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IQM3: Information Quality Management Maturity Model

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Abstract: In order to enhance their global business performance, organizations must be careful with the quality of their information since it is one of their main assets. Analogies to quality management of classical products demonstrate that Information Quality is also preferably attainable through management by integrating some corresponding Information Quality management activities into the organizational processes. To achieve this goal we have developed an *Information Quality Management Framework* (IQMF). It is articulated on the concept of *Information Management Process* (IMP), based on the idea of Software Process. An IMP is a combination of two sub-processes: the first, a production process, aimed to manufacture information from raw data, and the second to adequately manage the required Information Quality level of the first. IQMF consists of two main components: an *Information Quality Management Maturity Model* (IQM3), and a *Methodology for the Assessment and Improvement of Information Quality Management* (MAIMIQ), which uses IQM3 as a reference model for the assessment and for the improvement goal of an IMP. Therefore, as a result of an assessment with MAIMIQ, an IMP can be said to have raised one of the maturity levels described in IQM3, and as improvement goal, it would be desirable to achieve a higher maturity level. Since an Information System can be seen as a set of several IMPs sharing several resources, it is possible to improve the Information Quality level of the entire Information System by improving the most critical IMPs. This paper is focused only on describing the foundations and structure of IQM3, which is based on staged CMMI.

Keywords: Information Quality, Data and Information Quality, Information Quality Management, Information Quality Management Maturity Model.
Categories: K.6.4, H.1.1, H.2.0, D.2.9

1 Introduction

[Lee, et al. 2006; Strong, et al. 1997a] have identified a set of common roots for Information Quality (hereafter IQ) problems and their manifestations in Information Systems. Many organizations suffer these kinds of problems, due mainly to the fact that IQ is not perceived as an organizational issue, but rather as an isolated problem which needs to be solved as soon as possible. Within organizations, valuable people usually provide *ad hoc* solutions for such problems. In order to avoid problems come back, it is necessary to institutionalize the successful findings by means of an IQ Management conceptual layout that must be defined, implemented and used [Aiken, et al. 2007].

This layout must observe the information production process and the role of Information Systems in the process. Some authors like [Ballou, et al. 1998] have proposed conceptualizing an Information System as an Information Production / Manufacturing System (like a factory), where data, playing the role of raw material, is used to produce a *Data Product* by following a pre-established manufacturing process, typically implemented in the Information System [Wang 1998]. From this data product, one can extract an *information product* as being processed by a user for developing a project in a specific scenario [English 1999]. One of the most typical and referenced scenarios in which an Information Product is used to develop a project, is that in which a qualified worker has to make a tactical, strategic or operational decision. His or her decision will doubtlessly affect, somehow, some of the organizational business processes [Eppler and Wittig 2000; Gertz, et al. 2004; Pipino, et al. 2002; Price and Shanks 2005]. Independently of a worker's capacities, attitudes or training, the higher the IQ level of the Information Product, the higher the quality of the work done. But the IQ level of an Information Product depends on both manufacturing processes and raw materials [Wand and Wang 1996].

The most accepted definition for the term "*Information Quality*" is "*fitness for use*"[Ge and Helfert 2007]. This means that for a user be able to assess the quality of a piece of data, he or she must judge if the piece of data can be used for his or her purpose according to different "*IQ dimension"* [Strong, et al. 1997b]. Therefore, a user playing a role can observe as many IQ dimensions as necessary in a scenario for using an Information Product. As this usage is closely dependant on the role played by the user on the piece of data, the best-fitting IQ dimensions can vary between different usages, because the perception of the IQ level of a piece of data can be different for different tasks, even for the same user.

Rather than giving a definition for the IQ concept, it becomes more important for organizations to understand what IQ means to the different roles participating in the business process and how they can understand the related IQ dimensions as [Price and Shanks 2005] state. For organizations can deal with IQ, frameworks, criteria and ways to assess and improve IQ are strongly demanded [Dewan and Storey 2008]. Although a lot of researchers have proposed their own frameworks, there is not yet a universal set of IQ dimensions valid for any scenario nor an exhaustive set of corresponding measures which organizations can use on their IQ initiatives ([Berti-Équille and Scannapieco 2006; Cappiello, et al. 2004]).

The context-dependency of the proposed frameworks in IQ literature and the wide combination of roles and IQ dimensions may be unmanageable *ad hoc*. Due to

this reason, organizations might consider creating the position of IQ Manager as it has just been done with the Quality Manager. One of the responsibilities of this position might be to align the utilization of information to the organizational requirements. For this task, IQ Manager must define IQ policies, which identify and propose the appliance of techniques, tools and procedures in such a way "*that the organizational data resources have a level quality commensurate with the various current and potential use of the data*" as [Ballou and Tayi 1996] stated.

This need for enunciating principles and foundations for managing IQ as an intrinsic concept for organizations has been poorly observed by the IQ researching community [Baskarada, et al. 2006]. Authors like [Aiken, et al. 2007; Lee, et al. 2006; Scannapieco and Berti-Équille 2006] claim that a proposal and validation of frameworks is urgently required for helping organizations to take care of the quality of their data and information resources from an organizational point of view .

Our contribution to this claim is a framework named **Information Quality Management Framework (IQMF)**, which is based on our concept of Information Management Process (IMP) – an abstraction to address the different information manufacturing process and IQ management activities-. IQMF consists of two main components: a reference model (the **Information Quality Management Maturity Model,** hereafter **IQM3**) for the IMP, and based on staged maturity levels, as CMMI [SEI 2002] does for Software Processes, and a methodology for assessing and improving the IMP (the **Methodology for the Assessment and Improvement of Information Quality**, hereafter MAIMIQ) according to reference models such as SCAMPI [SEI 2001] does for Software Process. While the reference model is used to progressively improve the IQ level of an IMP as higher levels are reached, the methodology is aimed to raise the IMP to those required higher levels. In this paper, we are going to describe the **IQM3** as a part of our proposal of our IQMF.

The remainder of the paper is structured as follows: In the second section, the foundations of IMP are presented. In the third section, the reference model IQM3 is exposed. Finally, in the fourth section we will outline several conclusions and propose future continuation of this work.

2 Foundations of the IMP

We considered reinterpreting the Software Process concept given by [Fuggeta 2000] in order to articulate a new abstraction, which can be used a basis for our proposal, by integrating the different approaches, like the vision of information as a result of a manufacturing process or the Information Quality Management tasks identified by [Ballou and Tayi 1996]. The resulting concept was named *Information Management Process (IMP)*, and its main aim is to bring together both information manufacturing (in accordance with [Wang 1998]) and IQ management (in accordance with [Ballou and Tayi 1996]) processes in order to generate an Information Product that can be said to satisfy both user's requirements and user's IQ requirements. So, as a result of an IMP, an Information Product with the required IQ level might be obtained.

In order to truly bring together both technical (aimed at getting the proper Information Product) and managerial (aimed at getting the adequate IQ levels) requirements, an easy and comprehensive structure was required. As our final goal is to assess and to improve IQ, we also realized that a methodology for doing so was

needed. Bearing in mind the idea of Software Process, and existing well-known models and frameworks like CMM(I)[SEI 2002] or ISO 15504 [ISO/IEC-JTC1/SC7 2004] and their corresponding assessment methodologies (like SCAMPI [SEI 2001]for CMMI), we thought about using them directly; but after checking that none of them take into account the IQ issues among their quality goals, we concluded that we must develop our own reference model and our assessment and improvement methodology.

We figured out that the structure of staged maturity levels of CMMI with Key Process Areas (KPAs) would satisfy our intentions, since "*a staged model provides a predefined road map for organizational improvement based on proven grouping and ordering of processes and associated organizational relationships"*[Ahern, et al. 2003]. This structure also allowed us to fix well-defined IQ goals for our own reference model through maturity levels. Since many organizations are already familiar to CMMI, our reference model should be more understandable and applicable. Using the Action-Research method ([Baskerville and Wood-Harper 1996]), and KPAs of CMMI for identifying our own KPAs and their corresponding IQ goals, we proposed a set of specific IQ related KPAs ordered into appropriate maturity levels. The resulting maturity model has been named, after several reviews (the first was published in [Caballero, et al. 2004]), as **Information Quality Management Maturity Model (IQM3)**.

To provide a fully-usable framework (IQMF), we had to develop a methodology to assess and improve IMPs of an Information System in terms of the IQ maturity levels proposed in IQM3. We also studied the assessment and improvement methodologies associated with the aforementioned reference models for Software Process Assessment and Improvement, namely CBA-IPI, SCAMPI or ISO/IEC 15504. In the IQ field, there already exists a widely-used reference framework which can be used to assess and improve Information Products, the TDQM proposed by [Wang 1998], which is based on Deming's Plan-Do-Check-Act (PDCA) cycle. Taking all of them into account, we developed our own version of PDCA because TDQM is not IQ Management process-oriented but only Information Product oriented. The name we chose for the methodology was **Methodology for the Assessment and Improvement of Information Quality (MAIMIQ)**.

An Information System could be seen as a set of IMPs sharing hardware and software resources [Shankaranarayan, et al. 2003]. Therefore, by improving the most critical IMPs, the overall IQ level of the Information System can be also improved. So, IQMF can be used in order to improve the overall IQ level of an Information System as follows:

1. Identify the most critical or interesting IMPs of the Information Systems.
2. Apply MAIMIQ to the identified IMPs having IQM3 as reference.
3. Repeat step 2 until the required IQ maturity levels for the chosen IMPs are obtained.

3 IQM3: The Information Quality Management Maturity Model

When IQ improvement is required, the first step is to make an assessment of the current scenario to be improved. Unfortunately, in the IQ field there are not many reference models providing guidance to assimilate how good a scenario is, and how -the procedures-it can be optimized. Of course, much specific research has been conducted toward the definition of a set of valid IQ dimensions for specific contexts and their corresponding measures, together with an acceptance range of values for these IQ dimensions [Lee, et al. 2006].

But the evaluation of developed frameworks reveals that quite often those frameworks are context-centred and they cannot be applied to others [Eppler 2001]. For instance, it is possible to find specific ones for medical and healthcare [Al-Hakim 2004], military [Burzynski 1998], national security [English 2005], decision support systems [Gendron and D'Onofrio 2002; Shankaranarayan, et al. 2003], web [Caro, et al. 2008; Eppler and Muenzenmayer 2002], small-business [Leonowich-Graham and Willshire 2003], cooperative systems [Mecella, et al. 2002], corporate households [Madnick, et al. 2004] or asset management information in engineering organizations [Baskarada, et al. 2006; Koronios and Lin 2007] and so on.

It is important to highlight that IQM3 does not try to replace to any of the previously-mentioned frameworks. Indeed, its staged structure has a twofold intention: on the one hand, IQ Managers can use IQM3 to contextualize their own specific IQ issues by mapping them to the appropriate KPAs; and on the other hand, they can align their IQ improvement plans to IQM3 for more efficiently guiding their efforts, as if the reference model were an ideal IMP.

IQM3 is structured in staged maturity levels like staged CMMI. Five maturity levels have been defined, namely: (1) Initial, (2) Defined, (3) Integrated, (4) Quantitatively Managed and (5) Optimizing. Each one addresses a specific IQ management goal (see first column of Table 1). In order to get its IQ management goal, several Key Process Areas (KPAs) have been identified. Each KPA is focused on a specific IQ technical or managerial goal [see columns 2 and 3 of Tab.1], although some of them can straddle the line between both aspects. It is important to realize that in the second column [Tabs 1 and 2], the names and their corresponding acronyms for the KPA appear for better understanding and readability of the paper.

The set of technical KPAs is related to the Manufacturing -or engineering- subprocess [Ahern, et al. 2003] (MfP) and the set of management ones is related to the IQ Management subprocess (MnP). The KPAs of IQM3 have been mapped from CMMI [See third column of Tab 1 and 2.], and addressed in the corresponding levels according to CMMI, our IQ experiences and corresponding IQ literature.

In the following subsections, the levels are exposed and a brief description of each KPA is provided. Throughout the paper, together with a brief introduction for each KPA, we have added a table containing the main activities and their corresponding subactivities in order to structure the appropriate method for obtaining the IQ goals of each KPA. In these tables we have also included the necessary input products and the expected outputs, together with the list of participants and a set of suggested tools and techniques.

IQM3 Level (*IQM Goal for Maturity Level*)	**IQM3's KPA**	**Related CMMI's KPA**	**IQM GOAL for KPA**
(1) Initial *No IQ Management Goals have been defined*			
(2) Defined *An IMP has been defined and planned. So the process is repeatable.*	(MIQMT) – Management of an IQ Management Team.	Integrated Teaming (3).	Handle an IQ Management Team charged with responsibility in order to lead the assessment and improvement initiatives.
	(URM) – User Requirements Management.	Requirement Management (2) and Development (3).	Gather, manage and trace IQ user requirements for IMP, Information Product and Information System.
	(IPM) – IMP Project Management.	Technical Solution (3), Project Planning (2) and Project Monitoring and Control (2).	Manage a project to define all issues concerned with the implementation of the IMP.
	(IQM) – IQ Management.	Measurements and Analysis (2).	Define qualitative and corresponding quantitative issues for IQ measurements of the components of the IMP.
	(DSTM)- Data Sources and Data Targets Management.	Supplier Agreement Management (2) and Integrated Supplier Management (3).	Identify and characterize both data sources and targets for Information Product.
	(DSM)-Data Store Acquisition, Development or Maintenance Project Management.	Configuration Management (2), Technical Solution (3), Requirement Management (2) and Development (3).	Provide a data store that can adequately support all IQ users' requirements.
(3) Integrated *IMP is defined and aligned to Organizational IQ. So the process can be managed according to organizational policies about IQ.*	(VV)-Information Product and IMP Components Verification and Validation.	Verification (3) and Validation (3).	Develop a plan for validating and verifying both IMPs and their results.
	(RM)- Risk and Poor Information Quality Impact Management.	Risk Management (3).	Delimit the scope and document all related risks affecting the IMP due to poor IQ.
	(OIQPM)- Organizational Information Quality Polices Management.	Organizational Process Definition (3).	From IQ knowledge of the organization and from their necessities regarding IPs, the aim of this KPA is to establish and document organizational policies.
	(IQSM)- Information Quality Standarization Management.	Organizational Process Focus (3) and Organizational Training (3).	Create an organizational culture on IQ through learnt lessons.

Table 1: IQ Goals of each level and for KPA in IQM3 (levels 1 to 3)

IQM3 Level (*IQM Goal for Maturity Level*)	**IQM3's KPA**	**Related CMMI's KPA**	**IQM GOAL for KPA**
(4) Quantitative Managed *IMP is integrated, and Plans to obtain measures are developed and automated. Thus, the IMP can obtain repeatable and reliable measures.*	(MM)- IMP Measurement Management.	Organizational Process Performance (4) and Quantitative Project Management (4).	Develop plans for getting the measures obtained in IQM.
	(AMP)-IMP Measurement Plan Automation Management.		Automate the plans outlined in the MM.
(5) Optimizing *IMP is Quantitatively Managed and Measures are used to improve its performance. So the process is under continuous improvement.*	(CADPM)- Causal Analysis for Defect Prevention Management.	Causal Analysis and Resolution (5).	From measures obtained in MM, this KPA is aimed at making an analysis to identify the root causes of poor IQ.
	(IODM)- Information and Organizational Development Management.	Organizational Innovation and Deployment (5).	From results obtained from analysis in MM, the main aim of this KPA is to improve the performance of the IMP.

Table 2[Cont. Tab1]: IQ Goals of each level and for KPA in IQM3 (levels 4 and 5)

As our aim is to propose a framework which is as universal and usable as possible, we have decided to suggest a set of tools and techniques used and borrowed directly from the Software Engineering and Database field. The reason for this decision is that as IQ is still an undeveloped field, we have not found many specific techniques oriented to IQ management in literature; moreover, we have realized that each organization uses those tools and techniques that best fit for their context, or those which are familiar to them (not necessarily the best ones).Some organizations do not apply any, thus executing the corresponding activity or subactivity *ad hoc.* In any case, those appearing in the tables are extracted from study cases of CMMI, but always attempt to use international standards from ISO/IEC and IEEE related to software (due to its similarities to data and information) in order to endorse our work to well-known and well-proven references.

For this reason, it is still not possible to enumerate a list of the best tools and techniques. Furthermore, it is rather challenging for researchers to make a classification of the best techniques and tools for each activity in each context. In this sense, the ones proposed in the tables are thought to be a good starting point for the development of new IQ Management oriented tools and techniques.

[Fig.1] contains a suggested ordered path to achieve the different KPAs of the IQM3. These KPAs are going to be explained in the following subsections.

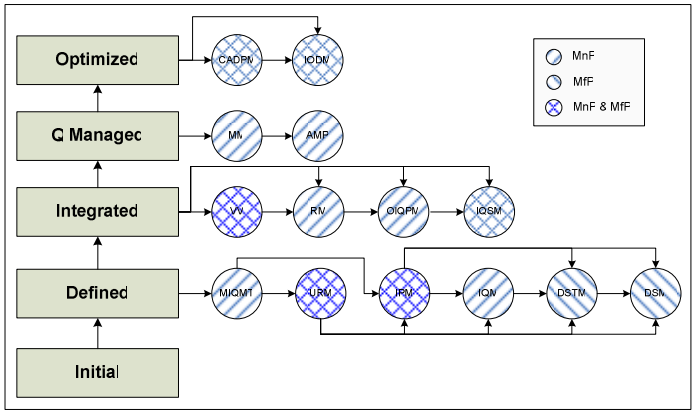

Figure 1: KPAs of IQM3 and Mapping of IQM3's KPAs vs CMMI's KPA.

3.1 Initial

An IMP is said to be at **Initial Level** when no efforts have yet been made to achieve any of the IQ goals proposed in [Tab.1.]. No KPAs need to be defined.

Activities	**MIQMT.1. Determination of the IQ Management Team**.	**MIQMT.2. Definition of an operative environment**.
Subactivities	MIQMT.1.1. Identification of the necessary roles for Data and Information Quality.	MIQMT.2.1. Establishment of a working code.
	MIQMT.1.2. Identification and assignation of roles to the fittest persons.	MIQMT.2.2. Definition of effective ways of communication.
		MIQMT.2.3. Election of best fitted tools and techniques for each KPA of IQM3.
Input	• Management Hierarchy of the organization. • IMP Documentation. • Available technical resources. • Available human resources.	• List of Roles and responsibilities. • IQ policies. • Local and National Legislation and standards related to security of Data.
Output	• List with necessary roles and responsibilities assigned to roles. • People playing roles.	• Working code for IQMT according to organizational policies. • Effective ways of communication.
Participants	• Members of IQMT. • Top Managers of Organization.	• Members of IQMT.
Suggested tools and techniques	• Work Sessions. • Framework proposed by [Giannoccaro, et al. 1999]	• Work Sessions. • Evaluation of tools and techniques for each KPA.

Table 3: Artefacts (activities, subactivities, inputs, outputs, participants and suggested tools and techniques) for the MIQMT KPA.

3.2 Defined

An IMP has raised the **Defined Level** when it has been defined and planned [Ahern, et al. 2003]. This implies identifying all of its components and the relationships between them. Once an IMP has achieved this level, one can assure that the IMP is repeatable, and the same results can be obtained each time the IMP is executed. To perform this goal, the following six KPAs need to be satisfied:

- **(MIQMT) Management of an IQ Management Team.** This KPA is aimed to constitute and organize an IQ Management Team which has enough responsibility and experience with IMP to support improvement initiatives. The IQ Management Team must guide the initiatives according to organization's ideas, policies and trends about IQ [Ballou and Tayi 1999]. It also must identify roles and responsibilities for these roles, and a working code for underlying operations. Besides having specific abilities on IQ, this team must be multidisciplinary and it must also have managerial skills [Chung, et al. 2002], which must be used to encourage the entire organization (firstly committing the top managers) to align to IQ policies. Techniques or tools related to management of human resources, teaming and coaching may also be used when developing this KPA [see Tab. 3].

Activities	**URM.1. IMP- User Requirements Management**.	**URM.2. Information Product-User Requirements Management.**	**URM.3. IQ- User Requirements Management**.
Subactivities	URM.1.1. Gathering and documentation of user requirement for IMP.	URM.2.1. Gathering and documentation of user requirement for Information Product.	URM.3.1. Gathering and documentation of requirements for IQ.
	URM.1.2. Management of changes to the IMP-URS.	URM.2.2. Management of changes to the Information Product-URS.	URM.3.2. Management of changes to the IQ-URS.
	URM.1.3. Validation of the IMP-URS.	URM.2.3. Validate the Information Product-URS.	URM.3.3. Validation of the IQ-URS.
Input	• User Requirements for IMP.	• User Requirements for IPs.	• User Requirements for IQ.
Output	• Validated IMP-URS.	• Validated Information Product-URS.	• Validated IQ-URS.
Participants	• Users of IMP. • Members of IQMT.	• Users of IMP. • Members of IQMT.	• Users of IMP. • Members of IQMT.
Suggested tools and techniques	• Work Sessions. • Interviews. • Standard IEEE 830.1 or related organizational guides. • IP-MAP, SPEM or UML, BPMN.	• Work Sessions. • Interviews. • IEEE 830.1 or related organizational guides. • IP-MAP, SPEM or UML, BPMN.	• Work Sessions. • Interviews. • IEEE 830.1 or related organizational guides. • IP-MAP, UML, or BPMN, proposals by [Pierce 2007]

Table 4: Artefacts for the URM KPA

- **(URM) User Requirements Management**. Three kinds of requirements must be identified, documented and reported in the corresponding User Requirements Specification (URS) documents for any IQ scenario [Wang and Madnick 1993]: those related to the final product of information (Information Product-URS), those related to IMP (IMP-URS), and those related to IQ (IQ-URS).
  All these obtained documents are the starting point for adapting the current data model and the process model for the IQ Management subprocess of the IMP. Standards like IEEE 830 ([IEEE 1998]) or specific organizational guides can be used to format these documents. For modelling IP manufacturing processes, in the IQ field there is a very important graphical technique named IP-MAP provided by [Shankaranarayan, et al. 2000], which has become a *de facto* standard. For modelling a database or data warehouse, together with IQ issues, it is possible to use an extended entity-relationship model proposed by [Wang and Madnick 1993]. [Tab. 4] shows the main artefacts for this KPA.

Activities	**IPM.1. Definition of IMP components and their relationships**.	**IPM.2. Definition and Implementation of the IMP implantation project**.
Subactivities	IPM.1.1. Definition of the scope of the IMP.	IPM.2.1.Establishment of an agenda for the necessary activities.
	IPM.1.2. Definition of a life cycle for the IMP.	IPM.2.2. Establishment of a budget for the IMP project.
	IPM.1.3. Definition of the technical project to be developed.	IPM.2.3. Definition of the implantation project for the IMP.
	IPM.1.4. Management of URS for both Process Model and Data Model.	IPM.2.4. Determination of the viability of the project.
	IPM.1.5. Estimation of the necessary resources and their rates of use.	IPM.2.5. Design of a Process Model.
	IPM.1.6. Estimation of development times for each necessary activity.	IPM.2.6. Design of a Data Model.
	IPM.1.7. Management of project risks.	IPM.2.7. Execution of the implantation project.
Input	• IMP-URS. • Information Product-URS. • IQ-URS.	• Definition of IMP Project.
Output	• Full Definition of IMP Project.	• Process Model. • Data Model. • Report with the main results of the implantation of IMP Project.
Participants	• Members of IQMT.	• Members of IQMT. • Top Managers. • IMP users.
Suggested tools and techniques	• Work Session. • IQM3. • Time and Budget Estimation. Techniques and Tools. • Risk Identification Techniques and Tools.	• Work Sessions. • Gant and PERT Diagrams. • IEEE 1058.1 [IEEE 1987]

Table 5: Artefacts for the IPM KPA

- **(IPM) IMP Project Management**. The main goal of this KPA is to create and implement a plan for coordinating efforts and resources when designing, developing and implementing the IMP. The result of this KPA is a document that describes an agenda of activities and a budget for the implementation of the IMP. This document must also include a description of the scope of the IMP, its technical and managerial phases and its activities. The plan can also include an estimation of the costs, and human resources that are necessary to achieve the marked goals. Not having a specific guide in the DQ field, the document can be formatted by following the recommendations of Software Engineering standards, for instance, IEEE 1058.1[IEEE 1987] for Software Project Plans. Among the products to be obtained as a result of the execution of the plan, it is important to highlight that a modified process model and a modified data model might be developed. Both of these models would support the corresponding URSs and the organizational business models across the IMP. [See Tab. 5] for further information about this KPA.
- **(IQM) Information Quality Management**. There is a need to quantitatively judge IQ in order to quantify how good a scenario is and how much it must be improved. Consequently, as described in the introductory section, it is necessary to identify what the IQ dimensions from the IQ-URS are [Hoxmaier 2001; Huang, et al. 1999], as well as the measures for each one of selected IQ dimensions [Eppler 2003; Kahn, et al. 2002; Pipino, et al. 2002]. Literature does not provide an exhaustive set of measures that organizations can apply [Cappiello, et al. 2004]. Anyway, descriptions of IQ dimensions and discussions about which are the most important ones can be found in [Ballou, et al. 1998; English 1999; Eppler 2003; Gertz, et al. 2004; Grimmer and Hinrichs 2001; Huang, et al. 1999; Kahn, et al. 2002; Lee, et al. 2001; Shankaranarayan, et al. 2000; Wang 1998]. The classification of IQ dimensions proposed by [Strong, et al. 1997b] is highly recommended as a starting point for most IQ managers who are working to find the ones that are most suitable for their particular context. To draw the corresponding measures from identified IQ Dimensions, generic Software Engineering standards might be used, such as IEEE 1061[IEEE 1992], ISO 15939[ISO/IEC 2000] or GQM [van Soligen and Berghout 1999]. Some authors like [English 1999] have proposed a more specific IQ measurement framework with several specific issues to measure; it consists of breaking down the organizational categories which are susceptible to accepting IQ measurement, like the IQ of data models, the IQ of data values, and the IQ of data representation. Moreover, [Loshin 2001] also proposes measuring the IQ of information policies. On the other hand, some authors like [Ballou, et al. 1998; Bouzeghoub and Kedad 2000; Talburt, et al. 2007; van Soligen and Berghout 1999] have proposed measuring the IQ levels of specific components of what we have named IMP. But getting general IQ measures is not an easy task, because it may be possible to find several different measures for the same IQ dimension: there are several factors affecting the definition of the measures, like the role of the person who is measuring; his or her intention for the value or simply, which data has been sampled to be measured. In Section 3.4, we will explain how to organize all these issues

around the IQ Measurement Plan. So, it is important to model the context of the measures so as to determine different use cases of applications with their corresponding particularities. [Tab. 6] contains the main elements defined for this KPA.

Activities	**IQM.1. Identification of IQ Dimensions**.	**IQM.2. Identification of measures for each IQ dimension**.
Subactivities	IQM.1.1. Identification of IQ dimensions for both data sources and information product targets.	IQM.2.1. Identification of IQ dimensions for both data sources and information product targets.
	IQM.1.2. Identification of IQ dimensions for workers.	IQM.2.2. Identification of IQ dimensions for workers.
	IQM.1.3. Identification of IQ dimensions for each component of the IMP.	IQM.2.3. Identification of IQ dimensions for each component of the IMP.
Input	• IMP-URS. • Information Product-URS. • IQ-URS.	• IMP-URS. • Information Product-URS. • IQ-URS. • List of IQ Dimensions.
Output	• List of IQ Dimensions for each component of IMP.	• List of IQ Metrics for each Dimension.
Participants	• Members of IQMT. • Users of IMP. • IQ Experts.	• Members of IQMT. • Users of IMP. • IQ Experts.
Suggested tools and techniques	• Work Sessions. • Brain Storming. • Interviews.	• Work Sessions. • Brain Storming. • IEEE 1061 [IEEE 1992] • GQM [van Soligen and Berghout 1999] • Interviews.

Table 6: Artefacts for the IQM KPA

- **(DSTM) Data Sources and Data Targets Management**. Nowadays, due to new technologies, it is quite easy to get data from any source. This may give rise to new problems like having different values for the same item coming from different sources, or having out-of-date data due to the short life of some specific kinds of data, such as that related to Stock Markets, which expires several times a day. On the target side, there are a lot of referenced examples about data with a poor DQ level causing problems when it is used, like people complaining about problems with the delivery of material goods bought through the Internet [Batini and Scannapieco 2006; English 1999]. Due to particular intrinsic characteristics of data, all data sources, Information Product targets and interchange procedures must be identified, documented and reported to whom it may concern, in order to establish mechanisms to avoid future problems. [Ballou, et al. 1998; English 1999; Hinrichs and Aden 2001] discuss these issues, and propose several ways for treating incoming information from multiple sources. There are already some specific fields in which researchers and practitioners have realized the importance of data acquisition and Information Product delivery mechanisms. For instance, in data warehouse environments, where tools like

ETL could be used to unify the semantics and formats of incoming data [Ryu, et al. 2006]. Taking into account the growing importance of Internet in business, another very important example is the definition of new interchange formats based on standards like the XML family for their use through web services to communicate data between applications in Service Oriented Architectures [Verbo, et al. 2007] or even in Semantic Web environments [Caballero, et al. 2008; Preece, et al. 2008]. [Tab. 7] gathers the elements related to the activities of this KPA.

Activities	**DSTM.1. Data Source Description and Characterization**.	**DSTM.2. Targets Description and Characterization of Information Products**.
Subactivities	DSTM.1.1. Identification of candidate sources of data.	DSTM.2.1. Identification of candidate targets of Information Products.
	DSTM.1.2. Selection of the most adequate source amongst the candidates.	DSTM.2.2. Selection of the most adequate target amongst the candidates.
	DSTM.1.3.Definition of Data Acquisition Process.	DSTM.2.3.Definition of Data Delivery Process.
Input	• IMP-URS. • Information Product-URS. • IQ-URS. • Process Model.	• IMP-URS. • Information Product-URS. • IQ-URS. • Process Model.
Output	• List of candidate data sources. • Adapted Process Model to Acquisition Process.	• List of candidate data and Information Product targets. • Adapted Process Model to Delivery Process.
Participants	• Users of IMP. • Members of IQMT.	• Users of IMP. • Members of IQMT.
Suggested tools and techniques	• Work Sessions. • Tools and Techniques for Data Mining. • ETL tools. • Methodology by [Grimmer and Hinrichs 2001]	• Work Sessions. • Tools and Techniques for Data Mining. • ETL tools. • Methodology by [Grimmer and Hinrichs 2001]

Table 7: Artefacts for the DSTM KPA

- **(DSM) Data Store Acquisition**, **Development or Maintenance Project Management**. Let us call any place devoted to storing data a *Data Store*, for example a database, a data warehouse, an XML file, a Semantic Web document, a data mart, etc. This KPA is focused on establishing the data model for supporting the activities of the IMP. Having IQ as our goal, it is necessary that this data store can support all kinds of IQ User Requirements. In order not to forget any requirement, it is fundamental to define a project for acquisition, development or maintenance of a data store supporting aforementioned URSs. It is important to highlight that the resulting data store must be valid for all or, at least, most of the IMPs of the Information System, because it may be anti-economical to have different data stores for different IMPs that share the same data model. A recommendable practice is the optimization of the design of the data schema, taking into account the quality of data models through dimensions like completeness or

comprehensibility. Data Model design can be backed by using some of the measures proposed by [Calero and Piattini 2002; Genero, et al. 2005; Piattini, et al. 2001a; Piattini, et al. 2001b]. In [Tab. 8] one can find further information about this KPA.

Activities	**DSM.1. Definition of an acquisition, development, or maintenance project for data store.**	**DSM.2. Execution of the Project**.
Subactivities	DSM.1.1. Definition of viability of alternatives. DSM.1.2. Election of the best alternative.	DSM.2.1. Execution of the best plan.
Input	• IMP-URS. • Information Product-URS. • IQ-URS. • Data Model.	• Acquisition, development, or maintenance project. • Data Model.
Output	• Acquisition, development, or maintenance project.	• Execution Project Report. • Data Store.
Participants	• Members of IQMT. • Stakeholders.	• Members of IQMT. • Participants.
Suggested tools and techniques	• Work Sessions. • Conceptual and Logical Models. • Project Management Tools. • DBMS. • Measures for data model designs.	• Work Sessions. • Project Management Tools.

Table 8: Artefacts for the DSM KPA

3.3 Integrated Level

The subject of the **Integrated Level** is to get the IMP, not only being defined (Defined Level has been achieved), but also aligned to organizational IQ requirements expressed by the IQ standards and policies. This involves the effort of standardizing the different lessons learnt through the different IQ initiatives, for gathering and documenting IQ standards and policies, and then assuring that they are available to be used when designing new IMPs. The aim of this level is to provide mechanisms for implementing specific organizational solutions to IQ problems in order to avoid previous errors and enable better IMPS for the future. The following KPAs must be satisfied:

- **(VV) Information Product and IMP Components Validation and Verification**. IMP components (like data models or manufacturing processes) must be verified and validated to correct defects and/or discordances with both User Requirement Specifications for the IMP and for IQ, and the organizational IQ policies and standards. A technique that could be adapted to IQ issues and applied to the components of IMP, is that of software inspections [Fagan 1976; Gilb and Graham 1993]. A more specific framework that can be used is *data testing* proposed by [Kiszkurno and Yankelevich 2001], but extended to IMP. In any case, in order to coordinate efforts, a plan for testing could be designed and drawn up by following, for example, IEEE 1012 [IEEE 1986]. Please, consult [Tab. 9] for the main elements of this KPA.

Activities	**VV.1. Design of a Plan for Verification and Validation**.	**VV.2. Execution of the Plan for Verification and Validation**.
Sub Activities	VV.1.1. Design of a Plan for Verification and Validation for the components of IMP and IPs.	VV.2.1. Execution of the Plan for Verification and Validation the IMP.
Input	• IMP-URS. • Information Product-URS. • IQ-URS. • IMP. • Information Product Plan.	• Plan for Verification and Validation (VV.1).
Output	• Plan for Verification and Validation.	• Report of VV Project Execution. • List of defects to be fixed.
Participants	• Members of IQMT. • Users of IMP.	• Users of IMP. • Members of IQMT.
Suggested tools and techniques	• Work Sessions. • Test Design. • Software Inspection. • Enhanced Data Tests Design.	• Project Related Tools.

Table 9: Artefacts for the VV KPA

Activities	**RM.1. Estimation of the impact of poor IQ**.	**RM.2. Definition of contingency plans to minimize effects of risks**.
Subactivities	RM.1.1. Identification and search of risks and their sources.	RM.2.1. Definition of solutions for avoiding the risks.
	RM.1.2. Estimation of the impact of the risks on the IMP.	RM.2.2. Definition of solutions for mitigating the risks.
		RM.2.3. Definition of a contingency plan for avoiding or mitigating the risks.
		RM.2.4. Estimation of the viability of the contingency plans.
		RM.2.5.Implantation of the contingency plans.
Input	• IMP-URS. • Information Product-URS. • IQ-URS. • IMP. • Information Product Definition.	• List of risks which can affect IMP, impact factor for each one, and an estimation of injury on IMP.
Output	• List of risks which can affect IMP, impact factor for each one, and an estimation of injury on IMP.	• Approved Contingency plans with actions for mitigating risk impacts.
Participants	• Users of IMP, namely *stakeholders.* • Members of IQMT.	• Users of IMP. • Members of IQMT.
Suggested tools and techniques	• Work Sessions. • Risk Management Tool.	• Work Sessions. • Risk Management Tools.

Table 10: Artefacts for the RM KPA

- **(RM) Risk and Poor IQ Impact Management**. It is up to the IQ Management Team to quantify the extent of the impact of risks, caused by poor levels of IQ, on the performance of an IMP. [Getto 2002] proposes a methodology which can be adapted to IQ issues for the purpose of collecting and documenting all risks. For each one of the identified risks, a contingency plan must be drawn up in order to minimize their effects on the IMP. Contingency plans must be conveniently evaluated in order to determine if they are feasible. If not, it is necessary to assume and to estimate what the consequences are going to be should the risks become reality. If possible, actions must be executed in order to modify the IMP to avoid these risks or to support their impact. [See Tab. 10] for further information about this KPA.
- **(OIQPM) Organizational IQ Policies Management**. All learnt lessons through previous IQ experiences should be properly gathered, reported and transmitted to the organizational knowledge base by defining suitable organizational IQ policies [Dewan and Storey 2008; Loshin 2001]. An organizational policy is a set of rules which might be applied to any actions of the organizations in order to work under the same criteria. Therefore, IQ organizational policies are a way to "*universalize*" several issues regarding to how manage IQ dimensions, IQ risks, and how to modify data models and process models to support the "*best organizational IQ practices*". These policies, backed by the top managers, are intended to affect not only single IMPs, but also the whole organization. [Loshin 2001] presents the elements that are the subject of IQ policy design for achieving an IQ culture. Organizations can be said to have an IQ culture when all their processes, related or not to information and IQ management, take into account IQ issues. These policies must also observe the best practices related to data management process [Aiken, et al. 2007]. [See Tab. 12] for the main elements of this KPA.

Activities	**OIQPM.1. Design of Organizational IQ Policies.**
Subactivities	OIQPM.1.1. Design of IQ Policies about IQ Dimensions and Metrics.
	OIQPM.1.2. Design of IQ Policies about Data and Process Models.
	OIQPM.1.3. Design of IQ Policies about IQ Risk.
	OIQPM.1.4. Design of IQ Policies about IQ Analysis Techniques.
Input	• Organizational IQ Policies Catalogues.
Output	• Reviewed and Extended Organizational IQ Policies Catalogues.
Participants	• Executives. • Members of IQMT.
Suggested tools and techniques	• Work Sessions. • IMP Inspections. • Techniques for Validation of findings.

Table 11: Artefacts for the OIQPM KPA

- **(IQSM) IQ Standardization Management**. Only by incorporating the latest IQ management experiences, would the IMP performance be higher than otherwise. If, in the previous KPA learnt lessons from experiences were

translated into organizational policies, the main aim of the current one is to incorporate the best practices collected by the organization into the IMP by adding specific requirements to the URS. It is important to realize how data models and process models can be modified through the incorporation of specific requirements for the URS. After this, new changes must be propagated to the Information System. In [Tab. 11] one can find further information about this KPA.

Activities	**IQSM.1. Election of standards for IQ**.	**IQSM.2. Election of Organizational Policies of IQ.**	**IQSM.3. Review and completion of URS according to selected Standard and Policies.**
Subactivities	IQSM1.1. Election of IQ standards.	IQSM.2.1. Election of Organizational Policies of IQ.	IQSM.3.1. Review and extend URS to satisfy chosen IQ standards. IQSM.3.2. Review and extension of URSs to satisfy chosen organizational IQ policies. IQSM.3.3. Management of changes to different URSs.
Input	• Organizational and International IQ Standards Catalogues. • IMP Plan.	• Organizational IQ Policies Catalogues. • IMP Plan.	• IMP/Information Product/IQ-URS, IMP-Plan Definition. • Both lists containing IMP issues affected / modified by IQ Standards. • IQ Policies.
Output	• List containing IMP issues affected/modified by IQ Standards.	• List containing IMP issues affected/modified by IQ Policies.	• Reviewed and Extended IMP Plan Definition.
Participants	• Members of IQMT. • IQ Experts. • IMP Users.	• Members of IQMT. • Top Managers. • IMP users.	• Members of IQMT. • Users of IMP.
Suggested tools and techniques	• Work Sessions.	• Work Sessions.	• Work Sessions.

Table 12: Artefacts for the IQSM KPA

3.4 Quantitatively Managed Level.

An IMP is understood to be at a **Quantitatively Managed Level** when, besides being integrated (integrated level has just been achieved) some measurement plans have been developed, implemented and automated to get values for the designed measures. The main advantage is the capacity to have a quantitative compliance that the IMP performance over a reasonable time period remains as consistent as required in terms of variation and stability through a reliable set of measurements [Grimmer and Hinrichs 2001; Loshin 2001]. In so far as it is possible, the measurement process must

be automated in order to get more reliable measures [Burgess, et al. 2004; Hinrichs and Aden 2001].

Therefore, it is necessary to automate the measurement plans. This level has the following two KPAs:

- **(MM) IQ Measurement Plan Management.** In IQM KPA (Defined Level), a set of IQ dimensions and corresponding measures were obtained. There, measurements were made *ad hoc*, although as [English 1999; Loshin 2001] state, a plan for quality measurements starts with the decision to take measures. There are a lot of factors which can affect the proper measurement process making the collected values invalid. [Caballero, et al. 2007] analyze such kinds of factors by mapping the terms and concepts found in the IQ literature to those supposed to be equivalent and appearing in ISO 15939 [ISO/IEC 2000]. Hence, the aim of this KPA is to draw up measurement plans, taking into account the factors affecting the measurement processes, in order to get measures which will be used to check conformity of IMP and Information Products to specifications [Meredith 2002]. As examples of such kinds of factors, the following could be proposed: the dependency among different IQ dimensions [DeAmicis, et al. 2006; Klein and Callahan 2007], the time necessary for measuring or the right moment for doing it [Redman 2000], the election of the appropriate measurement method [Batini and Scannapieco 2006], which role must develop the measures [English 1999] and so on.

  Finally, it is important to delimit how and to whom the results of measuring must be presented. Many authors like [Humphrey 2002] propose the use of several control diagrams, or [Hinrichs and Aden 2001] who propose Kiviat's diagrams as ways to represent IMP measurements. More details for this KPA can be found in [Tab. 13].

Activities	**MM.1. Definition of measurement plans for each measures**.	**MM.2. Execution of measurement plans**.
Subactivities	MM.1.1. Identification of context of each measure. MM.1.2. Definition of specific measurement plans for each measure.	MM.2.1. Execution of measurement plans.
Input	• Metrics obtained at IQM.2. • IQ/Information Product/IPM-URS.	• List containing specific measurement plan for each measure.
Output	• List containing specific measurement plan for each measure.	• Measurement Plan Report for each measure and its values.
Participants	• Members of IQMT. • Users of IMP. • IQ Experts.	• Members of IQMT.
Suggested tools and techniques	• Work Sessions. • GQM.	• Work Sessions. • Project and Plan Management Tools.

Table 13: Artefacts for the MM KPA

- **(AMP) Management of Automation of IQ Measurement Plan**. In order to avoid systematic random errors, and to increase the reliability and repeatability of measures as many authors like [Gebauer, et al. 2005] claim, measurement plans (previously defined at MM KPA) must be as automated as possible [Hinrichs and Aden 2001]. This KPA aims to study all the issues regarding the automation of these measurement processes, in order to determine if it is possible. If so, other related issues must be taken into account, such as where and how to store the results of the measurements. The options are: in the same data store (which implies modifying the schema of the data model to support the new data) or in another data store (which implies defining the store and the processes to interchange the new data). Regarding the automation itself, it is worth highlighting the proposal by [Savchenko 2003], who provides a software architecture for a tool supporting the automated measurement. Moreover, some authors [Caballero, et al. 2008; Missier, et al. 2006; Shankaranarayan and Wang 2007] have recently suggested that the usage of Semantic Web technologies can help to achieve the goal of automating the measurement plans. Consult [Tab. 14] for the elements of the APM KPA.

Activities	**APM.1. Definition of the scenario in which measurement plans can be automated.**	**APM.2. Implementation of automated measurement plans.**
Subactivities	APM.1.1. Identification of the measures can be automated.	APM.2.1. Modify process and data models with automated measurement plan.
Input	• Context of each measure. • List containing specific measurement plan for each measure.	• Process and data models. • List containing specific measurement plan for each measure. • Report containing aspects about the possibility of automating each measurement plan.
Output	• Report containing aspects about the possibility of automating each measurement plan.	• Reviewed measurement plans for measures with automation aspects.
Participants	• Members of IQMT. • IQ Experts. • Software Engineers.	• Members of IQMT.
Suggested tools and techniques	• Work Session. • Semantic Web Technologies.	• Work Sessions. • Semantic Web Technologies.

Table 14: Artefacts for the APM KPA

3.5 Optimized Level

An IMP has achieved the **Optimized Level** when, as well as being quantitatively managed, the measurements obtained are used to implement continuous improvements to the IMP. This can be done in order to eliminate defects, or to propose and implement several improvements for the IMP. It is important to highlight that this KPA is oriented towards improving the IMP itself. It must not be confused

with the focus of the MAIMIQ (identified in the introductory section), whose main goal is to approximate the studied IMP to the ideal one described by the reference model. The following two KPAs must be satisfied:

Activities	**CADPM.1. Creation of a report with founded defects.**	**CADPM.2. Analysis for identifying defect sources.**	**CADPM.3. Design of solutions to avoid and erase both defects and their sources.**	**CADPM.4. Implementation of solutions for avoiding and erasing both defects and their sources.**
Sub-activities	CADPM1.1. Identification of founded defects in the IMP.	CADPM.2.1. Performance of a study for root causes of defects identification.	CADPM.3.1. Re-engineering process models to fix the defects.	CADPM.4.1. Implementation and validation of the proposed solutions.
Input	• List of non-approvals about Information Product and IMP. • Measurement Plan Report for each measure and its values. • Data and Process Models.	• Values of Metrics. • List containing defects which cause non-approvals.	• IQ/Information Product/IPM-URS. • List containing defect sources.	• Accepted and Viable Plan for removing defects from IMP.
Output	• List containing defects which cause non-approvals.	• List containing defect sources.	• Accepted and Viable Plan for removing defects from IMP.	• Reports containing the success of the Plan for removing defects.
Participants	• Members of IQMT.	• Members of IQMT.	• Members of IQMT.	• Members of IQMT.
Suggested tools and techniques	• Work Sessions. • Identification and Selection of Quality Tools. • Sampling Rules or Standards.	• Statistical Quality Tools (Histograms, Pareto's, Ishikawa's diagrams, etc.).	• Typical Project Tools for Time and Budget Management.	• Typical Project Tools for Time and Budget Management.

Table 15: Artefacts for the MIQMT KPA

- **(CADPM) Causal Analysis for Defects Prevention Management.** From the study of the measurements results, some typical quality diagrams (histograms, Pareto's, Ishikawa's), techniques and tools (such as Statistical Control Process) can be applied to detect defects of IQ and thus, identify their root causes. The obtained conclusions must provide a basis for enabling a corresponding maintenance process for the IMP, whose purpose is to

remove the detected defects in affected resources. The framework for defect prevention proposed by [Smith and Heights 2002] may be used. Further information can be found in [Tab. 15]

- **(IODM) Innovation and Organizational Development Management.** This KPA is aimed at implementing the concept of continuous improvement for IMP. In this KPA, the results obtained from measurements are going to be used to improve the IMP in terms of achieving higher performance, more efficiently planned execution time, or even lower computational costs or budget in terms of human resources. By making the corresponding analysis, one can identify how and where the IMP must be re-engineered in order to get better values for the measures. [See Tab. 16] for the elements of this KPA.

Activities	**IODM.1. Creation of Report highlighting possible improvements.**	**IODM.2. Data Analysis for organizational improvement.**	**IODM.3. Design of proposals for IQ Improvement.**	**IODM.4. Implementation of solutions for improving chosen issues of IMP.**
Sub-activities	IODM.1.1. Identification of possible improvements in the IMP.	IODM.2.1. Performance of a study for identification of available improvements.	IODM.3.1. Re-engineering process model to enhance the performance.	IODM.4.1. Implementation and validation of the proposed solutions.
Input	• List of improvable issues about Information Product and IMP.	• Values of Metrics. • List of issues to be improved.	• Actions about how to improve selected issues.	• Accepted and Viable Plan for improving chosen issues from IMP.
Output	• List of issues to be improved.	• Actions for improving selected issues.	• Accepted and Viable Plan for improving chosen issues from IMP.	• Reports containing the success of the Plan for removing defects.
Participants	• Members of IQMT.	• Members of IQMT.	• Members of IQMT.	• Members of IQMT.
Suggested tools and techniques	• Work Sessions. • Identification and Selection of Quality. Tools. • Sampling Rules or Standards.	• Statistical Quality Tools.	• Typical Project Tools for Time and Budget Management.	• Typical Project Tools for Time and Budget Management.

Table 16: Artefacts for the IODM KPA

4 Conclusions

Information is, together with human resources, one of the most important assets for organizations. Indeed, in order to have a high organizational performance, companies must assess and improve the quality of the information used by their most critical business processes. Information is not an isolated resource, but it flows within organization and, consequently, its quality must be tackled as an organizational issue. Information Quality literature has provided a great amount of proposals for assessing the quality of information, but there is still a lack of a context-independent framework for assessing and improving the quality of information from an organizational point of view. Since the best way to achieve our goal is through management, we have elaborated a framework (IQMF) aimed at enhancing the IQ management process. It is based on the concept of IMP, which brings together the manufacturing process and the information quality management process. IQMF is composed of two main components: an *Information Quality Management Maturity Model* (IQM3), which has been the aim of this paper; and a *Methodology for the Assessment and the Improvement of Information Quality Management* (MAIMIQ). IQMF consists of the continuous improvement of the IQ level of the Information System by applying MAIMIQ to the most critical IMPs of the organization, having as reference the maturity levels provided by IQM3.

The main contribution of the presented model is the structure of maturity levels for the IMP, which makes it easier to achieve partial IQ goals through management in an increasing way.

IQM3 is flexible enough to accept new proposals for tools and techniques for the contained activities, since the definition of KPAs is generic enough that each organization can select their most suitable tools and techniques for its convenience. It is challenging for researchers to depict or adapt new tools and techniques oriented towards IQ management, having as a basis those used in Software Engineering and Database fields.

Finally, it is important to realize that the IQM3 represents a systematic and concise set of criteria for IQ assessment, enables proactive management and measurement of IQ, provides a conceptual map for the research community in order to address a wide variety of approaches, theories and IQ related phenomena, and gives a schema to analyze and solve information quality problems. These facts satisfy the conditions that [Eppler and Wittig 2000] consider that a good IQ framework must posses.

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