A quality management based on the Quality Model life cycle

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A B S T R A C T

Managing quality is a hard and expensive task that involves the execution and control of processes and techniques. For a good quality management, it is important to know the current state and the objective to be achieved. It is essential to take into account with a Quality Model that specifies the purposes of managing quality. QuEF (Quality Evaluation Framework) is a framework to manage quality in MDWE (Model-driven Web Engineering). This paper suggests managing quality but pointing out the Quality Model life cycle. The purpose is to converge toward a quality continuous improvement by means of reducing effort and time.

1. Introduction

Nowadays, Quality management means an expensive set of activities, processes, techniques and resources that involves high costs. It is expensive for a lot of organizations to carry out quality management with effectiveness and efficiency. In these lines, one interesting area where quality management can be applied is the Model-driven Engineering (MDE) which is a software development paradigm consisting in the creation of models or abstractions closer to a particular domain rather than concepts or a specific syntax. In this paradigm, models are transformed into other models or code using automatic transformations. As far as MDE quality is concerned [36], models are the prime artifacts, and developing high-quality systems depends on designing high-quality models and performing transformations that preserve quality or even improve it. The MDE specific domain environment for Web engineering is called Model-driven Web Engineering (MDWE) [11]. Thus, the Object Management (OMG) has defined the standard Model-driven Architecture (MDA) [40] which defines an ar-chitecture platform for approaches based on the Model-driven para-digm. In recent years, the growing interest in the Internet has generated a high number of Web development approaches which offer a frame of reference for the Web environment [10]. OOHDM (Oriented Hypermedia Design Method) [39], UWE (UML-based Web Engineering) [45], WebML (The Web Modelling Language) [46], OOH4RIA [34], RUX-Method [41] or NDT (Navigational Development Techniques) [38] are examples of these diverse approaches. All of them have in common a lack in the use of standards and scarcity of both practical experience and tool support. Besides, the approach Properties that the designer has to offer as well as the Quality Characteristics implicitly assured with these Properties remain unclear. There is no consensus on a quality management strategy for MDWE approaches. Designers are not aware of either user's expectations or the Quality Characteristics to be associated to these needs. Besides, if a strategy is not defined, a Model to reach cannot be determined when carrying out an efficient quality management. So, in this situation, an important need to manage the existing methodologies of quality arises.

In order to carry out a quality management of Quality it is necessary to define a Quality Model, that means, the required goals or Properties to be achieved. The definition of goals or the state to be achieved is not an easy task and some organizations do not have a strategy to define quality management target. Besides, a problem may arise if Quality Model is not clearly designed or defined since there is not any goal to achieve.

In order to design a good Quality Model which fulfills the previous expectations, it is necessary to firstly define a good strategy which allows lying out the bases for the Quality Model design. Another issue to be highlighted is the constant change technology is suffering every day. This can provoke changes in the Quality Model defined by some organization. In that sense, it is essential to design different policies and protocols to know what to do in these cases and define the transition of each artifact. As Quality Model is used to manage quality, our required Quality Model has to be compared with our current state in order to know what can be improved to reach the required Quality Model. Although the main process is quality management, there are several activities the Quality Model uses to

manage quality such as analysis, evaluation and quality continuous improvement. Finally, during the quality management it can be learned how to improve the own quality management process by monitoring it and in terms of results, better the Quality Model and the quality management process. So, it is also important to carry out a quality continuous improvement in order to develop the quality management.

QuEF (Quality Evaluation Framework) is a framework which was initially developed for the analysis and evaluation of quality on MDWE environments, but it has been extended to cover all quality management process. This work analyzes the life cycle and the different process to develop the MDWE quality management approaches.

The main goal of this research is to lay the basis for the quality management environment based on Quality Model management for Model-driven Web approaches. Every phase is explained together with the processes and artifacts that participate in each process. Another goal is to automate the quality management for this type of approaches since in the software industry there is a greater need to produce faster and cheaper high quality Web applications. The MDWE approach is crucial to achieve this objective. Nevertheless, it is also important to know the goals of these approaches; the Properties (user's needs and the environment description) and the Quality Characteristics implicitly associated to the properties. Consequently, it is necessary to define a Quality Model to make the use of these approaches in real environments more effective and efficient, as well as to have suitable tools to analyze, evaluate and plan the improvement of MDWE approaches automatically based on the Quality Model life cycle management.

The paper is organized into the following sections: Section 2 presents the necessary elements to elaborate this work according to some quality standards and context work. Then, Section 3 shows a global analysis of the situation and some related work. Section 4 defines the value of an approach in order to understand how to perform the quality management based on the Quality Model life cycle management. Section 5 presents the complete Quality Model QuEF (Quality Evaluation Framework) life cycle and every process and artifacts. Section 6 studies the future application of the proposed QuEF to real environments. Finally, in Section 7, a set of conclusions, contributions and possible future work are given.

2. Quality standards and work context

2.1. Quality standards

IT service management (ITSM or IT services) [44] is a discipline for managing information technology (IT) systems, philosophically centered on the customer's perspective of IT's contribution to the business. ITSM stands in deliberate contrast to technology-centered approaches to IT management and business interaction. The following represents a characteristic statement from the ITSM literature [44]: “Providers of IT services can no longer afford to focus on technology and their internal organization, they now have to consider the quality of the services they provide and focus on the relationship with customers”. ITSM is process-focused and in this sense has ties and common interests with process improvement movement (e.g., TQM [32], Six Sigma [33], Business Process Management [35], CMMI [4]) frameworks and methodologies. The ISO/IEC 15504 [22], also known as SPICE (Software Process Improvement and Capability Determination), consists of a set of technical standard documents for the computer software development process and related business management functions.

ITIL [15,30] advocates that IT services must be aligned to the business needs and underpin the core business processes. ITIL gives organizations guidance on the use of IT as a tool to facilitate business change, transformation and growth. The ITIL best practices are currently detailed within five core publications which provide a systematic and professional approach to IT service management. They enable organizations to deliver appropriate services and continually ensure that they are meeting business goals and delivering benefits. The five core guides map the entire ITIL Service Lifecycle, beginning with the identification of customers' needs and IT driver requirements, going through service design and implementation to operation and finally, ending with the monitoring and improvement phase of the service. Adopting ITIL can offer users a wide range of benefits that include: improved IT services, reduced costs, better customer satisfaction through a more professional approach to service delivery, improved productivity, developed use of skills and experience and a better delivery of third party service.

ISO/IEC 20000 [24] standard offers IT organizations the chance of having their IT Service Management certified. In contrast to the ITIL books, ISO/IEC 20000 does not offer specific advice on how to design the processes. A set of requirements must be met in order to be qualified for ISO/IEC 20000 certification. ISO/IEC 20000-1:2011 was conceived to fill in this gap. Initiated by two organizations, itSMF and BSI (British Standard Institute), it is modeled upon ITIL principles and for the first time. The ISO/IEC 20000 series enables service providers to understand how to enhance the quality of the service delivered to their customers, both internal and external. The ISO/IEC 20000 series draws a distinction between the best practices of processes, which differ from organizational form or size and organizational names and structures. The ISO/IEC 20000 series applies to both large and small service providers, and the requirements for best practice service management processes are different from the service provider's organizational form. These service management processes deliver the best possible service to meet customer's business needs within agreed resource levels, i.e. service that is professional, cost-effective and with understood and managed risks.

- ISO/IEC 20000-1:2011 [24] is a standard service management system (SMS). It specifies requirements for the service provider to plan, establish, implement, operate, monitor, review, maintain and improve an SMS. The requirements include the design, transition, delivery and improvement of services to fulfill agreed service requirements.
- ISO/IEC 20000-2:2005 [25] represents an industry consensus on guidance to auditors and offers assistance to service providers planning service improvements or to be audited against ISO/IEC 20000-1.
- ISO/IEC 20000-2:2005 [25] is based on BS 15000-2, which has been superseded. Organizations require increasingly advanced facilities (at minimum cost) to meet their business needs.
- ISO/IEC TR 20000-3:2009 [26] provides guidance on scope definition, applicability and conformance demonstration for service providers either aiming to meet ISO/IEC 20000-1 requirements, or planning service improvements by intending to use ISO/IEC 20000 as a business goal.
- The purpose of ISO/IEC TR 20000-4:2010 [27] is to facilitate the development of a process assessment model according to ISO/IEC 15504 process assessment principles. ISO/IEC 15504-1 [22] describes the concepts and terminology used to evaluate processes. ISO/IEC 15504-2 [23] describes the requirements for conducting an assessment and a measurement scale for assessing process capability.
- ISO/IEC TR 20000-5:2010 [28] is an exemplary implementation plan offering guidance to service providers on how to implement a service management system to fulfill ISO/IEC 20000-1 requirements or service providers who are planning service improvements by using ISO/IEC 20000 as a business goal. It could also be useful for those advising service providers to know how to best achieve ISO/IEC 20000-1 requirements.

The ISO 9000 family of standards represents an international consensus on good quality management practices. It consists of standards

and guidelines dealing with quality management systems and related supporting standards. ISO 9001:2008 is a standard that provides a set of normalized requirements for a quality management system, regardless of the user's company, its size, or whether it runs either in the private or public sector. It is the only standard in the family against which organizations can be certified — although certification is not a compulsory requirement of the standard.

The other standards in the family cover specific aspects such as fundamentals and vocabulary, performance improvements, documentation, training and financial and economic aspects. The eight quality management principles on which the quality management system standards of ISO 9000:2000 [16] and ISO 9001:2008 [17] series are based are defined in ISO 9000:2005 [17], Quality management systems Fundamentals and Vocabulary, and in ISO 9004:2000 [18], Quality management systems Guidelines for performance improvements. These principles can be used by senior management as a framework for guiding their organizations toward improved performance. The principles are derived from the collective experience and knowledge of the international experts who participate in ISO Technical Committee ISO/TC 176, Quality management and quality assurance, which are responsible for developing and maintaining ISO 9000 standards. This document offers the standardized descriptions of the principles as they appear in ISO 9000:2005 and ISO 9004:2000. In addition, it provides examples of the benefits derived from their use and actions which managers typically take in applying the principles to improve their organizations' performance. This set of principles provides a general view on the quality management underlying ISO 9000:2000 series. It gives an overview of these principles and shows how, collectively, they can form a basis for performance improvement and organizational excellence. There are many different ways of applying these quality management principles. The nature of the organization and the specific challenges it faces will determine how to implement them. Many organizations will find it beneficial to set up quality management systems based on these principles.

ISO/IEC 25000:2005 [29] gives guidance on the use of the new series of International Standards named Software product Quality Requirements and Evaluation (SQuaRE). The purpose of this guide is to provide a general view of SQuaRE contents, common reference models and definitions, as well as the relationship among the documents, allowing users of this guide to correctly understand those series of International Standards, according to their purpose of use. This document contains an explanation of the transition process between the old ISO/IEC 9126 [19] and the ISO 14598 [21] series and SQuaRE, and also gives information about ISO/IEC 9126 and the ISO 14598 series in their previous form.

2.2. Work context

Web development is currently being an important task to consider since Web applications are becoming more developed every day. In this context, Model-driven Engineering (MDE) paradigm plays a key role as it aims to increase the return a company derives from its software development effort basically by using models and automatic transformations. In this regard, the Object Management Group (OMG) has introduced Model Driven Architecture (MDA), which is a new approach for achieving the concept of platform independence, thus models may have the quality of being independent from the features of any technological platform. MDA is an approach that will change the way an organization designs and develops software by separating an application's business logic from the infrastructure on which it runs. MDA principles are being used to successfully address the construction, evolution and adaptation of Web applications. In addition, MDA is based on the construction and transformation of models which represent a computational independent viewpoint (CIM), a platform independent viewpoint (PIM) or a platform specific viewpoint (PSM). The growing interest in the Internet has led to generate high number of proposals offering a frame of reference for the Web environment.

MDWE (Model-driven Web Engineering) is the application of the model-driven paradigm to the domain of Web software development, where it is particularly helpful due to the continuous evolution of Web technologies and platforms. Different concerns of Web applications are captured by using separate models, e.g. for the content, navigation, process and presentation concerns. These models are then integrated and transformed to code, and then a code comprises Web pages, configuration data for Web frameworks as well as traditional program code. During the last years, the Web engineering community has proposed several different methodologies for Modeling Web applications with different concepts and definitions such as OOHDM (Oriented Hypermedia Design Method) [39], UWE (UML-based Web Engineering) [45], WebML (The Web Modelling Language) [46], OOH4RIA [34], RUX-Method [41] or NDT (Navigational Development Techniques) [38] approaches. In these lines, there is not a standard consensus among them, but a lack in the use of standards and scarcity of both practical experience and tool support. In fact, every methodology has a set of advantages and disadvantages that have already been explained in literature [11,43].

3. Related work

There is lot of work related with quality. As far as quality is concerned, Planguage [13] (a planning language) is based on well-defined rules for specification, numeric process entry and exit conditions, well-defined engineering processes, and well-defined concepts. T. Gilb [12] proposes that a set of specific practical tools for articulating objectives and strategies is outlined to make sure that they are in fact aligned to the core.

In P. Mohagheghi and J. Aagedal [37], some quality goals for MDE which state that the quality of models is affected by the quality of modeling languages, tools, modeling processes, the knowledge and experience of modelers, and the quality assurance techniques applied are presented. That work stated that quality in modeling and, specially, in MDE is composed of several aspects that cover technical factors, psychological factors and Human-Computer Interaction factors. In [14], M. Herrera et al. study the importance of Web portal quality in use. This paper aims to find a quality model to assess Web portal level of quality in use. The model mentioned is found in ISO/IEC 25010 standard, and on some related work in the literature.

On the contrary, Strategic management is a key discipline that permits companies to achieve their competitive goals. An effective and explicit alignment and integration of business strategy with SPI initiatives based on measurement are essential to prevent loss of income, customers and competitiveness. By integrating SPI models and measurement techniques in the strategy management process, an organization's investments will be better aligned with strategy, optimizing the benefits obtained as a result of an SPI program. In [35], H.A. Mitre et al. propose BOQM (Balanced Objective-Quantifiers Methodology) a methodology that integrates properly strategic management, process improvement and quantitative measurement to manage software engineering organizations' competitiveness. In [43], W. Schwinger et al. present an embedded quality framework for a strategic quality management. Three dimensions of software products like product operations, product transition and product revision are described. The Critical to Quality (CTQ) factors defines all Product Engineering dimensions, Instrumental Qualities for these CTQs and Metrics for measuring these instrumental qualities. The authors explain that effective adoption of this framework firstly depends on defining the desired range of the metrics for the chosen product at the outset. The metrics need to be measured, analyzed, improved and controlled for a successful deployment of this framework. P. Becker and L. Olsina [2] present an integrated strategy whose rationale is supported by a well-defined measurement and

evaluation process, a conceptual framework (C-INCAMI) that relies on an ontological base, and quality evaluation methods. In that paper the authors discuss some process views for specifying project context, nonfunctional requirements, measurement, evaluation and analysis.

Other work related to QuEF has already been published. In [5] an initial version of QuEF is described. In that version, a set of QuEF components focused on the analysis and quality evaluation of MDWE approaches is determined. Other related work is [6], where a fuzzy group Analytical Hierarchy Process (AHP) [41] approach is used to get the weight values for defining the importance of each element, regarding the Properties in the Quality Model, in order to evaluate MDWE approaches. [7] propose a prototype for a tool support in order to carry out the analysis and the quality evaluation of MDWE approaches for QuEF.

The QuEF framework shares many principles and values from other methodologies like TQM [32], Six Sigma [33] or CMMI [4]. Its main difference lies in defining quality only through models. The idea consists in a quality management based on a Model-driven Quality which can automate quality management by means of generating artifacts. This way it can develop the automatic analysis, evaluations and plans with the aim of controlling and improving quality automatically by reducing effort and time.

Another issue to consider deals with improving quality from a Quality Continuous improvement of a Quality Model life cycle defining different phases such as Strategy phase, Design phase, Operation phase, Transition phase and Quality Continuous Improvement phase. The ISO/IEC 20000 [24] standard and the ITIL [30] best practices focus on the service management resulting into a very similar idea with a different purpose; the QuEF framework regards Quality Model management but not service management. Table 1 shows the relationship among other standards. It also represents the relation of these standards as well as best practices and approaches that have been applied in the QuEF framework in order to define QuEF itself and apply it on a specific domain like methodologies for Modeling Web applications. The study of all these approaches concludes that most of them cover a Strategy phase and some other phases like Operation or a Quality Continuous Improvement, among others. The QuEF framework intends to define methods and tools for each phase through a quality management based on the Quality Model life cycle which covers a Strategy phase, a Design phase, a Transition phase and a Quality Continuous Improvement of the Quality Model, representing the latter as the main element to manage quality.

4. The value of an approach

In this work, an approach is a Model-driven Web approach for the development of Web applications. Only Web modeling approaches are considered in the framework, although it can be extended to other domain. An MDWE approach provides a set of guidelines, processes and/or tools that approach designers cover to users. Nevertheless, approach designers have to assure users that not only these Properties have to be covered, but also a set of Quality Characteristics of the approach, such as Usability, Functionality or Maintainability. In other words, it can be said that the real value of an approach depends on these two factors: Properties and Quality Characteristics, as shown in the cause effect diagram below (Fig. 1).

As far as the Properties are concerned, it is necessary to identify them, as they are the description of approaches and user's and designer's needs to be covered. Properties constitute all the necessary elements that an approach has to offer. For instance, it is essential that the metamodel of the approach be easy to maintain. This necessity is

Table 1
Related work application and context in the QuEF framework.

Work Context	Standard model, best practices and approaches	Work Application
The QuEF framework and the Specific domain (methodologies for Modeling Web applications)	*ISO 9000 standards*	*This standard means a basis for performance improvement and organization excellence. It determines the aspects to improve MDWE methodologies and QuEF framework itself.*
Specific domain (methodologies for Modeling Web applications)	*ISO/IEC 9126 ISO/IEC 25000:2005 (SQuaRE)*	*These standards provide the Quality Characteristics to evaluate a product. These ISO standards define aspects to be evaluated. They lay the foundations for the definition of the Quality Characteristics so as to evaluate the MDWE methodologies on QuEF. These methodologies are assessed as self-products although Quality Characteristics have to be agreed by the stakeholders' community on MDWE in the Strategy phase of QuEF.*
	ISO/IEC 15504	*The MDWE methodologies define processes and techniques to develop Web applications. This standard determines the computer software development process and related business management functions.*
The QuEF framework	*ISO/IEC 20000 ITIL*	*The ISO/IEC 2000 standard and the ITIL best practices deal with improving service quality based on a Quality Continuous improvement of the service life cycle. For instance, ITIL defines a Strategy phase, a Design phase, an Operation phase, a Transition phase and a Quality Continuous improvement phase. QuEF covers the same idea with a different goal since QuEF framework manages quality based on a Quality Continuous improvement of the Quality Model life cycle.*
	TQM, Six Sigma, CMMI Planguage, C-INCAMI or CTQ, among others.	*The QuEF framework defines different phases with artifacts, methods and tools for each phase. Most of these approaches could be adapted and applied in some phases of QuEF. They cover the similar aspects between the QuEF and the quality management Strategy and Operation phase. For instance:* - *TQM is a management integrative philosophy aims at continuously improving the quality of products and processes. It could be applied in the Strategy and QCI phases in QuEF.* - *Six Sigma is a business process management strategy very similar to TQM working with many established quality-management tools. Most of them could be used in the Strategy phase and Operation phase of QuEF.* - *CMMI is a process improvement approach that intends to help organizations improve their performance. Therefore, it could be applied on the Strategy and Quality Continuous improvement phases.* - *Planguage could be applied in the Strategic phase of QuEF for specifying quality.* - *C-INCAMI provides a domain (ontological) model defining all the concepts and relationships needed to design and implement processes. Hence, it could be used in a Strategy and Operation phase.* - *The CTQ could also be applied in the Strategic phase, the Design phase and the Operation phase of QuEF for specifying project context, nonfunctional requirements, measurement, evaluation and analysis.*

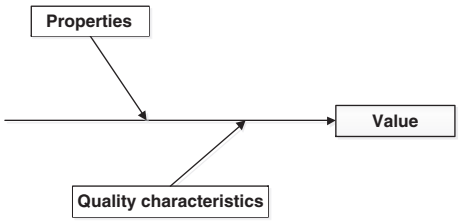

Fig. 1. Cause effect diagram about the value of an approach.

hidden for users, but it is important for designers and for the general quality of the approach.

The concept value should be considered competitive. In addition, approach designers can be competitive with their approaches if they focus on users' needs and cover what they really need. However, they cannot forget their designer needs in order to be competitive. Besides, these needs have to be satisfied with a set of Quality Characteristics. For instance, if approach users need a tool to build a model in order to develop Web applications, they also need to understand that the way of building the models has to consider the usability, the functionality and the maintainability of the process building. It is very important to define the value of an approach in order to be competitive, so approach designers have to be efficient while defining Properties and Quality Characteristics. As T. Gilb said "it is not a matter of quantity of time spent, but how well the time is spent getting the requirements right" [13]. Therefore, when Properties are going to be defined, approach designers have to guarantee that they are fit for user's and designer's needs to be covered and Quality Characteristics to be assured together with these needs.

Now, we can have a function to know the real position of an approach in the market. In order to compare an approach or approaches, users can choose the best option (these approaches must have both the same Properties and Quality Characteristics). Thus, it is important to look at the price (implemented Properties costs) and budget (estimated costs) of all Properties that have to be implemented with the aim of reaching the Quality Model. Therefore, the current competitiveness of the approach and the estimated competitiveness in the market can be known also considering the Properties to be implemented and their estimated costs. In formula (1) the Competitiveness (*Competitiveness* variable) is calculated as the current approach Value (*Value* variable) is divided by the current approach cost (*Cost* variable).

$$\frac{Value}{Cost} = Competitiveness. \tag{1}$$

Next, in formula (2) the estimated Competitiveness (*SCompetitiveness* variable) is calculated as the sum of the current value (*Value* variable) with the estimated value (*SValue*) divided by the sum of the current cost (*Cost* variable) with the estimated cost (*SCost* variable).

$$\frac{Value + SValue}{Cost + SCost} = SCompetiveness. \tag{2}$$

The Operation phase of QuEF enables to get a value in terms of the Properties and Quality Characteristics. The Properties value can be calculated regarding the Current and Required Properties that are explained in Section 5.1. The Quality Characteristic value demands to define the relations and influences of the Properties according to the Quality Characteristics. Finally, the total amount is calculated considering these two values (the Properties and Quality Characteristic values). Besides, the costs are set on each property together with the necessary estimated time to be implemented.

5. Quality management based on the Quality Model cycle life

QuEF has been extended to involve all quality management processes with the definition of a complete life cycle. This life cycle is focused on the quality management of the Quality Model definition. The set of processes of each phase has been built taking into account the eight principles on which the quality management system standards of ISO 9000:2000 and ISO 9000:2008 series are based. These principles have been adapted and are explained below:

Principle 1 (users needs focus but do not forget designer's needs): the approach and its purpose depend on their users and designers, therefore they should understand current and future Properties and Quality Characteristics implicitly associated to these needs, they should meet user's needs and strive to exceed user's expectations. However, some Properties are hidden to users, like metamodels, but are important to keep in mind for the approach quality.

Key benefits are:

- Increased revenue and market share obtained through flexible and fast responses to market opportunities.
- Increased effectiveness when using the approach enhancing user's satisfaction.
- Improved user's loyalty leading to repeat business.

Applying the principle of user's focus typically leads to:

- Research and understand user's needs and expectations.
- Ensure that the objectives of the approach are linked to user's needs and expectations.
- Communicate user's needs and expectations throughout the approach possibilities.
- Measure user's satisfaction acting on the results.
- Manage user's relationships systematically.

Motivation: to succeed, an approach should offer users what they really expect.

Principle 2 (Design focus): designers join unity of purpose and direction of the approach purpose. They should create and maintain an approach in which users become fully involved trying to reach the approach objectives.

Key benefits:

- Users and designers will understand and will be motivated with the approach goals and objectives.
- Processes, techniques and tools are evaluated, aligned and implemented in a unified way.
- Miscommunication between different designers will be minimized.

Applying the principle of design typically leads to:

- Consider all users' needs.
- Establish a clear vision of the approach's future.
- Set challenging goals and targets.
- Create and sustain shared values for approaches.
- Establish trust and eliminate fears.
- Provide users with the required resources.
- Inspire, encourage and recognize people's contributions.

Motivation: the approach designers have to be concerned about a good design.

Principle 3 (users' and designers' involvement): users and designers are the essence of a good approach and a full involvement enables their abilities to be used for the approach benefit.

Key benefits:

- Motivated, committed and involved people.
- Innovation and creativity in furthering the approach's objectives.
- People being accountable for their own performance.
- People eager to participate and contribute to progressive improvement.

Applying the principle of users' and designers' involvement typically leads to:

- Users' and designers' recognition of their contribution and role importance in new approaches' design and improvement.
- Users' and designers' constraint identification to their performance.
- Users' and designers' acceptance of their problems and the responsibility for solving them.
- Users' and designers' performance evaluation against their personal goals and objectives.
- Users' and designers' active search for opportunities to enhance their competence, knowledge and experience.
- Users' and designers' free shared knowledge and experience.
- Users' and designers' open problems and issues discussion.

Motivation: to improve approaches, designers and users have to be informed in order to know these improvements' key factors. Users have to tell designers about their expectations and designers must communicate what they will offer.

Principle 4: process definition: a more efficient result is achieved when activities and related resources are managed as a process.

Key benefits:

- Lower costs and shorter cycle through effective use of resources.
- Improved, consistent and predictable results.
- Focused and prioritized improvement opportunities.

Applying the principle of process definition typically leads to:

- Systematically define the necessary activities to obtain a desired result.
- Establish clear responsibility and accountability for managing key activities.
- Key activities analysis and measurement.
- Interfaces identification of key activities.
- Focus on factors such as resources, methods, and materials that will improve the approach key activities.
- Assess risks, consequences and impacts of activities on users and other interested parties.

Motivation: the motivation is to get a set of processes that combine all the defined activities automatically.

Principle 5 (System approach to management): identifying, understanding and managing interrelated processes as a system contributes to design approaches with effectiveness and efficiency when achieving its objectives.

Key benefits:

- Processes integration and alignment to best achieve the desired results.
- Ability to focus effort on the key processes.
- Provide confidence to the interested parties as well as consistency, effectiveness and efficiency to the approach.

Applying the principle of system approach to management typically leads to:

- Structure a system to complete the approach objectives in the most effective and efficient way.
- Understand the interdependencies between the system processes.
- Structure approaches that harmonize and integrate processes.
- Provide a better understanding of the roles and responsibilities necessary to accomplish common objectives and thereby reduce cross-functional barriers.
- Understand process capabilities by establishing resource constraints prior to action.
- Target and define how specific activities within a system should operate.
- Continually system improvement through measurement and evaluation.

Motivation: You can't improve what you can't control and you can't control what you can't measure. So, it is necessary to define a management system to carry out a complete quality management.

Principle 6 (Continual improvement): continual improvement of the approach overall performance should be a permanent designers' objective.

Key benefits:

- Performance advantage through improved approach designer capabilities.
- Improvement activity alignment at all levels to a strategic approach design.
- Flexibility to quickly react when facing opportunities.

Applying the principle of continual improvement typically leads to:

- Carry out a consistent process-wide to continual improvement for the approach performance.
- Train designers on continual improvement methods and tools.
- Making continual product, process and system improvements.
- Establish goals to guide and measures to track continual improvement.
- Recognize and acknowledge improvements.

Motivation: the Quality Model and other processes have to be improved. The philosophy is: *If you think your approach is already perfect, then it will never be.*

Principle 7 (Factual approach to decision making): effective decisions are based on data and information analysis.

Key benefits:

- Informed decisions.
- An increased ability to demonstrate the effectiveness of past decisions through reference to factual records.
- Increased ability to review, challenge and change opinions and decisions.

Applying the principle of factual approach to decision making typically leads to:

- Ensure that data and information are sufficiently accurate and reliable.
- Make data accessible to those who need it.
- Analyze data and information through valid methods.
- Make decisions and take actions based on factual analysis, balanced with experience and intuition.

Motivation: the data results and the fact of applying an approach in different real projects help to decide on decision-making.

Principle 8 (Mutually beneficial supplier relationships): suppliers that offer resources to approach designers and approach designers themselves are interdependent, and a mutually beneficial relationship enhances their ability to create a value.

Key benefits:

- Increased ability to create value for both parties.
- Flexibility and speed of joint responses to changing market or users' needs and expectations.
- Costs and resources optimization.

Applying principles of mutually beneficial supplier relationships typically leads to:

- Establish relationships that balance short-term gains with long-term considerations.
- Join expertise and resources with partners.
- Identify and select key suppliers.
- Promote a clear and open communication.
- Share information and future plans.
- Establish joint development and improvement activities.
- Offer suppliers' inspiration, encouragement and recognition of improvements and achievements.

Motivation: some approaches are supported by suppliers, for instance, NDT [38] is supported by Enterprise Architect [9]. The

relationship with suppliers has benefited the integration of other tools like JIRA [31] to work with issues.

Then, for the quality management based on the Quality Model life cycle, all these principles are taking into account in order to do an effective and efficiency quality management. Additionally, everybody (users and designers) can take advantage of the consequences of applying these principles. So, the quality management life cycle of QuEF is organized in the following phases:

- Quality Model Strategy phase: the Quality Model Strategy phase is conceived in the center of the Quality Model life cycle concept and its main objective concludes that the quality management becomes strategically active.
- Quality Model Design phase: the Quality Model Design phase deals with the Quality Model design, processes, and other aspects of the Quality Model final design management effort. Significantly, design within QuEF is understood to encompass all relevant elements to design the Quality Model.
- Quality Model Transition phase: the Quality Model transition consists in changing the Quality Model, without influencing the Operation phase. This phase relates to the Quality Model change management.
- Quality Model Operation phase: it deals with performing analysis, evaluation and plan of the approaches' continuous quality improvements. In this phase the Quality Model is used to manage the quality of approaches.
- Continual Improvement phase: this phase aims to align and realign the Quality Model with the Properties to be covered and Quality Characteristics to be assured with the approach users. The Quality Model can change due to identifying new trends or technology changes.

In Fig. 2, all phases of the life cycle are represented by two pinion wheels which the Continual Improvement phase make the rest of phases and the Quality Model to go up until to reach the best value of Quality in a hill for the process. The pinion wheel going up is a continuous cycle where the Quality Model Strategy phase is performed followed by the Quality Model Design phase, the Quality Model Transition phase and finally, by the Quality Model Operation phase. All of them work for the Quality Model which is conceived as the quality management heart.

5.1. Quality Model strategy

In the Quality Model Operation phase the Quality Model and all artifacts are designed and developed and the processes to carry out the Quality Model Operation phase are prepared. It deals with ensuring that approach designers are able to provide users with operational effectiveness and efficiency. Its last goal consists in making the approach designers think and act strategically. This phase is essential for the Quality Model life cycle concept and its main objective is that the quality management became strategically active when clarifying and giving priority to quality management. More generally, the Quality Model Strategy focuses on helping designers and users to improve and develop over the long term. In both cases, Quality Model Strategy largely relies on a market-driven approach. Key topics covered include Quality Model value definition, Quality Model assets, market analysis, and Quality Model existing references.

During the strategic phase it is important to well define Properties since they are, in fact, the goals which indicate the required state to be achieved in this approach. For instance, if this approach has a Usability of 60%, that means that the 60% of the Properties that influence Usability has been implemented. So, it is necessary to assure users of the remaining 40% in order to achieve all the goals. In this

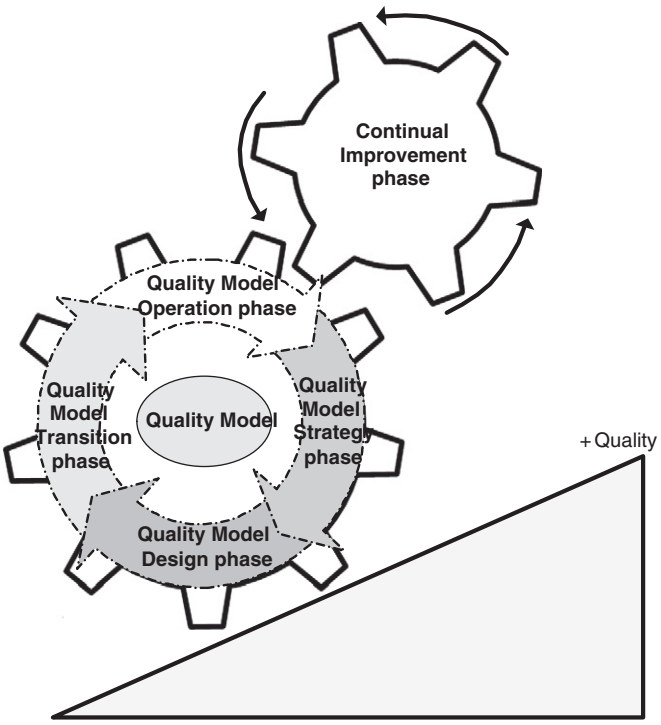

Fig. 2. Quality management based on the Quality Model life cycle.

phase, Properties should be defined under two strategic points of view:

- The first one deals with defining Properties to cover the description of approaches, but considering how these Properties are going to influence the Quality Characteristics. According to this view, Properties are ready to cover all the needs that approach users have. Later on, the influence of each property in each Quality Characteristic is identified. For example, one property can be that an approach needs standard Model as the UML model language. When this property has been identified, the second step consists in knowing which Quality Characteristics have been influenced. In this case, for instance, the UML model language would improve Usability.
- The second point of view deals with defining Properties to cover the description of approaches, but considering how Quality Characteristics can be improved. According to this view, the Properties are elements which will improve every Quality Characteristics. These Properties are needs that will assure approach users of the Quality Characteristics. For example, for the Functionality Quality Characteristics it is essential to think about how this Quality Characteristic can be improved by defining new properties. A new property could be the Transformations among models. This is a functional aspect that improves Functionality. If we have not defined this property, we have to include it in the set of properties.

In this work, a Quality Model consists in a set of Properties and Quality Characteristics and the relationship among them, which provides the basis for quality management. The quality model may be defined as “conformance to requirements” and/or “fitness of use”. In simple terms all the approach designers must be well aware of Properties (they are the description of approaches and users' needs and expectations to be covered), Quality Characteristics to be assured and impact on Quality Characteristics, strategic quality management and contribution of this strategy toward achieving the goal. Fig. 3 shows the Quality Model metamodel and the relation among the

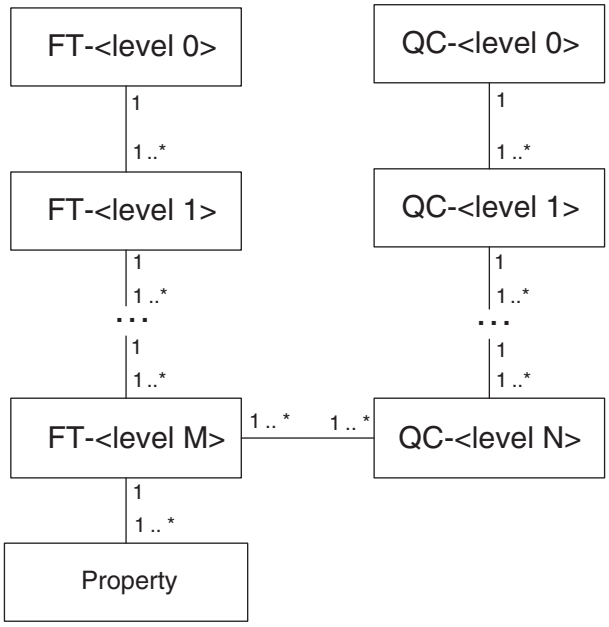

Fig. 3. Quality Model metamodel.

different elements in the Quality model. The elements are described and explained below:

- <*Quality Characteristics (QC)*: these are the Quality Characteristics that have to be assured to the approach users by the approach designers. This is a quality aspect that affects an item quality.
- *Features (FT):* these are a set of Properties of the same issue of an approach. It is the way in which Properties are organized.
- *Property*: in the Quality Model, the Properties should indicate the approach description and needs to be covered.
  - *Required Properties*: these are the Properties that an approach does not implement, although it must be implemented in order to improve quality.
  - *Current properties*: these are the Properties implemented by the approach. These current Properties can have different states. They depend on the different states designed. For example, it can be Supported, Partly Supported or Not Supported.
- *Required Quality Model*: it is the Quality Model which includes the set of necessary properties.

For each Feature and Quality Characteristic in the last level we have to define:

Table 2, shows the necessary basic description for defining each Property. They are composed by:

- *PR-<ID>:* it is the identification number for the property.
- <*Property description*>: it is the property description to be implemented or has already been implemented (in case of comparative studies).
- <*State*>: it is the property current state. It can be Supported, Partly Supported and Not Supported.
- <*Time to implement it*>: it is the necessary time to implement the property.
- <*Estimated cost*>: it is the estimated cost to implement the property in the time set for it.

Table 2
Template to define Properties for the last level of Features and Quality Characteristics.

PR-<ID>	*<Property description>*	*<State>*	*<Time to implement it>*	*<Estimated cost>*

The Quality evaluation target can be different. If the target consists in improving an approach, the defined Properties have to be required a property to improve the approach. Then, the Quality Model is a set of achieved Properties and required properties. So, with the approach analysis and evaluation, the current state of the approach is inferred and these results may help to plan the quality improvement of the approach. On the contrary, if the target consists in doing a comparative study about different approaches, all the approaches' Properties that are to be compared must be identified. Additionally, the approaches have to be similar in that they must have the same user's typology, cover the same needs and ensure the same Quality Characteristics.

Thus, the Properties in comparative studies are focused on all Properties to cover and assure approach users. If the approaches do not have the same needs to cover and the same Quality Characteristics to assure, they won't be able to be analyzed and evaluated. Consequently, they are similar approaches that focus on the same user's profile.

- Quality improvement of approaches: necessary Properties have to be defined. Current Properties can also be useful to know the current state of the approach.
- Comparative studies of several approaches: all common approaches Properties have to be defined. These approaches must be similar. In other words, their users must have the same profile, the same needs to cover and the same Quality Characteristics to assure by approach designers.
- Comparative studies and quality improvement of approaches: all common approaches' properties, even the required Properties have to be defined. These approaches must be similar.

To get this goal, it is essential to firstly determine what Properties should be covered and why they should be covered from approach users and market perspective. Their processes are:

- Financial management: it comprises the discipline of defining each Feature cost by ensuring that the property costs are controlled, so that, an approach designer can understand the costs of each implemented property and the Properties which will be implemented in the future in order to achieve the required quality model.
  - *Objective*: control the Properties costs (Quality Model past, present and future states).
  - *Artifacts*:
    - Resources Sheet: they are the set of resources that are necessary to implement the properties. For a good strategy, it is important to define past resources that were used to implement current implemented properties.
    - Resource Assignment Sheet: they are the assignment resources related to activities to implement the properties. For a good strategy, it is important to assign resources to tasks that have already been done to implement current properties.
- Technological Watch Management: it is organized, selective and permanent, to capture information from the outside and the organization of science and technology to select, analyze, disseminate and communicate it to turn it into knowledge to make decisions with less risk and be able to anticipate changes. Observe trends and technology on the rise. It also carries out a domain's State of the Art to manage.
  - *Objective*: to capture, organize and select permanent information and make confident decisions, as well as to be able to anticipate changes on the Quality Model
  - *Artifacts*:
    - Thesaurus and Glossary: the purpose is to improve the standardization of the access channel and communication between users of different MDWE methodologies.
    - SWOT Analysis Sheet: it is a sheet with the Internal factors (the internal strengths and weaknesses in the approach) and External factors (the opportunities and threats presented by

the external environment to the approach). The SWOT analysis is a strategic planning method used to evaluate the Strengths, Weaknesses, Opportunities, and Threats a project or a business venture is involved. In QuEF, it is used like a strategic method to organize information, analyze and evaluate approaches.

- Property Portfolio Management: it consists in selecting a strategy for approach designers and users to develop the set of Properties to be described on the Quality Model. To design and maintain a structured catalog and framework for all Properties. These Properties are stored in the portfolio (current and past Properties). The portfolio is a historical set of Properties to enable better strategic vision on user's and designer's needs and the description of the approach.
  - *Objective*: to gain control of Properties and deliver meaningful value to approach users. The Property Portfolio Management takes a holistic view of approach users over all Quality Model strategy.
  - *Artifacts*:
    - Portfolio of Properties: they are the set of Properties organized by Features. All Properties have to be registered in the Properties portfolio.
- Quality Characteristic Portfolio Management: to choose a useful strategy for approach designers and users to develop the set of Quality Characteristics to be guaranteed on the Quality Model. All Quality Characteristics are stored in the portfolio (current and past Quality Characteristics). It is a historical set of Quality Characteristics to enable better strategic vision on quality.
  - *Objective*: to gain control of your Quality Characteristics and deliver meaningful value to approach users. The Quality Characteristic Portfolio Management takes a holistic view of approach users on overall Quality Model strategy.
  - *Artifacts*:
    - Portfolio of Quality Characteristics: they are the set of Quality Characteristics. All Quality Characteristics have to be registered in the portfolio of Quality Characteristics.
- Quality Model Portfolio Management: it deals with deciding on a strategy to help approach designers and users and to develop the set of association links between Properties and Quality Characteristics on the Quality Model. All association links are stored in the portfolio (current and past association links). It is a historical set of association links to enable better strategic vision on these associations.
  - *Objective*: To get control of your Quality Characteristics and deliver meaningful value to approach users. The Quality Model Portfolio Management takes a holistic view of approach users on overall Quality Model strategy.
  - *Artifacts*:
    - Portfolio of Quality Model: they are the set of association links between Properties and Quality Characteristics. All the Quality Model has to be registered in the portfolio of Quality Model.

Fig. 4 shows the diagram activity for the Quality Model Design phase together with each process, data flow between processes and necessary artifacts.

5.2. Quality Model design

It provides guidance when designing the Quality Model, processes, and other aspects of the Quality Model final design management effort. Significantly, design within QuEF is understood to encompass all the relevant elements to design the Quality Model. As such, Quality Model design analyzes the Properties to be offered to approach users, the Templates to control and the Properties that have been implemented or not. It also studies the required Quality Characteristics to be assured to the approach users.

- Property Management: it defines the set of current Properties on the Quality Model Design phase. This process only involves the current needs designers have to offer to approach users in the operational phase.
  - *Objective*: to define a set of current Properties to be offered to approach users.

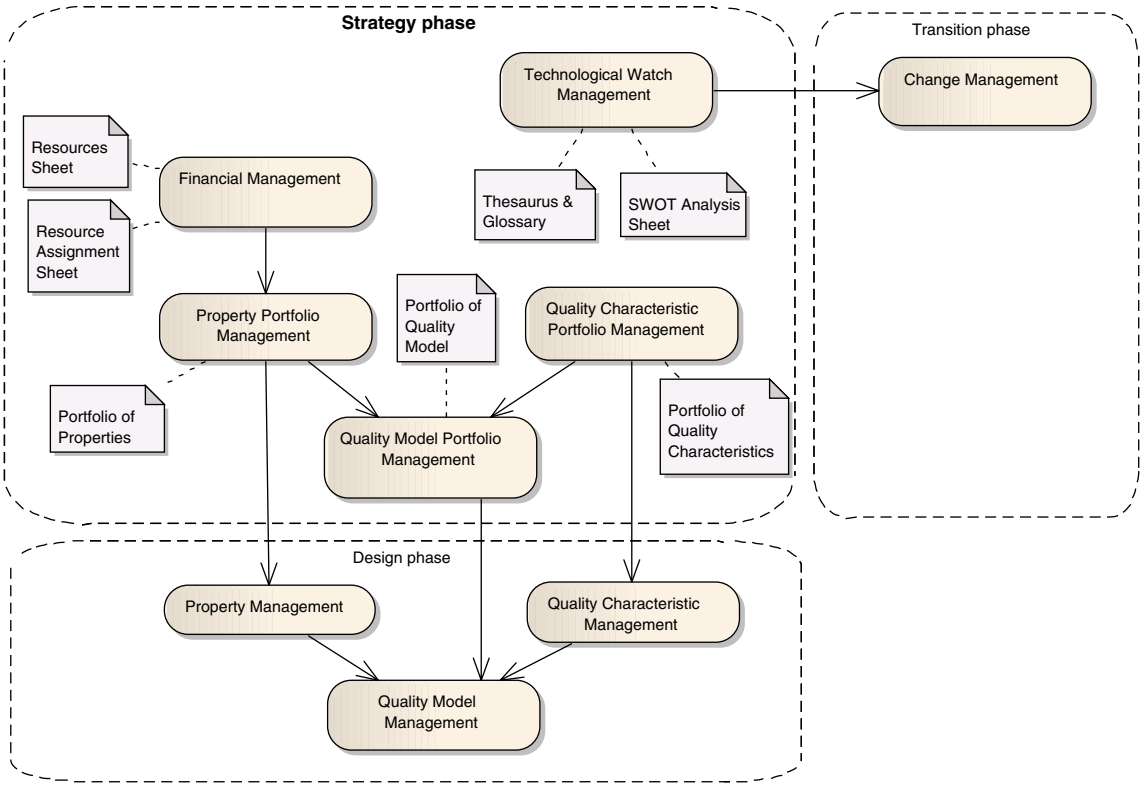

Fig. 4. The diagram activity for the Quality Model Strategy phase.

- *Artifacts*:
  - Properties: it provides current Properties' specifications.
- Quality Characteristic Management: it defines the set of current Quality Characteristics on the Quality Model. This process only involves the current Quality Characteristics designers have to give to approach users in the operational phase.
  - *Objective*: to define a set of current Quality Characteristics to be given to approach users.
  - *Artifacts*:
    - Quality Characteristics: it provides the specification of current Quality Characteristics that have to be assured together with the properties.
- Quality Model Management: it defines the current Quality Model and the association links between Properties and Quality Characteristics. This process only involves the current Quality Model designers have to offer to approach users in the operational phase. It is designed in terms of the Portfolio of Quality Model.
  - *Objective*: to define a set of current association links between current Properties and current Quality Characteristics. This is the current Quality Model.
  - *Artifacts*:
    - Quality Model: it provides the model with the specification of current Properties and Quality Characteristics.
    - MoI (Matrix of Influences): it provides the association links between the current Properties and Quality Characteristics.
- Templates Management: it defines the Templates for the analysis of approaches. These Templates are defined in terms of the Quality Model.
  - *Objective*: to develop a set of Templates for the Properties in order to be able to analyze the approach users and the set of needs that have already been covered.
  - *Artifacts*:
    - Templates: they are the description of the set of Properties to be covered. In this component, a set of Templates is defined for each Feature based on the Quality Model. This Template describes approaches and includes a set of Properties that should be implemented in the approach for it to reach the required Quality Model. These Templates are used in the analysis process and in the evaluation process to know the current state of the evaluated approach.

Fig. 5 shows the diagram activity for the Quality Model Design phase together with each process, data flow between processes and necessary artifacts.

5.3. Quality Model transition

Quality Model transition provides the guidance to do the changes in the Quality Model that has no influence on the Operation phase. This phase studies how to manage the changes on the Quality Model.

- Change Management: the change management process helps to coordinate changes with minimal disruptions and accepted risk.
  - *Objective*: to carry out the changes of all artifacts which are required in the quality management, if the Quality Model is changed with the minimal impact on the quality management process.
  - *Artifacts*:
    - TM (Traceability Matrix): it provides a matrix with the relation between different items and versions.
- Synchronization Management: it defines the synchronization for the changes in the artifacts that are used in the quality management process and performs them. It schedules a plan to do the new changes and the implementation.
  - *Objective*: To synchronize and plan all changes for the quality management process in case that the Quality Model is changed.
  - *Artifacts*:
    - SP (Synchronization Plan): it provides a plan for the set of activities to perform with the aim of applying changes in the different artifacts.

Fig. 6 shows the diagram activity for the Quality Model Transition phase, together with each process data flow between processes and necessary artifacts.

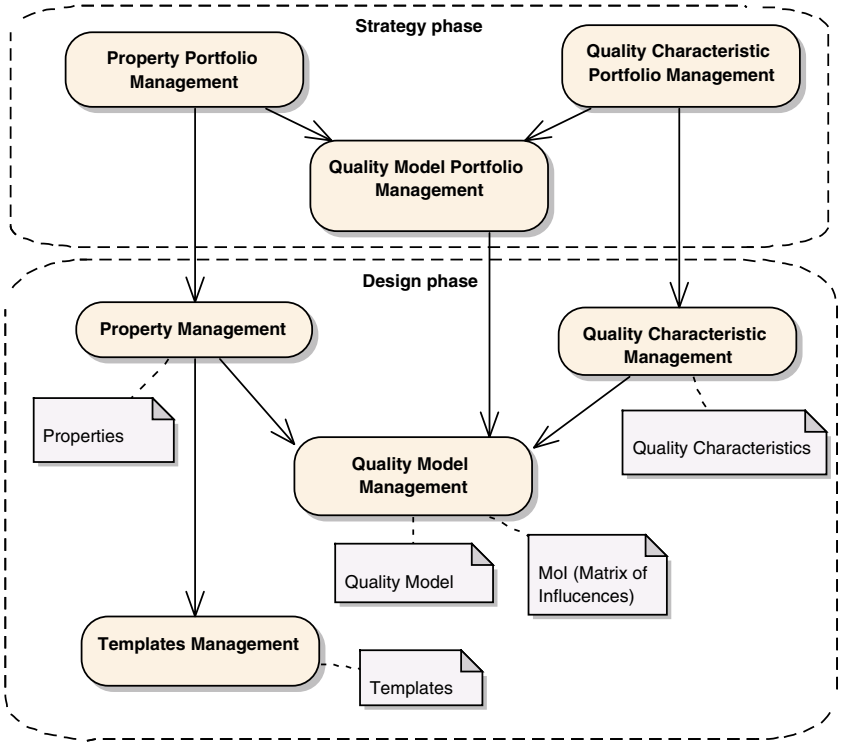

Fig. 5. The diagram activity for the Quality Model Design phase.

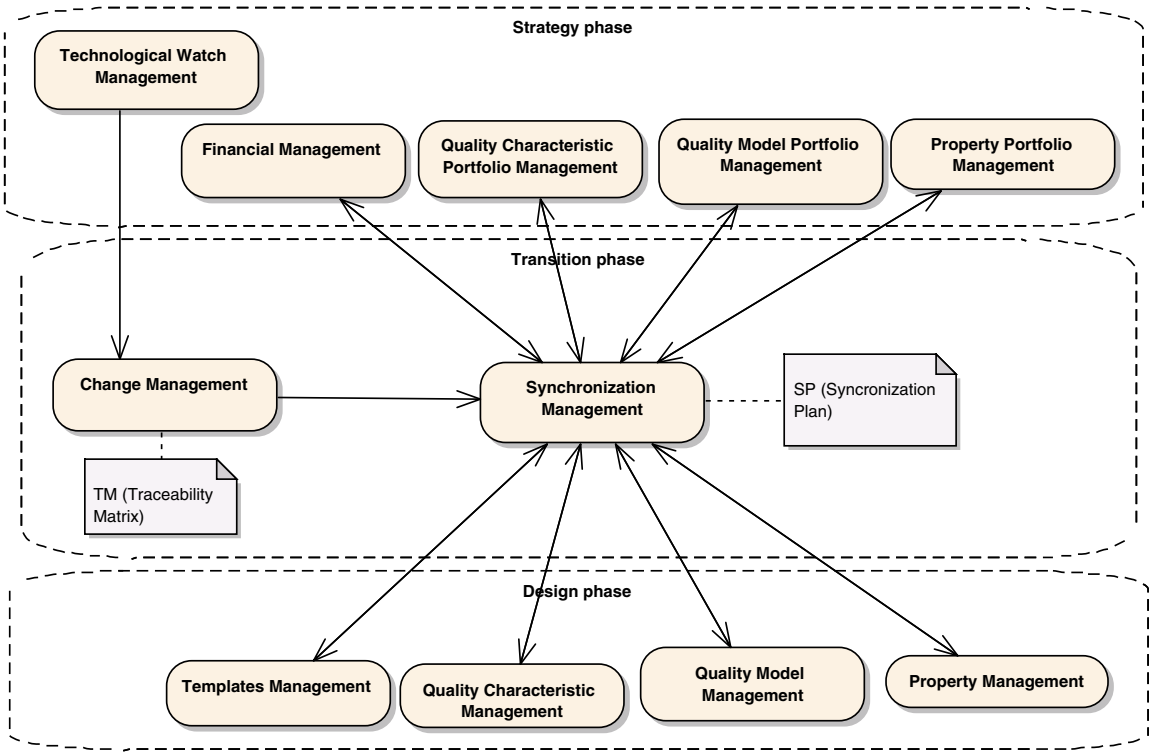

Fig. 6. The diagram activity for the Quality Model Transition phase.

5.4. Quality Model operation

It provides the guidance to perform the analysis, evaluation and the planning of the quality continual improvement of approaches. In this phase the Quality Model is used to manage the quality of approaches. The approach is analyzed using the Templates and it is evaluated to know the current state of the approach. The plan can also be performed as it can be generated in terms of the evaluation values. Attending to this parameter, this plan can automatically be customized in order to optimize the quality continual improvement of approaches.

- Quality Analysis Management: this process is responsible for carrying out the analysis of approaches using the Templates (they are designed in the Quality Model Design phase). The approaches are analyzed through the defined Templates.
  - *Objective*: to analyze approaches in order to know their current state.
  - *Artifacts*:
    - Template values: they are the filled Templates for each approach.
- Quality Evaluation Management: in this process the information from each input Template is compared with the information from the Quality Model. The idea is to determine which aspect needs to be improved in MDWE methodology. The results provide an assessment report of the methodology and this may be used in comparison with the evaluation of other MDWE methodologies.
  - *Objective*: to evaluate the approaches in terms of the analysis results.
  - *Artifacts*:
    - Reports and Charts: it provides Reports and Charts on the evaluation of approaches with the quality evaluation information.
- Quality Improvement Plan Management: this process consists in planning automatically the quality continual improvement of approaches. This plan is generated in terms of the set of necessary Properties in the Quality Model that are not fully implemented in approaches. These activities are generated in terms of the importance of the necessary property and the estimated time and cost to be implemented.
  - *Objective*: to plan the tasks to improve the new Properties in order to reach the Quality Model with the estimated time and resources.
  - *Artifacts*:
    - QIP (Quality Improvement Plan): it provides the plan dealing with quality improvement with the set of tasks to be implemented, the estimated time, resources and costs.

Fig. 7 offers the diagram activity for the Quality Model Operation phase together with each process data flow between processes and necessary artifacts.

5.5. Quality Continual Improvement

In this time of constant changes, we must have only one goal in the field of quality management based on the Quality Model life cycle; to better specified Properties adapted to our users' changing needs. It must be coped with through optimized internal processes in order to provide greater returns to investment and increased users' satisfaction.

This objective of improvement can be achieved only through constant monitorization and measurement of all activities and processes involved in the quality management.

- Compliance: processes fit the new models and protocols.
- Quality: predetermined goals are achieved in a specific way and period.
- Efficiency: processes are efficient and cost-effective for users.
- Value: the Quality Model defines the expected value and differs from the competition.

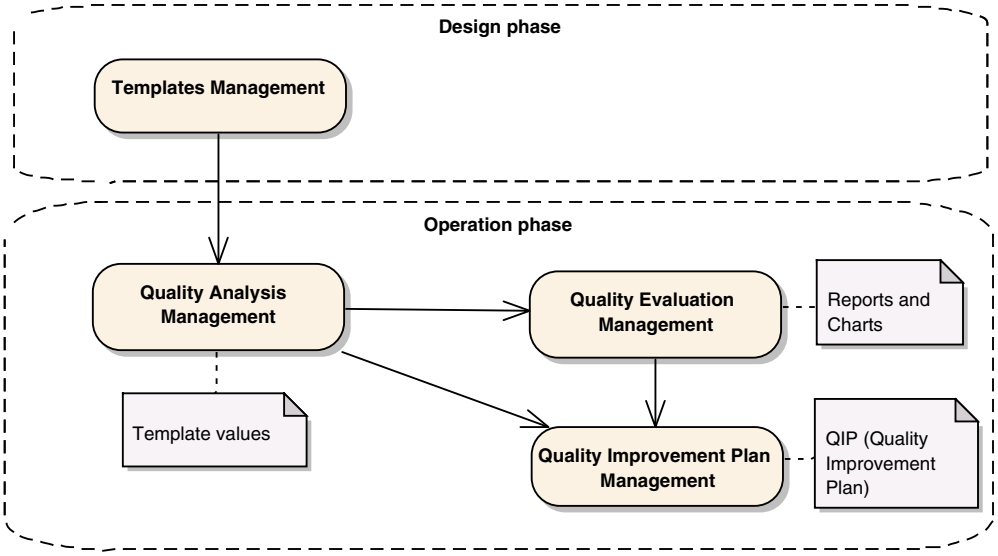

Fig. 7. The diagram activity for the Quality Model Operation phase.

The main goals of this phase summarizes as follows:

- To use methods from quality management in order to learn from past successes and failures. The QCI process implements a closed-loop feedback system, as specified in ISO 20000, as a means to continually improve the effectiveness and efficiency of the quality model management and processes to manage quality.
- To recommend improvements to all processes and activities involved in managing the Quality Model.
- To control and analyze the Properties and Quality Characteristics as well as to monitor and contrast them in real environments.
- To suggest improvements to increase ROI and VOI associated with properties.
- Support the Strategy and Design phases for the definition of new needs and Quality Characteristics or processes/activities associated with them.

The results of this phase of the life cycle must appear in Quality Model improvement plans that must incorporate all the information necessary to:

- Improve the quality of the Quality Model provided.
- Add new Properties and Quality Characteristics that best suit with users' Properties and market.
- Improve and streamline internal processes of the approaches.
- Process Evaluation Management: it evaluates processes on a regular basis. This includes identifying areas where the targeted process metrics are not reached, and meeting regular benchmarkings, audits, maturity assessments and reviews.
  - *Objective*: to evaluate all processes within the quality management process.
  - *Artifacts*:
    - Reports and Charts: it provides the Reports and Charts about the process evaluation.
- QCI Initiatives Management: it defines specific initiatives aimed at improving the Quality Model and processes, based on the Quality Model and Process evaluation results. The results are internal initiatives that require user's cooperation.
  - *Objective*: to plan initiatives in order to develop the processes.
  - *Artifacts*:
    - Initiatives: it provides the set of initiatives to improve the processes in terms of evaluation.
- QCI Monitoring Management: it verifies if improvement initiatives are proceeding according to plan, and introduces corrective measures where necessary.
  - *Objective*: to monitor and assure the QCI initiatives management process.
  - *Artifacts*:
    - Reports and Charts: it provides the Reports and Charts on the monitoring.

Fig. 8 represents the diagram activity for the Quality Continual Improvement phase together with each process, data flow between processes and necessary artifacts.

6. Future application in real environments

In order to QuEF became a business reality, we are currently developing a set of tools that support all processes and artifacts that are defined on QuEF. The idea is to automate all processes and the generation of artifacts defined on QuEF. For this reason, the research IWT2 (Web Engineering & Early Testing) group is developing QuEF-TS, that means, a set of tools for practical environments that support QuEF. Nowadays, the suite of QuEF-TS consists of the following tools:

- QuEF-S: it is the tool that supports the Quality Model Strategy phase.
- QuEF-D: it is the tool that supports the Quality Model Design phase.
- QuEF-T: it is the tool that supports the Quality Model Transition phase.
- QuEF-O: it is the tool that supports the Quality Model Operation phase.
- QuEF-QCI: it is the tool that supports the Quality Continual Improvement in quality management.

QuEF-S is the essential tool that relies on other tools that supports the Strategy phase. The Strategy phase is the first and most important phase in the quality management within QuEF as the remaining phases depend on it. So, we have already defined a first prototype of this tool that implements methods to establish the importance of Properties and Quality Characteristics in the Quality Model. Fig. 9, represents the QuEF-TS system architecture. The QuEF-TS has been divided in two elements, the QuEF Factory and the QuEF Web Application.

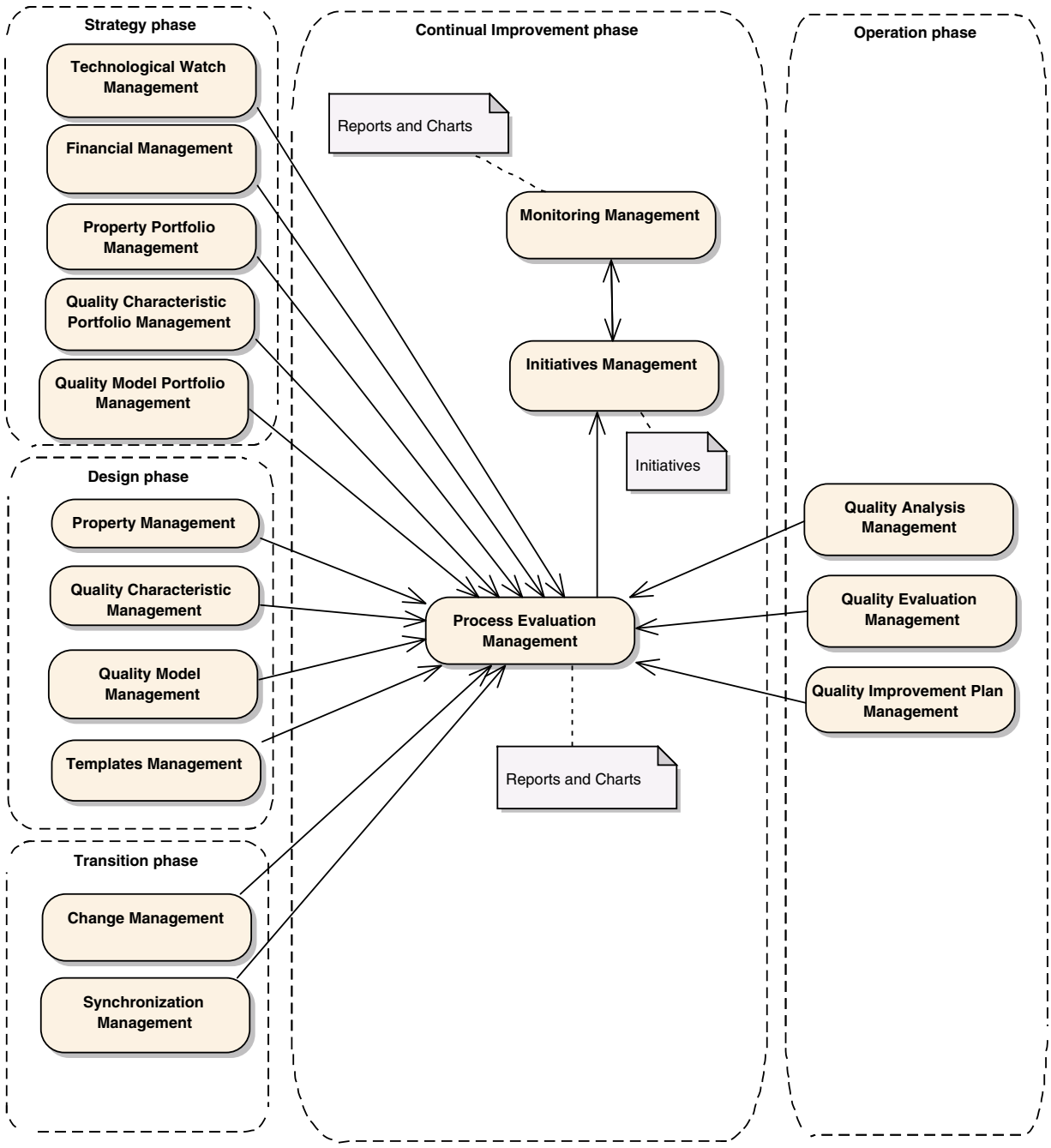

Fig. 8. The diagram activity for the Quality Continual Improvement phase.

The QuEF-Factory receives as input a Quality Model that helps generate the Web application code. The QuEF-Factory has been divided into different factories for each phase. Each of them produces the Web application for every phase. Additionally, all common components in the factory (QuEF Factory Core) and in the Web application (QuEF Web Application Core) have been centralized in a unique component for each of them.

As far as technology is concerned, we are currently using the .NET framework and Enterprise Architect (EA) for the implementation of the QuEF framework (Fig. 10).

EA enables the Quality Model to be defined, and by means of a plugging and an implemented application, it is possible to generate a Web application code in terms of these defined models. Fig. 11 shows the QuEF-TS generator application. In this application you can select the xml file that includes the Quality Model, the Directory to produce the Web application code and the QuEF phases or tools to be generated (QuEF-S, QuEF-D, QuEF-T, QuEF-O or QuEF-QCI tools).

Finally, the Web application with the selected tools is generated. Fig. 12 provides an example of the QuEF-S generated in terms of the Quality Model. In this example, the AHP method is used as a Strategy method in QuEF to identify the value of each element in the Quality Model.

We are also currently working in QuEF-O which is the tool is running the quality management. Some work has already been done in order to define this tool (QuEF-O). The idea is to automate the analysis, the evaluation and plan of quality continual improvement of approaches in terms of the Quality Model. We have started with these two phases (QuEF-S for Strategy and QuEF-O for Operation) because they are essential to start performing quality management of approaches.

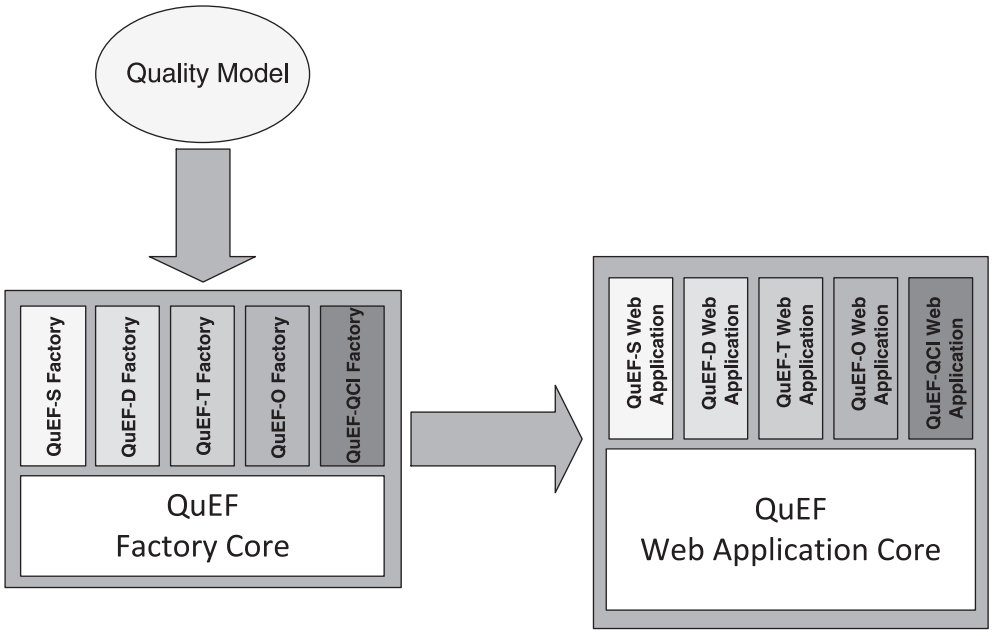

Fig. 9. The QuEF-TS system architecture.

Other future project is about the integration of QuEF-TS with NDT-Suite [10,38] in order to apply a quality continual improvement to the NDT methodology. NDT has evolved in the last years and offers a complete support for the whole life cycle. There are different papers published on NDT methodology, IEEE TSE [10]. NDT-Suite is a set of tools to apply the NDT methodology in practical environments. As far as the NDT methodology is concerned, the aim of the suite of NDT not only provides support to the development of projects using the NDT methodology, but also provides support to verify and validate the work with NDT. The NDT-Suite made an extension of the methodology itself and following the assumptions set out by the Métrica V3 methodology it was an extension to tackle the entire life

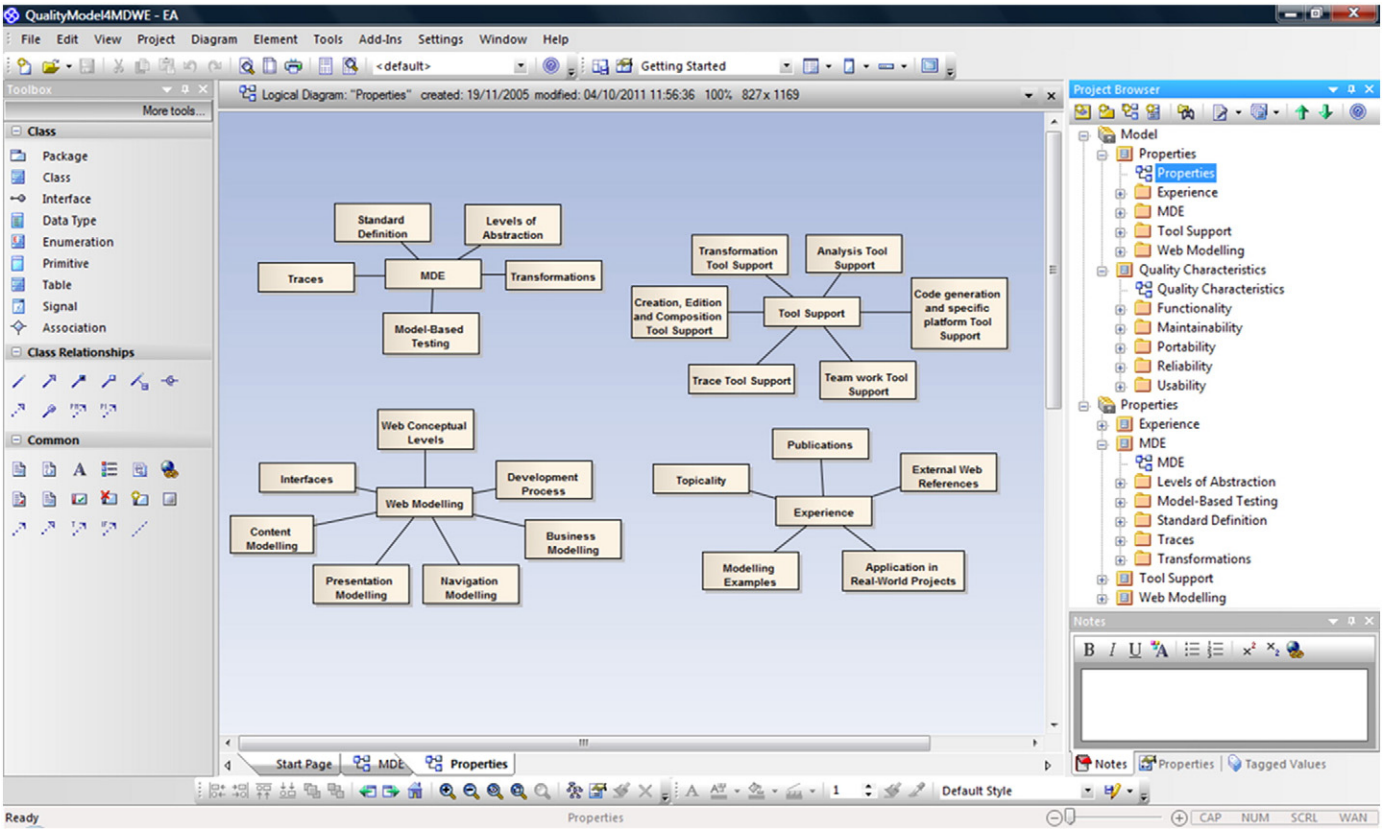

Fig. 10. The Quality Model is defined in Enterprise Architect.

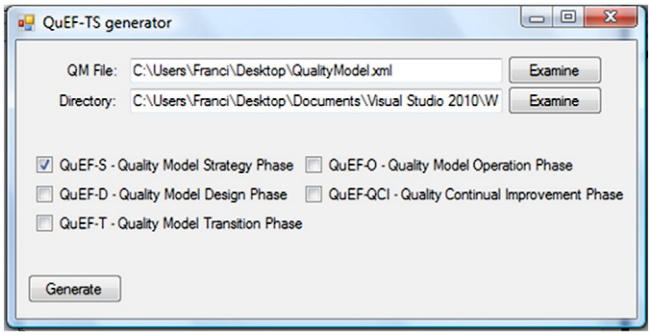

Fig. 11. The Web application QuEF generator tool.

cycle. So, in this future project QuEF-TS is going to be integrated to NDT-Suite in order to assure the quality management of the NDT-Suite environment.

NDT and NDT-Suite have acted in a high number of real projects in Spain. In fact, today they are applied in several projects carried out by different companies, either public or private and big or small. A high number of Web systems with different providers, users or development teams are working with them. Moreover, since 2004, an important project is being developed in liaison with the Andalusian Regional Cultural Ministry [3]. Another important project is being carried out in liaison with Emasesa [8], where the AQUA-WS project (AQUA-WebServices) is estimated to be finished in 2011. NDT was also widely applied in the e-health environment. In 2006, Alcer Foundation [1] used it within the system to manage patients' degree of handicap. As a future work, we are also working in the customization of QuEF-TS for the application of QuEF on other specific areas like capability and maturity or organizations that consider models like CMMI and standards like ISO/IEC 15504 and ISO/IEC 12207 [20]. This tool could make companies implement and evaluate their capability and maturity. Other specific future tools could be QuEF-TS for GreenIT, to analyze, control and evaluate the sustainability quality and reduce costs in companies.

7. Conclusion

This paper states the life cycle and the different processes to perform the quality management of MDWE approaches. QuEF (Quality Evaluation Framework) is a framework that was initially developed for quality analysis and evaluation on MDWE environments, but has been extended to cover all quality management process. With regard to the contributions obtained from this research, it can be concluded that establishing a good strategy is essential to reach a good quality level to approach users with effectiveness and efficiency. As this strategy is not an easy task, we have defined different processes and artifacts to support this phase.

Other important aspect is that a good quality management demands a Quality Model designed in terms of all goals or Properties defined in the strategic phase. Reaching the required model, all users' expectations will be guaranteed (Properties and Quality Characteristics be directly assured with these properties). In order to solve quality continuous changes in technology, it should be considered that the Quality Model can change, therefore, QuEF defines a Transition phase to clarify the protocols used, in case of changes that take place.

Finally, to manage quality, an Operation phase has been described together with the processes and artifacts to elaborate the quality improvement analysis, evaluation and plan of approaches. In the Operation phase, the Quality Model is specifically used to manage quality and our required Quality Model has to be compared with our current

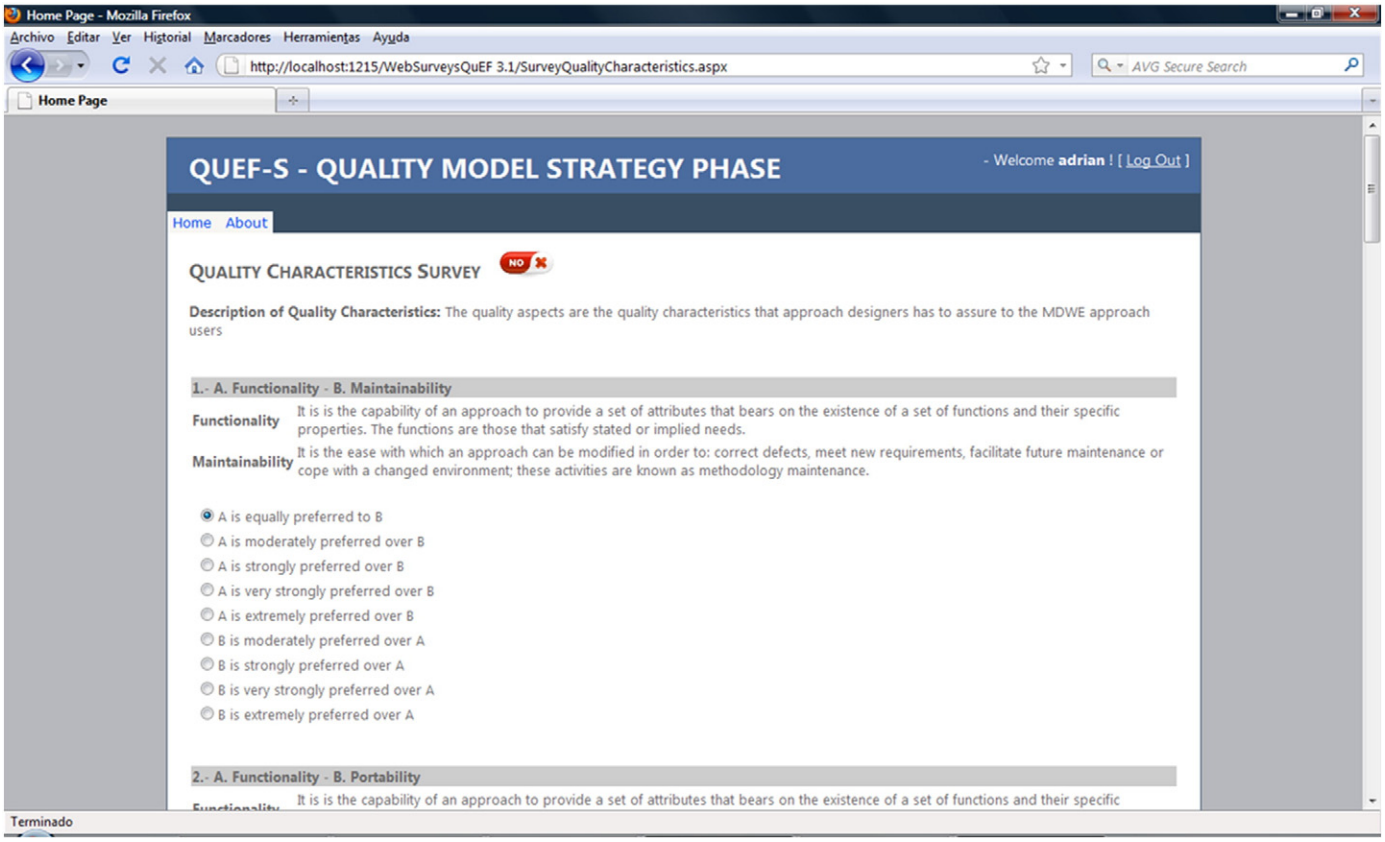

Fig. 12. Web application of QuEF-S with the AHP method.

state in order to know what can be developed to reach the required Quality Model. The quality management reveals we must learn how to improve the own quality management process by monitoring the process and, in terms of results, improving the Quality Model and the quality management process. To solve these aspects a quality continual improvement phase has also been defined in QuEF. The automation of all processes is currently being developed in QuEF-TS Suite, a set of tools that implement each phase within the Quality Model life cycle (Strategy, Design, Transition, Operation and Quality Continual Improvement) of QuEF. This Suite of tools will help to analyze, control, evaluate and improve the quality of MDWE approaches and other domains where QuEF has to be extended and applied.

Acknowledgments

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