Advances in Engineering Software 41 (2010) 1223–1237

Contents lists available at ScienceDirect

Advances in Engineering Software

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

MIS-PyME software measurement capability maturity model – Supporting the definition of software measurement programs and capability determination

María Díaz-Ley [a,*], Félix García [b], Mario Piattini [b]

[a] Sistemas Técnicos de Loterías del Estado (STL), Gaming Systems Development Department, 28234 Madrid, Spain
[b] University of Castilla-La Mancha, Alarcos Research Group – Institute of Information Technologies & Systems, Dep. of Information Technologies & Systems – Escuela Superior de Informática, 13071 Ciudad Real, Spain

A R T I C L E I N F O

Article history:
Received 22 December 2008
Received in revised form 1 February 2009
Accepted 23 June 2010
Available online 7 August 2010

Keywords:
Software measurement capability maturity model
Measurement program definition
Measurement capability determination
MIS-PyME
COMPETISOFT
Software process maturity

A B S T R A C T

One important reason for the failure of measurement program implementation is that the maturity of companies as regards measurement has not been taken into account during the definition phase. Unfortunately, the major methods and frameworks that support measurement programs – such as Goal Question Metric (GQM), Goal-Driven Software Measurement, GQ(I)M, PSM and ISO/IEC 15939 – do not address this issue explicitly. This can especially affect small and medium settings, where a low measurement maturity level is typical and where there are more measurement implementation limitations. This is the case both as far as software engineering is concerned and with respect to measurement knowledge. Nevertheless, companies do wish to define measurement programs adapted to the measurement maturity of the company and they want to improve their measurement maturity. There are few measurement assessment models and these are neither well-known nor applied in industry. This paper presents a measurement capability maturity model which supports companies both in defining their measurement programs, as adapted to the measurement maturity of the company, and in detecting measurement improvement suggestions.

1. Introduction

Literature shows us that many factors are involved in the successful implementation of measurement programs. For example, Gopal et al. [1] identified and checked some success factors by analyzing their effects on the success of measurement programs. Daskalantonakis also developed a good practice guide, based on his experience at Motorola [2,3]. He places major importance on the integration of measurement programs within the rest of an organization's software processes. He also argues that the best people to analyze measurement results are the project managers and engineers involved in the measurement program, since they are experts in that particular field and have a perfect understanding of the meaning of that data. Hall and Fenton identified 15 success factors, based on their experience [4].

In [5] Pfleeger states that it is necessary to link the establishment of a measurement program to the maturity level of an organization. For example, an organization that is immature as regards measurement should not attempt to implement a predictive model. This may lead to results that are unexpectedly negative, positive but spurious, difficult to interpret, or difficult to build on in subsequent studies [6]. Moreover, measurement cannot exceed the software process: if the development process does not define the types of tests, it is not possible to evaluate the efficiency of some tests in comparison with others. Therefore, when the measurement program defined in the company is not adapted to the measurement maturity of the company, the measurement program implementation is destined to fail.

The tendency towards failure in the successful implementation of measurement programs is particularly outstanding in the context of small and medium enterprises (SMEs) [7], the reason being that the factors which characterize these companies usually become the cause of the problem. Generally, SMEs do not have enough resources to promote serious measurement program initiatives; training is more difficult and software measurement knowledge is especially poor in this context. The work of Kasunic [8] shows how measurement practices are not as popular as in medium or large companies: the use of software measurement increases as the size of the organization increases. These aspects are particularly important if we take into account that SMEs represent the major part of software industry around the world [9,10].

In this paper we look at how the link between the measurement program and the measurement maturity level of an organization (success factor stated in [5]) has been integrated in MIS-PyME, a methodological framework for defining software measurement programs focusing on small and medium enterprises (SMEs) or

* Corresponding author.
E-mail addresses: maria.diaz.ley@gmail.com (M. Díaz-Ley), Felix.Garcia@uclm.es (F. García), Mario.Piattini@uclm.es (M. Piattini).

0965-9978/$ - see front matter © 2010 Elsevier Ltd. All rights reserved.
doi:10.1016/j.advengsoft.2010.06.007

settings. As a result, a measurement capability maturity model (MCMM) has been defined to support the measurement analyst in defining measurement programs adapted to the measurement maturity of the organization. The measurement capability maturity model also helps organizations: to improve their software measurement maturity by means of assessing their measurement maturity and identifying measurement improvement aspects and to understand the measurement goals that they are able to implement and which are suitable for their measurement maturity.

This paper is organized as follows: Section 2 brings this work into context by summarizing existing software measurement maturity models. Section 3 introduces MIS-PyME. Section 4 describes the MIS-PyME measurement capability maturity model (MIS-PyME MCMM). Section 5 gives an example of a real-life application of the MIS-PyME MCMM, underlining its advantages, and Section 6 sums up the contents of this paper and outlines future research.

2. Related work

This section provides a summary of the major measurement maturity methods and models found in the literature. It is first important to consider the Daskalantonakis [3] method for assessing an organization's software measurement technology, which is consistent with the SEI Software process assessment methodology [11]. This method is based on a number of assumptions which determine the focus of the Measurement Technology Assessment. From these assumptions, 10 themes are derived, according to which the company is characterized and evaluated. These themes are as follows: formalization of the development process, formalization of the measurement process, scope of measurement within the organization, implementation support for formally capturing and analyzing knowledge, measurement evolution within the organization, measurement support for management control of software projects, project improvement using measurement technology, product improvement using measurement technology, process improvement using measurement technology and predictability of project, product, and process characteristics.

For each theme, five evolutionary stages are defined. A software development organization may follow these in an effort to attain the highest level of maturity for that particular theme. These five evolutionary stages correspond to the five levels of software process maturity as defined by SEI: initial, repeatable, defined, managed and optimized. Some questions have been classified by maturity level for the assessment. In addition, a guide for evaluating software measurement based on the Daskalantonakis model is described in [12].

Niessink and Vliet define a capability maturity model for measurement as being that which can be used to assess the measurement capability of software organizations and to identify means of improving their measurement capability [13]. The model measures the measurement capability on a five ordinal scale which matches Daskalantonakis' maturity stages. However, Niessink and Van Vliet define a set of pre-established key process areas which are different for each level and which must be in place if an organization is to reside at that level.

As regards dealing with measurement in software capability maturity models, we must highlight CMMI [14], which includes a key process area called Measurement and Analysis. This process area defines good practices for implementing a measurement process in an organization and for reaching maturity level 2, but it is not a complete measurement assessment model in itself. However, CMMI [14] deals with many of the measurement aspects, such as scope of measurement, management support, etc. across most of the key process areas: software project planning at level 2, integrated software management at level 3, and quantitative process management at level 4 [15]. It does not, however, deal with this information in a separate module where all measurement aspects are clearly aligned to each maturity level.

The MIS-PyME measurement capability maturity model is aligned on the standard ISO/IEC 15504 [16] as regards the assessment process, the capability levels, the assessment attributes, and the capability maturity rating. The MIS-PyME maturity model, moreover, takes into account the Daskalantonakis [3] method and the measurement evolution in CMMI [15], which tackles mainly the scope of measurement as regards what is measured, and the Niessink and van Vliet [13] proposal, which focuses, in the main, on the establishment of the measurement process, together with the tools required. However, in MIS-PyME MCMM the assessment aspects which must be achieved in order to attain a certain maturity level are more detailed and complete than the other models as regards: the process performance and establishment, the measurement scope, the measurement purpose, and the measurement support tools. In addition, it is clearly aligned to the standard 15504, which eases the formality and understanding of the model. Finally, the measurement assessment process not only indicates the organization's measurement maturity capability and the measurement improvement areas, but also suggests the typical measurement goals that the company is able to implement based on its maturity, and advises against implementing the other measurement goals.

As regards the support to the methodology for the definition of a measurement program, as far as we know none of the most common methodologies: Goal Question Metric (GQM) [17], Goal-Driven Software Measurement GQ(I)M [18], PSM [19] and ISO/IEC 15939 [20] clearly take into account the measurement maturity of the organization in defining measurement programs which are adapted to the measurement maturity of the company.

3. MIS-PyME methodological framework

MIS-PyME is a methodological framework which focuses on defining measurement programs based on software indicators in small and medium enterprises or settings (divisions of companies). It takes as its focal point software development and maintenance companies or settings with the typical characteristics of SMEs as regards measurement activities, namely:

- The people that are involved in the measurement program, including the measurement analyst, are from within the company and do not always have any great expertise in the field.
- Poor measurement maturity: poor measurement culture, knowledge and training; measures collected in the company are few and the measurement process is not established in the unit or company, or does not even exist.
- The personnel are reluctant to use measurement.
- A small or medium software development company or unit with limited resources and with fewer than approximately 50 people.

MIS-PyME has been developed in accord with the COMPETISOFT model, which aims to support software process improvement in small companies [21]. In developing this model 17 companies have participated: five from Colombia, four from Peru, three from Spain, and one each from Argentina, Chile, Ecuador, Mexico, and Uruguay, respectively. So far, eight case studies have been conducted (the results obtained in 4 of them are shown in [22]).

The main difference between MIS-PyME and other popular measurement program methodologies such us Goal Question Metric (GQM) [17], Goal-Driven Software Measurement GQ(I)M [18], PSM [19] and ISO/IEC 15939 [20] is that the process for defining measurement programs are adapted to SMEs, in terms of roles and activities, and MIS-PyME provides a set of work-products whose aim is to assist the measurement analyst in developing the measurement program and which make definition and implementation easier, more reliable and adapted to the measurement maturity of the company. A detailed description of MIS-PyME and the differences of this framework with respect to other existing methods can be found in [23].

The MIS-PyME framework, therefore, is formed of two main parts: the MIS-PyME software measurement program definition methodology and the MIS-PyME measurement capability maturity model (MCMM) (see Fig. 1).

The MIS-PyME software measurement program definition methodology (see Fig. 2) is based on GQM [17] and GQ(I)M [18,24] but it is designed to define indicators which are probably required in most small and medium software development settings [23,25,26].

As already mentioned, it provides a set of work-products which are the following:

- *MIS-PyME measurement goals table:* the MIS-PyME framework proposes a set of structured measurement goals that are usually required in order to implement improvement activities related to software processes. These process improvement goals are based on the processes, practices and goals specified in the COMPETISOFT software process model.
- *MIS-PyME indicator templates*, which are designed to guide users and help them to define indicators (and the related measures) for each specific measurement goal and whose format is an adaptation of the template proposed in GQ(I)M [24]. Among other aspects, the MIS-PyME template helps users to know if it is possible to implement the indicator as regards the measurement maturity of the company and its format. It also outlines some practices for successfully implementing the indicator: how to integrate this indicator into the software process, who should be responsible, etc. Additionally, the typical questions which the indicator tries to answer, its outcomes and related analysis and its potential are shown. An example of an indicator template of MIS-PyME is provided in Table 1.
- *MIS-PyME indicator database:* MIS-PyME provides some indicators which have been implemented with success in a company. The aim is to reuse these indicators and help other measurement analysts in defining their measurement programs.

A detailed description of MIS-PyME measurement goals table and MIS-PyME Indicator Templates can be found in [27] .

The MIS-PyME measurement capability maturity model (MCMM), which is the focus of the present paper, provides:

- *The maturity levels, and the attributes* which the measurement process must fulfill in order to achieve each maturity level (to see Fig. 3).
- *An assessment process* which aims to determine the measurement capability of the organization and to detect and carry out the software measurement improvement areas. This process uses a questionnaire to obtain measurement related data which help to determine the maturity level (see Appendix A).
- *An interface with MIS-PyME methodology* which provides sufficient information to define measurement programs adapted to the measurement maturity of the company.

MCMM may be used by any type of companies (not only SMEs) but its interface eases its use in those SMEs which use MIS-PyME Methodology.

The following sections focus on describing the MIS-PyME MCMM and its application in a case study.

4. MIS-PyME measurement capability maturity model

For the development of the MIS-PyME MCMM the Action Research method was applied [28,29]. As a result of the first iteration, a preliminary version of the model was obtained and applied to develop a measurement program adapted to the measurement maturity of the company and using MIS-PyME [23,30]. This model was redefined in the second iteration, to make this model capable of assessing the measurement maturity of the company. Based on the feedback obtained about the measurement activities in the participating companies of COMPETISOFT [21,22,31], some other aspects were also improved.

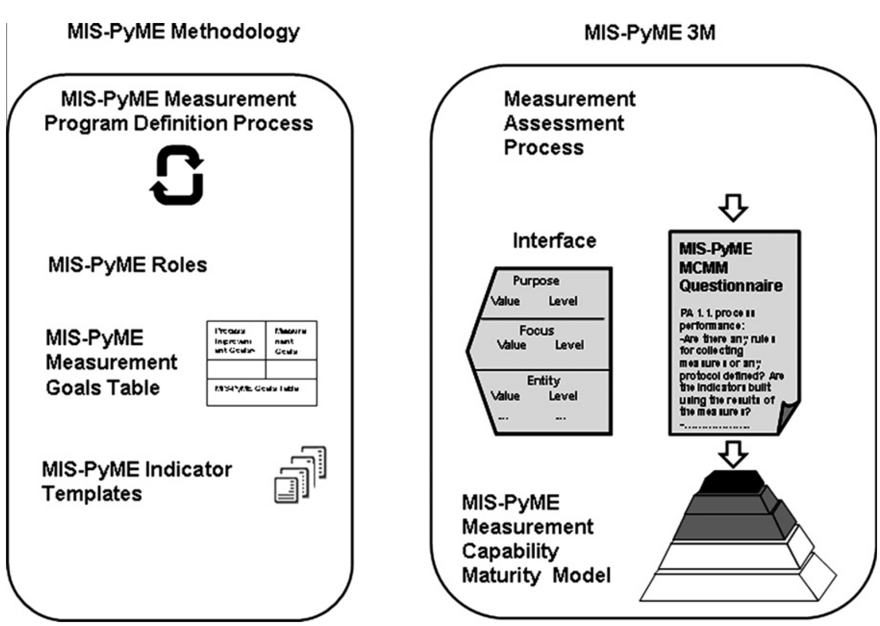

Fig. 1. MIS-PyME framework.

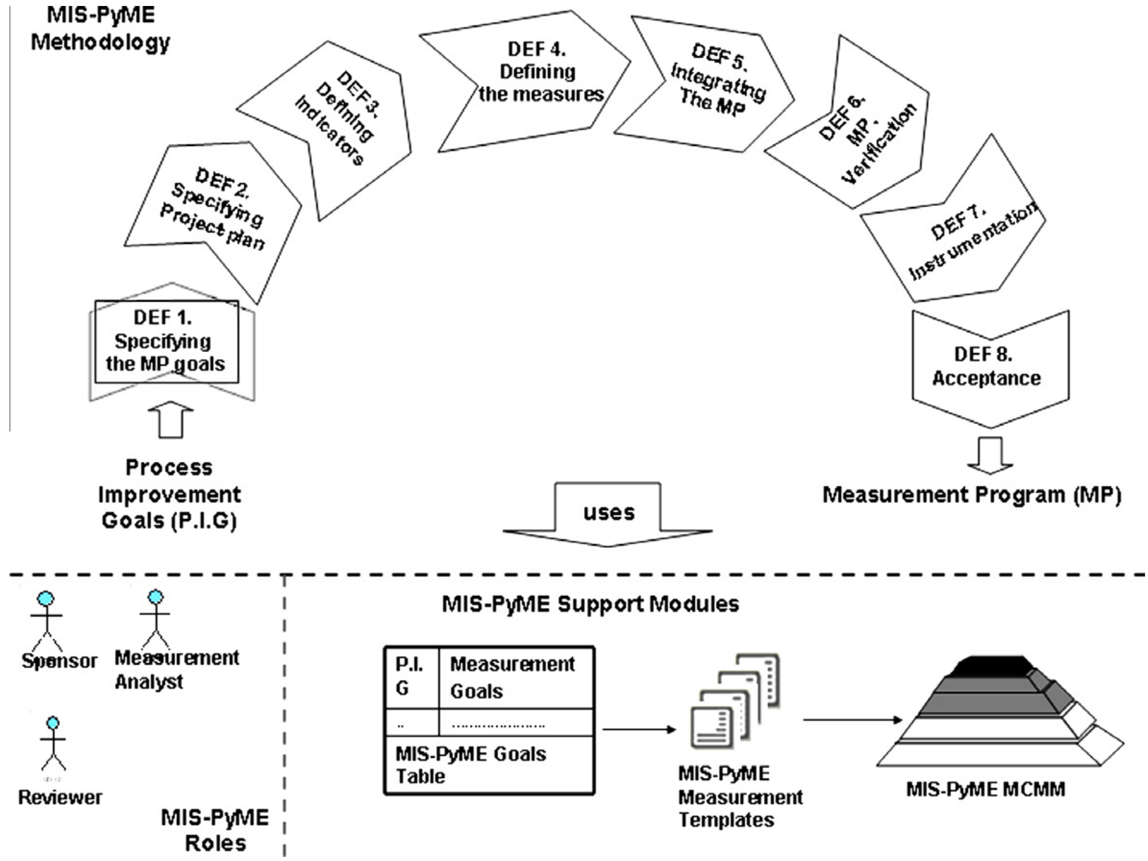

Fig. 2. MIS-PyME methodology.

Table 1
MIS-PyME indicator template example.

Example of indicator template
Goal: To evaluate the effectiveness of the tests performed in the project in order to improve future projects or the following phases of the project *Point of view*: Top manager, project management, quality control manager *Context*: Tested software projects *Questions*: How many failures were found in the phase being evaluated (e.g. integration)? (categorized by its severity/priority) How many failures were found in the following test phase? (categorized by its severity/priority) Do these failures exceed the threshold? Or do they exceed the threshold in comparison with failures found in the evaluated test phase? ... *Inputs*: Failures found in test phases ○ *DTI*: Defects (high, medium and low) detected in integration tests ○ *DTA*: Defects (high, medium and low) detected in acceptance tests ○ *DP*: Defects detected in the client site for 2 months (more or less) since the product was delivered to the client *Algorithms*: ... Assumptions: the number of failures – no. f (integration + system tests) > no. f (validation) > no. failures (acceptance) *Recommended maturity*: Maturity 3 *Integration*: This indicator should be analyzed for the specific project management process during the evaluation and control activity *Measurement activity information* ... *Analysis/interpretation* ...

The MIS-PyME measurement capability maturity model assumptions and the design goals related with these assumptions are as follows:

1. The measurement maturity of the company is higher, since the measurement process is better performed and established. It is therefore necessary to assess the measurement process performance and establishment used in the organization.
2. The measurement maturity of the organization is higher, since more ambitious measurement goals as regards its purpose are measured. The types of software measurement goals (and software indicators) which are part of the measurement process are assessed, therefore.
3. The measurement maturity of the organization is greater since the support tools, related procedures and other resources are better established. The measurement process will thus be performed more efficiently. The support tools and other resources of the measurement process are therefore assessed.

All the above being the case, the measurement capability maturity model determines three types of attributes based on the design goals stated above:

– A set of attributes whose values depend on the measurement process performance and establishment, which are identified as (P). This type of attribute is based on the attributes defined

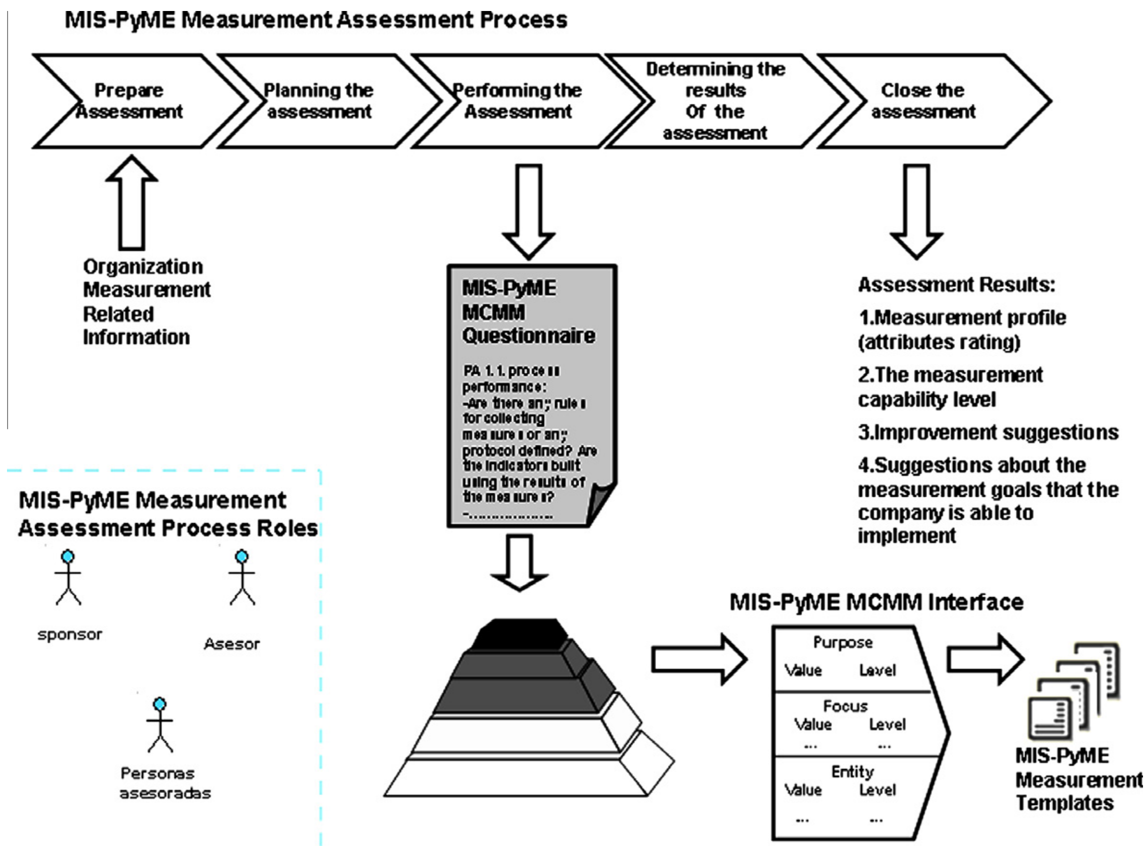

Fig. 3. MIS-PyME measurement maturity model.

in the ISO/IEC 15504 for assessing the process but these are specialized for the measurement process. The Niessink and Van Vliet capability model [13] was taken into consideration for this specialization.
- A set of attributes whose values depend on the software goals and indicators will be identified as (I). These are based on the Daskalantonakis model [3], the measurement evolution described in CMMI [14,15] and the Niessink and Van Vliet capability model [13].
- A set of attributes whose values depend on the resources required for the measurement process, which will be identified as (R) and which are based on the same approaches as the previous set of attributes.

For each attribute a set of indicators is defined and used as a basis for collecting the objective evidence that enables an assessor to assign ratings to the attribute.

The following sections provide a summary of the MIS-PyME capability maturity model: the levels and attributes, the assessment process and MIS-PyMe MMM interface.

4.1. MIS-PYME measurement capability maturity model: Levels and Attributes

This section shows the levels defined in the MIS-PyME measurement maturity model, the attributes of the process, of the process inputs and the tools that the process uses which should be fulfilled in each level.

4.1.1. Level 0: incomplete

The measurement process is not implemented, or fails to achieve its process purpose. There is little or no evidence of any systematic achievement of process purpose. There are few or no measures collected and integrated in any software measurement, development, management or quality process.

4.1.2. Level 1: performed process

The implemented process achieves its process purpose. Basic measurement processes are in place to collect and analyze the measures and provide feedback to software engineers and management. At this level the measurement process is usually carried out in-project with people experienced in software development and management. As regards software maintenance, reliability of the software in production is understood. The following attributes of the process demonstrates the achievements of this level:

- *PA 1.1 Process performance attribute:* The process performance attribute is a measure of the extent to which the process purpose is achieved. As a result of full achievement of this attribute:
  a. *Measure collection:* Level 1 measures are collected.
  b. *Measure analysis:* The collected measures are analyzed and interpreted with respect to the measurement goals.
  c. *Measurement feedback:* The measures, the measurement protocols, the collected measures and the results of the analysis are made available to the people involved in the measurement process.
- *PA 1.2 (I) Basic project and product focus performance attribute: This* attribute measures the extent to which the process purpose is achieved. As a result of full achievement of this attribute:
  a. The management development process tracks the project schedule phase-by-phase as against the plans, and takes reactive actions in the case of problems.

b. The maintenance process tracks the reliability of the main products of the organization in production, based on defects, taking reactive actions in the case of problems.
c. The management process tracks project effort and/or cost phase-by-phase as against the plans, and takes reactive actions in the case of problems.

– *PA 1.3 (R) Basic management tools implemented attribute:* This attribute measures the extent to which the measurement process is supported by basic software management tools. As a result of the achievement of this attribute:
a. Database tools are established in the organization to store and track incidents with products in production.
b. Project management tools related to schedule, effort and cost tracking are established in the organization.

4.1.3. Level 2: managed process

The previously described Performed process is now implemented in a managed fashion (planned, monitored and adjusted) and its work products are appropriately established, controlled and maintained. The following attributes of the process, together with the previously defined attributes, demonstrate the achievement of this level.

– *PA 2.1 (P) Performance management attribute:* The performance management attribute is a measure of the extent to which the performance of the process is managed. As a result of full achievement of this attribute:
  (a) Objectives for the performance of the process are identified.
  (b) Performance of the measurement process is adjusted to meet plans.
  (c) Responsibilities and authorities for performing the process are understood, assigned and communicated.
  (d) Interfaces between the parties involved are managed to ensure both effective communication and clear assignment of responsibilities.
  (e) Performance of the process is planned and monitored.
– *PA 2.2 (P) Work product management attribute:* This attribute measures the extent to which the work products produced by the process are appropriately managed. As a result of full achievement of this attribute:
  (a) Outcomes such as measures results, indicator analyses and interpretation, action plans are appropriately verified and adjusted if necessary.
  (b) Outcomes such as measures results, indicator analyses and interpretation, action plans and improvement suggestions are appropriately communicated to the people who may be interested in them.
  (c) Outcomes (indicator analyses and interpretation, action plans and improvement suggestions) are effectively used and managed to achieve the defined goals, such as corrective actions in-projects.
– *PA 2.3 (I) Basic project and product focus management attribute: This* attribute measures the extent to which the process purpose achieves the basic project and product management. As a result of full achievement of this attribute:
  (a) The management development process is able to understand total deviation from the project as against plans, in terms of cost, effort and duration. These data are used when estimations of new projects are performed, so as to plan them.
  (b) The management development process tracks the reliability of the main products being developed, based on defects.
  (c) The maintenance process tracks the time between the failure and the time it was fixed.
  (d) Customer satisfaction is measured by means of a simple questionnaire given to the client.
  (e) The company starts to understand other quality aspects such as cyclomatic complexity, repeated code, inheritance levels, modules/classes dependability, etc.
  (f) Development progress is managed using measurement results (# use cases developed, # components developed, # req developed, etc.)
  (g) Test progress is also managed using measurement results (coverage of code tested, number of test cases created or tested per day, etc.)
  (h) Requirement stability is measured. The company knows the number of requirements modified, new or deleted.
  (i) The process is also measured in terms of compliance.
– *PA 2.4 (R): management and development tools implementation attribute:* This attribute measures the extent to which the measurement process is supported by software tools such as defect and incident tracking tools, project management tools and other necessary resources, methods and information. As a result of the achievement of this attribute:
  (a) Project management tools related to test cases management are established in the organization.
  (b) Database tools to store and track defects are established in the organization.
  (c) Tools to manage requirements are also used in the organization.
  (d) Tools required to perform static analyses of the software are used.
  (e) Resources received by the provider (e.g. firmware) are managed in terms of the satisfaction with the resource (reliability, adaptability, suitability, etc.) and the service in terms of reception and problem resolution timing, etc.
  (f) Project estimation techniques are used to plan effort and schedule of projects; the results are not really reliable yet, however.

4.1.4. Level 3: established process

The Managed process described previously is now implemented using a defined process which is capable of achieving its process outcomes. The measurement process is well understood in the organization. All projects use a tailored version of the organization's standard measurement process, and the process is carried out with the necessary frequency. The measurement processes are well integrated into the other software processes.

– *PA 3.1 (P) Process definition attribute:* The process definition attribute is a measure of the extent to which a standard process is maintained to support the deployment of the defined process. As a result of full achievement of this attribute:
  (a) A standard process, including appropriate tailoring guidelines, is defined. describing the fundamental elements that must be incorporated into a defined process. For example, it may identify the mandatory and optional indicators that should be analyzed during the process, or it might identify the issues that cannot be adapted such as the measure result unit and the indicator formulas.
  (b) The sequence and interaction of the standard process with other processes is determined. The standard measurement process is completely integrated into the other software development, management and quality processes. The collected data are therefore integrated into people's normal work when they are performing the development, quality or management processes. The measurement reports may be integrated into the project review/monitoring results report, into the project closure reports, etc.
  (c) Required infrastructure and work environment for performing a process are identified as part of the standard process. The standard process identifies from where and how the

measure result data are collected, where the indicator and measure results are located, which tools are used to analyze certain indicators, etc.
   (d) Suitable methods for monitoring the effectiveness and suitability of the process are determined. These methods are used to review whether measurement data are collected and analyzed as specified, or whether the results are communicated as specified and to what extent the plan action and improvement suggestions are performed and the measurement process is eventually useful.

– *PA 3.2 (P) Process deployment attribute:* The process deployment attribute is a measure of the extent to which the standard process is effectively deployed as a defined process to achieve its process outcomes. As a result of full achievement of this attribute:
   (a) A defined process is deployed, based upon an appropriately selected and/or tailored standard process.
   (b) The personnel performing the defined process are competent with regard to appropriate education, training, and experience.
   (c) Appropriate data are collected and analyzed as a basis for understanding the behavior of the process, to demonstrate the suitability and effectiveness of the process and to evaluate where continuous improvement of the process can be made.

– *PA 3.3 (I) Advanced project tracking attribute:* this attribute measures the extent to which the purpose of the process is to track the project in an advanced fashion. As a result of full achievement of this attribute:
   (a) Since there is a standard measurement process, cross-project analyses are available; these may be used to identify improvements which can be implemented in the whole organization.
   (b) Planning and tracking is often performed at work-package level and still involves actual vs. planned performance.
   (c) Problem report status, review status, advance test status, are other measurement issues with which to monitor the project.
   (d) Rework effort in all phases are managed: analyzing, designing, coding and testing in order to improve current and future projects.
   (e) Ranges of satisfaction of the client with the project are known. Common problems can be analyzed and improved.
   (f) Normal ranges for project measurement in terms of effort, cost, rework, requirement stability are known for each phase (analyses, designing, coding and testing).

– *PA 3.4 (I) Advanced product tracking attribute:* this attribute measures the extent to which the product is tracked in an advanced fashion. As a result of full achievement of this attribute:
   (a) There is a broader understanding of quality in terms of usability, maintainability, efficiency, reliability, portability and functionality. It means that the company understands the internal aspects of the product that makes it usable, maintainable, etc.
   (b) Since there is a standard measurement process, cross-product analyses are available which can be used to identify common causes of problems; these analyses may lead to improvement actions which may be implemented in the whole organization.
   (c) Normal ranges of the most important quality aspects of the company start to be known in terms of reliability, maintainability, etc.
   (d) Ranges of satisfaction of the client with the product are known. Common problems can be analyzed and improved.

– *PA 3.5 (I) Process tracking attribute:* this attribute measures the extent to which the process purpose manages processes. As a result of full achievement of this attribute:
   (a) Other aspects of the process (maintenance and development process) are measured as regards efficiency, effectiveness and other characteristics.
   (b) Since there is a standard measurement process, analyses across defined processes are available in order to identify common problems which can lead to improvement actions which may be implemented in the whole organization.
   (c) Normal ranges in terms of the time for resolving failures in development and in production are understood.
   (d) Normal ranges of downtime due to maintenance actions are understood
   (e) Normal ranges as regards productivity are known.

– *PA .3.6 (R) Resources deployment attribute*
   (a) Organization Measure Database: Collected measures are stored in an organization-wide database and made available.
   (b) There is a life cycle configuration management tool for the requirements, models for analysis, coding, test cases, etc.
   (c) Training program: People are provided with the skills and knowledge needed to perform their roles.
   (d) Advanced estimations methods are known and managed
   (e) There is an advanced development environment which automatically provides product measures.
   (f) Procedures in the use of these tools are well understood and are standardized throughout the organization: people know how to introduce the information, what that information means and most people do this according the procedures.
   (g) Normal ranges of satisfaction with the resources and the provider are known and common causes of problems with the providers or the resource management process etc. can be analyzed and improved.

4.1.5. Level 4: predictable process

The established process described previously now operates within defined limits to achieve its process outcomes.

The following attributes of the process, together with the previously defined attributes, demonstrate the achievement of this level.

– *PA 4.1 (P) Measurement cost/benefit process attribute:* This attribute measures the extent to which the measurement process cost can be predicted. As a result of the achievement of this attribute:
   (a) The cost of the measurement process is measured and therefore known.
   (b) The benefits derived from the measurement process are quantitatively measured in order to understand the benefits of the measurement process and its usefulness.
   (c) The standard measurement process is adapted, based on the costs/benefit results.
   (d) The measurement process is improved based on the costs/benefit results.
   (e) The cost/benefit information is used to choose the technological support for the measurement process.

– *PA 4.2 (I) The measurement process aligned to the business goals attribute:* The process measurement attribute is a measure of the extent to which the measurement process ensures that performance of the process supports the achievement of relevant process performance objectives in support of defined business goals. As a result of full achievement of this attribute:
   (a) Process information needs which support relevant defined business goals are established.

(b) Process measurement objectives are derived from process information needs.
(c) Reliable estimations and plans can be performed using advanced estimation techniques which are adapted on the basis of historical knowledge of the organization.
(d) Quantitative objectives for process performance in support of relevant business goals are established.
(e) Measures and frequency of measurement are identified and defined in line with process measurement objectives and quantitative objectives for process performance.
(f) Results of measurement are collected, analyzed and reported, to monitor the extent to which the quantitative objectives for process performance are met.
(g) Measurement results are used to characterize process performance and are used to evaluate the measurement process.

– *PA 4.3 (I) Measurement control process attribute:* This attribute measures the extent to which the measurement process can be quantitatively managed to produce a process that is stable, capable, and predictable within defined limits. As a result of full achievement of this attribute:
(a) Relations between the characteristics of the process, the project and the product are understood and therefore analysis and control techniques can be determined and applied when required.
(b) It is possible to adapt processes and plans to achieve a certain degree of quality or other kinds of goals.
(c) Variation control limits are established for normal process, product and project performance.
(d) measurement data are analyzed for special causes of variation;
(e) Usual problems are controlled.
(f) Control limits are re-established (as necessary) following corrective action.
(g) It is possible to predict the product, service and other attributes before the product is in production.

– *PA 4.4 (R) Reliable database tool attribute:* This attribute measures the extent to which the measurement process is supported by a reliable historical database. As a result of the achievement of this attribute
(a) The organization has a reliable historical database.
(b) The organization has full control of its life cycle tools and takes full advantage of this.

4.1.6. Level 5: optimizing process

The Predictable process described above is continuously improved to meet relevant current and projected business goals. The following attributes of the process, together with the previously defined attributes, demonstrate the achievement of this level.

– *PA 5.1 (P) Process innovation attribute:* The process innovation attribute is a measure of the extent to which changes to the measurement process are identified from analysis of common causes of variation in performance, and from investigations of innovative approaches to the definition and deployment of the process. As a result of full achievement of this attribute:
(a) Appropriate data are analyzed, to identify common causes of variations in process performance.
(b) Appropriate data are analyzed, to identify opportunities for best practice and innovation.
(c) Improvement opportunities derived from new technologies and process concepts are identified.
(d) An implementation strategy is established to achieve the process improvement objectives.

– *PA 5.2 (P) Process effective change attribute:* This attribute measures the extent to which changes to the definition, management and performance of the measurement process result in effective impact that achieves the new measurement goals which support the new required process improvement goals or business goals. As a result of full achievement of this attribute:
(a) The measurement process is modified as needed and it is ready when required.
(b) The measurement process is modified at minimum cost.
(c) The organization implements a dashboard to keep quantitative track of achievements.
(d) The effectiveness and benefits of the process is quantitatively evaluated and compared to the process performance baseline if necessary.
(e) An analysis of whether results are due to common or special causes takes place.

– *PA 5.3 (I) Predictable attribute:* This attribute measures the extent to which the measurement process is able to predict problems and solve or prevent undesirable situations in advance:
(a) It is possible to predict and prevent problems.
(b) Technological needs and values are known thanks to the measurement.
(c) It is possible to qualitatively make improvements and understand what to improve to achieve the improvement.
(d) It is possible to perform casual process analysis to identify the causes of problems accurately and to understand the specific actions to take to prevent the occurrence of these defects and problems in the future.

– *PA 5.4 (R) Automatic measurement tool attribute:* This attribute measures the extent to which tools used by the measurement process are efficient:
(a) The measurement tools automatically obtain the information required to create the organization's software process control panel and business goal objectives.
(b) These tools also automatically generate the required reports.

4.2. MIS-PyME assessment process: determining the measurement capability of the organization

The measurement assessment model aims to assess the measurement process in relation to the levels and attributes defined in the MIS-PyME measurement capability maturity model. It determines the rating values for the MCMM attributes, the criteria to determine the measurement capability of the company and it provides an assessment process to follow. This part of this model is based on the ISO/IEC 15504 Software Engineering – Process Assessment Part: 2 [16] .

The assessment may be used for self-assessment, when the organization wishes to know its measurement capability maturity level so that it may detect improvement areas and identify which measurement goals the organization is able to implement as regards its maturity.

As regards the rating values, the extent to which the attribute of the measurement process is fulfilled is based on the following values set in ISO/IEC 15504 (not achieved, partially achieved, largely achieved and full achieved).

The capability maturity level of the measurement process will be that in which the attributes of this level are largely or fully achieved and the attributes of the lower levels are fully achieved.

The measurement process assesses the capability maturity of the measurement process. It specifies the activities as follows: prepare the assessment, planning, performing the assessment (adjusting, delivering and consolidating the questionnaire), determining the results of the assessment (final result of the assessment and determining the measurement improvement areas), close of the assessment (specifying the assessment report, reporting and delivering the measurement information).

During the execution, the questionnaire shown in Appendix A is used to determine the extent to which the attributes are achieved. The questionnaire contains a set of questions for each attribute specified in MIS-PyME MCMM. The answer to each question may be simply ‘‘yes” or ‘‘no”. If the company is only in charge of software development but not of software maintenance, those questions related to the maintenance process are ignored. If the answers to 0–15% of the questions are ‘‘yes” then the attribute is not achieved, 15–50% of the questions are ‘‘yes” then the attribute is partially achieved, 50–85% of the questions are ‘‘yes” then the attribute is largely achieved, and if the answers to 85–100% of the questions are ‘‘yes”, then the attribute is fully achieved. If a question cannot be answered, since it is not applicable to the context, this question is not taken into account. These thresholds are those proposed in ISO/IEC 15504 and all the questions have the same importance.

Even though there might be subjectivity in determining whether the indicators are fulfilled, the MIS-PyME questionnaire is used to reduce this subjectivity too and to help the assessor in understanding and determining if the indicator is fulfilled.

The most important outputs of the process are the following:

- The set of profiles of the measurement process, based on the attributes rating.
- The maturity capability level of the organization (*N*).
- Suggested measurement goals that the company is ready to implement according to its measurement maturity. The measurement goals which belong to level $N+1$ should be implemented with care, and the implantation of measurement goals related to higher measurement maturity levels is not recommended. MIS-PyME measurement goals table classifies the measurement goals in accord with its corresponding measurement maturity level (see Section 3).
- The set of issues to be improved, which will be the input of the measurement improvement process.

4.3. MCMM interface: integration of the measurement maturity model into MIS-PyME methodology

The MIS-PyME measurement maturity model is required mainly during the indicator definition phase of MIS-PyME methodology. When the measurement analyst defines the indicators, s/he will be supported by the corresponding MIS-PyME indicator template (see Section 3). This template includes (amongst other things) recommendations for measurement maturity in terms of indicator implementation. These recommendations come from the MIS-PyME measurement maturity model. Therefore, each of the indicator template includes information concerning the required measurement capability level that the company needs if it is to be able to implement the indicator successfully. In addition, the assessment questionnaire will help the measurement analyst in determining if the desired indicator is suitable for implementation in the company, by posing to him/her questions related to measurement maturity (see Appendix A).

Some indicator fields depend on the maturity of the company as regards measurement; these fields are particularly those which determine the goal of the indicator.

The measurement goals (which are the indicator goals) are defined by the following fields based on [17] and on [18]:

- *Purpose*: Why the object will be analyzed: characterization, monitoring, evaluation, prediction, control and change.
- *Focus of the indicator:* This states the particular attribute of the object under study that will be characterized, evaluated, predicted, monitored, controlled, or changed. Examples of focuses are cost, reliability, correctness, defect removal, changes, user friendliness, maintainability, etc.
- *Entity to be measured:* Target of the measurement activity. MIS-PyME defines the possible entities as follows:
  - ○ *PRJ*: The entity to be measured is the project. Therefore, the attributes of the project such as the duration and the cost, effort are measured.
  - ○ *PROC*: The entity to be measured is the process applied in the project. That being so, attributes such as the conformance, the effectiveness, and the efficiency are measured.
  - ○ *PROD*: The entity to be measured is the software product. Attributes such as its reliability are thus measured.
  - ○ *PRJORG*: The indicator analyses information related to all the projects in the organization, thus creating cross-project analyses.
  - ○ *PROCORG*: The indicator analyses information regarding the processes applied in the organization’s projects.
  - ○ *PRODORG*: The indicator analyses information with regard to the entirety of the organization’s products, in order to derive general problems and improvement areas.
- *Usefulness*: Final purpose of the indicator: ‘‘The indicator will be used for . . .”
- *Point of view:* A description of the public for whom the indicator is intended.
- *Context*: The environment in which the measurement will be performed, analyzed and interpreted. It also determines how the results can be generalized.

The fields of the indicator goal which determine the maturity of the indicator are the following:

- *Purpose*: Characterization signifies the understanding of an aspect of the project, product or process. This purpose may be facilitated by collecting data, obtaining the results of the measures and indicators, and analyzing the results. However, monitoring requires a fixed frequency to perform the same measurement activity, comparing results, storing the results, etc. It also requires a more formal activity and the measurement process must be more mature. Evaluation may require some knowledge of the normal ranges of the aspect to be evaluated if it is to be able to perform a reliable evaluation. Normal ranges require the habit of performing the measurement activity in the same manner, and also require that the results of the measurement activity be kept for a time which may be quite long, depending on the aspect to be evaluated. If the company does not comply with these requirements, therefore, it cannot implement such measurement goals. Prediction already requires a higher measurement maturity level, since measurement data must be reliable and rigorously collected for the time required, in order to be able to identify relationships between dependent and independent attributes. Control and change require that these relationships should be quantitatively managed.
- *Focus of the indicator: There* are certain concepts of the project, product or process that are easier to obtain than others. For example, there are some aspects that require measurement tools that may not be established in the company and there are certain terms that may also require a certain maturity level. As an example, the company must be able to understand what the cyclomatic complexity, or the dependability between modules means in order to understand the quality of the product being developed. It may also require certain tools such as static quality analysers that may be neither understood by, nor known in, the company. Additionally, it may be impossible to measure

certain aspects of the project or product, since these aspects are not considered in the company's development or management process, i.e., it is not possible to track integration test effectiveness if test phases have not been differentiated in the correct manner. It is generally easier to implement measurement goals related to basic project tracking, and product information such as defects, and make step by step improvements in order to establish a measurement framework for advanced project management, and advanced product quality management.

– *Entity to be measured:* This field determines the required measurement maturity level. This is because the measurement goals whose "entity" field is labelled as "ORG" cannot be implemented until there is a standard measurement process which is correctly applied in different projects, products and processes to perform cross-project, product or processes analyses. In addition, measurement related to the process generally requires a more mature measurement level since it is usually more complex to measure process aspects.

Tables 2–4 form the interface between MIS-PyME methodology and the MIS-PyME measurement maturity model. These tables highlight the possible values of each of the fields that depend on the company's measurement maturity and the suggested measurement maturity level where the company should be in order to implement the indicator with that field value. The measurement analyst should observe the suggested level (N); if s/he knows the measurement maturity level of the company s/he could already decide whether the indicator is suitable for implementation. If s/he does not know the measurement maturity level or would like more information, s/he would go to the questionnaire, and decide whether the indicator is suitable for implementation. MIS-PyME suggests that the indicator is suitable for implementation when the questions in at least level $N-1$ are largely fully achieved, if lower levels are fully achieved and the measurement analyst feels capable of achieving the conditions identified in level N, particularly in the resource attributes category. This assessment should be performed for each of the indicator fields that depend on maturity.

Table 2
MIS-PyME measurement capability maturity model interface based on the "Purpose" of the measurement goal.

Purposes	Suggested measurement maturity Level
Characterizing	Level 1
Monitoring	Level 2
Evaluating	Level 3 or level 4 if the evaluation is based on a previous prediction.
Predicting	Level 4
Optimizing	Level 5

Table 3
MIS-PyME measurement capability maturity model interface based on the "focus" of the measurement goal.

Focuses	Suggested measurement maturity level
Quality – reliability	Level 1
Quality (maintainability, portability, usability, etc.)	Level 3
Basic resources project progress	Level 2
Advanced resources project progress	Level 3
Basic schedule project progress	Level 1
Advanced resources project progress	Level 3
Product size and stability	Level 2
Process (compliance, effectiveness, efficiency)	Level 3
Client satisfaction	Level 2

Table 4
MIS-PyME measurement capability maturity model interface based on the "Entity" of the measurement goal.

Entities	Suggested measurement maturity level
Project (PRJ)	Level 1
Product (PROD)	Level 1
Process (PROC)	Level 3
Cross-project (PRJORG)	Level 3
Cross-product (PRODORG)	Level 3
Cross-process (PROCORG)	Level 3

5. MIS-PyME measurement maturity model – case study

In this section we show the case study whose objective was to explore whether MIS-PyME measurement capability maturity model (MCMM) helps the organization in defining measurement programs adapted to the measurement maturity of the company and in identifying measurement improvement areas. Therefore the "case" of the case study is the MIS-PyME measurement capability maturity model and there are two units of analysis: the measurement program defined and the assessment performed using MIS-PyME MCMM.

The theoretical basis of the case study are those presented in Section 2: on one hand none of the most common methodologies for defining measurement programs (GQM [17], GQ(I)M [18], PSM [19] and ISO/IEC 15939 [20]) includes guidelines for adapting the measurement program to the measurement maturity of the company, and on the other hand there exist other measurement maturity models which are the basis of the one presented in this paper. MCMM, however, aims to be more formal and complete.

The case study was performed in the software development and maintenance department of Sistemas Técnicos de Loterías del Estado (STL), which consists of 39 employees. This company was created by the Spanish Government and provides operational and IT development services for the national lottery. The director of the development and maintenance department wanted to improve measurement activities in there. He then wanted to define and implement a measurement program to support the process improvement goals as follows:

– *P.I.G 1:* Improving project plans
– *P.I.G 2:* Improving project monitoring
– *P.I.G 3:* Improving the process management. The company particularly wished to improve the effectiveness of the tests phases.
– *P.I.G 4:* Improving the development service. The aim of this goal was to improve the aspects of the project which most affect the client.
– *P.I.G 5:* Improving product quality as regards reliability.

The methodology used to define the measurement program was MIS-PyME. The detailed application of MIS-PyME and good practices for implementing measurement programs can be found in [23,25,26].

5.1. Case study: objective 1

The units of analysis for the first aim (explore whether MIS-PyME measurement maturity model helps the organization in defining measurement programs adapted to the measurement maturity of the company) was the measurement program which was to be developed.

The research questions were basically as follows:

- Does MCMM help to avoid defining indicators that require a more mature measurement process?
- Does MCMM help to avoid defining measurement programs which require resources that are not available and/or are difficult to get?
- Does the MCMM help to avoid defining measurement programs whose purposes are too ambitious as regards the measurement maturity of the company?

The method used to collect the data required to answer these questions is mainly based on interviews done with the measurement analyst and on inspections of documents such as the measurement program review report. The main questions asked to the measurement analyst in collecting data for the analysis of this case study were: ''to what extent does MIS-PyME help you perform your work?'' ''Could you give me a specific example?'' The results of the analysis of these data are thus based on the perception and opinion of the measurement analyst, and are mainly qualitative results.

Based on the answers to these questions, two examples of indicators were found that were initially to be defined, but the MIS-PyME measurement capability maturity model suggested that the user should not define them in that way, since these required a more mature measurement process:

- One of the indicator goals aimed to evaluate the reliability of the product developed in order to take corrective actions if necessary. This indicator was intended to evaluate the reliability of the company in relation to a fixed value meant to be a goal (the number of failures registered in production after the product had been installed). The intention of this indicator is to ''evaluate'' based on a predicted reliability goal, and this value is at level 4 according to the MIS-PyME measurement maturity interface of the methodology (see Table 3). However, even though the company knew (more–less) the reliability of the products in production, the measurement analyst realized that they were not experienced enough to be able to state what the precise value of the reliability of the product would on the basis of the characteristics of the product and the project being developed. The questionnaire of the MCMM made him reflect on this, since he was not able to answer the following questions: ''Do you measure the reliability of the product and other aspects that may have a relationship with the reliability of the product in a rigorous, frequent and organized fashion?'', ''Could you set reliable goals based on the available data?'', Are there reliable and defined methods to control dirty data in the historical measurement database of the organization?, Are there quantitatively measured benefits gained from the results of the measurement process? etc. These answers and others were negative. He therefore decided to evaluate indicators based on a range of values (good, normal, not too good, not acceptable). In this case, even though the maturity level required was still high (level 3) as regards reliability in production, the measurement analyst felt able to implement this indicator successfully and was therefore able to answer the questions posed in an affirmative manner: they could reliably define the ranges of reliability of the product developed, which would depend on the type of project: high, medium, low.
- The indicator Ind-PRJ-Test Conformance was also modified for it to be better adapted to the maturity of the company. This indicator was defined so as to achieve the first process improvement goal: monitoring conformance with test phases. Initially, this indicator assessed the efficiency of the test phases, based on the failures detected during each test phase and compared with a threshold. However, the company was not mature enough to define a threshold for each testing activity and depending on the product and project developed, the company fails to answer level 4 questions. On the other hand, they were mature enough to define a normal percentage ratio between test phases (e.g. more than 70% of the failures should be detected during integration test). The first indicator purpose was at level 4 and the one finally defined was at level 3.

These are two examples that positively answer the research questions defined for this case study. At the end of this section threads to validity are commented on.

5.2. Case study: objective 2

The unit of analysis of the second part of the case study was the company's self-assessment using the MIS-PyME assessment model. The goal was to determine the company's capability and to identify improvement issues.

The research questions were:

- Is MCMM suitable for defining the measurement capability of the company?
- Is MCMM suitable in identifying measurement improvements?
- Is MCMM suitable in understanding the measurement goals that the company is able to implement?

The procedure of the case study was mainly to follow the measurement assessment process. The data to analyze for the case study was basically the final report of the measurement analyst and her perception and opinion of the assessment model. Again, therefore, the resulting data is qualitative.

The person who performed the assessment was the measurement analyst who had defined the previous measurement program. The measurement program defined for the first part of the case study was implanted at the beginning of 2007 and the assessment was performed in May 2008. The information required to be able to perform the assessment was the following: list of projects performed in the organization during that period of time, their project and quality plan (and its various versions) the tracking project reports, the project closure reports, the measurement reports performed every 6-months as defined by the measurement processes, the list of products, and the measurement processes defined in the company.

The measurement analyst had quite a good knowledge of the measurement activities performed in the software and development department; she asked the questions proposed in the questionnaire with regard to the measurement assessment process, and she indicated the reasons for her answers and addressed the documentation in which the evidence could be found.

The results of the assessment were that level 1 maturity attributes were fully achieved, since a basic measurement process for tracking the reliability of the products in production had existed for quite some time. In addition, basic project tracking was performed in all projects. Project managers had to include the schedule deviation, its causes and the actions to be performed in their project tracking reports. Level 2 was largely achieved: the measurement program was clearly specified, project closure reports asked project managers to sum up the results of the development of the project and therefore other measures such us cost, and effort, duration deviation, and reliability had to be indicated. Other indicators were also analyzed during the project, thereby tracking the reliability of the product developed, client satisfaction, product quality, etc.

There is one important aspect in relation to the PA 2.1 (P) Performance management attribute and the PA 2.2 (P) Work product management attribute which must be improved, however: responsibilities are clear with regard to the collection of data, analysis of results and feedback. But in some cases it is not clear who the person responsible for the measurement process is, nor who the main parties interested in this are, or what their responsibilities may be. In the measurement process for project tracking, measurement analysis results are used for decision making purposes and the project manager is aware of this. But this is not the case in other measurement results concerning, for example, product reliability tracking in production. In these measurement processes, indicators are analyzed and improvement issues are identified, but it is not clear who is responsible for carrying out these improvement initiatives, so it is not entirely evident who the main person interested in, and responsible for, the measurement process is. As a consequence, measurement results in these cases are not usually used to improve development projects and the maintenance process.

With regard to level 3, one attribute was largely achieved: the PA 3.1 (P) Process definition attribute, PA .3.6 (R) Resource deployment attribute was partially achieved. The remaining level 3 attributes were not achieved, however. Some of the issues identified were the following: there were standard measurement processes that defined indicators for cross-product and project analyses, there were other more advanced indicators for project tracking: test status and requirement status, etc. However, the standard process for project monitoring purposes was not rigorously applied as specified in real-life projects. With regard to cross analyses, the analyses were not performed in such profundity as they should have been, responsibilities for analyses and feedback were not clear and results were not used to carry out improvement actions. Table 5 shows the measurement attributes profile of the development department.

As a result of the assessment, the most important measurement maturity improvement actions identified were the following:

- To strengthen the knowledge of the measurement processes implemented in the company in order to attain a better understanding of the responsibilities, the goals and the measurement process itself. The intention of this is to encourage the person responsible for the measurement program to use measurement results for their purposes and to apply the standard process correctly. In order to achieve this improvement goal, a training program will be defined and given to the headquarters of the company, the quality department and the project managers.

Table 5
Measurement attributes profile of the development department.

Attribute	Assessment results
PA 1.1 (P) Process performance attribute	Fully achieved
PA 1.2 (I) Basic project and product focus performance attribute	Fully achieved
PA 1.3 (R): Basic management tools implemented attribute	Fully achieved
PA 2.1 (P) Performance management attribute.	Largely achieved
PA 2.2 (P) Work product management attribute	Largely achieved
PA 2.4 (R): Management and development tools implemented attribute	Fully achieved
PA 3.1 (P) Process definition attribute	Largely achieved
PA 3.2 (P) Process deployment attribute	Not achieved
PA 3.4 (I) Advanced product tracking attribute	Not achieved
PA 3.5 (I) Process tracking attribute	Partially achieved
PA .3.6 (R) Resources deployment attribute	Largely achieved

- To formalize and supervise the improvement initiatives programs in the company. To achieve this goal, a presentation will be given at the company's headquarters, highlighting the importance of the improvement programs as projects, also to encouraging the project management office to supervise and support improvement programs.

A further conclusion of the assessment is that the software development and maintenance department is at level 2 of the measurement capability. Therefore they should not have any problems in defining levels 1 and 2 measurement goals, and they must take care when they desire to implement a level 3 measurement goal. Levels 4 and 5 measurement goals are not recommended.

The measurement analyst answered that MIS-PyME MCMM helped to identify the measurement maturity and the measurement improvements. This person also stated that even if a company understands its measurement deficiencies, a measurement capability maturity model is important, since it objectively identifies these problems and encourages their resolution and the carrying out of process improvement initiatives. It should be said that improvement initiatives are suggested in a feasible and progressive manner, rather than promoting just any improvement initiative, without any order and without taking into account whether or not the company is prepared to carry it out successfully. In addition, MCMM can be useful for determining the suitable MIS-PyME measurement goals which the company can implement.

5.3. Conclusions and threads to validity

By means of this case study it was analyzed in a real scenario if MCMM helps the measurement analyst in defining measurement programs adapted to the measurement maturity of the company and in determining the measurement maturity level, measurement improvements and suitable measurement goals for the company. As a result, the first pieces of evidence about the usefulness of the MIS-PyME were collected and encouraging results were obtained, namely: the measurement program performed was seen to be adapted to the measurement maturity of the company, some indicators were fixed based on MIS-PyME MCMM for this purpose, and MIS-PyME MCMM was useful for determining the measurement maturity level of the development and maintenance department of STL. A set of attributes was presented and evaluated, measurement improvement issues have been identified and the limitations as regards the measurement goals that the company is able to implement are also identified.

The main weakness of this case study is that it was only applied in one company and, what is worse, the case study results are based on the measurement analyst's understanding of the experience and is therefore based on one person's opinion. It would be advisable to reinforce the results by performing other case studies in other companies in several contexts, to demonstrate that, given different context conditions, the benefits of the model can be replicated too. This would also help us to understand the appropriate context conditions where this model can be applied with success. All this being so, more case studies must be performed if the results obtained in this research are to be reinforced.

6. Conclusions and further research

This paper highlights two factors which must be taken into account if measurement programs are to be successfully implemented. They are those defining measurement programs which are adapted to the measurement maturity of each company and those which promote continuous measurement process improve-

Table A1
An excerpt from the MIS-PyME measurement capability model assessment questionnaire.

Level 1: Performed process

PA 1.1 (P) Process performance attribute.

(a) Are any rules available to collect the measure, or is any protocol defined? Is it determined when the measure should be collected? Do measure collectors have a more or less similar understanding of how to collect the data?
(b) Are measurement results in terms of schedule tracking and reliability of products in production properly analyzed? With regard to the failures measure, are the causes of failure and its impact analyzed? ...

PA 1.2 (I) Basic project and product focus performance attribute

(a) In large projects, does the project manager track the schedule and identify deviation against what was planned?
(b) Are there specific indicators and measures for tracking the effort and/or cost of the project?...

PA 1.3 (R): Basic management tools implemented attribute

(a) Has the organization established any tool to track the scheduled progress of the projects?
(b) Is an incident tool implemented in the organization to store the failures identified and detected in production, as well as the defects detected during test activities?

Level 2: Managed process

PA 2.1 (P) Performance management attribute

(a) While you may have 'measurement goals' in measurement programs, do you have measurement goals in-project or in quality programs? .....

PA 2.2 (P) Work product management attribute

(a) Are measurement results verified?
(b) Are analyses results and interpretation, along with decisions and the action plan, communicated, discussed and adjusted if required? Are analyses results and interpretation, decisions and the action plan communicated to the people interested in the measurement process?...

PA 2.3 (I) Basic project and product focus management attribute

(a) Are the specific and defined measures used to control the deviations?
(b) Is the reliability of the product developed being tracked by checking the defect and problem reports observed by the testing team or the client? Does the company perform any action when the reliability is not good? Does the company take into account the reliability observed in the product at the testing phase in order to decide whether the product can be delivered or not?
(c) Does the company measure the time required between when the failures appear and when the defects are fixed? Does the company perform any action when in the majority of cases this gap in time is not as expected?...

PA 2.4 (R): Management and development tools implemented attribute

a. Has the organization established any tool to track cost and effort of the projects?
b. Do project managers use tools to keep the measurement information concerned with their projects?
c. Are there any databases which keep basic information on the project characteristics and its progress, which project managers can go to in planning their projects, etc.?
d. Is there a tool in the company for requirement management? Is there any ad hoc tool (excel sheet) developed by the project manager to manage requirements?...

Level 3: Established process

PA 3.1 (P) Process definition attribute

(a) Is there a standard measurement process which is adapted when it is applied in-projects or in other cases (quality, management process)? Are there guidelines which ease the adaptation and explain which parts of the process cannot be modified and which parts can be modified, guidelines as regards the size and scope of projects, etc.?
(b) Is the measurement process completely incorporated into the standard software quality, development and management processes? Do the report templates of these processes include measurement information as required, such as project tracing reports, close of project reports, and quality reviews reports? Are the data collection, analysis and feedback activities included in these processes? ...

PA 3.2 (P) Process deployment attribute

(a) Are the measurement processes applied in accordance with the standard process?
(b) When performing the measurement process, are the roles assigned as defined in the standard process? .....

PA 3.3 (I) Advanced project tracking attribute

(a) Are there cross-project analyses performed in terms of cost, effort, duration deviation, etc.?
(b) Are projects tracked in terms of cost, effort and schedule in a more detailed fashion, by work package or activities instead of phase-by-phase tracking?
(c) Is project management based on measurement? Are other aspects of the project therefore tracked, such as product size stability, report status, test status, review status?
  ○ Does your company perform any re-planning and understand the effects of requirement changes?
  ○ Does the company monitor the progress of problem reports opened as against those solved? Does the company perform any action based on this progress when there are time limitations or where there is no satisfaction with this problem report solving?
  ○ Does the company measure the defects found in revisions and do they control whether these have been applied?
  ○ Does the company measure the time required to define and/or perform a test case? Does the company manage the productivity in defining and performing the test phase as against what was planned? Does the company manage the % of the code that has been tested against what was planned?...

PA 3.4 (I) Advanced product tracking attribute

(a) Does the company measure sufficient quality measures or is it able to understand the most interesting quality measures so as to be able and build an indicator to understand maintainability, efficiency, reliability, portability, functionality?, etc.

(*continued on next page*)

Table A1 (*continued*)

(b) Does the company measure and use the same product- related indicators (quality indicators) for all the products maintained and developed in the organization? Is the company then able to perform cross-product analyses and does the company detect common cusses of problems related to the product? Does the company propose improvement organization initiatives to avoid these problems? …
PA 3.5 (I) Process tracking attribute
– Is the effectiveness of reviews measured?
– Is the effectiveness of the test phases measured?
– Are there cross-process analyses in terms of their results when they are applied in-projects, regarding efficiency, effectiveness and conformance? Does the organization perform analyses to identify common problems and carry out improvement initiatives for the processes of the whole organization?
– Are normal ranges of process efficiency, effectiveness and conformance understood?…
PA .3.6 (R) Resources deployment attribute
(a) Is there any organizational database to store the results of the measures?
(b) Is there a life cycle configuration management tool for each requirement, models for analysis, etc.
(c) Are Training Programs performed as needed for the people involved in measurement to correctly perform their roles?
(d) Do the project managers understand the existing estimation mechanisms and are they trained in this? ….
Level 4: Predictable process
PA 4.1 (P) Measurement cost/benefit process attribute
….

ment. A measurement capability maturity model is therefore proposed.

The paper describes the MIS-PyME measurement capability maturity model (MIS-PyME MCMM), showing the measurement capability levels, the attributes which should be fulfilled for each measurement capability maturity level and how this model is integrated into the MIS-PyME methodology process to define measurement programs adapted to the measurement maturity of the company. In addition, a measurement capability assessment process is presented.

A case study was presented to show the usefulness of the MIS-PyME measurement capability maturity model when it was applied in a small software department. The aim of the first part of the case study was to understand the usefulness of MIS-PyME MCMM in helping the measurement analyst to define measurement programs adapted to the company's measurement maturity. Two examples were given where MCMM helped the measurement analyst in changing the definition of these indicators so that they were adapted to the measurement maturity of the company. The second part of the case study identifies the usefulness of MIS-PyME MCMM in assessing the company's measurement capability to identify improvement issues and to understand what the measurement goals which are most suitable for implementation in the company are. The results of the second part of the case study were that MIS-PyME MCMM allowed us to understand, in an objective fashion, at what level the measurement capability of the software development and maintenance department was: level 2. This allowed the company to understand the measurement goals that the company should easily be able to implement-namely levels 1–3, but they had to be aware that this last level should be applied with care. The study also allowed the company to identify the measurement deficiencies and to propose improvement actions.

Understanding a company's measurement maturity level encourages the company to focus on the possible measurement goals that they are easily able to implement, and not to try to implement ambitious and difficult measurement programs, something which seems to be a tendency in industry. As regards the measurement improvement issues, an understanding of the measurement maturity level allows the company to promote feasible improvement initiatives in a progressive manner, rather than promoting just any improvement initiative, without any order and without taking into account whether or not the company is prepared to successfully carry it out. It therefore prevents companies from "putting the cart before the horse" as regards measurement.

Since the measurement maturity model in bibliography are not as complete as MIS-PyME measurement maturity models; and none of the measurement methodologies in the bibliography integrates a measurement capability maturity model, MIS-PyME and its measurement capability maturity model are indeed a contribution for research and to the industry, especially in SMEs where measurement information support is needed most; it has to be remembered that they represent the main part of the software industry sector.

Our future work will revolve around further validation of the MIS-PyME measurement maturity capability model in different companies in the quest to demonstrate the context conditions where this model is most suitable and to replicate successful results. Another task is that the questionnaire has to be improved on the basis of our experience. A study regarding whether the indicators of the model have to have the same weight should also be performed.

Acknowledgments

We would like to thank the staff of Sistemas Técnicos de Loterías del Estado (STL) for their collaboration. This research has been sponsored by the COMPETISOFT (CYTED, 506AC0287), PEGASO/

MAGO (Ministerio de Ciencia e Innovación MICINN y Fondo Europeo de Desarrollo Regional FEDER, TIN2009-13718-C02-01) and INGENIO (Junta de Comunidades de Castilla-La Mancha, PAC08-0154-9262) projects.

Appendix A

See Table A1.

References

[1] Gopal A, Krishnan MS, Mukhopadhyay T, Goldenson DR. Measurement programs in software development: determinants of success. IEEE Trans Soft Eng 2002;28(9):863–75.
[2] Daskalantonakis MK. A practical view of software measurement and implementation experiences within motorola. IEEE Trans Soft Eng 1992;18(11):998–1010.
[3] Daskalantonakis MK, Yacobellis RH, Basili VR. A method for assessing software measurement technology. Qual Eng 1990;3(1):27–40.
[4] Hall T, Fenton N. Implementing effective software metrics programs. IEEE Soft 1997;14(2):55–65.
[5] Pfleeger SL. Understanding and improving technology transfer in software engineering. Syst Soft 1999;47(2–3):111–24.
[6] Briand LC, Morasca S, Basili VR. An operational process for goal-driven definition of measures. IEEE Trans Soft Eng 2002;28(12):1106–25.
[7] Gresse C, Punter T, Anacleto A. Software measurement for small and medium enterprises. In: 7th International conference on empirical assessment in software engineering (EASE), Keele, UK; 2003.
[8] Kasunic M. The state of software measurement practice: results of 2006 survey. CMU/SEI-2006-TR-009. Software Engineering Institute; 2006.
[9] Richardson I, Wangenheim CGV. Why are small software organizations different? IEEE Soft 2007;24(1):18–22.
[10] ESI: Europe Software Institute; 2007. <www.esi.es/en/main/iitmark.html>.
[11] SEI. The capability maturity model: guidelines for improving the software process. Software Engineering Institute; 1995.
[12] Budlong F, Peterson J. Software metrics capability evaluation guide. T.S.T.S. Center, O.A. Logistics, H.A.F. Base; 1995.
[13] Niessink F, Vliet HV. Towards mature measurement programs. Software maintenance and reengineering; 1998. p. 82–8.
[14] Team CP. CMMI for systems engineering/software engineering, version 1.1 – staged representation (CMU/SEI-2002-TR-002, ADA339224). Software Engineering Institute, Carnegie Mellon University: Pittsburgh, PA; 2002.
[15] Weber C, Layman B. Measurement maturity and the CMM: how measurement practices evolve as processes mature. Soft Qual Pract 2002;4(3).
[16] ISO/IEC, ed. ISO/IEC 15504-2:2003. Process assessment – part 2: performing an assessment; 2003.
[17] Solingen RV, Berghout E. The goal/question/metric method – a practical guide for quality improvement of software development. London, England: Mc Graw Hill; 1999.
[18] Park RE, Goethert W, Florac WA. Goal-driven software measurement – a guidebook. Carnegie Mellon University Pittsburgh: Software Engineering Institute; 1996.
[19] PSM: Practical software and systems measurement – a foundation for objective project management version 4.0c. Department of Defense and US Army, November; 2000.
[20] ISO/IEC, ed. ISO/IEC 15939. Software engineering – software measurement process, ed. ISO and IEC; 2002.
[21] Oktaba H, García F, Piattini M, Ruiz F, Pino FJ, Alquicira C. Software process improvement: the competisoft project. IEEE Comput Soc 2007;4:21–8.
[22] Pino FJ, Ariel J, Hurtado A, Vidal JC, García F, Piattini M. A process for driving process improvement in VSEs. In: International conference on software process: trustworthy software development processes. Lecture notes in computer science, Vancouver, BC, Canada; 2009. p. 342–53.
[23] Diaz-Ley M, García F, Piattini M. Implementing a software measurement program in SMEs – a suitable framework. In: IET proceedings software, vol. 2(5); 2008. p. 417–36.
[24] Goethert W, Siviy J. Applications of the indicator template for measurement and analysis, software engineering measurement and analysis. Initiative Software Engineering Institute; 2004.
[25] Diaz-Ley M, García F, Piattini M. Software measurement programs in SMEs – defining software indicators: a methodological framework. In: Product focused software development and process improvement (PROFES'07), vol. 4589. Heidelberg, Riga, Latvia: Springer; 2007. p. 247–61.
[26] Diaz-Ley M, García F, Piattini M. Implementing software measurement programs in nonmature small settings. MENSURA, vol. 4895. Heidelberg, Palma de Mallorca: Springer; 2007.
[27] Diaz-Ley M, García F, Piattini M. MIS-PyME software measurement goals table – supporting the selection of measurement goals based on measurement organizational maturity. Soft Qual Prof (SQP) 2009;11(3):4–15.
[28] Wadsworth Y. What is participatory action research? Action Res Int 1998:2.
[29] Padak N, Padak G. Guidelines for planning action research projects. Ohio Literacy Resource Center; 1994.
[30] Diaz-Ley M, García F, Piattini M. MIS-PyME software measurement maturity model – supporting the definition of software measurement programs. In: Product focused software development and process improvement (PROFES'08), vol. 5089. Heidelberg, Frascati – Monteporzio Catone, Rome, Italy: Springer; 2008. p. 19–33.
[31] Pino FJ, García F, Piattini M. An integrated framework to guide software process improvement in small organizations. In: 16th European conference, EuroSPI, Alcala, Madrid, Spain; 2009. p. 213–24.