PO9.5	PM4.1, IM1.2, IM2.2, IM5.1	RE1, RE2, RE3	Clauses 4.1, 4.2, 14.1	SD3.5, SD4.5, ST4.1, CSI5.6.3
	P12	PO6.1, PO6.2, PO6.3, PO6.4, PO6.5	NA	NA	Clauses 10.1.2, 12.5.1, 12.6.1	ST4.2
	P13	DS5.1, DS5.2, DS5.3, DS5.4, DS5.5, DS5.6, DS5.7, DS5.8, DS5.9, DS5.10, DS5.11	NA	RR3.1, RR3.2, RR3.3	Clauses 5.1, 6, 8, 9, 10.1, 10.4, 10.6, 10.8, 10.9, 11, 12, 13, 15.1, 15.2	SD4.6, ST4.3, SO4.5, SO5
	P14	DS9.1, DS9.2, DS9.3	NA	RE3.1, RE3.2, RE3.3, RR2.1	Clause 7.1	ST4.3
	P15	ME4.1, ME4.5	VG1.1, VG1.4, VG1.5, VG2.1, VG5	RG1.1, RG1.2, RG1.3, RG1.4, RG1.8	Clause 6.1	SS3, SD3
PR5	P16	PO9.6	VG5, PM5, IM9	RR1.2, RR2.2, RR3.2	Clause 10.1	SD4.5, ST4.6, CSI5
	P17	ME1.2, ME1.3, ME1.4	VG5, PM5, IM9,	RE1.5, RR1.2	NA	SD3. SD4.2, ST4.5, SO5, CSI9.3
	P18	ME2.3, ME2.7	NA	RG1, RR1	Clauses 5.1, 6.1, 6.2, 10.1, 15.2, 15.3	NA
	P19	ME4	VG1, VG2, VG5	RG1, RG2	Clauses 5.1, 6.1, 10.1	Core concepts, SS4, SD3, CSI4.3
	P22	PO8.1, PO8.2	NA	NA	NA	SS4.4.4, CSI4, CSI5, CSI8
BASEL		COBIT 4.1	VAL IT	RISK IT	ISO 27002	ITIL V.3

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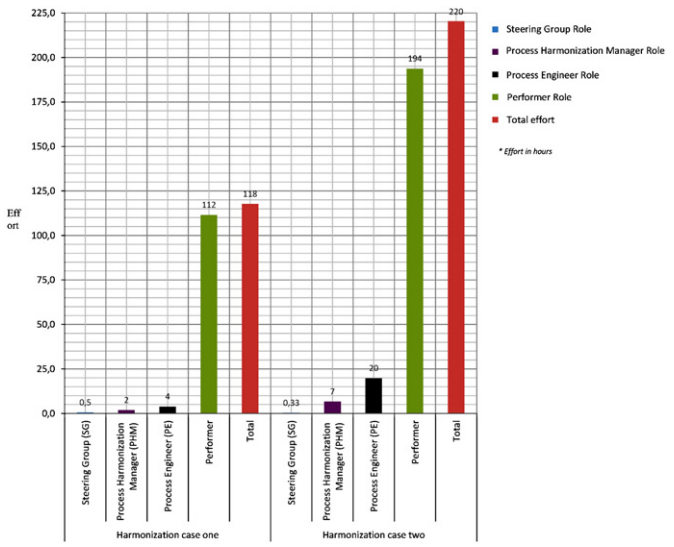

Fig. 6. Effort involved in the execution of roles of the harmonization process.

knowledge in the models involved could be a determining factor in accelerating the execution of the HStrategy, which involves knowing and understanding the models used. There could be many more characteristics which influence the effort performed in a harmonization project, e.g. the size of the models, their extension and complexity, the scope of the harmonization, the amount of models, and so on. In that sense, we can surmise that the effort performed in case study one is less than the effort performed in Two, because the PE in One had three years of experience in consultancy in ISO 20000 and ISO 27001, and although the PE in Two had previous experience in five of the models involved (Basel II, COBIT, Val IT, ISO 27002 and ITIL V2), this person had updated that knowledge with the new versions of ITIL V3 and Risk IT. In addition, in contrast to case study one, the harmonization goal in case study two involved the integration of the models; this means one more method.

Regarding the effort spent in activities A1, A2 and A4 (see Table 4), it is possible to see that it is very similar and that the activities have been performed taking into account a communications strategy, which consisted of: (i) carrying out face to face meetings and (ii) short daily meetings to keep the team on track and help them. This allowed us to establish a continuous flow of communication and feedback on the execution of each activity from HProcess. However, with all the facts mentioned above in mind, each HStrategy was executed using different objectives, goals and scope. For that reason, the effort spent in the execution of activity A3 in both case studies is significantly different.

We consider that the effort taken to apply the proposed process has been suitable for each case study involved in this work, since the people involved in the harmonization projects have carried out the execution of their harmonization projects in a suitable time.

5.7.3. General harmonization strategy

Based on the results obtained, it is possible to observe that, although each case study involved models which describe approaches, best practices and different objectives for improving the management systems of organizations, it has been possible, with the execution of the harmonization strategies followed, to find similarities in their descriptions and different levels of detail. That makes it possible to perform harmonization objectives that had already been defined, meaning that the harmonization strategies have allowed the case studies to follow a systematic process which is configured according to its needs. Similarly, HProcess has made it possible for each subject involved in the case study to define its own HStrategy. It is important to highlight that when we say "HStrategy", we refer also to the methods defined in HMethods. In that sense, each case study was free to choose its own methods and was at liberty too to set up its own HStrategy. It is clear, however that the strategies are a little similar in the two cases and they have some points in common. For instance, both cases used the same methods in the first and second activity of their harmonization strategies; these are (i) homogenization and (ii) comparison. Unlike the first case of study, the second one involved an additional method, which enabled the integration of the recommendations of the models analyzed.

In view of the similarities between the harmonization strategies defined, we can represent the particular process of each strategy in a general harmonization strategy. This general strategy provides support for the configuration of the harmonization strategies and identification of the methods to be used. In that sense, the general harmonization strategy consists of three particular events: (i) analysis, which is the first occasion that allows us to combine different methods to carry out the activities aimed at semantic, syntactic or structural analysis of the processes of the models to be harmonized, e.g. the syntactic analysis of the requirements in ISO models in case study one was carried out in accordance with a syntax table for identifying the requirements in ISO 9001, as defined in Pardo et al. (2009). This allowed us to analyze and identify the requirements by considering the "shall" and "should" statements, (ii) comparison, which makes it possible to use and configure comparison methods at a high and/or low level of abstraction, and (iii) integration, which allows us to support the combination and integration of the processes of various models that support the development of solutions to identified needs. These particular events do not necessarily have to occur in the order defined; the PE can define his/her own schedule or go directly to the implementation of activities or tasks defined in the methods selected. That said, it is important to define a way forward for the implementation of activities that make it easier to manage and harmonize the models involved. Something else to bear in mind is that the general harmonization strategy must make it possible to integrate any harmonization method besides those defined by our framework.

5.7.4. Main work products of the harmonization

With the execution of HProcess, it is possible to obtain two main work products of HFramework (see Fig. 1), which are the HStrategy and harmonized models. Although the harmonized models comprise a work product resulting from the execution of the strategy established, that is also a good measure to take into account in finding out whether the harmonization strategy was suitable. It is important to highlight, though, that without the support given by the harmonization process in defining, configuring and executing the HStrategy, this work product could not be obtained.

5.7.5. Benefits described by the case studies

The case studies reported that the harmonization work has brought about several benefits, the most significant of which are set out below:

- The set of activities, tasks, roles and work products described in HProcess has made it possible to achieve the identification and systematic configuration of the methods of homogenization, comparison and integration used for the harmonization of models involved in the case studies. According to statements coming from the case study subjects, the harmonization strategies obtained by means of the HProcess was a practical guide and it was seen by them to be useful for carrying out the work of harmonizing involved models.
- On the basis both of the results obtained and the experience gained, the organization of case study one has developed a tool

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to support the consultancy of ISO 20000. This software tool has been developed after taking into consideration information on the relationships found between processes of ISO 20000 and ISO 27001, obtained from application of the harmonization process. It is important to highlight the reuse of the information and results obtained here, because this has made it possible to reduce effort in the institutionalization of ISO 20000, due to the relationship between the clauses previously institutionalized by ISO 27001.
- In case study two, with the process and harmonization strategy executed as a basis, it has been possible to obtain a process model called ITGSM, which is the first Information Technology Governance Model that can be applied in any banking organization. At the same time support is given in different IT areas, as well as maintaining, managing investment, risk, information security and the life cycle of services.
- Furthermore, the iterative and incremental approach applied by HProcess and HStrategy that was defined during harmonization of models in each case study has led to the following advantages:
  - There was a reduction of complexity during the homogenization, comparison and integration of multiple models. This came about as a result of the definition and establishment of iterations that allowed management of their activities in a way that was agile and appropriate.
  - The regular monitoring allowed the reviewer to verify and validate the reliability of results.
  - With the management template for iterations it is easier to carry out the traceability.
  - The Management's being focused and directed by the goals of harmonization allowed results to be obtained which were fitted the needs that had been identified.

5.7.6. Plan validity and limitations of the case studies

To address threats and to permit the plan of validity to be carried out in the best way, we have considered different factors, which are described below.

- The designs of the case study and the data collection plan were compared with checklists for case studies in software engineering proposed by Höst and Runeson (2007).
- As regards construct validity, we used multiple sources of evidence, including interviews, participative observation and documentation archive. The evidence was obtained from the meetings held, where each one of the participants carried out the specific roles assigned to them.
- Regarding internal validity, we have been able to determine that the implementation of the harmonization process in the case studies has allowed us to meet the needs identified in each case. At the same time, we have borne in mind the benefits reported for the case studies, which were described above.
- For external validity, although the process was applied in two case studies, these were supported by two advisers, who also had a part to play in the working group, performing the roles of PHM and PE. The observations and lessons learned were collected, aiming to refine the protocol and field procedure so as to be able to perform a replication in future case studies.
- Regarding reliability, we developed the replication material of the case studies, and this was distributed to the Tutorship by the ARMONÍAS Adviser, as well as to each role of the HProcess defined in the case studies. It was observed that by following this material for conducting case studies, similar findings and conclusions were found.

The limitations considered in the case studies are:

- There being a very small population (two case studies), this is not a representative sample, and that could limit the power of generalization; these harmonization projects therefore represent a low percentage of the overall population. In this regard, the harmonization process must still be replicated on a larger number of case studies, to ensure an adequate analysis and subsequent generalization of the results obtained.
- Bias in the case study with regard to: (i) subjectivity in handling events and data developed by the *Performer* role, and (ii) non-natural development of activities and tasks to be monitored continuously.

5.7.7. Limitations of HFramework and its elements

The limitations considered after applying HFramework in the case studies are related to:

- The homogenization method provides a suitable process to guide the resolution of differences between multiple models. What it did not do, though, was provide a way to carry out the correspondence of process elements of models according to the CSPE structure, i.e. a criteria to rearrange the content of a particular model within the process elements defined in CSPE, e.g. homogenizing COBIT 4.1 according to CSPE, the domains are Process Categories, processes are processes, artifacts or products are outputs, and so forth. The correspondence will arise from standards and models homogenized. We therefore expect to apply this structure and its method in more case studies or experiences.
- The correctness of their results from a theoretical analysis. A risk in this sense is the subjectivity in handling events and data developed by the Performer role, as well as his/her knowledge and understanding about the models. We have tried to supersede this threat, by incorporating an additional role of "*Reviewers*", who cover and monitor the methods and HProcess continuously. However, this may not be enough. In response to that possibility, it is our intention that in the next case studies, there will be more than one person covering each role, e.g. two performers and two reviewers could work independently, to avoid influence or bias. After completing their activities, they can merge their results. This would reduce the subjective aspect and bias in each activity, task or step, e.g. the bias between the mapped practices of two models. There could be relationships that have been missed; they may even be incorrect.
- Although a set of criteria to support decision-making was used during the integration of practices of different models in case study two, the performer described the lack of a more detailed criterion which would allow him to address specific integration situations, e.g. what to do and which elements must be integrated if the content of a practice of a Model A is more detailed than a practice related to a Model B, but the content of B is better than that of A. It will be necessary to address several other possible situations and this may make it easier to make decisions, perhaps also reducing time involved in integration. This reduction in time is currently only a hypothesis, however, waiting to be rejected or confirmed in our future work.

6. Comparison of proposals

Taking into account the situation set out in Section 2, Table 7 presents a comparison of the studies which tackle the fifth category mentioned in the section regarding related work, i.e. studies that provide a solution designed to support multi-model harmonization, i.e. PrIME Project (Siviy et al., 2008a,b,c), Ferchichi's ontology for the integration of quality standards (Ferchichi et al., 2008), VM XT Project (Biffl et al., 2006), Kelemen's proposal (Kelemen, 2009), and Ferreira (Ferreira et al., 2011). This comparison uses some characteristics from a taxonomy to compare SPI Frameworks

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Table 7
Comparison of proposals multi-model.

Category	Characteristic	Proposals					
		Author or project					
		PrIME	Ferchichi's ontology	V-Modell XT	Kelemen	Ferreira	ARMONÍAS project
General	Proposal name	Reasoning framework	Ferchichi's ontology	V-Modell XT abbrev. VM XT	Kelemen's proposal	Ferreira's proposal	HFramework
	Geographic origin/spread	Software Engineering Institute (SEI), USA	Laboratoire de Génie Industriel de Lille, France	Germany	BUTE University, Hungary	University of Minho, Portugal and Carnegie Mellon University, USA	UCLM and UNICAUCA Universities, Spain and Colombia
	Language	English	English	German and English	English	English	Spanish and English
	Development/stability	Under development since 2008	Since about 2008.	Since 1997 as V-Modell 97 and V-Modell XT with its upgrade since 2004	Under development since about 2008	Under development since about 2009	Since 2008, it is accessible from 2009
	Context of application	Amongst others, models of IT Government, any Software models...	Models of IT Government, any Software models	Software models	Amongst others, models of IT Government, any Software models	ISO models and CMMI	Amongst others, models of IT Government, any Software models...
	Harmonized models	There are still non-harmonized models.	ISO 9001:2000 and CMMI	It has been widely used as a standard in the IT Projects in the public sector in Germany	A comparison of MSZ EN ISO 9001:2000 and CMMI-DEV v1.2	Comparison of ISO models (ISO 9001, ISO 15288 and ISO12207) and CMMI-DEV	It has been used in the harmonization of: (i) ISO 27002 and ISO 20000-2 and (ii) COBIT 4.0, Basel II, VAL IT, RISK IT, ISO 27002 and ITIL V3
	Prescriptive/descriptive	NYD	Both	Prescriptive	Prescriptive	NYD	Both
	Adaptability	NYD	Yes	Limited	NYD	NYD	Yes
Process	Oriented to the objectives of the business	Yes	Yes	?	Yes	?	Yes
	Assessor	Yes	?	Yes	?	Yes	Yes
	Process of harmonization	A reasoning framework is being developed	A multi-model approach to integrate different quality Models has been developed	A mapping approach for comparability and compatibility has been developed	A process-based unification of process-oriented software quality approaches is being developed	It defines a high level process supporting harmonization	A harmonization process has been developed
	Actors/roles/stakeholders	?	?	?	?	Some (process engineering)	Work infrastructure
	Process Artifacts	?	S	?	?	Comparison Ferreira et al. (2011) and some attributes such as complexity and size, to support the comparison of models (Ferreira et al., 2010b)	A, T, S, R, WP, TEM
	Methods or techniques	?	Mapping based on Mutafelija and Stromber (2003a,b)	Mapping	Comparison		Homogenization (Pardo et al., 2009) and Comparison (Pino et al., 2010) Integration and a criterion of integration (Pardo et al., 2012)

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Table 7 (*Continued*)

Category	Characteristic	Proposals					
		Author or project					
		PrIME	Ferchichi's ontology	V-Modell XT	Kelemen	Ferreira	ARMONÍAS project
	Agile principles	?	?	?	?	?	Yes
	Reference model basis	It uses the Generic Goals and Practices that are detailed in the CMMI as institutionalization elements	Neither	V-Modell XT or VM XT	Neither	Neither	Neither
Other elements contributing to complement the proposals		?	?	?	A schema of a meta-model for process based quality approaches and methods; it is only a proposal, see Kelemen et al. (2008)	?	– A guide for determining the harmonization goals – The criteria for the selection and configuration of the harmonization strategy Two ontologies: – H2mO (Pardo et al., 2011b), an ontology of key concepts to support the harmonization of multi-models, and – PrMO, an ontology of key elements to express process-based approaches of any reference model. (Pardo et al., 2009)
Organization	Organization size	All	All	All	All	All	All
	Implement cost	?	?	LC	?	?	LC
Tool support	?	?	Name ?: EPG	QMIM Quality Organizer (Kelemen et al., 2007): ST but it is not accessible. Based on CMMI	?	HProcessTOOL (Pardo et al., 2011c): PF, ST and EPG. It supports any model	
Public available	Yes	?	Yes	?	?	Yes	

Tools support: PF, paper forms; ST, software tool; EPG, electronic process guides.
Implement cost: LC, low cost; MC, medium cost; HC, high cost.
Process artifacts: A, activities; T, tasks; S, step; R, roles; WP, work products; TEM, templates.
General conventions: ?, no information found; NYD, not yet determined.

Table 8
Stages of the harmonization proposals.

Name project	Harmonization proposal	Stages
PrIME project	Reasoning framework	(1) Alignment of organizational and improvement objectives, (2) strategic categorization of improvement technologies, (3) design of your improvement solution and (4) implementation (or execution) of your multi-model process improvement solution
Ferchichi's ontology	Multi-model approach to integrate different quality models	(1) Choice of models, (2) analysis of model synergy, (3) construction of integrated model and (4) the adaptation of the integrated model to the enterprise context
V-Modell XT	Mapping approach for comparability and compatibility	(1) Map each software process to the VM XT: (i) structure analysis, (ii) initial mapping and (iii) refine mapping, and (2) analyze the compatibility of the two software processes and build on the results of the first phase
Kelemen process	Process-based unification of process-oriented software quality approaches	(1) Analysis of the multi-model process improvement problem, (2) analysis of the process-oriented software quality approaches, (3) developing a process based unification method for multiple process-oriented software quality approaches, (4) developing unified peer review material, (5) expert consultation, (6) redesign based on expert consultation, (7) conducting case study on peer review process, (8) redesign based on case study experience, (9) conducting redesigned study on peer reviews, (10) final expert consultation and (11) evaluation and generalization
Ferreira	Supporting audits and assessments in multi-model environments	It defines a high level process supporting harmonization. However, we did not find a systematic solution described as a process, activities, tasks, and so forth
ARMONÍAS project	HProcess (for more details see Section 3)	(1) Start-up the harmonization project, (2) analysis and definition, (3) execution and (4) revision

which is presented in Printzell and Conradi (2001). Moreover, some more specific characteristics, such as tool support, public availability, harmonized models, and other related characteristics were added.

From the comparison presented in Table 7, it can be observed that all the proposals were compared with each of the characteristics. However, it is also important to highlight that our proposal, HFramework, fulfilled all the characteristics. In this sense, we can note that, unlike other proposals found, only HFramework puts forward a detailed solution for facilitating and carrying out harmonization projects which has been validated with its application in multiple models, e.g. COBIT 4.1, Basel II, Val IT, Risk IT, ISO 27001 and 27002, ITIL V3, ISO 20000, CMMI, amongst others. HFramework uses the CSPE template as a common structure to harmonize the models. That being the case, its application does not depend on, or start from, a model or standard as a specific base model, as most of the proposals that currently exist do. HFramework is thus independent of the implementation approach and can thereby be applied using any model. As for tools support, HFramework provides HProcessTOOL, which is a software tool for supporting the execution of the process and strategies of harmonization. In the cases of the other proposals, only Kelemen's provides tools support. It focuses only on the software domain, however, and on a particular model, CMMI.

Table 8 shows a more detailed view of the projects and their harmonization proposals, with their stages. As far as a consideration of the alignment of organizational and improvement objectives is concerned, only the Reasoning Framework of SEI and HFramework take this characteristic into account. As may be noted, this is done in stage 1 of the Reasoning Framework; it is important to highlight, however, that in the same stage HProcess includes activities that support the definition of a harmonization proposal based on the particular business needs and the prioritized harmonization requirements. On the other hand, the Reasoning Framework and Ferchichis's Ontology, along with the VM XT, consider the synergy analysis, comparison and integration of multiple models as the main objectives to cover through their stages. These have been defined as dependent sequential units, while HProcess focuses on defining a suitable harmonization strategy to address these objectives. So it may be concluded that the HProcess offers a process that is much more flexible and which can adapt to business needs.

7. Conclusions and future work

In this article HProcess, a process for harmonizing multiple models has been presented, within HFramework and developed by the ARMONÍAS project to harmonize and integrate Quality and Security Models. Its application has been presented in two cases studies carried out in the ARMONÍAS project and the results obtained have been satisfactory.

The harmonization process proposed sets out the elements needed for a step-by-step guide towards the definition of harmonizing strategies that support strategic business objectives, by bringing the elements of different models into consonance. From the initial application in two case studies and bearing in mind the effort involved, the knowledge of processes acquired, the harmonized models and the benefits described by the organizations, it is possible to see that HFramework, HProcess, HMethods, H2mO and PrMO ontologies and other components of harmonization proposed and used can be suitable for harmonizing multiple models in IT Organizations. With the information generated and the findings obtained by the harmonization of several models, two models were harmonized in one case study and six in the other. The case study subjects are currently using the harmonized models. In the case of the consultancy company the models are used in the transition of ISO 27001 to 20000-2. In the research project for the Banking sector in Guatemala, the harmonized models are used to give support in risk and investment management for IT as regards the integration of the models: BASEL II, COBIT 4.1, Val IT, Risk IT, ISO 27002 and ITIL.

In future work, we aim to track the case studies to find out whether the HProcess has implied a reduction in effort and costs associated with the implementation of a new model as over and against one that is already institutionalized. In a similar vein, our aim is also to refine and replicate the process with its implementation in new harmonization projects and by the presentation of (i) the integration method followed for the integration of the models by the banking sector, together with presentation and validation of (ii) PrMO ontology and (iii) updating of the HFramework. That updating would apply especially to HProcess and HMethods, tackling and addressing the limitations that have been identified.

As has been described, HFramework supports the harmonization of multiple models and it thereby allows organizations to improve their processes from several practices defined in

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multiple models. In future work, we hope that HFramework can also be used to support the audit and assessment of the processes of organizations when multiple models are present. This would allow auditors and consultants to take advantage of relationships identified between models analyzed by means of HFramework. They would thus be able to design and carry out audits and assessments in multi-model environments for those models that include some kind of certification.

Acknowledgments

This work has been funded by the projects: ARMONÍAS (JCCM of Spain, PII2I09-0223-7948), PEGASO/MAGO project (MICINN and FEDER, TIN2009-13718-C02-01), ARCA (CEC – JCCM of Spain – and FEDER, HITO-2009-06). Caracterización exploratoria del estado del arte en el desarrollo de software del sur occidente colombiano (code 144, University of San Buenaventura).

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Please cite this article in press as: Pardo, C., et al., From chaos to the systematic harmonization of multiple reference models: A harmonization framework applied in two case studies. J. Syst. Software (2012), http://dx.doi.org/10.1016/j.jss.2012.07.072