Assessment and Improvement of Information Quality through Information Management Process Concept

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Abstract — It is a well known fact that information is one of the most important assets for today's enterprises since it is the basis for organizational decisions. However, as information is produced from data, both data and information quality must be assured. Although many researches have proposed technical and managerial solutions to some specific information quality problems, an integrative framework which brings together these kinds of solutions is still lacking. Our proposal consists of a framework for assessing and improving information quality through the concept of Information Management Process (IMP). An IMP is assessed according to an information quality maturity model by using an assessment and improvement methodology. The framework provides a consistent roadway for coordinating efforts and resources to manage information quality with a strategic perspective. As an application example, a study case has been included in the paper.

Index Terms — *Information Quality, Information Quality Management, Information Quality Assessment*

1 Introduction

As [39] states, information can be obtained as the result of a data manufacturing process, where data must be considered as non-ideal raw material for this process. Data is said to be non- ideal due to different and specific potholes related to special characteristics of data: multiple sources of data can generate different values; systematic errors can generate information losses; a large amount of data can be unmanageable for an application in a reasonable time; distributed and heterogeneous systems can generate inconsistent formats, values or definitions, … [37]. These potholes are all sources of ongoing information quality problems, like unused data, barriers to data accessibility or data utilization difficulty. The need to consider data and information as one of the most important assets for organizations [19] (and therefore one of the most precious resources [30]) has been demonstrated since it is the basis for tactical, strategic or operational decisions [33, 36]. Poor data and information quality will have a negative impact on the global efficiency of organizations [33].

Fortunately, more and more organizations have at last realized the importance of information quality and they try to implement some of the frameworks proposed by researchers [1, 7, 13, 19, 23, 28, 30, 33, 36, 38, 40] for improving specific information quality issues, although many of these organizations do not yet have the right techniques, tools and practices to achieve a high information quality level [25]. One of the reasons for this fact, is that information quality problems are not usually understood as a global problem by the entire organization. It is a matter for the quality management team, encouraged by organization heads, who must implement several quality management concepts like information quality policy, information strategy, information quality planning, information quality control and information quality assurance through organization [16, 17], implying all the workers and trying to coordinate efforts and commitments in order to control and improve information quality issues [29].

Unfortunately, there is not an integrative framework that guides organizations to achieving information quality goals through management by implementing the abovementioned concepts [14, 23]. In spite of the fact that some researches have provided several information quality measurements and/or assessment methodologies [7 19, 30, 33, 40], none of them are focused on group efforts or commitments extending to the entire organization in both analytic and pragmatic ways [9]. What is required is to know how an organization works, and to develop the ability to identify major problems or standardize an information quality culture by implying both leaders and infrastructure [15, 20] in technical and management tasks.

In an effort to fill this void, we propose an integrative framework in which information is considered as a product (what allows the user to take an engineering point of view of information quality [4, 23]) and taking into account the Software Process definition given by [12] (what allows the identification of who is doing what, when, using which resources and how), a perception of both Information Management and Information Quality Management activities can be created as an Information Management Process (IMP). An IMP is intended to model what how information quality might be managed by drawing the relationship among the main components of the Information Systems. Having in mind this perception, entire organizational in-

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formation quality can be managed by assessing and improving each IMP in organization taking into account that several IMP can share several resources. It is true there are several frameworks for assessing and improving software processes such as CMM (Capability M [20, 31], CMMI [35], ISO 9001 [5], BootStrap [3] and SPICE [21]; but none of them have focused on information quality nor have they even taken it into account.

In [9] four conditions for a good information quality framework are established :

1. it should provide a systematic and concise set of criteria according to which information can be evaluated.
2. it should provide a scheme to analyze and solve information quality problems.
3. it should provide the basis for information quality measurement and proactive management.
4. it should provide the research community with a conceptual map that can be used to structure a variety of approaches, theories, and information quality related phenomena.

Our proposal defines two main components:

- An information quality model based on maturity staged levels, known as **CALDEA**, which main aim is to coordinate the relationships among the IMP's components by creating several growing maturity levels with growing information quality goals and requirements. For each level, several Key Processes Areas (KPA) are described proposed. These KPAs are focused on management and technical issues. For each KPA, some tools, techniques, standards, and practices and metrics as required, are proposed, but not imposed, although due to length restrictions they are not included in this paper.
- An assessment and improvement methodology, known as **EVAMECA**L, in the style of CBA-IPI [6], SCAMPI [34] or SPICE [22] which consists of a set of steps that provides a basis for data/information quality measurement and proactive management. The main element is a set of questionnaires for assessment and a rule system for identifying the path to improvement based on the results of this assessment.

This structure satisfy the [9]'s four conditions: as CALDEA is structured in maturity levels with KPAs, a systematic and concise set of criteria for information quality assessment is provided, satisfying the first condition. By defining KPAs for each level, some of which are focused on management issues, the basis for proactive management and measurements is provided, satisfying the third condition. And finally, by being structured in such staged levels describing KPAs and proposing (not imposing) tools, techniques, and standards, a conceptual map has been provided for the research community in order to address a variety of approaches, theories and information quality related phenomena, satisfying the fourth condition. On the other hand, EVAMECAL provides a schema for analyzing and solving information quality problems, satisfying the second condition.

The main idea of the framework is to use EVAMECAL for assessing and improving an IMP using CALDEA's levels as reference in the guidance of the optimization of the information quality in organizations. By optimizing the most important and critical IMPs, an organization can reach a satisfactory information quality state.

The remainder of this paper is structured as follows: section 2 describes CALDEA; section 3 presents a brief summary of EVAMECAL. Section 4 shows the results of applying EVAMECAL to a specific kind of organization. Lastly, some conclusions and futures lines of research related to the model are explained.

2 CALDEA: AN INFORMATION QUALITY MODEL BASED ON MATURITY LEVELS

CALDEA defines five information quality maturity levels for an IMP: Initial, Definition, Integration, Quantitative Management and Optimizing. The levels are ordered by taking into account several information quality goals and their relative importance, providing a systematic and concise set of criteria according to which information can be evaluated. Thus, at higher levels where more information quality issues are assured, it would be possible to state that more organizational requirements are satisfied. It is also possible to affirm that the higher the information quality maturity levels an organization has reached for its most important IMPs, the more competitive this organization can be due to the absence of information quality problems. The levels are drawn like the staged ones of CMMI, because it appears to be easier to work with a well-defined sequence of improvements (which cover from basic management project fundamentals to complex data quality management issues). As previously explained, for each level, CALDEA addresses specific KPAs, which meet specific information quality goals. These KPAs are focused on not only technical but also managerial issues, providing the basis for information quality measurement and management and integrating both aspects in order to compensate the lack of integrative frameworks mentioned in the introductory section. Each KPA has been divided into activities and tasks, which can be satisfied by using several techniques, practices and tools in order to transform a set of incoming products into other outgoing ones. In order to make the framework as universal and general as possible, none of the techniques, practices and tools are mandatory as previously mentioned, but organizations must choose the best suited to each KPA on their own. We should emphasize that the chosen KPAs are based on CMMI's KPAs [35] and the chosen activities and tasks on our experiences with industrial and scientific initiatives regarding information quality, which have been the main rationale for their choice. Anyway, the contents of this research paper are in continuous progress in order to achieve theoretical validation. In the other hand and, due to paper length restrictions, neither techniques nor tools will be looked at in detail

2.1 Initial Level

An IMP is said to be at Initial Level when no efforts are made in order to achieve any information quality goals.

2.2 Definition Level

An IMP is said to be at Definition Level or Defined when it

has been defined and planned. This implies identifying all its components and their relationship to the requirements. To achieve this goal, the following KPAs need to be satisfied:

- **(IQATM) Information Quality Assurance Team Management.** The aim of this KPA is to form a team composed of people having direct responsibility for information and for its integrity. This team will encourage the entire organization to take on commitments regarding information quality policies [2] and make corresponding efforts in order to support the activities of this maturity model.
- **(IPM) IMP Project Management.** This is a management KPA aimed at developing a plan for IMP in order to coordinate both managerial and technical efforts and elaborate all related documentation.
- **(URM) User Requirements Management.** User Requirements must be collected and documented. Three kinds of requirements might be identified: those related to final product (URS), those related to IMP – which must be gathered in the User Requirement Specification for IMP document (URS-IMP) document - and those related to Information Quality –which must be gathered in the Information Quality User Requirements Specification (URS-IQ).
- **(DSTM) Data Sources and Data Targets Management.** Due to the intrinsic characteristics of data, both data sources and targets must be identified and documented, in order to avoid problems like uncontrolled data redundancy or problems with data format interchange [28].
- **(ADMPM) Database or Data Warehouse Acquisition, Development or Maintenance Project Management**. In order to improve information quality, it is highly recommendable to draw up a project for acquisition, development or maintenance of a database or a data warehouse management system, supporting both URS-IQ and URS-IMP.
- **(IQM) Information Quality Management in IMP Components**. For each information quality component, information quality dimensions from URS-IQ must be identified, controlled and monitored. It is necessary to identify from the URS-IQ the dimensions of quality of information that must be controlled [19], as well as the metrics adapted for each one of those dimensions [23, 32].

2.3 Integration Level

An IMP is said to be at Integration Level or Integrated when besides having been Defined (Definition level has been achieved), many efforts are made in order to assure that the IMP is in compliance with organizational information quality requirements and standards. This implies standardizing different information quality learned lessons in order to avoid previous errors and improve future work.. The following KPAs must be satisfied:

- **(VV) Information Products and IMP Components Validation and Verification**. Both information products (obtained as a result of data transformation process) and IMP components must be verified and validated to correct defects and/or discord with the USR-IMP, USR-IQ and the organizational information quality policies.
- **(RM) Risk and Poor Information Quality Impact Management.** Authors like [7] affirm that it is necessary to determine the impact of risks due to the poor quality of information in the IMP in order to limit them at organizational level.
- **(IQSM) Information Quality Standardization Management**. All lessons learned through specific experiences should be properly gathered, documented and transmitted to all new people who are going to be part of an IMP. Thus, IMP performance will be higher than it would otherwise be.
- **(OIQPM) Organizational Information Quality Policies Management**. The means by which all the efforts previously mentioned can be implemented, consisting of defining policies of information quality based on the previously defined standards affecting not only single IMPs, but also the whole organization.

2.4 Quantitative Management

An IMP is said to be at a Quantitative Management Level or quantitatively managed when after having been Integrated (Integration level has been achieved) several Measurement Plans have been developed and implemented and measurement procedures have been automated. Therefore, the main information quality goal of this level is to obtain a quantitative compliance that IMP performance over a reasonable time period, remains as consistent as required in terms of variation and stability through a reliable set of measurements [11] of information quality characteristics of IMP. This level is composed of the following KPA:

- **(MM) IMP Measurement Management**. Since metrics about IMP components have been drawn up at definition level, the aim of this KPA is to define when and how to make the measurements and how to represent the results and to whom. These metrics are used to check conformity to specifications [15, 24]
- **(AMP) IMP Measurement Plan Automation Management**. In order to increase the reliability and repeatability of measures, measurement procedures must be automated as required by [18]. This KPA aims to study all the issues related to the automation of these management procedures.

2.5 Optimizing Level

An IMP is said to be at Optimizing Level if when being quantitatively managed the obtained measurements are used to develop a continuous improvement by eliminating defects or by proposing and implementing several improvements. The following two KPAs must be satisfied:

- **(CADPM) Causal Analysis for Defect Prevention Management**. From the study of the measurement results, some typical quality techniques and tools like Statistical Control Process (SPC) or Ishikawa's diagrams can be applied to detect defects of information quality and identify their root causes. The obtained conclusions must form a basis for a corresponding

maintenance process for removing detected defects in affected resources.

- **(IODM) Innovation and Organizational Development Management.** Similarly to the previous KPA, here the results can be used to improve the IMP, in terms of performance, planned time or budget. This is the basis for the idea of continuous improvement.

2.6 Achieving higher levels of CALDEA

In the proposed framework, a KPA can be in one of these states: {"*Fully Satisfied*", "*Satisfied*", "*Partially Satisfied*" and "*Not Satisfied*"}. An information quality maturity level is said to be achieved when all contained KPAs are at least "*Satisfied*", that is to say, in order to achieve higher levels of CALDEA, the Information Quality Management Team must guide an IMP to the "*Satisfied*" state of all contained KPA for the lower level. This goal can be achieved by applying the assessment and improvement methodology, which is next described.

3 EVAMECAL: An Assessment and Improvement Methodology

As previously mentioned, an assessment and improvement methodology is required in order to guide organizations to reach higher information quality maturity levels for each IMP. Basically, the methodology consists of a PDCA cycle. The following is a brief summary of the steps to be taken:

1. Choose an IMP which needs to be optimized
2. Elaborate a Plan for its assessment.
3. Execute the assessment plan by conducting the surveys and measuring as required. (see section 3.1 where a set of surveys are described)
4. Analyze the results and elaborate an Improvement Plan.
5. Study the viability of the Improvement Plan and the solution.
6. Execute the Improvement Plan.
7. Confirm the improvements and obtain and standardize conclusions.

As demonstrated in this document, the numbering for sections upper case Arabic numerals, then upper case Arabic numerals, separated by periods. Initial paragraphs after the section title are not indented. Only the initial, introductory paragraph has a drop cap.

3.1 The surveys

For the assessment process, a set of surveys has been elaborated. This set consists of four different classes of questionnaires, with different goals:

A. In order to delimit and characterize the organization, a total of fifteen questions.

B. In order to delimit and characterize the IMP to be assessed, a total of six questions.

C. In order to assess the degree of achievement of each maturity level, several questions organized in different and selective blocks have been developed. The questions are focused on the KPAs, activities, tasks, proposed techniques, tools and practices and required developed products. The idea of organizing the questionnaire in several depth levels is so that questions will be asked from top down and only if necessary. Thus, the block of questions of the first depth level serves to evaluate if KPAs are satisfied or not, avoiding at this depth level other questions which are not important for establishing specific aspects about the accom-plishment of the more specific issues, which are dealt with in lower depth levels. So, if all the answers to the questions of the first depth level differ from "*Not Satisfied*", then questions in the level immediately below should be answered, and so on. Altogether one hundred and ninety questions would be answered in the case of all the answers to the questions of the first and the second depth level differing from "*Not Satisfied*". On the other hand, a maturity level of a given IMP can be achieved a level only if the lower ones have been achieved. Table 1 gathers the number of questions made by each maturity level and each depth level. Due to length restrictions none of the questions are included in this paper. It is important to say that we are working on checking the validity and efficiency of each block and question inside the blocks for each depth level. The answers to these questions must be a number between 0 and 100, in order to quantitatively assess the degree of satisfaction for each task, activity and KPA. Thus, it is possible to set a numeric qualification for each state by calculating a weighted average of the obtained qualification in each one of the KPAs for that level according to a proposed weight given by a critically degree. In the proposal, it has been established that if this qualification is between 0 and 20, the KPA is said to be "*Not Satisfied*"; if it is between 20 and 60 is said to be "*Partially Satisfied*"; if it is between 60 and 90 it is said to be "*Satisfied*"; otherwise it is said to be "*Fully Satisfied*". Table 2 shows in the first column the KPA of each level of maturity and in the second one, the degree of criticality of each KPA for that level. The degrees of criticality also serve as a criteria in order to choose which KPAs must be satisfied first in the third step of EVAMECAL. These degrees of criticality are a hypothesis according to the supposed degree of importance. It is a line of future research to determine these weights based on the demands of the different organizations interviewed and to set finely the ranges for qualification.

D. Finally, in order to collate and compare the answers

TABLE 1
Number of questions by maturity and depth levels.

Depth Level	1	2	3
Level Maturity 2	12	18	82
Level Maturity 3	8	7	24
Level Maturity 4	3	2	11
Level Maturity 5	4	2	11
Total Questions per depth level	28	31	131
Total Questions Questionnaire	190		

with previous questionnaires, there is a last block of questions with descriptive and textual language.

The surveys are going to be conducted at assessment time.

4 Experiences applying the framework.

In order to empirically validate the framework and test its practical applicability and efficiency, it has been applied to different IMPs from several organizations. The following shows the results obtained from applying the framework to a particular organization with proven experience in the information management field. EVAMECAL was first applied by following the steps previously detailed. The results of questionnaires A and B are presented in subsection 4.1 and 4.2; in 4.3 the results of questionnaire C and a list of proposed improvements are presented. Since finishing this paper, the organization has continued working on the improvement plan, although several subgoals have already been achieved.

4.1 Characterization of the company

The main activity of the company is software development with a solid knowledge of and training in software quality standards and Software Engineering (all the developments are carried out by following one of the most important and widely used national software development methodologies). The company has obtained an ISO 9000 certification. Their offered services are consulting, development, training courses, technical attendance, sale of licenses, database and data warehouse administration, system planning projects and migration to an important commercial DBMS (e.g. Oracle of which they are certified partners). With a total of eighty-nine employees, it is the eighteen of the department of systems who organize the resources of computing support for the rest of the departments.

4.2 Characterization of studied IMP

Among all the IMPs, the framework was applied to that related to the Training Management Process, which is a responsibility of the consulting department. The main goal of the IMP in question is to manage data regarding training, which consists of gathering both internal and external requests for training, choosing who are going to be the trainers, determining which resources are going to be used and managing several quality training issues This process is adequately specified and documented in the quality manual of the organization.

Some different forms exist for gathering data about course demands, assignations and quality evaluations of proposed exercises, didactic materials, trainer capability, installations, assistance and used resources.

The organization runs a software application, which is an internally developed tool to manage all previously mentioned data. One of the employees of the consulting department, normally always the same one, is responsible for transcribing data from the forms to the tool and for obtaining the information, which will be given to the adequate person.

TABLE 2
Criticality Degree for each KPA in CALDEA.

Criticality Degree	
Definition Level	
(IQATM) Information Quality Assurance Team Management	10 %
(IPM) IMP Project Management	15 %
(URM) User Requirements Management.	25 %
(DSTM) Data Sources and Data Targets Management.	10 %
(ADMPM) Database or data warehouse Acquisition, development or maintenance Project Management	25 %
(IQM) Information Quality Management in IMP Components.	25%
Integration Level	
(VV) Information Products and IMP Components Validation and Verification.	25%
(RM) Risk and Poor Information Quality Impact Management	25%
(IQSM) Information Quality Standardization Management	25%
(OIQPM) Organizational Information Quality Policies Management	25%
Quantitative Management Level	
(MM) IMP Measurement Management	70 %
(AMP) IMP Measurement Plan Automation Management.	30 %
Optimizing Level	
(CADPM) Causal Analysis for Defects Prevention Management	50%
(IODM) Innovation and Organizational Development Management.	50%

4.3 Assessment and Improvement of the IMP.

All the questions in the surveys were made to the head of the consulting department. In table 3 the main results of these surveys can be found. These results reflect that none of the KPAs belonging to level 2 or higher are at least "*Satisfied*". This means that the Definition level is at a "*Not Achieved*" state. As an example, the conclusions drawn are included:

- *(IQATM) Information Quality Assurance Team Management*. In spite of not properly satisfying this KPA, the organization presents a quality infrastructure that can adequately support information quality.
- *(IPM) IMP Project Management*. This KPA is also not satisfied.
- *(URM) User Requirements Management*. User Requirements have been managed for the training procedures, although information quality requirements have not been taken into account.
- *(DSTM) Data Sources and Data Targets Management*. In the IMP definition, both data sources and data product targets are identified and documented. There are some forms in order to standardize data interchange formats.
- *(ADMPM) Database or data warehouse Acquisition, de-*

velopment or maintenance Project Management. The database where data is stored is an organizational one adequately modified to support the training managerial software tool. Thus, data and procedure models were modified and extended, although none of the information quality issues were considered.

- *(IQM) Information Quality Management in IMP Components.* This KPA has not been satisfied because information quality is not one of the goals of the IMP.

Taking into account the criticality degree of each of the KPAs (see table 2) the following recommendations were proposed in order to satisfy KPAs at Definition level:

1. Create an Information Quality Assurance Team which assumes the responsibility of IMP project management
2. Adequately manage user requirements, both IMP and IQ ones.
3. Identify and define both data sources and data product targets, as well as the data interchange formats.
4. From these requirement specifications, adequately manage the information quality dimensions for each component of the system
5. Modify database or data warehouse to give support to the information quality
6. Plan a project for the development of the IMP.

TABLE 3
RESULTS OBTAINED FROM APPLYING EVAMECAL TO THE TRAINING MANAGEMENT IMP

RESULTS OF SURVEYS	
Definition Level	***Not Achieved***
(IQATM) Information Quality Assurance Team Management	*Not Satisfied*
(URM) User Requirements Management.	*Not Satisfied*
(DSTM) Data Sources and Data Targets Management.	*Partially Satisfied*
(ADMPM) Database or data warehouse Acquisition, development or maintenance Project Management	*Partially Satisfied*
(IQM) Information Quality Management in IMP Components.	*Not Satisfied*
Integration Level	***Not Achieved***
(VV) Information Products and IMP Components Validation and Verification.	*Not Satisfied*
(RM) Risk and Poor Information Quality Impact Management	*Not Satisfied*
(IQSM) Information Quality Standardization Management	*Not Satisfied*
(OIQPM) Organizational Information Quality Policies Management	*Not Satisfied*
Cuantitative Management Level	***Not Achieved***
(MM) IMP Measurement Management	*Not Satisfied*
(AMP) IMP Measurement Plan Automation Management.	*Not Satisfied*
Optimizing Level	***Not Achieved***
(CADPM) Causal Analysis for Defects Prevention Management	*Not Satisfied*
(IODM) Innovation and Organizational Development Management.	*Not Satisfied*

5 CONCLUSIONS AND FUTURE WORK

In this paper, an integrative framework for assessing and improving information quality for organizations has been briefly presented, and one experience of applying this framework has been described. The framework consist of two main components: CALDEA, an information quality model based on maturity levels which serves as references when assesing and guidance when improving; both activities, assessement and improvement are supported by the second component, EVAMECAL.

On one hand, the IMP concept with both CALDEA and EVAMECAL satisfies the four goals required for a good information quality framework [9]:

1. CALDEA provides a systematic and concise set of criteria for information quality according to which information can be evaluated.
2. EVAMECAL provides a schema for analyzing and solving information quality problems
3. Some KPAs in CALDEA provide the basis for information quality measurement and proactive management.
4. CALDEA is by itself a conceptual map that can be used to structure a variety of approaches, theories and information quality related phenomena since KPA does not propose a closed set of tools, techniques and methodologies.

On the other hand, the experience of applying the framework to real case studies has allowed both CALDEA and EVAMECAL to be refined and has demonstrated that although it is known that information quality is becoming increasingly important, organizations do not have or do not provide enough time or resources to deal with it. This fact is aggravated by the lack of an information quality enterprise culture.

Although the presented framework is becoming more widely used much work has to be done, beginning with a validation of both models, all the questionnaires of the surveys, and the criticality degrees for each KPA. Another line of work being pursued, consists of choosing (or even developing when they do not exist) some standards, practices, techniques and tools in order to satisfy the majority of the information quality requirements for the majority of the organizations.

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