MAMD 2.0: Environment for data quality processes implantation based on ISO 8000-6X and ISO/IEC 33000

Ana G. Carretero*, Fernando Gualo, Ismael Caballero, Mario Piattini

Alarcos Research Group. Institute of Software and System Technologies. Escuela Superior de Informática Paseo de la Universidad 4, 13071 Ciudad Real, Spain

ARTICLE INFO

ABSTRACT

Organizations are increasingly becoming realized that the higher the levels of quality of data they use in their business processes, the larger the organizational performance can be. Therefore, it is highly recommended to pay special attention to data quality by institutionalizing a set of the best practices related to the disciplines of data-related disciplines, namely, data management, data quality management and data governance.

After investigated on the field, and because of our research, we developed MAMD – *Modelo Alarcos de Mejora de Datos*-, a framework for assessing and improving the levels of data quality in organizations, in which we aligned and established the relationships between the three disciplines. Our aim was to provide organizations with sound artefacts, which can help them to efficiently implement data-related strategies to achieve adequate levels of data quality, and consequently, better organizational performance. Grounding our proposal on a process-oriented approach, we initially developed two components for MAMD: (1) a process reference model addressing the best practices of the previously mentioned data-related disciplines, and (2) an assessment and improvement model of the level of implantation of these practices. The process reference model is based on the principles of ISO 8000-61, which we complemented by adding specifics on data governance processes, and specifics on data management processes. The evaluation model is grounded on ISO 8000-62, and therefore aligned to ISO/IEC 33000. After having tested the usability of MAMD in several case studies, and after having analysed the conclusions raised from the learnt lessons, this paper describes the changes we introduced to the first version of MAMD to make the framework easier to apply (more easily auditable, and more easily implementable by consultancy). The paper also describes the application of the new version of MAMD to a new case study to check the efficiency of the changes. So, the main contribution of this paper is the presentation of the new version of MAMD.

1. Introduction

The potential of the organizations to develop their mission and to find new paths to innovate on an increasingly competitive market is mainly grounded on data. Due to this fact, organizations are becoming more and more conscious that the higher level of quality of the data, the higher the benefits they can obtain. So, they understand that enough resources in deploying solutions to achieve adequate levels of data quality shall be invested to meet intended and future uses of data in their business processes to ensure adequate levels of data quality.

This cannot be done in an isolated way, but it should involve the whole organization over the time. Hence, ensuring data quality is a task which must: (1) be planned well enough in advance; (2) consider clear objectives aligned with organizational strategy; (3) assign adequately

qualified human, and sufficient materials and economic resources. Only then, commensurate results with organizational potential can be guaranteed. It can be said that the assurance of data quality levels must be achieved by implementing running in an integrated way data management, data quality management and data governance programs. In this paper, we will discuss how organizations can achieve this goal by means of the continuous and integrated implantation of best practices of these three disciplines.

To face up with a solution, we thought about an approach based on the idea of assessing and improving the "data processes" of the organization, similarly to what is done with software process in software developing companies. This enabled us to ground our proposal in the domain of existing software process solutions. To facilitate software processes improvement to organizations, there are

---

* Corresponding author.
E-mail addresses: AnaIsabel.Gomez@uclm.es (A.G. Carretero), Fernando.Gualo@uclm.es (F. Gualo), Ismael.Caballero@uclm.es (I. Caballero), Mario.Piattini@uclm.es (M. Piattini).

alternatives based on *de iure* and *de facto* standards like COBIT [1], CMMI [2], ISO/IEC 15504 [3], ISO/IEC 33000 [4]... unfortunately, they do not specifically address low levels of data quality concerns, and it is not easy to use them directly with data management, data quality management and data governance disciplines.

However, in recent times, new process-oriented initiatives (DMM [5] or ISO 8000-60 [6]) emerged to cope with these disciplines. After a detailed study, we concluded that DMM had two important concerns: its application is not as easier as desirable (too deeply detailed, and too many requirements to meet), and it is focused primarily on financial domain. On the other hand, we realized that because of its general purpose, ISO 8000-6X is easier to apply and use than DMM, although it does not explicitly cover neither data government processes aspects and it nor does fully address data management processes.

To fill this gap, and because of our research we developed the Alarcos' Model for Data Improvement (MAMD stands for "*Modelo Alarcos de Mejora de Datos*" in Spanish). Our main goal was to create a framework that allows organizations to plan and execute continuous improvement projects based on PDCA cycle to progressively set up the best practices of the data-related disciplines, namely, data management, data quality management, and data governance. These three disciplines are strongly interrelated, and all of them working together are aimed to assure that the organization is using data with adequate levels of quality. This means that the used data has quality enough as to make successful the execution of the organizational business processes.

According to other software process approaches, MAMD consists of two main components:

A process reference model that extends ISO 8000-61 [7] with the foundations and best practices of data governance processes and some data management processes, not already included. More details about the process reference model will be introduced in Section 3.2.

An assessment and improvement model based on ISO/IEC 33000 [4]. We decided to ground our proposal on ISO/IEC 33000 because it is a generic framework for the assessment and improvement of some process characteristics (like capability and maturity); in this sense, ISO/IEC 33000 supersedes ISO/IEC 15504, mainly focused on software processes. As part of the assessment and improvement model, an organizational data maturity model was also included. This data maturity model specifies in an ordered way of achievement, the set of processes that companies should implement to warranty that they are using data with the adequate levels of quality for their business processes. In Section 3.3, the assessment and improvement model will be described.

After conducted several case studies [8] in order to check the usability of the framework, we realized that it was not as much easier to apply as we intend, and consequently, it would not help organizations to assure adequate levels of data quality. In our investigation, "easier to apply" is meant to be both "easily auditable" (it is easy to conduct an assessment of the organizational maturity level of the organization with regard to the three data-related disciplines), and "easily implementable" (it easily guides organizations in achieving changes to their structure to set up those best practices which contribute to assure adequate levels of data quality, that is to say, to achieve a more mature organization with regard to the three data-related disciplines.) In this sense, we analyzed the learnt lesson after the case studies, and we decided to make changes to the framework, to make it easier to apply. These changes affect to both components of MAMD, which has evolved to MAMD v2.0.

The main contribution of this paper is the presentation and description of the structure and components of MAMD framework v2.0, to better enable organizations to assure better levels of quality for the data used in their business processes.

This paper is structured as follows: Section 2 presents works related to the existing maturity models (both for software process and for "data process"). Section 3 presents the rationale of the changes we made to evolve MAMD from v1.0 to v2.0. Section 4 describes a new case study

we conducted to check the usability of MAMD v.2.0. Section 5 introduces some conclusions raised and introduce some future lines of work that we consider necessary to continuously improve MAMD. Lastly, we include some acknowledge and references.

2. Related work

This section brings to the arena some related work corresponding to the core knowledge necessary to understand the scope and content of our proposal.

2.1. Data management, data quality management, and data governance concepts

The MAMD framework is based on the three aforementioned data-related disciplines: data management [9], data quality management [10,11] and data governance [12]. They are strongly dependant one from the others, and it does not make sense to implement them independently, because all working together better contributes to assure adequate levels of quality. This dependence is observed by [13]- where is revealed that the actual investigation in data quality involve the obvious need of adding certain governance, management, and technical aspects. The description of the three disciplines is showed below:

1. **Data governance** is aimed to design and implement data management and data quality strategies, which allows the alignment of data strategies to business organizational strategies. Such strategies are implemented as organizational policies. This will give support to the business needs by providing the necessary resources to both areas and monitoring the use of the resources regarding the strategic objectives of the organization.
2. From our perspective and for the sake of simplicity, we consider that **data management** implements and maintains a technological data infrastructure that must support business requirements. The requirements will be expressed through the data management policies. Likewise, the specific data quality requirements and their management shall be supported by the technological infrastructure.
3. **Data quality management** implements and maintains a data quality organizational culture that shall produce, maintain, perform, and communicate data quality management good practices that must be applied by data management. The actions previously mentioned shall satisfy the data quality specific requirements that ensure the organization processes success.

2.2. Scope of the existing data maturity models

A maturity model can be understood as a tool used to organize a set of elements ordered according to a given criterion [14]. In the domain of this work, the criterion is related to organizational maturity with respect of guarantee the success of business processes by means of the implementation of best practices of data quality management, data management and data governance, what enables adequate levels of data quality for the tasks at hands.

The first researcher to apply the concept of maturity model in the field of computer science was probably Humphrey in 1987 [15]. He used it to explain organizations; how to have more capable processes to produce high quality software. Specifically, in data quality domain, English was the first one to apply the maturity concept to data management at the same time as he included the notion of "data quality" in [14]. Since then, there has been many works related to data management that try to address this issue. Following subsections will go deep into such data quality management maturity models.

Regarding the scope of "*data management practices*" [16], it is easy to see how the evolution of the field has found data quality management and data governance. By the end of the twentieth century,

Fig. 1. Adapted from Aiken et al. [16] by using Trends.google.com.

Table 1
Data maturity models classification according to their scope.

Framework	Data management	Data quality management	Data governance
English [14]	X	X	
CALDEA [19]	X	X	
IQM3 [20]	X	X	
IQM [22]	X	X	
Aiken et al. [16]	X		
DMM [5]	X	X	X
IAIDQ [30]	X	X	X
ISO 8000-61[7]	X	X	
DAMA [18]	X	X	X

organizations began to be aware of the need for data quality. It is difficult to provide a data quality definition because of multiple interpretations of the concept. In [11], Prof. Wang establishes a data quality definition as "*fitness for use*", and this definition has been widely used all over the last years as reference to the development of both research and practitioner works on the data quality management area. Nonetheless, soon, organizations realized that Data quality management needs an integrative support from high management. The concept of data governance was presented for the very first time in the middle of the previous decade. Their objective is to align the data strategy to the organizational business strategy, what implies to invest the necessary efforts to carry out data management and data quality management [17,18]. Fig. 1 shows data management's evolution over time since 1950 to nowadays.

The three mentioned disciplines are not on the focus of all the existing frameworks and currently only DMM [5] and MAMD - that is to be presented in this paper - address the three disciplines as it will be shown below. However, it is possible to find: (i) maturity models whose purpose is address only one of the three disciplines, as English [14], Caballero et al. [19,20], Ryu et al. [21] or Baskarada [22] and (ii) frameworks that are not presented as a maturity model and include the three disciplines, like DAMA [18].

Along this work, "data maturity model" term is going to be used to refer to all maturity models that integrate data management, data quality management and data governance.

2.3. Frameworks considered as basis

Considering that the idea of maturity models was firstly applied to software processes, and up to now some software process maturity models have been developed, it makes sense that existing and new research works on data maturity models have used and will use these software maturity models as a basis [23].

A framework, which is used as reference, should provide not only a structure for a process reference model, but also the other necessary components to proper use the framework as an assessment methodology and an improvement model. CMMI [24] provides a process reference model that can be used along with SCAMPI [25] or CBA-IBI [26], while ISO/IEC 15504 [27] provides an assessment model, including criteria that represents a maturity model and an assessment model which can be used with ISO 12207 [28].

In this sense, the process reference model, which has inspired most of the data maturity models is CMMI. The two representations of CMMI – staged and continuous – have been used in different proposals. To mention a few of them: IQM3 [20] is presented as a staged model, while IQMM [22] or recently DMM [5] are described as continuous models.

ISO 8000-6x project [29] includes a process reference model,

namely ISO 8000-61, as well a maturity model (ISO 8000-62) structured according to the established principles in ISO/IEC 33000.

Furthermore, it is also noteworthy to mention the model proposed by Pierce et al. in [30] that is based on COBIT 4.1. Additionally, it is necessary to highlight the fact that many authors in the field of data quality use "data" and "information" as synonyms.

2.4. Classification of existing models

We classified existing contributions against two criteria: reference framework and scope. In scope, there are three possible values: {"*data management*", "*data quality management*", "*data governance*"}, while in the reference framework the next values are been classified: CMMI, ISO/IEC 15504, COBIT and others. Table 1 gathers this classification.

Table 2 presents data maturity models classification according to the reference framework used.

3. MAMD v2.0, an improved version of the Alarcos' data improvement model

MAMD was first described in [31]. We conducted several case studies to check the usability of the framework. After the case study presented in [8] we found that the application of the framework was not as easily as we intended. Our aim was to provide organizations with a framework that easily allow them to set up those best practices of data-related processes. We conducted a SWOT analysis of the framework and we realized that some changes were necessary to make it easier to apply. Easier to apply means that the framework should be easily used for the assessment and the improvement of the organizational maturity level. On a hand, saying "easily used for the assessment" we mean that the efforts required by a team to conduct an audit of the organization is commensurate with the size of the organization and with the complexity of the business processes using data. On the other hand, and analogously, saying "easily used for the improvement", we mean that the efforts required to both identify the weaknesses of the organization regarding the implementation of the best practices of the three data-related disciplines, and the efforts required to depict and

Table 2
Data maturity models classification according to the reference framework used.

Framework	CMMI	ISO 15504	COBIT	Others
English [14]				X
CALDEA [19]	X			
IQM3 [20]	X			
IQMM [22]	X			
Aiken et al. [16]	X			
DMM [5]	X			
IAIDQ [30]			X	
ISO 8000-61[7]		X		
DAMA [18]				X

execute improvement plans are affordable, and the cost-benefit analysis is suitable.

We raised the conclusion that to make the model easier to apply we had to make some changes to both process reference model and assessment model. We classify the changes in "general changes", "changes to make the framework more auditable" and "changes to make the framework more implementable".

The "general changes" (contributing to make both auditable and implementable) were:

- A deep description of the processes within the process reference model was provided. In this sense, we introduced a new section in the description of the processes aimed to describe the work products, and we described the process by means of SPEM [32]. This also implies the identification of the various roles in data-related disciplines (data stewards, data governor, data quality manager) that can be responsible for the various data-related resources. See Section 3.1.
- We provided a structure for a knowledge basis that enabled the better understanding of the processes within the process reference model.

The "changes to make the framework mode auditable" were:
- We adapted the structure of the knowledge base to contain a classification of the evidence that any auditor can look for during an audit. In this sense, we listed for every process within the process reference model the various artefacts that can be considered as direct evidence and indirect evidences. See Section 3.2 and Section 4.
- We redesigned the questionnaires to make possible that the conduction would take less time. In addition, we identified some questions that were unnecessary to ask considering the relationship between the processes within the process reference model.
- We designed several templates to better document and classify the various types of evidences, so that, depicting results could be more visual and takes less time.
- We aligned the "audit process" to the one of our national agency for standardization and certification, borrowing some specific requirements for the members of the audit team or for reporting results.

The "changes to make the framework more implementable" were:

- We changed some of the process in the process reference model to a lower granularity because their description could lead reader to ambiguity.
- We reviewed the description of the process of the process reference model to better address the best practices of the existing frameworks listed in the Related Works Section.
- We changed the order in the maturity model of the assessment model to better reflect the need of assuring the implementation of processes considered more urgent or critical than others (e.g. assuring that the organization firstly implements process related to data security rather than those related to data governance, which are supposed to be less critical for the survival.)
- We have better established the relationships between the process in the lower maturity levels, by making clear the traceability of some of the work products.
- We adapted the knowledge base to store specific examples of the evidences and the context in which the evidence was found. This enable any consultancy worker to propose to implement a specific resource that can largely contribute to deploy mechanisms to better manage data.

Some of these changes affected to the process reference model, some other to the assessment and improvement model, and some other to both. These are the two main components of the framework (see Fig. 2). Sections 3.1 and 3.2 will describe the impact of some of these
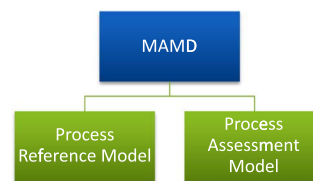

Fig. 2. Main components of MAMD framework.

changes to both components, and some other will be shown during the execution of the case study to illustrate how our team benefitted from having the renewed version of the components.

3.1. Process reference model version 2.0

According to the stated in clause 5.3.1 of ISO/IEC 33004 [33], a process reference model (PRM) is defined as a set of processes that can collectively provide support to the organizational processes. The processes reference model of MAMD is composed by twenty-one (21) processes grouped around the three disciplines: data management, data quality management and data governance. These processes have been now identified by mapping ISO 8000-61, DMM, COBIT, and DAMA (see Table 3 for a mapping between ISO 8000-61, MAMD and DMM).

After this and other studies, the principal changes made on the process reference model are shown in Table 4:

Some of these changes have been motivated after realizing that some processes could be more easily achievable in a separated way. As an example of this is DG.2 process. After the case study, we realized that data lifecycle management and data value management should be split up into two different processes to make easier organizations focus on their specific goals. One of the most important reasons is the fact that the data lifecycle management should be performed as a necessary process in earlier phases. However, data value management implies a high organizational maturity and a high management.

On the other hand, and regarding Data Quality Management processes, we considered that splitting up the two processes into four would benefit organizations in addressing better their efforts. In addition, this change make MAMD be more aligned to ISO 8000-61.

In the following, the goal of each one of the processes in the PRM MAMD 2.0 is to be introduced, although the full description is not done due to paper length restrictions. However, we introduce as an example the process DQM.2. Data Quality Control and Monitoring.

3.1.1. Data management processes (DM)

- **DM.1. Data requirement management.** This process aims at collecting and validate requirements referral to necessary data to manage the organization successfully.
- **DM.2. Technological infrastructure management.** The goal of this process is to specify and maintain the necessary technological infrastructure to support data meaning shared between applications.
- **DM.3. Historical data management.** The process addresses how to maintain and perform necessary policies to organizational historical data management.
- **DM.4. Data security management.** This process is aimed to define and enable mechanisms to make possible confidentiality, integrity, accessibility or availability, authenticity, non-repudiation, consistency, isolation, and data audit.
- **DM.5. Configuration management.** The process addresses how to define the processes by which an organization demand, determines, approves, and implements the reachable plans and evaluates the changes of data lifecycle.
- **DM.6. Master Data management.** This process is aimed to identify the relevant concepts to organization business domain and the organizational data strategy alignment around these master

Table 3
DMM and ISO 8000-61 processes mapped to MAMD 1 [31] processes.

MAMD	DMM	ISO 8000-61
DM.1. Data Requirements Management	DO 4.1	I 1.1
DM.2. Technological Architecture Management	PA 5.1, PA 5.2, PA 5.3	DRS 2.1
DM.3. Historical Data Management	PA 5.5	
DM.4. Data Security Management	SP 6.4	DRS 2.4
DM.5. Configuration Management	SP 6.5	
DM.6. Master Data Management	DMS 1.1, DG 2.1	
DM.7. Data Design	DG 2.2, DG 2.3	
DM.8. Establishment of Data Sources and Data Targets	DO 4.3	DMS 2.2
DM.9. Data Integration	PA 5.4	I 1.8, DMS 2.2
DQM.1. Data Quality Measurement	SP 6.1, DQ 3.1, DQ 3.3	I 1.5, I 1.7, I 1.10
DQM.2. Data Quality Improvement	SP 6.1, DQ 3.1, DQ 3.3	I 1.11, I 1.12, I 1.14
DG.1. Establishment of Data Strategy	DMS 1.1, DQ 3.1, DG 2.1, DMS 1.2	I 1.2, I 1.4, I 1.5
DG.2. Management of the Data Lifecycle and Value of Data	DO 4.2	
DG.3. Definition of Standards, Policies and Procedures	DG 2.1, DMS 1.2, DQ 3.1, DQ 3.2, PA 5.2	I 1.3, I 1.9
DG.4. Human Resources Management	DMS 1.3	RP 3.2
DG.5. Financial Resources Management	DMS 1.5	
DG.6. Monitoring of Organizational Data Strategy	DG 2.1, DMS 1.1	I 1.7
DG.7. Management of Changes to Data Strategy	DMS 1.1	

Table 4
Principal changes of the process reference model.

Processes in PRM of MAMD version 1	Processes in PRM of MAMD version 2
DG.2. Management of the Data Lifecycle and Value of Data	DG.2. Data Lifecycle Management
	DG.3. Data Value Management
DG.3. Definition of Standards, Policies and Procedures	DG.4. Standards, policies and procedures definition
DQM.1. Data Quality Measurement	DQM.1. Data Quality Planning
	DQM.2. Data Quality Control and Monitoring
DQM.2. Data Quality Improvement	DQM.3. Data Quality Assurance
	DQM.4. Data Quality Improvement
DG.4. Human Resources Management	DG.5. Human Resources Management
DG.5. Financial Resources Management	DG.6. Financial Resources Management
DG.6. Monitoring of Organizational Data Strategy	DG.7. Monitoring of Organizational Data Strategy
DG.8. Management of Changes to Data Strategy	DG.8. Management of Changes to Data Strategy

data.

- **DM.7. Data design.** The goal of this process is to develop a consistent data model, complete, comprehensive and extensible that covers the data requirements of all organizational units. In addition, the data model shall be aligned to the organizational data strategy.
- **DM.8. Data sources and data targets establishment.** The process addresses how to identify and characterize each data sources and destinations used in original business processes, as well as the agreements and interactions with providers and customers.
- **DM.9. Data integration.** The goal of this process is to ensure data integrity through flow control and relationships with transferred data to application systems or data bases.

3.1.2. Processes related to data quality management (DQM)

DQM.1. Data Quality Planning. This process is aimed at introducing the corresponding data quality actions and mechanisms into the various organizational resource dealing with data.

DQM.2. Data Quality Control and Monitoring. The main aim of this process is to establish the corresponding actions to monitor the levels of quality on the data used through the organization as well as to fix the found non-conformities in data.

DQM.3. Data Quality Assurance. This process is aimed at implementing the necessary changes to organizational resources so that it can be assured that levels of data quality will be enough to

successfully run the organizational business processes.

DQM.4. Data Quality Improvement. The goal of this process is to implement a continuous improvement cycle based on PDCA model to data in organizational repositories and business processes.

3.1.3. Processes related to data governance (DG)

DG.1. Data strategy establishment. The process addresses how to identify and prioritize data management objectives, and work according to these prioritizations to give support to the corporate strategic objectives.

DG.2. Data lifecycle management. The goal of this process is to identify the importance degree of data have to different business processes in corresponding stages.

DG.3. Data Value Management. This process is aimed at determining the organizational value of data according to the data strategy.

DG.4. Standards, policies and procedures definition. This process is aimed to establish those standards, policies, good practices and procedures to data management, data quality management and data governance to support as better as possible the data quality strategy.

DG.5. Human resources management. The process address how to manage needs adequately to required specific formation to the human resources specifically destined to data management, data quality management and data governance.

DG.6. Financial resources management. The goal of this process is to develop plans for financial resources provisioning and maintaining that can give support to organizational data strategy.

DG.7. Data organization strategies monitoring. This process is aimed to develop and measure key indicators for monitoring the achievement of data management strategy and check that it is being aligned with the organizational data strategy.

DG.8. Change management in data strategy. The goal of this process is to maintain coherently organizational data strategy according to the evolution of corporate strategic objectives.

Every process was initially described by following the schema provided in ISO 8000-61. As part of the improvements made to the PRM version 1, the R & D team decided to add a new section describing the work products of each process. As an example, the process *"Data Quality Control and Monitoring"* is described in Table 5:

As part of our efforts to better describe the process reference model, we used SPEM to represent the process. In Fig. 3 we used EPF Composer to represent the process DQM.2.

Due to paper length restriction, we do not include the structure used for the knowledge base, although some examples of classifying

Table 5
Example of DQM.2 process of MAMD version 2.

DQM.2. Data quality control and monitoring	
Goal	The main aim of this process is to establish the corresponding actions to monitor the levels of quality on the data used through the organization as well as to fix the found non-conformities in data.
Process Outcome	PO1. Business process information needs are identified.
	PO2. A set of measures based on the information needs are identified and developed.
	PO3. Measure activities are identified and planed.
	PO4. Required data is collected, stored and analyzed, and the results are interpreted.
	PO5. The information obtained is used to support the decisions and give a base to communication.
	PO6. The measures and the measurement process are evaluated.
	PO7. The improvements are communicated to the measurement responsible.
Activities	A1. Develop a measurement strategy. To define an adequate measurement strategy to identify, realize and evaluate the measurement activities and his results based on the organizational project needs. [PO3]
	A2. Identify the measurement information needs. To identify the measurement information needs to use in the organizational processes. [PO1]
	A3. Describe the measures. To identify and to develop a set of adequate measures based on the measurement information needs. [PO2]
	A4. Collect and store measurement data. To identify, to collect and to store the measurement data, including the needed context information to verify, to understand and to evaluate data. [PO3, PO4]
	A5. Analyze measurement data. To analyze and to interpret measurement data and, to develop information products.
	A6. Use the information products of the measurement to make decisions. To make precise and updated measurement information products available to make decisions on any process.
	A7. Communicate the results of the measurement. To communicate the measurement information to stakeholders and to collect feed to evaluate his correctness to the expected use.
	A8. Evaluate and to communicate the information products and activities of measure to the process responsible. To evaluate the measurement information products and activities in front of the identified information needs and the measurement strategy. To identify possible improvements on measurement and, to communicate any potential improvement identified to the owner processes.
Work Products	• Customer satisfaction data. [PO4]
	• Process performance data. [PO4]
	• Customer satisfaction survey. [PO5]
	• Measures on the data quality characteristics for data sets. [PO4]
	• Process measures. [PO4, PO5]
	• Project measures. [PO4, PO5]
	• Quality measures. [PO4, PO5]
	• Service level measures. [PO4, PO5]
	• Processes description. [PO6, PO7]
	• Issues register. [PO6]
	• Analysis report. [PO4, PO5]
	• Evaluation report. [PO4, PO5]
	• Process performance report. [PO4]

evidence would be introduced during the presentation of the case study.

3.2. Evaluation model v2.0

Evaluation Model of MAMD is grounded on ISO/IEC 33000. So, in the following, we will discuss how the evaluation model has been changed, and we explain how we have redesigned the corresponding maturity model.

3.2.1. Process capability levels and process attributes for MAMD based on ISO/IEC 33000

As stated in ISO/IEC 33020 [34], process capability is defined on a six point ordinal scale that enables capability to be assessed from the bottom of the scale, incomplete, through the top end of the scale, innovating. The scale represents increasing capability of the implemented process – from failing to achieve the process purpose through continually improvements.

ISO/IEC 33020 defines process capability on a six-point ordinal scale. The scale starts on level 0 labelled as "incomplete" and ends on level 5 labelled "innovating". Also, the scale represents capability of the implemented process.

To compute the process capability level is necessary to observe and assess the evidence of the achievement of the process attributes. For a detailed description of the full meaning of the process capability and the process attributes can be consulted in clause 5.2 of ISO/IEC 33020.

To calculate the process capability level is necessary to assess and observe the evidence of the achievement of the process attributes. The meaning of the process attributes and the process capability are described in ISO/IEC 33020. Table 6 summarises the processes attributes and capability levels that should be achieved. Note that achieving the next level involves obtaining own level and above.

3.2.2. Rating process attributes and process capability

Rating a process attribute consists of a judgement of the extent to which a specific process attribute has been achieved for the assessed process. A process attribute (PA) is a measurable property within this process measurement framework of process capability. The capability levels and process attributes are described in ISO/IEC 33020 in clause 5.2 and the ordinal scale for rating capability levels are described in clause 5.3. In Table 6 the capability levels and process attributes, and in Table 7 the corresponding values and the ordinal scale are shown. Because of length paper restrictions, we have not included the way the development to compute the assessment indicator as ISO/IEC 33004 requires.

Hence, when an organization is to be assessed regarding the data quality management, assessors shall investigate on an evidence-basis how much data quality management processes from the data quality management process reference model are achieved. Thus, it can be stated that one specific organizational process can address the data quality management process with the level indicated by the ordinal.

To collect evidence that enable the compute of the maturity level, we designed a knowledge base containing some generic types of direct and indirect artefacts. Auditors can look for instance of these types of artefacts as evidence. Due to paper length restriction, we cannot include the knowledge base, although we will introduce some of them during the presentation of the case study in Section 4.
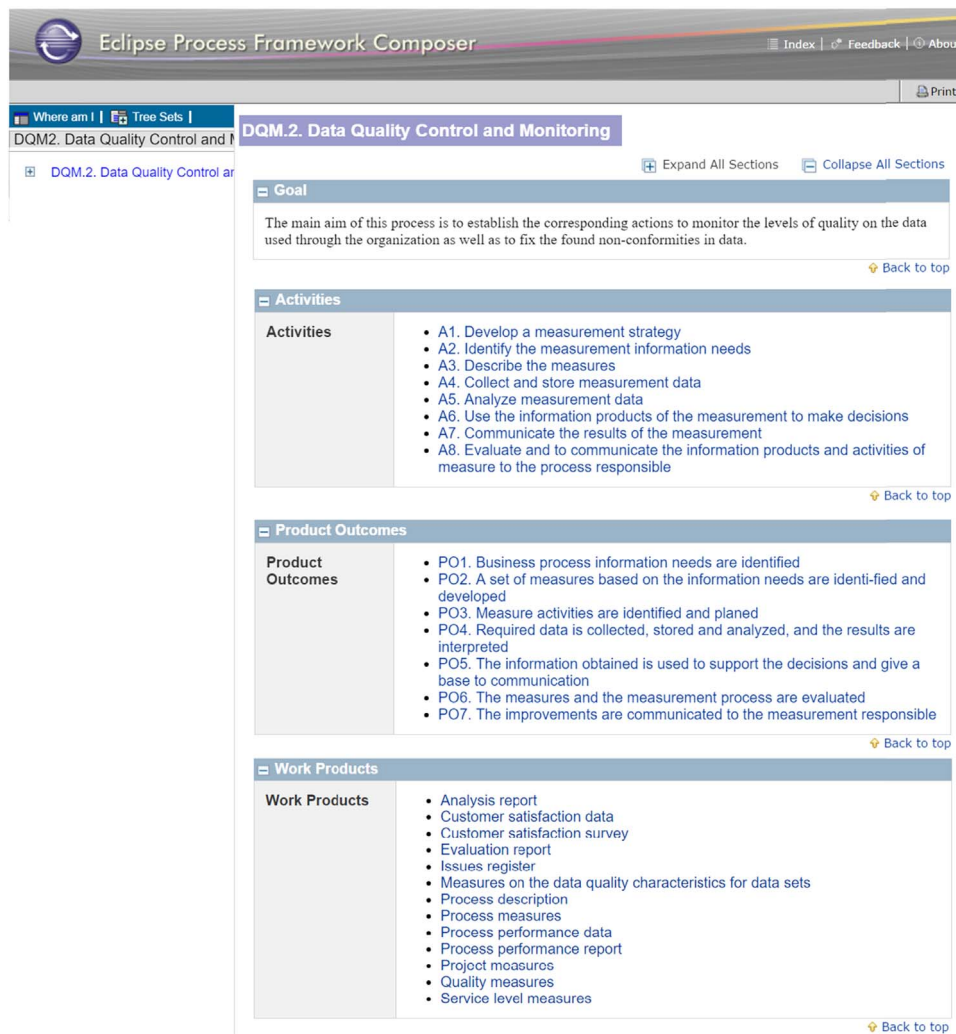
Fig. 3. DQM.2. process represented in EPF Composer.

Table 6
Capability levels and process attributes according to ISO/IEC 33020.

Process capability level	Process attributes
Incomplete process	n/a
Performed process	PA.1.1. Process performance
Managed process	PA.2.1. Performance management
	PA.2.2. Work product management
Established process	PA.3.1. Process definition
	PA.3.2. Process deployment
Predictable process	PA.4.1. Quantitative analysis
	PA.4.2. Quantitative control
Innovating process	PA.5.1. Process innovation
	PA.5.2. Process innovation implementation

3.2.3. Maturity model v2.0 of MAMD

In the context of data quality management provided in this paper, a maturity level indicates how well the organization achieves the goals required for data quality management processes by using the resources provided by the organization.

The processes identified for each maturity level have been included by different criteria: priority of the processes for the business, relevance of the processes in other models, complexity, and necessary resources that the organization should make available to assure the necessary data quality levels.

As well as in the process reference model, the maturity model has been improved based on the experience on case studies and the study of existent maturity models.

We realized that in the previous version of the evaluation model,

Table 7
Ordinal scale for rating capability levels (see ISO/IEC 33020).

Ordinal	Meaning
N - Not achieved	There is little or no evidence of the defined process attribute in the assessed process.
P - Partially achieved	There is some evidence of an approach to, and some achievement of, the defined process attribute in the assessed process. Some aspects of achievement of the process attribute may be unpredictable.
L - Largely achieved	There is evidence of a systematic approach to, and significant achievement of, the defined process attribute in the assessed process. Some weaknesses related to this process attribute may exist in the assessed process.
F - Fully achieved	There is evidence of a complete and systematic approach to, and full achievement of, the defined process attribute in the assessed process. No significant weaknesses related to this process attribute exist in the assessed process.

Table 8

Evolution of the processes in maturity model from the first version to actual version of MAMD.

Maturity model MAMD version 1		Maturity model MAMD version 2	
Maturity Level	Processes	Maturity Level	Processes
1	DM.1. Data Requirements Management	2	DM.1. Data Requirements Management
	DM.2. Technological Architecture Management	2	DM.2. Technological Architecture Management
	DM.5. Configuration Management	2	DM.5. Configuration Management
	DM.8. Establishment of Data Sources and Data Targets	3	DM.8. Establishment of Data Sources and Data Targets
2	DM.3. Historical Data Management	2	DM.3. Historical Data Management
	DM.4. Data Security Management	2	DM.4. Data Security Management
	DG.1. Establishment of Data Strategy	3	DG.1. Establishment of Data Strategy
	DG.2. Management of the Data Lifecycle and Value of Data	2	DG.2. Data Lifecycle Management
		4	DG.3. Data Value Management
	DG.3. Definition of Standards, Policies and Procedures	2	DG.4. Standards, policies and procedures definition
3	DM.6. Master Data Management	3	DM.6. Master Data Management
	DM.7. Data Design	3	DM.7. Data Design
	DM.9. Data Integration	3	DM.9. Data Integration
	DQM.1. Data Quality Measurement	3	DQM.1. Data Quality Planning
		2	DQM.2. Data Quality Control and Monitoring
	DQM.2. Data Quality Improvement	4	DQM.3. Data Quality Assurance
		5	DQM.4. Data Quality Improvement
	DG.4. Human Resources Management	3	DG.5. Human Resources Management
4	DG.6. Monitoring of Organizational Data Strategy	4	DG.7. Monitoring of Organizational Data Strategy
5	DG.5. Financial Resources Management	4	DG.6. Financial Resources Management
	DG.7. Management of Changes to Data Strategy	5	DG.8. Management of Changes to Data Strategy

some processes seem very hard to be achieved in lower maturity levels. So, the R & D team decided to rearranged the maturity model. The changes made in the maturity model are shown in Table 8.

The maturity levels that are proposed in MAMD, together with their meaning and the processes that are included are detailed below:

- **Maturity level 0 or Immature:** the organization cannot provide evidence about the effective implementation of good practices addressed by the process reference model. Therefore, there are no guaranties that their data is being used adequately.
- **Maturity level 1 or Basic:** the organization can evidence that it uses a set of good practices oriented to provide the minimum support necessary to the data management required to successfully support their business processes. Nevertheless, no special attention is given to data governance and data quality.
- **Maturity level 2 or Managed:** the organization can evidence that uses a set of good practices oriented to guarantee that the data used in business processes are aligned to organizational strategy. Consequently, there are guarantees that the organization has implemented the minimum necessary data governance processes to ensure the success in their business processes.
- **Maturity level 3 or Established:** the organization can evidence that it uses a set of good practices oriented to data quality management to guarantee that data used in their business processes have adequate quality levels.
- **Maturity level 4 or Predictable:** the organization can evidence that it uses a set of good practices oriented to monitoring that organizational data strategies are effectives.
- **Maturity level 5 or Innovating:** the organization can evidence that it uses a set of good practices oriented to guarantee that organizational data strategies are evolving. An organization will be said to be at maturity level 5 when it monitors their data strategies and it executes the following processes of process reference model. This processes are oriented to update data strategies to improve known defects and can be used to improve the global performance.

The new maturity model is shown in Table 9.

The maturity level is computed based on the capability level of processes on the process reference model included in the evaluation. The capability level is calculated considering the degree of institutionalization of good practices and process attributes described in ISO/IEC 33020.

Table 9

Ordinal scale for rating capability levels.

To calculate the capability level of this processes the different kind of evidences shall be inspected and it will be recollected to each business processes instances that have been chosen to make the evaluation. As result of the capability level a classification will be obtained. The classification for each one of the process attributes according to ISO/IEC 33020 is: "*Not Achieved (N)*", "*Partially Achieved (P)*", "*Full Achieved (F)*", and "*Largely Achieved (L)*".

To collect the evidence, the questionnaires previously developed in MAMDv1.0 was redesigned to adapt the changes of the new version of the maturity model. In addition, and in order to conduct more efficiently the questionnaire, some questions were reformulated in order to better collect the traceability of the changes required to be done to the organizational resources (for example, work products). Due to copyright permissions, we cannot include part or the totality of the questionnaires, given that they are now part of the adaptation to the assessment process of the national agency of standardization and certification we made.

4. Case study

It is important to state that to decide if MAMD v2.0 was easier to

apply than v1.0, we need to compare the efforts required in conducting and assessment with MAMD v1.0 versus MAMD v2.0.

We are working on some relevant indicators that allow us to better describe the measurement of the required efforts, our initial approach is based on the time required to conduct the whole assessment. Once depicted such indicator, we can proceed with the comparison. As measure unit for the indicator we chose the "*number of days necessary to conduct an assessment*".

So, the main aim of this case study was to measure the time required to conduct the assessment when using MAMD v2.0. We are conscious that for a comparison can make sense, both assessment with MAMD v1.0 and MADM v2.0 should be conducted on the same organization, with the same processes. If this is not possible due to the mere fact that once auditors have conducted the assessment with MAMD v1.0 in a specific context, their learning would modify the results during the conduction of the assessment with MAMD v2.0. In addition, the efforts would not be justified in repeating the same work.

So, we are aware, that for the comparison make sense we had to choose organizations with similar size, running processes of similar complexity, with personnel with similar skills and knowledges on the data-related disciplines. Although this was not especially easy, for the case study which is to be reported, we could count on an organization, which could be assumed to be similar to the previous case study presented in [8]. Hence, we would like the reader would be realized that the aim of this case study is not to check the efficiency of MAMD v2.0 in improving the levels of data quality (something that could be checked after executing the improvement plan after the assessment), but to check if the changes introduced to MAMD v2.0 really makes easier the application of the framework.

In this section, the results of the application of MAMD framework to the Library of the University X (LUX - for confidentiality reasons) will be described, which has allowed to refine and validate the model. The evaluation was performed following the principles of evaluation model provided by MAMD, which are grounded on ISO/IEC 33010 [35].

4.1. Description of the organization

The LUX provides support to a university community formed -date of 2014- by 31,203 students, 1,044 management and service staff, and 2,227 academic members and research staff spread across several campuses with a total of 13 service points, and 3 readings rooms that allow a ratio of 6.6 students per study places.

In 2014, LUX managed a bibliographic collection of 1,140,509 volumes computerized, as well as access to 46,411 electronic journals and 487,077 electronic books, apart from other services. From these resources, a total of 289,388 loans of bibliographical material were counted, a total of 339,279 downloads of e-books and a total of 588,520 searches in the databases of references were made. All of this is supported by a total of 78 professionals from different categories and ranges scattered across all the facilities. It has a budget of €1,321,172 for its implementation during 2015.

Apart from the management of literature, LUX also manages other services such as loaning equipment for teaching and learning, training courses, management of social networks, etc. All this activity is supported by a technological infrastructure managed by the data center of the university, which allows the use, not only of the equipment used by the staff, but also of the 964 fixed and portable reference positions scattered across all reading rooms. Furthermore, human and technological resources are used in the integration of data from other institutions.

We assume, under a certain error, that the size of the organization and the skills and knowledge of people responsible for data-related process are similar to one presented in [8], and hence, it makes possible the comparison of the results of both case studies.

4.2. Scope of the evaluation

As this was also a pilot experience, and given that part of the case study was to determine the effort of evaluation, it was decided to evaluate only until level 2 of the maturity model of MAMDv2.0, similarly to what was done to the case study presented in [8]. As it is an assessment of the organizational maturity level, then an assessment Class 1 is required. This implies the inspection of evidence of the institutionalization of best practices of the process within the process reference model in at least four instances of organizational processes: one main process and three auxiliary ones. However, to simplify the effort by the staff of the LUX, it was decided to choose only three processes, which were identified during the planning phase (see Section 4.3). Choosing only three process instances is not against the foundations of ISO/IEC 33000.

4.3. Evaluation planning

Two important moments during the planning can be distinguished during the evaluation planning: (1) a first initial meeting with the directors of LUX, where the processes that would be analyzed during the evaluation were decided, and (2) a second contact that, after deciding the processes, it was planned who and when would participate to provide evidence during the evaluation, depending on their level of responsibility on the processes chosen. Some instances of the following processes were chosen:

– Main Process (MP): cataloging procedure.
– Auxiliary process 1 (AP1): funds movement procedure
– Auxiliary 2 (AP2) Process: user load procedure / external users

The assessment was planned to be held during five days. The personnel from the service point from one of the localizations, which were either responsible or related to the three identified processes, was interviewed. The auditing team was composed by three people, who have a major on Information Systems with specialization in data quality, and one of them holding the CISA certification, and the remainder ones in preparation for the exam. So, it can be said that the auditing team has expertise enough to successfully conduct the assessment.

4.4. Evidence collection

To collect evidence necessary for the evaluation, a working script that included a checklist with expected results was prepared, as well as a questionnaire with specific questions for people involved in the implementation of the selected processes.

Table 10
Documentation provided by the work team of the LUX. Evidence are classified according to the knowledge base.

Process	Documentation provided-direct evidence
PP	Technical documentation provided (BIB-34).
	Technical instructions (IT 08, 09, 10).
	Technical process manual from the library.
	AbsysNet manual.
	MARC21 manual.
	Z39-50 model and capture from REBIUN collective catalog [36].
PA.1	Loan funds (BIB-35).
	Access rules and LUX loan.
	AbsysNet manual.
	GTBIB manual [37].
PA.2	User management (BIB-15).
	Access rules and LUX loan.
	AbsysNet manual.
	User load from applications CCUX technical procedure

The questionnaire, which covered the processes included in level 1 and level 2 of MAMD, and the attributes PA.1.1 process, PA.2.1, PA.2.2, included questions for people identified during the planning (see Section 4.3). Process attributes are described in ISO/IEC 33020 clause 5.2, and the ordinal scale to calculate the level of capacity is shown in clause 5.3. Apart from the answers, LUX workers provided some other evidence, such as relevant documentation (see Table 10). It is important to highlight the fact that all the typical processes in the LUX are conveniently documented by technical instructions and manuals processes publicly accessible. Due to paper length restriction, the complete catalog of the obtained evidence cannot be included. We only include the conclusions that have resulted from the inspections and interviews conducted for each of the processes evaluated in the process reference model are included.

4.4.1. Discussion about evidence found on the process of the process reference model

In the following we introduce some of the conclusions we raised about the inspection of the evidence collected. We documented and classified the evidence according to the template generated as part of the changes made to MAMD. Due to paper length restriction, we cannot include the specific format of the template.

DM.1. Data management requirements. In the MP, fully described in the BIB-34 documents and technical instructions IT 08, IT 09, and IT10 (see Table 10), the data requirements have been adequately identified and documented evidence were obtained, and through interviews where the DM.1 process runs in the MP. This would satisfy the PA.1.1. In this situation, looking for evidences for DM.1. in AP1 and AP2 would no longer be needed, but given the chance to make the case study, it was decided to look for them and found documented evidence in both the document BIB-35 (see Table 10) AP.1, and in the document BIB-15 (see Table 10) to AP.2. When inquiring through the specific aspects of PA.2.1 and PA.2.2 (see clause 5.2 of ISO/IEC 33020 for a more detailed description), it is possible to conclude that in any of the three instances of selected processes, the data management requirement as such, is managed, as well as the management of work products. Regarding the management of the process, we discovered that the objectives are identified when managing requirements, and the process is planned. Although it is not monitored and though enough resources to do homework are devoted, people responsible for implementing the process choose ad hoc, without a pre-established assignment. As concerns managing work products, we could observe that although there are predefined templates for collecting data requirements, and various controls and reviews of generated documents were made, these tasks are performed on an ad hoc basis.

DM.2. Technology infrastructure management. The MP is adequately supported by a technology infrastructure fully integrated in the ICT services of the LUX, and conveniently maintained and updated by the computer center of the University according to the improvements that are introduced in the different business processes. The management of the infrastructure is therefore conducted in an externalized way, but in the LUX, there are technical managers who are responsible to collect, validate and report changes to be done in the technology infrastructure requirements to the data center. For instance, in the case of MP, one of the main tools for the listing procedure is Absys, and all necessary specifications are properly managed.

DM.5. Configuration management. The LUX is fully adapted to the rules existing in the network of libraries in their country. This implies to take into consideration and spread to the library processes the corresponding changes and developments in the definition of the data that are managed. For example, in the case of MP, when the MARC 21 [38] format was assimilated, it was carried out a process of configuration management and versioning of data model so that new definitions were consistent in all applications involved. Interviewees informed us that since changes in data models is something that happens frequently, and the LUX responds reactively to them.

Consequently, they do not consider it necessary to develop specific procedures for data configuration management. Therefore, there is no formally detailed definition of the process and when it had to be done, it was made with ad hoc.

DM.3. Management of historical data. The LUX maintains a series of very detailed policies, among which the corresponding ones to the management of historical data are found. In the case of MP, to discontinue a book means to move their data from the documentary collection production to the discontinued documentary collection and managing the consequences of a document of becoming discontinued (for example, canceling loans allocated to users). This process is performed by the head of the documentary collection, which is the sole authority to discontinue a work. In the case of AP.1, the policy taken into consideration is to delete the corresponding data from the movement of funds with more than three years old. With respect to AP.2, the policy employed is to delete user data at the beginning of next course once they have finished their studies. Indeed, we found that the execution of the management of historical data in any of the instances of the process is fully automatized, so that work products are properly managed.

DM.4. Data security management. The LUX is very careful as concerns personal data. In fact, it inherits from the LUX all the procedures of data protection. This means that for any of the three instances of the processes, access to data is properly managed preventing unauthorized users view or modify data. However, the most sensitive data move during AP.1 process, since these are data users and the works that are borrowed, and it may disclose confidential information about sensitive aspects of the LUX users. On the other side, the data of works, whose management did not require special protection, were there. It is precisely for this reason that it was decided to inspect the instance of AP.1. It was concluded that the implementation of appropriate historical data management policies is done by people who have been assigned the responsibility to do so, which is a planned process that uses the resources that have been allocated although it is not monitored and it is perfectly adequate. Furthermore, the security policy catalog responds to a scheme matured along LUX life, and therefore, it documents, controls and transfers accurately.

DQM.2. Data Quality Control and Monitoring. It is interesting to highlight that although the LUX managers are not aware of being doing what is understood as data quality management, they have been doing so for a long time. In this sense, they are acutely aware of the importance of having the right data and adequate data quality levels. For example, to communicate with other libraries from other universities or to integrate data of external users. However, although there is an obvious application, the process of control and monitoring data quality is not defined or specified explicitly, and all initiatives have made ad hoc by some workers of the LUX in an independent manner, and often without the possibility to devote resources to the process of control and monitoring data quality, even though devoting resources to initiatives that have emerged.

DG.2. Data lifecycle management. There is no evidence of an explicit definition of the management data lifecycle process and data value. It has always been done on an ad hoc without being aware that it was taking place. From the interviews, it can be observed the concern of the directors of the LUX to have the best possible data in the best possible way, and to be aware of the need to implement mechanisms for data, but without associating the fact that different data can have different value, and that this may change throughout their life cycle.

DG.4. Standards establishment, policies, good practices and procedures. As part of the management of the LUX, it has been adequately defined and implemented a series of policies, good practices and procedures that are based on the general policies of the LUX. Many of these policies are strongly oriented to properly manage data, and somehow their quality. Moreover, when it is possible, they are treated as part of international standards policies. For example, some standards for MP, agreed at the urging CRUE -Presidents of Universities

Table 11
Process atributes rating and maturity level organizational computing of data management, data governance and data quality management in the LUX.

AP.2.2	L	F	P	L	F	N	N	L
AP.2.1	L	F	P	F	F	P	N	N
AP.1.1	F	F	F	F	F	F	F	F
	DM.1	DM.2	DM.5	DM.3	DM.4	DQM.2	DG.2	DG.4
	Maturity Level 2							

Spanish Conference- use ISO 2709 [39], are identified. Thus, there is a catalog of data policies and it is assumed that it should be prepared by the directors of the LUX as part of their job responsibilities, but although the catalog of policies is managed, at no time the process itself is managed: no responsibilities are assigned, neither resources are explicitly allocated, or planned, nor monitored, of course.

4.5. Data validation

The assessment team confirmed the objectivity of the evidence collected and then, they validated them with respect to other evidence provided for the same processes. It was considered that the overall evidence provided was sufficient and representative for the purpose and scope of the evaluation.

4.6. Derivation of results

Based on the conclusions on the evidence collected (see Section 4.8) and, following the guidelines provided in clause 4.2 of ISO/IEC 33010 to evaluate the attributes of processes, we proceeded to derive the results for each of them -shown as {N, P, L, F} in Table 11.

To consider a maturity level to be consolidated, it requires that all processes included in the previous level are in the "F" state, and processes of such level are in an "L" state at least. For instance, it is considered that level 2 of maturity to be consolidated when, having obtained all processes from level 1, an "F" for the attribute process PA.1.1, all new processes have obtained an "F" for the PA.1.1, and all processes -those belonging to level 1 as well as those belonging to level 2, have obtained at least one "L" for the attributes PA.2.2 and PA.2.1. Based on this, the organizational maturity level computing of data governance, data management and data quality management, according to MAMD model, was derived. These results are shown in Table 11.

As it can be seen, all maturity level processes 1 are evaluated as the PA.1.1 F (Fully Achieved), which consolidates the maturity level 1. However, some of the processes included in the maturity level 1 (DM.5) and others included in the maturity level 2 (DQM.2, DG.2, DG.4) have not obtained the minimum qualification required of L (Largely Achieved) for PA.2.1 process attributes and / or PA.2.2, which, even having consolidated the maturity level 1, it is not possible to consolidate the maturity level 2.

4.7. Report the results

Finally, after conducting a field work of four days of collecting evidence (over five planned), and investing three days in computing the results, the auditing team celebrated a meeting with the directors of the LUX to inform about the results. In this meeting, it was reported, not only the maturity level obtained (maturity level 1 or basic), but also the strengths (many of the processes are documented and numerous policies of LUX are inherited) and non-conformities with respect to MAMD (the responsibilities from most processes are neither assigned nor properly documented. It is necessary to define the processes corresponding to DQM.2, DG.2, and DG.4).

Finally, the evaluation team recommended the planning and

implementation of an improvement project to resolve nonconformities obtained and to reach the maturity level 2.

4.8. Conclusions about the case study

After the case study using MAMD v2.0, we can assert that the qualitative perception of the efforts required to plan and execute the assessment was really less than in the case study presented in [8]. Regarding the time invested in raising a conclusion about the organizational maturity level -as our first way to measure the required efforts- we invested seven days in getting the results versus the fifteen days in completing our case study of reference, done in similar conditions.

It can be thought that as we have gained some expertise after the conduction of several case studies, can justify the lower invested efforts, we should recognize that the changes made to the framework, have largely helped in this last case study. From our point of view, the most important change was the knowledge base, which represent our larger expertise.

Raised this point, we can conclude that the introduced changes have made MAMD v2.0 "more easily auditable". We recently began to work with people at LUX to implement the improvement plan. Only after completing the execution of the improvement plan, we will be able to determine is MAMD v2.0 is also "more easily implementable". And consequently, we will be able to state that MAMD v2.0 is "easier to apply" than MAMD v1.0. Anyway, the partial works achieved until now in the execution of the improvement plans allows us to predict that MAMDv2.0 will be "more easily implementable".

5. Conclusions and future work

Having data with adequate levels of quality for the organizational business processes enable organization to have data which is to be processed. The efforts devoted to assure such levels of data quality should not be done in isolation, but adequately made into the context of the organization so that the organizational data strategy can successfully support the organizational strategy.

To help organizations to achieve this goal, we developed MAMD, a process approach framework aimed at assessing and improving the level of data quality of the organization. MAMD has two main components: (1) A process reference model and (2) an assessment model. After conducted several case studies we realize that both components will be changed to make the framework easier to conduct assessment with the framework and it could be easier to depict and execute improvement plans to assure better levels of data quality in the organization.

In this paper, after analysing the lessons learned from the conduction of a previous case study, we have generated MAMDv2.0. Using this new version in a new case study, considering similar conditions, we have concluded that the introduced changes have made easier the application of this new version of the framework.

In the future, we want to quantitatively establish to what extent the improvement of the level of data management maturity, data governance and data quality management poses a clear advantage for organizations.

Apendix. List of acronyms that appears on the text with their corresponding meaning

Acronym	Meaning
MAMD	Alarcos' data improvement model
SWOT	Strengths, Weaknesses, Opportunities and Threats
PRM	Process Reference Model
PAM	Process Assessment Model
DM	Data Management
DQM	Data Quality Management
DG	Data Governance
PA	Process Attribute
ML	Maturity Level
LUX	Library of University X
MP	Main Process
AP	Auxiliary Process

References

[1] ISACA, COBIT 5: Enabling Information, ed. ISACA, 2013
[2] Team, C.P., Capability Maturity Model® Integration (CMMI SM), Version 1.1. CMMI for Systems Engineering, Software Engineering, Integrated Product and Process Development, and Supplier Sourcing (CMMI-SE/SW/IPPD/SS, V1. 1), 2002
[3] ISO/IEC-JTC1/SC7, Information Technology - Process Assessment - Part 1: Concepts and Vocabulary, International Organization for Standarization, Geneva, Switzerland, 2004 (ISO/IEC 15504-1:2004).
[4] ISO, ISO/IEC 33000: Information Technology: Process Assessment, ISO, 2015.
[5] SEI, DMM: Data Management Maturity Model, SEI: Pittsburgh, 2014.
[6] ISO, ISO 8000-60: Data Quality Management: The Overview of Process Assessment, ISO, 2015.
[7] ISO, DIS/ISO 8000-61: Data quality: Information & data quality management process reference model, ISO, 2015.
[8] A.G. Carretero, et al. A case study on assessing the organizational maturity of data management, data quality management and data governance by means of MAMD, in: Proceedings of the 21th International Conference on Information Quality (ICIQ), 2016.
[9] T.C. Redman, Data Driven: Profiting from Your Most Important Business Asset, Harvard Business School Press, 2008.
[10] Ballou, D.P., Tayi, G. K., Managerial issues in data quality. Paper presented at the, in: Proceedings of the First International Conference on Information Quality (ICIQ'96), MIT, Cambridge, MA, USA, 1996
[11] R.Y. Wang, A product perspective on total data quality management, Commun. ACM **41** (2) (1998) 58–65.
[12] B. Otto, Organizing data governance: findings from the telecommunications industry and consequences for large service providers, Commun. Assoc. Inf. Syst. 1 (45-66) (2011) 29.
[13] Sadiq, S., M. Indulska, V. Jayawardene. Research and industry synergies in data quality management, in: Proceedings of the International Conference on Information Quality, Adelaide (South Australia), 2011
[14] L. English, Improving Data Warehouse and Business Information Quality: Methods for Reducing Costs and Increasing Profits, Willey & Sons, New York, NY, USA, 1999.
[15] W.S. Humphrey, Characterizing the Software Process: A Maturity Framework, Software Engineering Institute. Carnegie Mellon University, Pittsburgh, PA, USA, 1987.
[16] P.H. Aiken, et al., Measuring data management practice maturity: a community's self-assessment, IEEE Comput. **40** (4) (2007) 42–50.
[17] J. Ladley, Data Governance. How to Design, Deploy, and Sustain and Effective Data Governance Program, Morgan Kauffman, 2012.
[18] M. Mosley (Ed.)The DAMA Guide to Data Management Body of Knowledge (DAMA-DMBOK Guide)-First Edition 118, Data Management International, USA, 2009.
[19] Caballero, I., Ó. Gómez, M. Piattini., Getting better information quality by assessing and improving information quality management. in: Proceedings of the Ninth International Conference on Information Quality (ICIQ'04), MIT, Cambridge, MA, USA, 2004
[20] I. Caballero, et al., IQM3: information quality maturity model, J. Univers. Comput. Sci. **14** (2008) 1–29.
[21] K.-S. Ryu, J.-S. Park, J.-H. Park, A data quality management maturity model, ETRI J. **28** (2) (2006) 191–204.
[22] S. Baskarada, IQM-CMM: Information Quality Management Capability Maturity Model, Vieweg+Teubner Research, 2009.
[23] P. Clarke, et al., Exploring the relationship between software process adaptive capability and organisational performance, IEEE Trans. Softw. Eng. **41** (12) (2015)

1169–1183.
[24] SEI, CMMI® for Development, Version 1.3 (CMMI-DEV, V1.3), In Improving Processes for Developing Better Products and Services, Technical Report, 2010.
[25] SEI, CMMI® for SCAMPI Class A Appraisal Results 2011 End-Year Update, Software Engineering Institute - Carnegie Mellon University, Pittsburgh, PA, USA, 2012.
[26] D.K. Dunaway, CMM SM -Based Appraisal for Internal Process Improvement. (CBA IPI) Lead Assessor€™s Guide (CMU/SEI-96-HB-003), Software Engineering Institute, Pittsburgh, PA, USA, 1996.
[27] F. Pino, M. Piattini, C.M. Fernandez, Modelo de Madurez de Ingeniería del Software de AENOR, España: AENORediciones, Madrid, 2015.
[28] ISO, ISO/IEC 12207-2008. Systems and software engineering — Software life cycle processes, International Standards Organization, 2008.
[29] S. Kim, C. Lee, The process reference model for the data quality management process assessment, J. Soc. E-Bus. Stud. **18** (2013) 4.
[30] E. Pierce, et al., The state of information and data quality. 2012 industry survery & report. Understanding how organizations manage the quality of their information and data assetsInternational Association for Information and Data Quality (IAIDQ) University of Arkansas at Little Rock (UALR-IQ): Little Rock (AR), USA, 2012.
[31] A.G. Carretero, I.Caballero , M.Piattini, MAMD: Towards a data improvement model based on ISO 8000-6X and ISO/IEC 33000, in: Proceedings of the International Conference on Software Process Improvement and Capability Determination, Springer, 2016.
[32] O. Group, Software & Systems Process Engineering Meta-Model SpecificationVersión, 2008.
[33] ISO, ISO/IEC 33004: Information technology: Process assessment: Requirements for process reference, process assessment and maturity models., ISO, 2015.
[34] ISO, ISO/IEC 33020: Information technology: Process assessment: Process measurement framework for assessment of process capability, ISO, 2015.
[35] ISO, ISO/IEC 33010: Information technology: Process assessment: Guide to performing assessment, ISO, 2015.
[36] BUX, Modelo Z39-50 y captura desde Catálogo Colectivo REBIUN, [12/12/2015], Available from: ⟨http://www.rebiun.org/documentos/Documents/GTCATALOGO/Manualdeprocedimiento_CatalogoColectivo_enero2014.pdf⟩, 2014.
[37] BUX, Manual GTBIB, [12/12/2015], Available from: ⟨http://www.gtbib.net/manual/sod/indice.htm⟩, 2014.
[38] BUX, Manual MARC21, [12/12/2015], Available from: ⟨http://www.bne.es/es/Micrositios/Guias/Marc21/⟩, 2014.
[39] ISO, ISO 2709: Information and documentation, Format for information exchange, ISO, 2008

Ana G. Carretero has an M.Sc. and now is Ph.D. Student in Computer Science at the University of Castilla – La Mancha (UCLM). Researcher in Alarcos Research Group. Her research interest includes data management, data quality, data governance and maturity models. Contact details: Escuela Superior de Informática (UCLM), Ciudad Real, Spain; AnaIsabel.Gomez@uclm.es

Fernando Gualo has a B.Sc. and now is M.Sc. Student in Computer Science at the University of Castilla – La Mancha (UCLM). Researcher in Alarcos Research Group. His research interest includes data management, data quality, data governance and data quality improvement. Contact details: Escuela Superior de Informática (UCLM), Ciudad Real, Spain; Fernando.Gualo@uclm.es

Mario Piattini is a full professor of computer science at the University of Castilla-La Mancha, Spain. His research interests include Global Software Development and Green Software. Piattini received a Ph.D. in Computer Science from the Universidad Politécnica de Madrid. His email is Mario.Piattini@uclm.es

Ismael Caballero works as associate professor at the University of Castilla-La Mancha, Spain. His main Research interests are on data and Information Quality management, and Data Governance. His e-mail is Ismael.Caballero@uclm.es