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A CORE QUALITY MODEL FOR WEB APPLICATIONS

ROBERTO POLILLO

Department of Informatics, Systems and Communication
University of Milano Bicocca
roberto.polillo@unimib.it

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This paper discusses a methodological approach to define quality models (QM) for Web applications of any kind, including Web 2.0 sites. The approach stresses the practical use of a QM, not only in requirement definition and quality assessment, but also in quality improvement processes. The primary requirement for such QMs is *organization mapping*, which allows those who are in charge of quality management to easily identify the actors in the organization responsible for implementing or improving each specific quality characteristic. A *core* QM is proposed, collecting the main common characteristics of Web applications. This is not a complete QM, but requires adaptations to cope with specific application classes, organization and project needs and practical purposes. An example of such an adaptation is given for a simple class of Web sites. The core QM is compared with ISO/IEC 25010 QMs for software products and software-intensive computer systems.

Key words: quality, quality model, web, web engineering, web 2.0, ISO/IEC 25010

1 Introduction

According to ISO/IEC 25000:2005 [1], a *quality model* (QM) is a "defined set of characteristics, and of relationships between them, which provides a framework for specifying quality requirements and evaluating quality." This paper, which expands a previous work of the author [2], discusses how to define quality models for Web applications, and proposes a "core" QM to be used as a starting point for defining QMs for specific sub-classes of these systems.

By *Web application*, following [3], we mean *a software system based on technologies and standards of the World Wide Web Consortium that provides Web specific resources such as content and services through a user interface, the Web browser*. This very broad definition includes a wide class of systems, ranging from small, static Web sites to large, dynamic sites supporting interactive and transactional functions, such as Web portals, e-commerce, social media, and the like. Note however that, by mentioning "Web specific resources", we exclude all those systems in which a Web browser merely provides the interface to traditional software systems such as ERPs, CRMs, control systems and so on. By asking that access be through a Web browser, we also exclude applications requiring a software component to be downloaded from the Internet and installed on the specific access device.

Therefore the above definition, although very general, reasonably describes what users nowadays mean by *Web site*. In the following, the terms *Web site* and *Web application* will be used interchangeably.

QMs are very important in Web engineering. Having a good QM at hand can be extremely useful in all phases of a Web site life cycle. In the requirement specification phase, a QM helps in elicitating and in orderly describing all important facets of the site to be designed. Indeed, the table of contents of a good requirement specification could strictly mirror the QM, by assigning to each quality characteristic a specific section of the document (e.g., as in [4]). During the development process, a QM helps the project team to focus on all desired quality characteristics of the system to be implemented. In assessing the quality of an existing site, or different sites for comparison or benchmarking, a QM provides a structured approach for the evaluators, helping them to stay focused on the important issues. In the operation phase, a QM provides the site management with a "compass" to keep its evolution on the right track. Indeed, all Web sites are very dynamic; their evolution is constant and substantial: it is therefore essential to continuously monitor their quality, to avoid that each of the frequent changes disrupt an initially sound project. This is particularly important for social media applications, whose evolution is determined not only by the site management, but also by the (possibly large and uncontrollable) user community. A "suitable" QM is the indispensable supporting tool for all these monitoring actions.

But *how* do we choose the model? The selection of a QM is a delicate task because it may have a strong impact on the site's success, and is not a trivial task at all, for a number of reasons. The first reason is the extreme *variety* of Web applications. Even if they share aspects which clearly differentiate them from other software systems, it is not possible to define a single QM which fits every need. The second reason is the *lack of orthogonality*. We would like to describe the quality of Web applications in terms of a set of well defined, independent characteristics. But this is very difficult to achieve, because most quality attributes of a Web site interact in complex ways. The third reason is *subjectivity*. We would like to associate objective, quantitative *measures* to quality characteristics, as recommended by the mentioned ISO/IEC standards, but we soon realize that many of them are subjective, thus defining metrics is really a difficult task.

There is a lot of literature on Web quality, and a number of QMs for Web sites have been proposed over the years, approaching the problem from different perspectives, as we will briefly discuss in the next section. However, there seems to be no general consensus on their definition and characteristics. This paper will contribute to this debate, by suggesting an approach specifically oriented to the needs of the people responsible for the *management* of a Web site and by proposing a QM family which can be proficiently used by managers both in site development and operation. This is an extension and further elaboration of an earlier, simpler QM for Web 1.0 sites defined by the author in [5].

Section 2 will summarize related work on QMs for Web applications, including the ISO/IEC standards for software and computer systems' QMs. Section 3 will discuss the peculiarities of Web applications with respect to the software systems addressed by ISO/IEC standards. Section 4 will discuss *organization mapping*, the main requirement for the proposed QM. After having introduced the concept in Section 5, Section 6 will define a *core* QM for Web sites, and Section 7 will compare it to ISO models. Section 8 will show an example of how to adapt the core QM to a specific class of Web sites, and Section 9 will draw some conclusions.

2 Related Work

In the software engineering literature, software QMs have been discussed for many years. The ISO/IEC 9126, issued as an International Standard in 1991 [6] and revised in 2001 [7], is the best known reference in this area. Part 1 of this multi-part document provides a very general QM for software products' external and internal quality, based on a set of 6 *quality characteristics* (*Functionality*, *Reliability*, *Usability*, *Efficiency*, *Maintainability*, *Portability*) and 27 *sub-characteristics*. A second QM defines 4 characteristics for *Quality in use*, *i.e.* "the user view of the quality of the software product when it is used in a specific environment and a specific context of use".

This ISO standard has been recently replaced by ISO/IEC 25010 [8], which updates the previous QMs in various ways. It now addresses, more generally, "software products and software-intensive computer systems" of any kind, and defines two QMs. The *Product quality model* encompasses internal and external qualities of the system, and is composed of 8 characteristics and 31 sub-characteristics (Fig.1A).

A.ISO/IEC 25010 PRODUCT QUALITY MODEL

Characteristics	Sub-characteristics
Functional suitability	Functional completeness
	Functional correctness
	Functional appropriateness
Performance efficiency	Time behavious
	Resource utilization
	Capacity
Compatibility	Co-existence
	Interoperability
Usability	Appropriateness recognizability
	Learnability
	Operability
	User error protection
	User interface aesthetics
	Accessibility
Reliability	Maturity
	Availability
	Fault tolerance
	Recoverability
Security	Confidentiality
	Integrity
	Non-repudiation
	Accountability
	Authenticity
Maintainability	Modularity
	Reusability
	Analysability
	Modifiability
	Testability
Portability	Adaptability
	Installability
	Replaceability

B. ISO/IEC 25010 QUALITY IN USE MODEL

Characteristics	Sub-characteristics
Effectiveness	
Efficiency	
Satisfaction	Usefulness
	Trust
	Pleasure
	Comfort
Freedom from risk	Economic risk mitigation
	Health and safety risk mitigation
	Environmrntal risk mitigation
Context coverage	Context completeness
	Flexibility

C. ISO/IEC 25012 DATA QUALITY MODEL

Characteritics
Accuracy
Completeness
Consistency
Credibility
Currentness
Accessibility
Compliance
Confidentiality
Efficiency
Precision
Traceability
Understandability
Availability
Portability
Recoverability

Fig. 1. ISO/IEC 25010 and 25012 quality models

The *Quality in use model* is now composed of 5 characteristics and 9 sub-characteristics (Fig.1B). Note that quality in use is a superset of *Usability*, classically defined in ISO/IEC 9241-11 [9] as "the degree to which a product or system can be used by specified users to achieve specified goals with *effectiveness*, *efficiency* and *satisfaction* in a specified context of use." Indeed, it adds two characteristics to *Effectiveness*, *Efficiency* and *Satisfaction*: *Freedom from risk* and *Context coverage*, defined as the degree to which the product can also be used in contexts beyond those initially explicitly identified.

According to ISO documents, each QM sub-characteristic may be further hierarchically decomposed. Quality characteristics at any level should be *measurable*, either directly or indirectly, through a set of associated *measurable properties*. Fundamental in the ISO approach is the distinction between the *internal properties* of a product (which contribute to the *internal quality*), its *external properties* (which contribute to the *external quality*), and its *quality in use properties*, i.e. properties which can be measured when the product is in use in specific contexts. All these properties influence each other and the resulting quality in a complex way, as schematized in Fig.2.

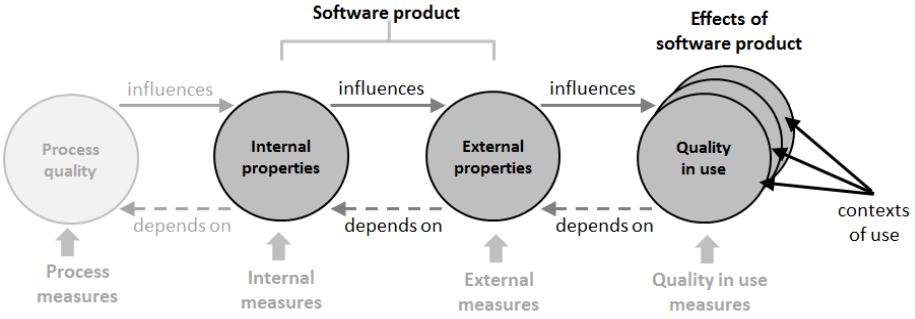

Fig. 2. Conceptual approach to quality, according to ISO/IEC 25010

ISO/IEC 25010 belongs to the SQuaRE series of International Standards (see [1]). In SQuaRE, ISO/IEC 25012 [10] defines a third QM, called *Data quality model*, for data retained in a structured format within a computer system, composed of 15 characteristics (Fig.1C).

A number of QMs have been proposed over the years for Web sites. Although – not surprisingly – some have been strongly influenced by the ISO/IEC models, a variety of proposals can be found in the literature. All of them stress the multi-dimensional aspect of Web quality, possibly defining a hierarchy of (hopefully measurable) characteristics. Among the various approaches, we can – very roughly - identify some different perspectives:

Software perspective. These models consider Web sites primarily as software systems, and use the ISO/IEC standards as a basis, with suitable additions to take into account the peculiar aspects of the Web. Some authors propose a three-dimensional quality model, with three orthogonal axes [11], [12]. One axis represents the ISO/IEC 9126 quality characteristics, while the second axis represents life-cycle processes (*development*, *exploitation* and *maintenance*). The third axis represents three basic Web aspects (*content*, *presentation*, *navigation* according to [11], or different *application domains*

according to [12]). More recently, Lew at el. [13] propose adding *information quality* as a main characteristic to the ISO/IEC 25010 Product Model. Herrera et al [14] propose to modify the ISO/IEC 25010 Quality in Use model to be more appropriate for Web portals[a]

Communication perspective. These models view a Web site primarily as a hypermedia system, therefore stressing the communication issues. An interesting example is the "rethoric" 2QCV3Q model [15], which uses Cicero's seven *loci* or *argumenta* described in his *De Inventione.* Seven top-level characteristics are identified: Quis? (Who? – *Identity*), Quid? (What? – *Content*), Cur? (Why? – *Services*), Ubi? (Where? – *Location*), Quando? (When? – *Management*), Quomodo? (How? – *Usability*), Quibus Auxilius (With what means and devices? – *Feasibility*). Communication is also the main concern in Maiocchi's QM [16], which considers a Web site as a particular example of hypertext.

Information Systems perspective. According to Yang et al. [17], a Web portal is essentially an Information System, consisting of digital information and an information delivery infrastructure. Accordingly, they separate information quality (determined by *Usefulness of content*, and *Adequacy of information*) from system quality (determined by *Usability*, *Accessibility* and *Interaction*).

Service perspective. Here Web sites are viewed as systems providing services to users, with the goal of meeting their needs (expressed or implied). PQM (Portal Quality Model) by Moraga et al. [18] uses the SERVQUAL quality-of-service model [19] as a basis, adapting it and adding *Data quality* to its five classic dimensions (*Tangible*, *Reliability*, *Responsiveness*, *Assurance* and *Empathy*). Guida [20] aims at a "strong semantic separation" of characteristics, and chooses 9: *Operativity*, *Security*, *Accessibility*, *Simplicity*, *Usability*, *Affectivity*, *Vitality*, *Usefulness*, *Efficacy*.

User perception perspective. Emphasizing the user point of view, Moustakis et al. [21] conducted an experimental survey in order to identify a set of quality features that describe user perceptions and preferences.

Automatic assessment perspective. Signore [22] correlates external quality to internal features, in view of a possible automation of the quality evaluation process, with automatic code analysis.

Development process perspective. In this case, the starting point is the Web site development process, with the idea that each phase in the process contributes specific aspects to the final overall quality (Polillo, [4],[5]).

Some authors have concentrated on *data quality*. For example, PDQM (Portal Data Quality Model) has been defined by systematically reviewing the existing literature on Web data quality characteristics, and then defining a QM comprising all "independent" characteristics considered by the researchers ([23],[24],[25],[26]). Subsequently, PDQM has been aligned to the SQuaRE data quality model, leading to SPDQM [27].

Table 1 compares the top-level characteristics of some of the above proposals. It can be easily seen that, while some models share a few common characteristics (typically, *Content* and *Usability*), the different perspectives lead to substantially different models. There seems to be no general consensus

[a] Both [13] and [14] consider a draft version of ISO/IEC 25010, subsequently modified in the final standard.

on what is the "best" model. Furthermore, no model includes characteristics specifically addressing Web 2.0 features.

Communication perspective		**Information system perspective**	**Service perspective**		**User perception perspective**	**Automatic quality assessment**	**Development process perspective**
Maiocchi 2000 [16]	**Mich et al. 2003 [15]**	**Yang et al. 2005 [17]**	**Moraga et al. 2004 [18]**	**Guida 2011 [20]**	**Moustaki et al. 2004 [21]**	**Signore 2005 [22]**	**Polillo 2004 [5]**
Goal	Identity	Usefulness of content	Tangible	Operativity	Relevance	Correctness	Architecture
Content	Content	Adequacy of information	Reliability	Security	Usefulness	Presentation	Communication
Structure	Services	Usability	Responsiveness	Accessibility	Reliability	Content	Functionality
Usability	Location	Accessibility	Assurance	Simplicity	Specialisation	Navigation	Content
Coherence	Management	Interaction	Empathy	Usability	Architecture	Interaction	Management
Manageability	Usability		Data quality	Affectivity	Navigability		Accessibility
	Feasibility			Vitality	Efficiency		Usability
				Usefulness	Layout		
				Efficacy	Animation		

Table 1. The top-level characteristics of some Web sites QMs

3 Why ISO Models are not Suitable for Web Sites

The ISO/IEC standards provide a very general conceptual framework for defining QMs for complex systems with a substantial software component. The basic approach in defining a hierarchy of quality *characteristics*, and *measurable properties* which can be aggregated to obtain quantitative measures of characteristics, provides a sound foundation for defining *any* QM, in *any* domain. Moreover, the ISO model is the result of three decades of discussions about the basic quality dimensions of software-based systems. Its categorization and terminology can be discussed and - in a few cases - may also be considered somehow obscure, but certainly cannot be ignored in any approach to quality in software engineering.

On the other hand, it should be clearly understood that the ISO documents only provide a *conceptual framework* and not a ready-to-use QM. To be of practical use this framework must be tailored to the specific [class of] system[s] under consideration. This may not be a simple task, especially when these systems do not fit well with the systems considered in classical software engineering, such as ERP, command & control and embedded systems. This is the case of Web sites, which possess a number of peculiarities that greatly differentiate them from the above systems, i.e.:

Information content. In the large majority of cases, unstructured information content prevails on structured data. Emphasis is on user navigation, not on data management and computation. Therefore, a fundamental dimension of quality relates to *information architecture* [29]. Information architects are more and more involved in large Web sites, together with *content editors*, who create and manage information content. Information-rich sites may employ a large editing staff, with an organization in some ways similar to that of traditional magazines, something never seen in traditional software systems.

Communication and branding. In most cases, Web sites can be considered machines whose main purpose is communication, rather than computing and data management. This is also true for e-commerce or other sites offering transactional services. Web sites address a global audience, in a strongly competitive, "open" environment. There is no user lock-in: competition is only a few clicks away, so visitors' loyalty must be won on a day-by-day basis. User attention span can be extremely short, so his/her interest must be captured in brief time-intervals. Thus big efforts are required for communication and branding, and professionals typically not seen in traditional software projects are usually involved (visual designers, art directors, communication and marketing people).

Community support and user engagement. Social media sites have acquired an extremely large user base on the Web. While traditional sites typically supported one-way communication (from the site publisher to the user), communication in "social" sites is many-to-many: users interact to socialize, share ideas, opinions, and multimedia content of many types. Sites like Facebook, Twitter, Flickr, YouTube, and the like are a complex mix of user created content, interaction and socialization. This is also increasingly true for e-commerce applications, where product selection and buying is only part of the user experience, which includes social activities such as rating products, writing comments, and interacting with other users with similar interests.

Continuous evolution. Web sites are living organisms. Their contents are constantly updated, and even their information architecture changes frequently. This is true for *any* site, not only for information portals. Visitors of a site often expect its contents to be updated practically in real time. Site managers must strive hard to comply with these expectations, just to keep their site reputation. Interactive services and the user interface are frequently modified and improved. According to the *perpetual-ß* concept, the software behind these services is continuously modified to better serve user needs. These – in turn – change as new possibilities are discovered, in a constant *co-evolution* of usage patterns and system functions. In a word, managing the evolution of a Web site sets pressing requirements to site administrators, and this should be taken into account seriously in any QM designed for these systems.

Virtualization. Present Web applications are often composed of information and computing resources distributed over the Internet, developed, maintained and operated by independent parties. We are facing a paradigm shift, from a traditional design-implement-deliver-maintain cycle to perpetual, "organic" evolution steered by a multiplicity of independent actors. Even the infrastructures on which applications run may be distributed, and can dynamically change, both in physical and logical structure. Availability and stability of these resources is a critical issue for Web application quality.

The ISO quality characteristics shown in Fig.1 seem remotely distant from this scenario. Reasoning in terms of *Functional suitability*, *Performance efficiency*, *Compatibility*, *Usability*, *Reliability*, *Security*, *Maintainability*, *Portability* as the main (i.e. top-level) and only quality dimensions does not capture the nature of the present day Web applications. Indeed, the overall quality of these systems does not come only from the technical characteristics and proper design of the software engines involved in their operations: there is a lot more. Quality of Web applications stems from the coordinated work of many heterogeneous components and professionals from many different disciplines and practices.

Therefore, starting from the ISO model and changing it piecemeal, adding or modifying a few [sub-] characteristics to take into account the above aspects, does not seem the right way to proceed. We prefer to start anew, defining first the main requirements for a Web application QM, and seeing where they lead. This will be done in the next sections.

4 Organization Mapping as the Primary Goal for Web Site Quality Models

The ISO definition of a QM, quoted in the Introduction, emphasizes the practical purposes of any QM, which is not viewed as a mere categorization of the quality attributes of a system, but rather as a *practical tool*, to steer design ("specifying requirements") and evaluation processes ("evaluating quality"). To these goals, we add a third requirement that seems equally important, given the strongly evolutionary nature of Web sites: QMs should steer *improvement processes*. Web site quality, so to speak, must be "kept on track" along the entire life cycle, and the QM must help to achieve this goal as simply as possible. This is particularly important for Web 2.0 sites, whose quality is the outcome of many, heterogeneous actors and forces.

We will call *influencers* all those elements – of any nature – which may affect a quality characteristic, either improving or worsening it. A QM facilitating improvement action would then allow to easily identify all the relevant influencers of its [sub-] characteristics. In other words, we require that there be as simple as possible a mapping (ideally, one-to-one) between quality [sub-] characteristics and their influencers. *In our model, the influencers of a certain quality characteristic will be, simply, the specific professional roles responsible for implementing and improving it, which we call "quality actors".* More precisely, by [*quality*] *actor* we mean any Web site stakeholder with an active role in creating/maintaining some quality characteristic, such as Web designers, visual designers, content editors, software developers. Note that actors are *roles*, and not specific individuals.

Therefore, our goal is to identify quality characteristics with a relation as simple as possible with the different actors involved in the management of our Web site. In this way, responsibility for different quality characteristics can be easily allocated and tracked, being always clear who is responsible for what. We call this attribute of a QM *organization mapping*. In Fig. 3, QM has a better mapping than QM' because responsibilities can be better isolated and quality characteristics improvements are easier to manage. Note that, in any case, even in the "good" QM at the left, there may be characteristics (e.g. C5) influenced by more than one actor.

Good organization mapping is a crucial requirement of a Web site QM because there are many actors involved in Web projects, with extremely varied skills. In a multi-disciplinary team, different cultures, practices and value systems may sometimes create interaction difficulties, as anybody involved in medium to large Web site development or operations may have experienced. To avoid these problems, it is necessary that the teams be correctly organized, with a clear allocation of responsibilities on the different system components and associated quality characteristics.

Of course, the goodness of the mapping does not depend only on the QM, but also on the actual organization which develops and manages the site. A chaotic organization will nullify the practical utility of even the best QM. Nevertheless, after fifteen years of Web engineering experiences, the roles and functions of the different actors involved in Web projects are nowadays sufficiently well

understood. This allows defining good QMs, which are reasonably applicable to most Web organizations.

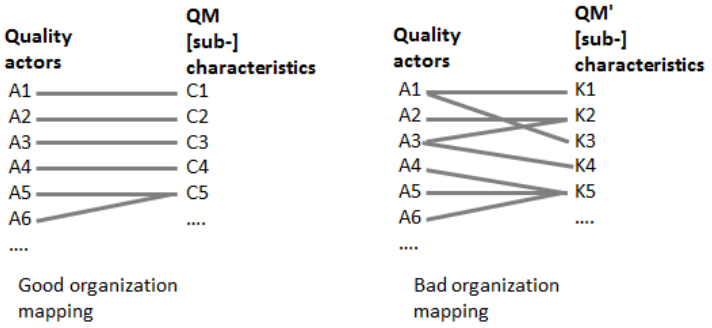

Fig. 3. Different organization mapping complexity

The quality actors that will be considered in the construction of the proposed QM are shown in Table 2. The actor names may change from organization to organization. Note that they are identified by their activities and are not related to any specific organizational structure; the left column is merely indicative: it is only intended to suggest typical departments in a large Web organization.

Department	Quality actors	Typical responsabilities
Marketing	*Web marketing*	User intelligence (Web analytics), search engine marketing (SEM), search engine optimization (SEO), social media optimization (SMO), direct marketing, [advertising management],…
Product design	*Web designer*	Wireframe design, information architecture, site navigation structure
	Visual designer	Art direction, brand identity, graphic design, style guide definition, …
	Usability professional	Usability and accessibility guidelines, usability and accessibility testing
Editorial	*Content editor*	Editing of site information; application data base population
	Community manager	Building, growing and managing on-line user communities
Information Technology	*Software architect*	Application platform design and evaluation
	Function designer	Analysis and design of interactive functions
	Software developer	Software implementation, software testing and maintenance
	DB manager	Implementatio and maintenance of application data base
Data centre	*Server administrator*	Configuring, maintaining, optimizing and monitoring the server equipments. Includes capacity planning, backup management, …
	Network administrator	Configuring, maintaining, optimizing and monitoring the network equipment

Table 2. Typical quality actors of a Web application

Note that different roles may not necessarily be played by different people. For small sites, a single person may even impersonate all of the above roles, with the possible exception of *Server administrator* and *Network administrator*, where these functions are outsourced to a hosting service, as often happens.

In a typical Web 1.0 site, end users have a passive role, so they are not considered actors because they do not contribute to its quality: they only navigate the site and possibly interact with it in

predefined transactions (as in e-commerce). In Web 2.0 sites the situation is completely different. The users can typically create and upload content, embed content from other sites, tag, comment or rate content created by other users and share it with their "friends", and interact with them in many ways. This is true not only for large social media sites such as Facebook, Twitter, YouTube and Flickr, but also for an increasingly large number of small sites, due to the many available tools which allow to easily implement these functions (plugin, widget, …).

Therefore, in Web 2.0 sites, *the users themselves must be considered quality actors* and critical ones indeed, since they can have a big impact on the global functioning of the site. Even a site perfectly designed and implemented can fail as a consequence of "bad" (or unexpected) user behaviour. Thus, users must be continuously monitored and in some way controlled or stimulated, requiring the presence of new roles (denoted as *community management* in Table 2), and in some cases the evolutionary modification of specific site functions, intended – so to speak – to improve the user-generated quality. A typical example was the evolution of the community content moderation mechanisms in Yahoo!Answer, where they had to oppose the unexpected volume of user spam and troll activity, that seriously risked crashing the site [30].

5 What is a "Core" Quality Model and Why it is Needed

Web applications may differ in size, in technology, in purpose, in complexity, in relationship with the users (from purely informative to interactive to social), and in impact on their activities (from critical to non-critical). Therefore it is not realistic to expect that it would be possible to define a single QM valid for any purpose in any context: there is no universal QM for Web applications. On the other hand, we intuitively feel that, despite this variety, Web applications show many common features, as discussed in Section 3. Therefore, rather than developing a taxonomy of Web applications and defining a specific – and different – QM for each element of the taxonomy, we aim at the definition of – at least – a common set of top-level characteristics and, for each of them, a number of typical sub-characteristics. We call this common set a *core* QM.

A core QM should somehow capture the fundamental quality aspects of *all* Web applications, but would require some adaptations to be usable for the different classes of sites under consideration. As suggested in [31], building a QM starting from a core model and adapting it to specific domains and purposes may be the best practical solution in most cases. Indeed, "fixed" QMs may be applicable only to a limited number of situations. At the other extreme, building a QM from scratch every time for a specific class of applications requires intensive expert efforts. Even the ISO/IEC 25010 itself allows for some adaptations, explicitly stating that "the set of sub-characteristics associated with a characteristic have been selected to be representative of typical concerns without necessarily being exhaustive" ([8], pag.2).

In defining a core QM, our goal is to identify a stable nucleus of top-level characteristics, which stays essentially the same in every class of Web applications. These are the "foundations" of the QM, and therefore should be easily recognizable by anybody as the basic dimensions of the quality of any Web site. They would constitute the main sections of the requirement specifications of any Web development project and the main aspects to be considered in *any* assessment or improvement project. QM adaptation should then be mainly localized in the lower levels of the hierarchy of characteristics, to cope with specific applications, site complexity and purposes. This will be mostly done by adding or

dropping [sub-] characteristics or defining further levels in the hierarchy. We will add a [sub-] characteristic when we need to emphasize a particular aspect not taken into account in the core, or we split a [sub-] characteristic in two or more, when we want a finer "resolution" to our model. On the contrary, we may also merge two or more [sub-] characteristics when we want to simplify our model, and use a lower resolution. Also, we may drop a [sub-] characteristic when it is not needed in the particular context.

Fig.4 illustrates this concept. The core [sub-] characteristics are represented by continuous line boxes. The adapted QM is shadowed. [Sub-] characteristics represented by dotted boxes are not part of the core, and have been added in the adaptation. Thus, [sub-] characteristics represented by white boxes are part of the core, but have been dropped. Note that two core sub-characteristics have been merged in the adaptation.

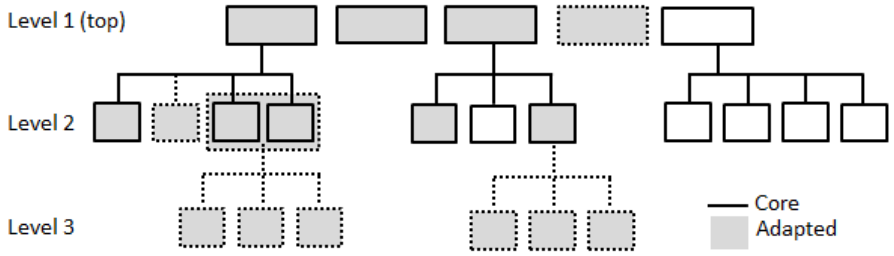

Fig.4. Adaptation of a core QM

Adaptation of a core QM may entail a multi-step process (Fig.5). Starting from the core QM for Web sites, we first adapt it to a specific class of Web applications, producing a QM for this class. This new QM may then be further tailored to different site *profiles*. Then we might adapt the result for use within a specific organization, and finally for a specific project within this organization.

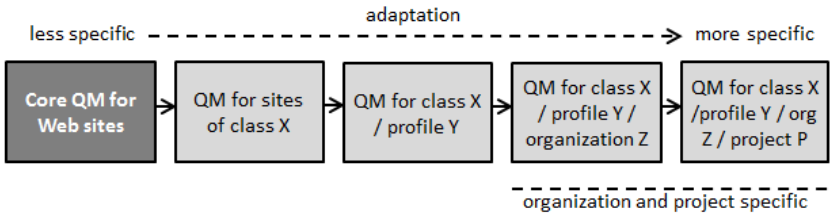

Fig.5. Multi-step adaptation of the core QM

To clarify the concept with an elementary example, let's consider the class of hotel sites. We first adapt the core QM to obtain a QM for the general needs of hotel sites (HQM). Then we may consider different hotel types, such as holiday resorts, business hotels, family hotels, bed and breakfasts (B&B). To cope with these different types, we can simply assign a different weight to some [sub-] characteristics of HQM (a zero weight would of course mean that it is not needed at all). For example, while HQM would allow us to consider the quality of the *Online room reservation* functions, this sub-

characteristic would be assigned a low weight in the B&B profile. Indeed, it may be acceptable that small B&B sites do not offer such a function, which should instead be mandatory for business hotels. A further step would be to adapt HQM to a specific organization (e.g. a Web agency specialized in designing hotel sites), to take into account its specific terminology, practices, technology and organization. Finally, HQM might be further adapted to the specific goals and requirements of the project in which it is used. For example, when using it to compare a hotel site with the sites of its competitors, we usually do not have access to information about their internal software structure and their data centres. Thus, we drop all [sub-] characteristics related to these issues.

6 A Core Quality Model for Web Sites

6.1 Defining the Top-Level Characteristics

According to the organization mapping requirement discussed in Section 4, we start by defining a general model of a Web application, showing its main logical components, its main quality actors and the relationship between actors and components. The model consists of a set of nested logical components, as shown in Fig.6.

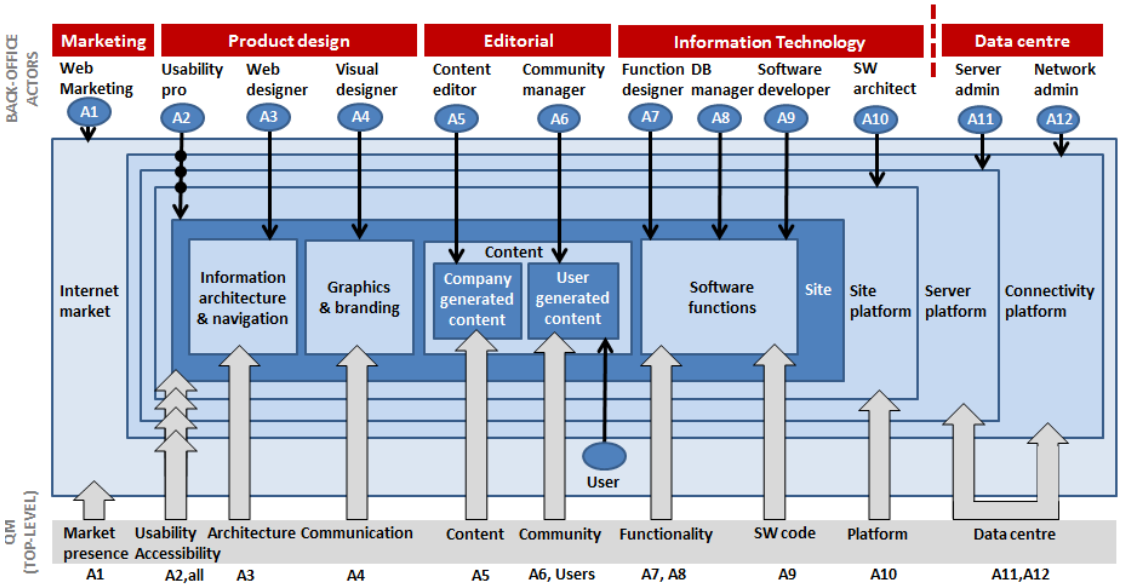

Fig. 6. A general model of Web site components and quality actors, and the resulting core QM

Referring to Fig.6, the *Site* component is decomposed into five logical sub-components: *Information architecture & navigation*, *Graphics & branding*, *Company-generated content*, *User-generated content (for Web 2.0 sites)* and *Software functions*. This decomposition is essential for our purposes because these sub-components are managed by different quality actors. The *Site* component,

in turn, is nested within a *Site platform*, representing the middleware components used in the specific installation (typically, a Content Management System or an application server, a DBMS and so on). The *Site platform* is nested within a *Server platform* component, representing the server infrastructure (hardware and software) hosting the site, which is in turn nested within a *Connectivity platform*, representing the network infrastructure. Finally, everything is nested within a logical component, generically called *Internet market*, representing the Internet and its users as a whole.

In Fig.6 each logical component is associated to its (prevailing) quality actor, with reference to Table 2. Quality actors are represented as ovals and are all members of the back-office organization[b], except *User(s)* (which in Web 2.0 sites must also be considered quality actors), represented within the *Internet market* component. For example, the *Company generated content* component is under the responsibility of *Content editor(s)*, while for *Software functions* we have identified three different actors: *Function designer(s)*, *DB manager(s)* and *Software developer(s*). Note that *Usability professional(s)* are graphically associated to all components (with the exclusion of *Internet market*), to indicate that usability and accessibility are the results of the harmonic cooperation of *all* components.

The bottom line in Fig.6 shows the 11 top-level characteristics of the proposed core QM: *Market presence*, *Usability*, *Accessibility*, *Architecture*, *Communication*, *Content*, *Community*, *Functionality*, *Software code*, *Platform*, *Data centre*. Note that in most cases there is a one-to-one relationship between characteristics and [main] actors, as shown in the schema: so the QM has good organization mapping, as required.

Market presence is a characteristic not usually seen in traditional QMs. It is the result of all the activities performed to attract visitors to the site or, more generally, to increase its presence in a specific market. They include Web analytics and any action intended to promote the site visibility: search engine marketing (SEM) and optimization (SEO), promotion of the site in the social media, and so on. These activities are critical to the success of the site, and constitute a significant and continuous effort of the team which manages the site operations, especially in Web 2.0 contexts. Therefore they must be considered in our core QM.

Usability is considered here as a synonym of *Quality in use*, as defined by the ISO documents (Fig.1B). *Accessibility* is intended in its broadest sense, as the "degree to which a system can be used by people with the widest range of characteristics and capabilities to achieve a specified goal in a specified context of use" ([8], pag.13). To keep the model simple, we have also assigned responsibility on coordinating *Accessibility* issues to the *Usability professional*, without introducing another specific quality actor.

Architecture refers to information architecture [29], including site navigation facilities, and has nothing to do with the internal software architecture, which is considered in other characteristics. Its associated actor is therefore the *Web designer* (or *Information architect*, as he/she may sometimes be called).

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[b] We do not make any hypothesis on the specific organization structure; therefore the names of the departments shown on top of Fig.6 are purely indicative. Of course, in specific situations some roles may be outsourced, as is often the case with the *Data centre*. This is suggested by the dotted vertical line on top of Fig.6.

Communication refers to all aspects of site communication, typically prescribed in the site Style Guide defining branding, graphics, typography, multimedia usage, accessibility constraints and user experience issues. The associated actors are called *visual designers* because in small/medium sites this responsibility is usually assigned to them. Note, however, that larger sites may have a more complex organization, involving art directors, communication staff, and the like.

Content collects all the sub-characteristics related to the company-generated content of the site (structured data and unstructured information), assigned to the responsibility of the *Content editor(s)*.

Community is mostly used for Web 2.0 sites, and considers user-generated content: the associated actors are site *Users* and the site *Community manager(s)*.

Functionality has the same meaning of the ISO *Functional suitability* [8], i.e. "the degree to which the site provides functions that meet stated and implied needs when used under specified conditions". Note that *Functionality* does not include navigation functions (menus, breadcrumbs, and so on), which are considered in *Architecture*, being under the responsibility of different quality actors (i.e. the *Web designer*).

Software code refers to the technical quality of the software specifically developed for the site (therefore excluding platform components acquired on the market), whose quality actors are the *Software developers*. This characteristic will be dropped when the internal quality of the site is not considered.

Platform considers the middleware used by the site (CMS, application servers, DBMS, and similar components), and is under the responsibility of the *Software architect.* Its sub-characteristics are both static (i.e.: is the selected software architecture adequate?) and dynamic (i.e.: are their performances adequate?).

Data centre considers both the servers hosting the site (hardware and software) and the network infrastructure, both from the static and dynamic point of view. The involved quality actors are, respectively, the *System administrator* and the *Network administrator*. Note that *Data centre* and *Platform* have been kept separate to comply with the organization mapping requirement, because server and network administration are often outsourced, while the platform may be managed internally. In this case, *System administrator* and *Network administrator* may not be directly visible to the customer organization and may be interfaced by an *Account manager* of the outsourcer, which would then be considered a quality actor.

The names chosen for the top-level characteristics are very mundane and very different from the usual quality terminology. This has been done on purpose, to facilitate comprehension of the QM. In this way, a site evaluation profile can be easily communicated to *all* site stakeholders, e.g. with a radar diagram as in Fig.7, in which each top-level characteristic has been assigned a "grade" within a certain numeric range. This immediately shows the site strengths (in the example, a good platform and sound information architecture) and weaknesses (a low market presence and unsatisfactory community management, and a data centre which is not working properly).

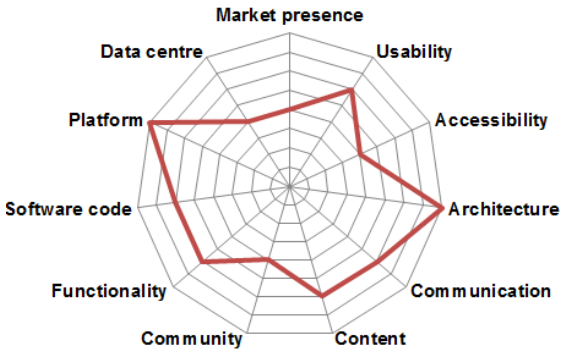

Fig. 7: The evaluation profile of a Web site

6.2. Defining the Sub-Characteristics

Once the top-level framework is defined in compliance with the organization mapping requirement, the selection of sub-characteristics to be included in the core QM is less critical and can be performed in different ways. On one side, we would like to facilitate the adaptation of the core QM to specific classes of applications by providing a comprehensive, ready to use set of sub-characteristics. On the other side, we need to allow good flexibility in the adaptation process, and keep the core QM as general and simple as possible. Table 3 shows our selection, based on 42 second-level characteristics.

CORE QUALITY MODEL FOR WEB APPLICATIONS		
Characteristics	**Sub-characteristics**	**Definition**
Market presence	Visibility	Degree to which the site is visible, e.g. to search engines and to other relevant referrer sites such as directories, social media and partner sites
	User engagement	Degree to which users are actively and recurrently involved in the site
	Conversion rate	The percentage of users that, upon coming to the site, perform the task that the site invites them to do (e.g. purchasing or downloading a product, or clicking on a banner ad)
	Conversion count	Number of specified tasks performed by the users on the site in a specified unit of time (e.g., purchasing or downloading a product, or clicking on a banner ad)
Architecture	Information architecture	Degree to which the site information architecture is appropriate to the accomplishment of specified tasks and objectives.
	Navigation	Degree to which the site navigation tools (menus, breadcrumbs, site maps, ,,,) are appropriate to the accomplishment of specified tasks and objectives
Communication	Home page	Visual impact and quality of the site home page
	Brand identity	Degree to which the site is coherent with and reinforces the brand identity of the organization
	Visual design	Degree to which the site visual design is aesthetically pleasant and appropriate for the site purposes, intended users and contexts of use
	Typography	Degree to which site typography (character fonts, style, size, colour, spacing, alignment, legibility, …) is aesthetically pleasant and appropriate for the site purposes, intended users and contexts of use
Functionality	Functional adequacy*	Degree to which the site interactive functionalities (excluding back-office functionalities) are appropriate to the accomplishment of all the specified tasks and objectives by all their intended users
	Back-office functions adequacy	Degree to which the administration functionalities are appropriate to the (back-office) management of the site

	Functional correctness*	Degree to which the site functionalities provide the correct results with the needed degree of precision
	Security*	Degree to which the site protects information and data (stored or in transmission) so that persons or other systems have the degree of access appropriate to their types and levels of authorization
Content	Information quality*	Degree to which the characteristics of the site (unstructured) content satisfies stated and implied needs when used under specified conditions
	Data quality*	Degree to which the characteristics of the site (structured) data satisfy stated and implied needs when used under specified conditions
	Content currentness*	Degree to which the site content (structured data and unstructured information) has attributes that are of the right age in a specific context of use
	Internationalization and localization	Degree to which the site content is appropriately adapted to different languages and regional differences of its target audience
	Style guide compliance	Degree to which the site content conforms to the editing rules specified in the site Style Guide (including rules – if any - to guarantee accessibility of content to user with disabilities).
Community	User relations	Degree to which appropriate and timely actions are taken to answer user inquiries and suggestions posted through the site
	Community management	Degree to which appropriate actions are taken to build, grow and manage the online community of active site users
Usability	Effectiveness*	Accuracy and completeness with which users achieve specified goals
	Efficiency*	Resources expended in relation to the accuracy and completeness with which users achieve goals
	Satisfaction*	Degree to which user needs are satisfied when the site is used in a specified context of use
	Freedom from risk*	Degree to which the site mitigates the potential risk to economic status, human life, health or the environment
	Context coverage*	Degree to which the site can be used with effectiveness, efficiency, freedom from risk and satisfaction in both specified contexts of use and in contexts beyond those initially explicitly identified
Accessibility	Compatibility	Degree to which the site can be correctly operated from a specified variety of access devices (mobiles, tablets, laptops, …), browsers and client operating systems
	Bandwidth requirements	Bandwidth required to use the site with effectiveness, efficiency, freedom from risk and satisfaction in specified contexts
	Users with disabilities	Degree to which the site can be used by users with specified disabilities to achieve specified goals with effectiveness, efficiency, freedom from risk and satisfaction in specified contexts of use
Software code	[Sw code] functional suitability*	Degree to which the software code implemented for the specific site provides functions that meet stated and implied needs when used under specified conditions
	[Sw code] performance efficiency*	Degree to which the software code implemented for the specific site meets performance requirements relative to the amount of resources used under stated conditions (time behaviour, resource utilization and capacity)
	[Sw code] maintainability*	Degree of effectiveness and efficiency with which the software code implemented for the specific site can be modified by the intended maintainers (this includes installation of updates and upgrades)
	[Sw code] reliability*	Degree to which the software code implemented for the specific site performs specified functions under specified conditions for a specified period of time
	[Sw code] compatibility*	Degree to which the software code implemented for the specific site can exchange information with other products, systems or components and/or perform its required functions, while sharing the same hardware or software environment. This includes compliance with standards.
Platform	[Platform] functional suitability*	Degree to which the site platform (middleware software components) provides functions that meet stated and implied needs when used under specified conditions

	[Platform] performance efficiency*	Degree to which the site platform meets performance requirements relative to the amount of resources used under stated conditions (time behaviour, resource utilization and capacity)
	[Platform] maintainability*	Degree of effectiveness and efficiency with which the platform can be modified by the intended maintainers (this includes installation of updates and upgrades)
	[Platform] reliability*	Degree to which the site platform performs specified functions under specified conditions for a specified period of time
	[Platform] compatibility*	Degree to which the site platform can exchange information with other products, systems or components and/or perform its required functions, while sharing the same hardware or software environment
Data centre	Data centre adequacy	Degree to which the data centre supports the execution of all the required operations
	Data centre performance*	Degree to which the data centre meets performance requirements (relative to time behaviour, resource utilization and capacity)
	Availability*	Degree to the which the data centre services are operational and accessible when required for use

Table 3. The core QM for Web applications

Whenever convenient, for some sub-characteristics (indicated with a * in Table 3) we have maintained (or adapted to the context) the terminology and definitions of ISO/IEC 25010 and ISO/IEC 25012.

For *Usability*, we used the sub-characteristics of the ISO/IEC 95010 model for *Quality in use*. Indeed, the ISO/IEC 25010 specifies that "usability can either be specified or measured as a product quality characteristic in terms of its sub-characteristics, or specified or measured directly by measures that are a subset of quality in use." We prefer the second option, closer to the "classical" definition of usability [9].

6.3. Evaluating the Sub-Characteristics

When using a QM to evaluate a Web application, we should be able to grade every [sub-] characteristic with a numeric value within a certain range. This process may be left entirely to the discretion of an expert evaluator, but in most cases it is much better to give him/her a proven set of guidelines to follow. The simplest and most practical way is to define a suitable questionnaire, to be answered by the evaluator. The questions should be answered by direct site inspection *and* by conducting user tests, as deemed appropriate in the particular situation.

Since we wish to associate a numerical grade to the sub-characteristics, all questions should have a numerical answer. Therefore we formulate each question as a Likert-scale item, i.e. a *statement* which the respondent is asked to evaluate, expressing his/her level of agreement or disagreement. To the usual 5 response levels, we prefer a "forced choice" 4-level scale, in which the neutral option is unavailable. In this way, the evaluator is obliged to continue the analysis until a non-neutral choice is made:

1: Strongly disagree 2: Disagree 3: Agree 4: Strongly agree

As we shall see in the final example (Section 8), in the case of Web applications most questions would require a purely qualitative analysis, so the grading would still be in some way discretionary and dependent on the experience of the evaluator. This is usually acceptable, since we are mainly interested in finding the strengths and weaknesses of our site, to be able to improve it or to compare it with its competitors, and not in an "objective" measure of quality – whatever it may mean. However, for a (usually limited) number of sub-characteristics, the evaluation cannot be done in absolute term, but would depend on the fulfilment of stated site requirements, or on the level of achievement of project-dependent goals. In these cases, the evaluator should be provided with suitable indications, such as, for example:

Sub-characteristic:	Market presence/User engagement
Statement to evaluate:	The number of unique site visitors is satisfactory
Stated goal/requirement:	The number of unique site visitors should grow 30% every 6 months

When a more prescriptive approach is desired, the evaluator may be provided with formal "grading rules" such as:

Grading rule:	Let be N the number of unique site visitors in the last six months and N_{-1} the number of unique site visitors in the previous six month period. Then:
	If N > =N_{-1} * 1,4 then 4:Strongly agree else
	If N >= N_{-1} * 1,3 then 3:Agree else
	If N > =N_{-1} then 2:Disagree else 1:Strongly agree

The questionnaires associated to the core QM would be rather "coarse-grained": they would only contain general statements, meaningful for any kind of Web site and, of course, would not contain any stated goal or requirements for specific projects. During the adaptation process of the core QM, the questionnaires would require modifications and additions, until a specific QM is produced. At the end of the adaptation, the questionnaires will only be associated with the leaves of the QM tree of characteristics.

Characteristic	P	G	Sub-characteristic	P	G	Statement	1 2 3 4	Notes
Communication	1	**2,7**	Brand identity	1	**3**	…	…	…
			Visual design	1	**2**	…	…	…
			Typography	1	**3**	All the character fonts used are very readable on screen monitors	□ □ X □	
						The site does not use too many different fonts	□ □ □ X	
						The different character fonts are used consistently and harmoniously in all the pages	□ □ X □	
						There is always a good contrast between text and background colors	□ □ □ X	
						Long blocks of text always use sans-serif fonts	□ □ □ X	
						Long blocks of text are never in italics or all-caps style	□ □ □ X	
						Paragraph spacing and length is consistent in all the pages and makes for easy reading	X □ □ □	Paragraphs too long !

Table 4. Fragment of an evaluation spreadsheet

By averaging all the answers to the questionnaire associated with a given sub-characteristic, we obtain the evaluation. The same would be done going up along the hierarchy: at the end of the evaluation, all the top-level characteristics will have a grade in the 1-4 range. The evaluation may be supported by a simple spreadsheet, like the example in Table 4, relative to the *Communication* characteristic. Here the grades of the [sub-] characteristics (G columns) are computed by taking the averages from the bottom up (i.e. from right to left). The evaluator should be free to correct the computed grades, to better reflect his/her overall judgement. For example, in Table 4, the computed grade for *Typography* (3,3) has been manually corrected to 3 because the evaluator considered that the excessive paragraph length should weigh even less than 1:Completely disagree.

During the evaluation process, the evaluator would of course record the detailed motivations for unsatisfactory grades (column "Notes" in the spreadsheet). These motivations would be subsequently analysed to suggest the proper improvement actions and their priority levels.

As discussed in Section 5, for each class of Web applications we may need to define different profiles, each associated with a specific QM (Fig.5). We may use a unique evaluation spreadsheet for all the profiles of the same class, by adding a "Profile definition" column (named "P" in Table 4) to every level of [sub-] characteristics. The value of P would be a number between 0 (when the [sub-] characteristic is not included in the profile) and 1 (when it is included). Intermediate values, if desired, would "weigh" the relevance of the characteristic in the profile.

7 Comparison with ISO/IEC 25010

A comparison between ISO/IEC 25010 and the core QM is shown in Fig. 8, where only the top-level characteristics of both models are listed.

Top-level characteristics *Market presence*, *Architecture*, *Communication*, *Content* and *Community* and their sub-characteristics, which differentiate Web sites from traditional software systems, are not considered in ISO/IEC 25010 models, and the same for *Data centre*. Structured data – which are part of *Content* in our model - are considered in ISO/IEC 25012, but not in ISO/IEC 25010.

Functionality is included in both models (though with slightly different names). In the core QM, *Security* (a first level characteristic in ISO/IEC 25010) is a sub-characteristic of *Functionality* in the core QM (as it was in ISO/IEC 9126:2001), but it might be promoted to top-level in specific adaptations to give it particular relevance whenever convenient (e.g. in Web banking). Note that in the core QM *Functional suitability* is also a sub-characteristic of *Software code* and *Platform* for their respective functions.

Usability is included in both models. Our model uses the characteristics of the ISO Quality in use model, which we feel are easier to understand and to evaluate in usability tests.

In ISO, *Accessibility* is a second level characteristic of *Usability*. We promote it to level 1, given its importance in Web applications.

Compatibility, *Performance efficiency*, *Reliability*, *Maintainability* and *Portability* are given great emphasis in ISO/IEC 25010, but they do not need a top-level position in our model. Web applications are single-copy systems, so *Portability* is rarely needed. The other characteristics are considered separately, in the core QM, as sub-characteristics *of Software code* and *Platform*. In our model

Compatibility is also an important sub-characteristic of *Accessibility* to evaluate site compatibility with the different user access devices: mobiles, tablets, laptops, different browsers and OSs.

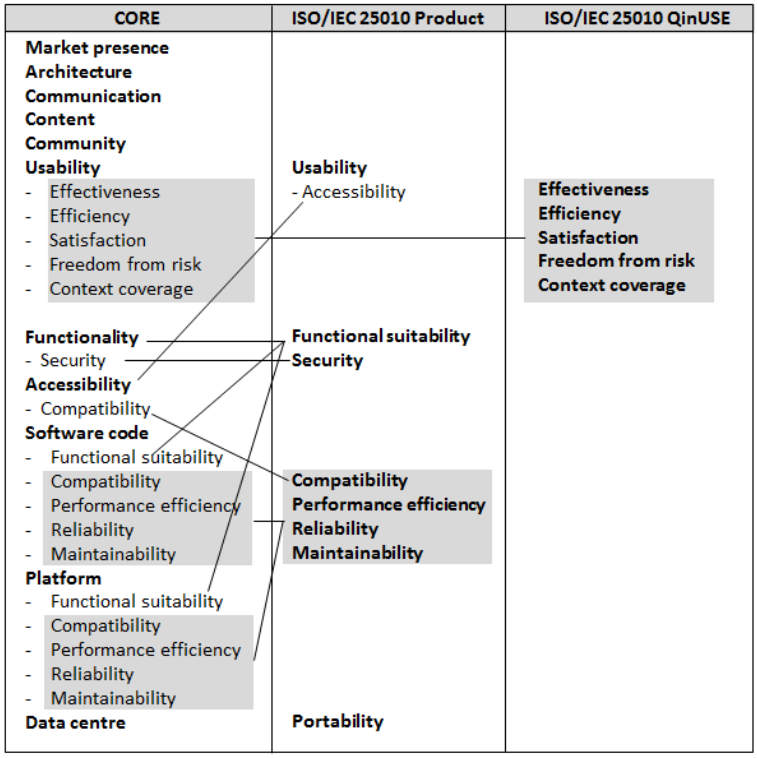

Fig.8. Comparison of ISO/IEC 25010 QMs and the core QM. Top-level characteristics are shown in bold.

8 Adapting the Core Quality Model: an Example

As an example of how the core QM can be adapted, in this Section we will develop a QM for a simple class of Web applications: the institutional sites of Non-Governmental Organizations (NGO), i.e. non-profit organizations whose main purpose is social solidarity and international cooperation in developing countries[c]. When defining a QM for a specific class of sites, we should first identify the typical content sections and functionalities of that class, to properly adapt *Architecture*, *Functionality*, *Content* and *Community* by adding the necessary sub-characteristics. An analysis of Italian NGO sites [32] shows a number of typical features, which may be present or not in specific instances. These can be summarized as follows.

Architecture. Although actual names, placement in the information architecture and content organization may be different from case to case, NGO sites typically present a number of recurrent sections, describing *Who we are*, *What we do*, *Where we are*, *Our projects* (which may be geo-

[c] Usage of the term NGO varies between countries. Here we use it according to the Italian practice.

referenced on maps), *News* and *Events*, *How to help* (either by offering voluntary work or donations). Many sites show a *Multimedia gallery* of photos and/or videos and some allow a number of documents to be downloaded, containing studies or informative papers of various kinds (e.g. the yearly balance sheet). Navigation to social media profiles such as Facebook and Twitter is often provided.

Functionality. Since the information content of these sites is often sizeable, an *Internal search* function is usually available. News may be received by subscribing to a *Newsletter* or simply to the site *RSS feeds*. Many sites offer the possibility of making *Online donations* (one-time or recurrent, child or project sponsorships, …) using various payment systems, such as Paypal. A few sites have *Merchandising* sections.

Content. Since NGOs operate in different countries, content is often multilingual. Photos (and sometimes videos) are often used to illustrate conditions and projects in target countries.

Community. Although many organizations use established social media for community building, forums and private social networks may sometimes be available. Blogs are rarely used.

Implementation of NGO sites may be done either with CMS platforms (often open-source), or directly in HTML, using HTML generators. Professional ICT support is rarely available within the smallest organizations, and most NGO sites are outsourced to hosting services.

Italian NGO sites show two typical profiles [32]: *static* (no online donations, no merchandising) and *interactive* (with online donations and/or merchandising). Both profiles may be either *social* or *non-social*, depending on the presence or absence of some community functions.

Starting from the above analysis, we can easily adapt the core QM to NGO needs. A possible result is shown in Table 5, where the NGO-specific adaptations are shadowed (sub-characteristics dropped from the core QM are crossed-out). In the same table we have defined the *non-social static* profile by putting a 0 in column P (Profile definition, as in Table 4) for *Online donations*, *Merchandising functions*, *Payment system*, *Online fundraising*, *Confidentiality*, *Accountability* and also for *Community functions* and *Community management*.

Since typical NGO sites are structurally simple (although they may contain plenty of information content), we kept the QM as simple as possible, avoiding over-detailing of characteristics. Third (and even fourth) level characteristics have been added whenever useful to draw attention on features particularly relevant for NGO sites. This is the case of *Functional adequacy* and *Information quality*, where typical functionalities and sections of NGO sites have been explicitly listed, to be individually considered. In other cases, this has been done to emphasize features which are often neglected in these sites (e.g. *Internationalization and localization for back-office*, *Domain name memorability*, *Compatibility with mobile devices*).

LEVEL 1	LEVEL 2	LEVEL 3 AND 4	P	NOTES
Market presence	Visibility	Search engine visibility	1	● Domain name memorability is noteworthy, considering the large use of acronyms in NGO names and also because some NGOs use 3d level domains under their provider's domain ● Conversion count has been renamed "Online fundraising"
		Visibility in related sites	1	
		Visibility in social media	1	
		Domain name memorability	1	
	User engagement	In the site	1	
		In the site community	0	
	~~Conversion rate~~		NA	
	Online fundraising		0	

Architecture	Information architecture		1	● Links to social media allow navigation to the social media profiles of the NGO. ● Site map and Link to social media have been put at level 2 (and not at Level 3) for greater evidence
	Navigation		1	
	Site map		1	
	Links to social media		1	
Communication	Home page		1	● Brand identity includes communication coherence with the NGO social media profiles
	Brand identity		1	
	Visual design		1	
	Typography		1	
Functionality	Functional adequacy	Internal search	1	● Sharing functions allow sharing of specific contents with other users (via email or social media) ● Confidentiality regards stored and transmitted information and data (e.g. during online payments) ● Accountability, according to ISO, is the degree to which actions of an entity can be traced uniquely to that entity. In this case, users should be guaranteed that their online donations are credited to the NGO bank account
		RSS feeds	1	
		Print functions	1	
		Sharing functions	1	
		Registration/login/logout	1	
		Newsletter	1	
		Online donations	0	
		Merchandising functions	0	
		Payment system	0	
		Community functions - Blog - Forum - Internal social network - Intranet	0	
	Back-office functions adequacy		1	
	Functional correctness		1	
	Security	Confidentiality	0	
		Accountability	0	
Content	Information quality	Who we are	1	● Data quality is applicable when an application data base is used ● Information and data quality should be evaluated in terms of accuracy, completeness, consistency, understandability. For sites available in multiple languages, Information quality sub-characteristics must be evaluated for each language. ● Internationalization and localization should be evaluated for each specific target language and country. ● Content currentness refer to timeliness of information updates in all used languages
		What we do	1	
		Where we are	1	
		Our projects	1	
		How to help	1	
		News / Events	1	
		Multimedia usage	1	
		Financial reports	1	
	Data quality		0	
	Content currentness		1	
	Internationalization and localization	For site visitors	1	
		For back-office	1	
	Style guide compliance		1	
Community	User relations		1	
	Community management		0	
Usability	Effectiveness		1	● Freedom from risk is not used, since security of online payments is considered under Security ● Context coverage issues are considered in Accessibility
	Efficiency		1	
	User satisfaction		1	
	~~Freedom from risk~~		NA	
	~~Context coverage~~		NA	
Accessibility	Compatibility	Fixed devices	1	● Compatibility should also take into account obsolete browser and old OS releases used in developing countries where the NGO operates ● Bandwidth requirements consider network infrastructure of developing countries
		Mobile devices	1	
	Bandwidth requirements		1	
	Users with disabilities		1	
Software code	Functional suitability		1	
	Performance efficiency		1	
	Maintainability		1	
	Reliability		1	
	Compatibility		1	

Platform	Functional suitability		1	
	Performance efficiency		1	
	Maintainability		1	
	Reliability		1	
	Compatibility		1	
Data centre	Data centre adequacy	Hosting services adequacy	1	● Hosting services adequacy evaluates the general adequacy of hosting services, including availability, costs, help-desk and customer relationships ● Back-up services adequacy evaluates frequency of automatic back-ups and recovery procedures
		Back-up services adequacy	1	
	~~Data centre performance~~		NA	
	~~Availability~~		NA	

Table 5. A QM for NGO Web sites, with definition of non-social static profile

To complete the NGO QM we should define the questionnaires to steer the evaluation, as discussed in Section 6.3. A possible questionnaire is shown in Table 6: for brevity, only the statements for the *non-social static* profile are listed. For many sub-characteristics, we have used statements of a general nature, leaving room to the evaluator's experience. This seems reasonable, because most NGO non-social static sites are very simple. Note that only a few statements are specific to the NGO QM; all the others are applicable to any Web application, and therefore may be considered part of the core QM.

Before using the NGO QM for evaluating a site, it should be further adapted to the specific organization and project. In particular, a few statements should be added with the mentioning of the relative project requirements or goals, as discussed in Section 6.3.

MARKET PRESENCE

Visibility	
-Search engine visibility	● The site is easily findable through the most common search engines
-Visibility in related sites	● The site is adequately referenced in the important sites of the same market area
-Visibility in social media	● The site is adequately referenced in the main social media
-Domain name memorability	● The site URL is easily remembered ● The probability of different organizations owning similar URLs is low
User engagement	
-In the site	● The number of unique site visitors is satisfactory ● The number of unique site visitors is growing ● The visitor bounce rate is satisfactory

ARCHITECTURE

Information architecture	● The site structure is adequate to user needs and easly understandable ● There are no two sections with overlapping contents or confusing shortcuts ● All sections and pages are adequately named
Navigation	● The navigation tools are easily understandable and easy to use ● The organization logo is always a link to the home page ● It is difficult to loose one's bearings during navigation ● When following a link to an internal page, this is always visualized in the same window/tab ● When following a link to an external page, this is always visualized in a new window/tab ● It is always possible to go back with the browser BACK button ● All the site pages load quickly
Site map	● There is a site map clearly representing the site structure in all its parts ● The site map is easily accessible from every site page ● The site map is clickable to allow direct access to every site section ● The site map terminology is the same used in menus and section titles
Links to social media	● The site contains clearly visible links to the organization profiles on the main social media ● The organization profiles on social media link back to the site

COMMUNICATION

Home page	● The home page shows clearly the site purpose ● The home page has a good visual impact

Brand identity	● The organization logo is clearly visible and recognizable ● The site visual design and content are consistent with the brand image of the organization
Visual design	● The overall visual design is pleasant ● There is a graphical coherence in all the site pages ● The page layout is best viewed with the screen resolution most used by the site visitors ● Layout grids are consistent in every page and well respected ● Page visual design helps to quickly locate the most relevant information ● There are not background textures worsening page readability ● Colors are used in a pleasant and consistent way ● The usual associations of meaning to colors are respected (e.g. red=stop, green=go, and so on) ● Color-blind users are not disadvantaged in understanding the site content, messages and navigation ● There are no blinking or moving images and texts, which can be of nuisance to the user ● Ad banners are properly placed and do not jeopardize page usability
Typography	● All texts are easily readable on screen monitors ● The site does not use too many different character fonts ● The different character fonts are used consistently and harmoniously in every page ● There is always a good contrast between text and background colors ● Long blocks of text always use sans-serif fonts ● Long blocks of text are never in italics or in all-caps ● Paragraph spacing and alignment is consistent in every page

FUNCTIONALITY

Functional adequacy	
-Internal search	● The internal search function is clearly visible and easily recognizable ● The form used to specify internal search criteria is adequate and easily understood ● The results of the internal search are pertinent, complete and presented in order of relevance
-RSS feeds	● The site generates RSS feeds for all the relevant types of content updates ● It is easy to subscribe to the site RSS feeds
-Print functions	● There are adequate functions for printing content items
-Sharing functions	● There are adequate functions for content sharing (via mail and social media)
-Registration/login/logout	● Registration, login and logout functions are clearly visible ● During password definition/change, the site monitors password strength and gives proper feedback ● The site helps its users to easily recover lost user-ids and passwords ● The site adequately filters fake user logins (e.g. through captcha mechanisms) ● The information requested during registration is appropriate, and can be changed at user's request ● The policy regarding user privacy is correctly published ● The user-id of a logged-in user is always clearly visible on the screen
-Newsletter	● The user can easily subscribe/unsubscribe to the newsletter ● The newsletter is timely and regularly dispatched to all subscribers ● The newsletter administration functions are adequate
Back-office functions adequacy	● Back-office functions allow to adequately differentiate and manage user access permissions ● Back-office functions for site administrators are adequate ● Back-office functions for content editors are adequate ● Back-office functions to monitor site access (i.e. Web analytics) are adequate
Functional correctness	● During inspection and test of the site, its functions always provided the correct results ● During inspection and test of the site, all user errors were adequately handled

CONTENT

Information quality	
-Who we are	● Information about the organization is accurate, complete and well written
-What we do	● The vision, mission and main activities of the organization are well described
-Where we are	● All the locations and contacts of the organization are adequately mentioned
-Our projects	● The current and past projects are adequately described and documented
-How to help	● Suggestions on how to help the organization are adequately and clearly expressed
-News/Events	● The news about the organization is well reported in a timely and visible way on the site ● All the past news published on the site is archived online and easily retrieved ● The events in which the organization is involved are adequately and timely announced on the site ● All the announcements of past events published on the site are archived online and easily retrieved
-Multimedia usage	● The site uses videos, photos and images to adequately document the activities of the organization ● Multimedia contents are interesting and of good quality ● Multimedia contents are also available on the social media profiles of the organization
Financial reports	● The yearly financial reports are available online
Content currentness	● The site does not show obsolete information ● The information available online is usually updated with adequate timeliness
Internationalization & localization	
-For site visitors	● The language selection mechanism is adequately visible and clear ● The site has the same structure and content in all available languages ● The site content is correctly translated in all available languages ● When some content changes, all its translations are published online with adequate timeliness ● In the translations local conventions are correctly used (currency, units of measures, time, date, …)

-For back-office	● The back-office functions are available in all the languages required by the back-office users
Style guide compliance	● Texts are structured in short paragraphs, to improve readability ● Textual content is written in a uniform style in all the site pages ● The placing and size of embedded videos and photos are consistent in all the pages ● Content complies with the accessibility guidelines
COMMUNITY	
User relations	● User enquiries are always answered with timeliness ● Answers to user enquiries are always pertinent, exhaustive, polite and personalized
USABILITY	
Effectiveness	● In user tests, all users substantially completed the assigned tasks as expected
Efficacy	● In user tests, all users completed the assigned tasks in the expected amount of time
Satisfaction	● After user tests, users expressed their satisfaction with the site
ACCESSIBILITY	
Compatibility	
-Fixed devices	● The site can be used with the browsers/operating systems currently in use by the large majority of its users (desktop/laptop)
-Mobile devices	● The site can be used correctly with the mobile browsers/operating systems mostly used by its users
Bandwidth requirements	● The site can be used with effectiveness, efficiency and satisfaction with the network connection speeds typically available to its users
Users with disabilities	● The site is compliant with the accessibility guidelines
SOFTWARE CODE	
Functional suitability	● The software code specifically developed for the site meets stated and implied needs
Performance efficiency	● The performances of the software code specifically developed for the site are adequate
Maintainability	● The software code specifically developed for the site can be easily maintained
Reliability	● The software code specifically developed for the site is reliable
Compatibility	● The software code developed for the site is compatible with its hw & sw execution environment
PLATFORM	
Functional suitability	● The components of the software platform (e.g. DBMS) are functionally adequate to the site needs
Performance efficiency	● The components of the software platform have adequate performances (time, resources, capacity)
Maintainability	● The components of the software platform can be easily maintained
Reliability	● The components of the software platform are reliable
Compatibility	● The components of the software platform are compatible with the other systems in use
DATA CENTRE	
Data centre adequacy	
-Hosting services adequacy	● The hosting service cost/performances ratio is adequate to the organization needs (consider service continuity, available bandwidth, availability of technical support in relation to costs)
-Back-up services adequacy	● Back-up and recovery services are adequate (consider the frequency of automatic back-up and recovery procedures and times in relation to costs)

Table 6. Questionnaires for the NGO QM (non-social static profile)

9 Conclusions

This paper has described a methodological approach to define QMs for Web applications of any kind, including Web 2.0 sites.

A QM is considered a *practical tool* to steer the definition of requirements, quality assessment and improvement activities during the entire life cycle of the site. Therefore, the main driver for defining a QM has been the *organization mapping* criterion, and not the quest for a conceptually sound taxonomy of quality characteristics. Organization mapping allows those in charge of quality management to easily identify the actors in the organization responsible for implementing and improving each quality characteristic. This is of paramount importance for Web sites, given the number and diversity of the actors involved in design, development and operations.

Since Web applications differ in size, in technology, in purpose, in complexity, in functions and in user involvement, there can be no universal QM which can serve every site and purpose. Therefore, it

is convenient to define a *core* QM, which would somehow capture the fundamental quality aspects of *all* Web applications, but would require adaptations to be usable for the different classes of sites under consideration and for different purposes. A simple core QM has been proposed, compliant with the organization mapping requirement. It has 11 first-level characteristics and 42 sub-characteristics. For sake of simplicity and to leave maximum flexibility in the adaptation process, the core QM has been defined down to the second level only. Further levels in the hierarchy of characteristics can be added during adaptation, whenever needed. All [sub-] characteristics have been given names immediately understandable by everybody, and the usual quality-related jargon has been avoided.

To help in evaluating the QM [sub-] characteristics, suitable Likert-style questionnaires are associated with the lowest-level sub-characteristics, possibly complemented by project-specific requirements. Evaluators would respond to the questionnaires by direct site inspection and by conducting user tests, as appropriate.

In order to show how the core QM can be adapted to particular classes of sites, a QM for static non-social NGO sites has been described. The simplicity of the example should not be misleading; indeed, the model is meant to be applicable to sites of any complexity, and even to large Web properties such as online magazines, social media, e-commerce applications and the like.

The core QM includes many [sub-] characteristics not present in the ISO/IEC 25010, which has been for many years the term of reference for software systems' QMs. Indeed, as discussed in Section 3, Web applications show a large number of features not present in traditional software systems. Therefore, we have not refrained from departing from the ISO model whenever necessary, but we have strived to use the ISO terminology whenever possible.

In summary, with respect to ISO/IEC 25010, the proposed core QM considers a number of new top-level characteristics related to the specific nature of Web sites; it has a higher level of abstraction and allocates characteristics in a different way, according to their level of importance in Web sites and to the organization mapping criterion. Of course, the ISO/IEC 25010 sub-characteristics not mentioned in the core QM may be added at a further level of detail, when the site complexity requires it. If this is done, the resulting QM can be said to conform to the ISO standard, being a superset of it. Indeed, according to ISO/IEC 25010, "any quality requirement, quality specification, or evaluation of quality that conforms to this International Standard shall either; a)- use the quality models defined in it or b)- tailor the quality model, giving the rationale for any changes and providing a mapping between the tailored model and the standard model."

But this is a purely syntactic comparison. In more general terms, our proposal is conceptually remote from the ISO approach because of the differences between a traditional information system and a modern Web application. The first may be considered as a *container*, to be populated with *data*, conceptually independent from it. In addition, development time and operation time are well separated, and therefore it makes sense to distinguish internal and external quality from quality in use. This is not at all obvious in a Web application: the success of a "social" application may indeed depend more on activities performed during operations than on the static properties of the site. These activities involve not only content updates, but also on-going marketing initiatives to attract visitors, accurate community management and even continuous functional changes, to better suit the evolving needs of the customer base. The overall quality of the site heavily depends on all these activities. Rather than

speak of internal quality, external quality and quality in use, we should perhaps use the more comprehensive concept of *quality in operations*, encompassing all the quality characteristics that are continuously built and improved during site operations. Our quality model tries to consider all these aspects in a single conceptual framework.

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