Quality Developments in the Brazilian Software Industry and the Relevance of Strategic Issues for Software Quality

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***Abstract*—The software suffers the same demand that exists for other products and services when it comes to high levels of quality. Software product is used in different segments, as a single product or as a product that enables the delivery of other products. It requires from the software industry highest development efforts to deliver better results using specific frameworks like models, standards, guides, etc. To promote the improvement of software development and the quality of software product some models like CMMI were created and are still used by the software industry. Sometimes the implementation of these models requires specific analysis or preliminary assessment to sustain a strategic plan. Thus, this paper presents an overview on software quality and its relation to the software process improvement approach. It also discusses the importance of process engineering presented in the software quality models. Considering the Brazilian software industry developments, the paper presents the appraisals realized using the CMMI and the MPSBR (Brazilian Program for Software Process Improvement) a framework defined by a Brazilian software association and sponsored by the Brazilian government. The paper also considers the relevance of strategic issues to increase software quality.**

***Index Terms*—Software quality, process improvement, software maturity models, strategic planning.**

I. Introduction

In a society where the software technology is a fundamental product, whether in the economy, education, industry, commerce etc, its relevance becomes more and more evident either used as single product or as part of other products.

The software technology combined with other technologies favors the technology information and currently supports many activities of the contemporary society by means of powerful information systems.

It is evident on the information technology journey, especially for the software product, that quality is an issue that marks the main requirements for this relevant technology.

The quality for software industry undergoes constant evolution since its initial in the 1950s, when the first computer software for business was created [1]. It is widely discussed and addressed by scientific community, academia, governments and the software industry.

Quality according to [2] has caused a growing interest in the society, by industry, governments and by service sectors, but it is a critical feature given their complexities and difficulties. It is also critical for the software product, perhaps more critical because of the high complexity of software. In addition, more than the high complexity inherent to the isolated use of software is the complexity of its integration with other elements to generate specific applications to meet the quality demands of modern society.

Thus, this paper seeks to provide information relating the mechanisms of building the quality of software product considering the evolution of software as a product that becomes increasingly complex, if not by itself, but by complex integrating systems.

As a general objective the paper directs studies for the presentation of the concepts and practices that drives organizations towards adopting strategic mechanisms for software quality improvements, considering strategic drivers to formatting a strategic plan for quality. The paper also considers a set of specific goals, as: 1) the evolution of quality in Brazilian software industry; 2) the presentation of relationship of software process engineering with the Brazilian Program for Software Process Improvement (MPSBR); and 3) shows the appraisals of software quality in the Brazilian software industry.

To meet the paper objectives the following sections are presented: section two present an overview of software quality; section three considers aspects of quality in the software industry; section four discusses the software process related to software quality models; section five presents two software quality models used by the Brazilian industry and its appraisals; section six presents the concepts and practices of strategic issues for software quality; and the section seven presents the conclusions and related future works.

II. Quality Overview

A historical view of quality goes back to a pre-industrial era, since then man has demonstrated concern for this subject, but in a completely intuitive and subjective format, without focusing on application of models, standards, etc.; structures that were later defined.

As the software product is a relatively new product, many of the quality studies for software product are studies from other areas. Including part of what is revealed in the general history of quality can be the embryo for further study regarding the software quality. Including, the consideration related to the concept of continuous process improvement, for example, is associated with the PDCA Model defined in 1920 that is a fundamental concept used to define relevant models for software quality.

Walter A. Shewhart in 1920, an engineer at Bell Laboratories, introduced important elements that associated statistical concepts to production processes and favored

Manuscript received January 9, 2014; revised April 1, 2014.

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DOI: 10.7763/LNSE.2014.V2.143

measurement and quality control [3]. With a view that a product could be continuously improved, he proposed a cyclic model for process improvement. With this concept, he defined the PDCA Model. PDCA stands for Plan - Do - Check – Act, which uses a circular model emphasizing the need for continuous improvement as opposed to linear models used until then.

Some renowned researchers on this subject emerged and left their marks on this important subject as Philip B. Crosby, W. Edwards Deming, Joseph M. Juran, who creates some of the main concepts of quality management. Many of these concepts are not applicable directly to the software industry and to the software development but indirectly they stimulate the actions related to software quality [4]. Thus, some quality eras defined by [5] are presented as seen in Table I.

Following expert's theories and practices of quality associated with the software technology, stands out a renowned researcher - Watts S. Humphrey. He brought unique contributions to the software quality [6], and therefore for the software industry worldwide.

Initially, with the definition, publication and dissemination of a specific quality model for software called SW-CMM (Capability Maturity Model for Software) that provided significant changes to the software quality. Based on the concept of continuous process improvement and the dependency of software product from the process engineering, the SW-CMM model has revolutionized the software industry.

Models such as this favored the foundation of modern quality concepts for the software product, the ratio considered by these models on the quality and process improvement is another key point arising of this paper. Thus, the following sections presents in more details, the importance of process management for the software quality construction.

III. Software Technology and Quality

For [7], currently software takes on a dual role: it is a product and a vehicle for delivering products. This product has been able to substantially change the life of modern society, influencing the creation of new technologies and changing several existing ones. From being used for some specific purposes through the mass use by an increasing number of users.

TABLE I: Major Quality Eras (Adapted from [5])

	Inspection	**Quality Control**	**Quality Assurance**	**Strategic Quality Management**
Focus	Operational	Operational and Tactical	Tactical	Strategic
Method	Measuring Instruments	Statistic techniques	Quality Programs	Strategic Plan
Actions	Inspect, count, evaluate	Appling statistics techniques	Create Programs, Quality Planning, Results	Establish goals, Educate, training
Responsible	Inspection Area	Inspection Area and Engineer-ing	All – given the quality policy	All – with senior management exercising strong leadership
Orientation	Inspections	Control	Construct	Manage ment

Software technology is able to accelerate educational, financial, commercial and industrial activities, including the most advanced sectors of science and medicine and communications that have dramatically changed the life.

With its ability to intervene in the middle where it begins to be considered, the software technology associated with other digital technologies, culminate in powerful systems capable of rationalizing various personal and social processes and streamline daily activities and tasks performed.

The software has evolved over the years, as shown in Table II, and software development models followed this evolution. Its construction has been grounded on engineering principles, hence the software engineering.

The construction of software is based on software engineering principles and their development should not be managed as a manufacturing process [8]. So, the application of solid concepts of software engineering process should favor organizational commitment to software quality.

The essence of software engineering according to [8] directs the four main activities: 1) understanding the problem, 2) planning the solution, 3) implementing the plan (product development), and 4) examination of the results (quality).

Based on the fact that the software is not manufactured but designed and engineered, it is necessary to establish its development processes and these should be formalized, allowing the team's creativity and the consideration for specific standards for development.

Reference [8] proposes a broad vision for the components of a generic methodology for software engineering, considering:

1) Communication - refers to contact with the client to define the functions and features of the product;
2) Planning - refers to the initial estimation and formalization of the project plan;
3) Modeling - refers to analysis and designing a technical overview (architectural designs, components, interfaces, and database);
4) Construction – refers to the coding and testing, and;
5) Employment - that refers to the delivery and use feedback.

On this methodological view, the practices of quality should be applied for all phases. Strict measurement criteria should be established for the work products delivered based on the set of activities associated with these phases.

In this sense, the quality should not be a feature only inspected, but it should be built while executing each methodology phase. Given the focus of the quality eras, where one seeks in contemporary software development that

it is no longer simply inspected and passed to be built and managed strategically to give the best possible results.

TABLE II: SOFTWARE TECHNOLOGY EVOLUTION (ADAPTED FROM [1])

Name of the Era	Period	Software system characteristics
First	1950 to 60's	.batch processing oriented system . limited distribution
Second	1960 to 70's	. multi-user systems . real time systems . product software
Third	Mid 70's to late 80's	. distributed systems . embedded software . consumer impact
Fourth	Late 80's to just before Millennium	. powerful desktop systems . object oriented technologies . artificial systems . network computing
Current	-	. pervasive computing . internet based systems . e-commerce . wirelles computing

To determine the quality of a product, the initial characteristics must be considered and the degree to which they reach these characteristics during product development should be verified continuously. A constant measurement, according to different types of formal evaluation such as technical reviews, walkthroughs, inspections and audits should be applied.

For reference [9], McCall's Factor-Criteria-Metric Model, Boehm's Software Product Quality Model, SQUARE standards from ISO (General Guide of standards ISO 25000) are examples of standards which favor the measurement of software product.

Frameworks such as ISO / IEC 15.504 (derived from SPICE Project) and CMMI (Capability Maturity Model Integration) also consider the quality of the product, but do so through the processes used to develop it. In an approach of SPI (Software Process Improvement), these frameworks propose that the quality of the process is verified by their maturity, ie, the quality of a software engineering process is related, in a given viewpoint, to its maturity. This maturity is reflected on the quality of software product.

Thus, some frameworks are strictly focused on the quality of the product (SQUARE, for example), but others make use of processes and the concept of continuous improvement process to ensure quality. This will be detailed in the following two sections.

IV. PROCESS MANAGEMENT FOR IMPROVING SOFTWARE QUALITY

The quality of software is strictly related to the process used to develop it. As mentioned in [6] the quality of the software product is highly influenced by its development process.

A premise supported by SEI (Software Engineering Institute) is that software quality is highly influenced by the process used to develop it. Currently, this premise greatly contributes to a better understanding of the aspects of quality applied to software. According to [10], people cannot promote intuitively the software quality, but they believe that the implementation of a structured process will improve it.

To [11] "process is a sequence of steps performed for given a purpose" and, in fact, they are always present in product development and it is no different for the software product. Thus, the process exists, but for to be applied by those who act in the software industry, it must be mapped, defined, documented, approved and disseminated, accordingly [12]. These activities related to the process management are part of the discipline of process engineering.

The quality of the software product is a feature which cannot be achieved in a unique and specific moment, for example, at a time of inspection or testing. It needs to be built during the product development. So, it is necessary that the software process that was defined and implemented must be used to promote, construct and generate quality.

Thus the presentation of quality eras by [5] (see Table I) collaborates to note that it takes place not only with the application of the concepts proposed for the inspection or quality control. The focus was in the actions of those involved in inspection and control, but under strong requirements of software quality assurance programs, which considers the engineering process for its development and, consequently, directs the focus and actions for building and managing quality.

Reference [9] proposes a Quality Management System that prescribes a quality policy, procedures, manuals, templates and checklists that support the cycle of quality, associated with the software process improvement.

The quality policy should express the principles of quality perceived by the organization and set commitments to quality. The other elements of this system are derived from the quality policy, which should establish sentences related to vision and mission of the organization regarding quality.

The standard ISO 9001:2000, according to [9], [13], can be one of the standards which consider these elements in the structure of a quality organization - the definition of quality policy and a quality management system. And this system must involve people, technologies and tools, processes and other resources to promote quality.

To [14], the quality system must consider the technical and cultural aspects of the organization to achieve better results. And it proposes the preparation of the quality policy based on vision and mission, the implementation of practices which support an organizational commitment to quality.

The above scenario converges for the Brazilian organizations that are looking for quality management supported by specific models for software quality that will be presented in more details in the next section.

V. QUALITY MODELS ADOPTED BY THE BRAZILIAN SOFTWARE INDUSTRY

Brazilian industry has been adopting some specific software quality models in the last decade as the CMMI (Capability Maturity Model Integration) and more specifically CMMI-DEV version 1.3 [15], ISO standards as ISO / IEC 15.504 (Software Process Assessment) coming from the SPICE project and, after 2003, also the MPSBR (Brazilian Program for Software Process Improvement)

published by SOFTEX (Association for Promotion of Brazilian Software Excellence) as defined in [16].

The appraisals that occurred in Brazil in the last decade, and more specifically in the last four years presents the evolution related to the implementation of the CMMI and MPSBR models, which are the most used by the Brazilian software industry.

The MPSBR Program (from the acronym in Portuguese "Programa para a Melhoria de Processo de Software Brasileiro") is constituted of three main components: the MPS Reference Model (MR-MPS); the MPS Assessment Method (MA-MPS); and MPS Business Model (MN-MPS) [17], [18].

The MPSBR Program, as others specific quality models, considers process as the main element of its structure and defines in its Reference Model (MR-MPS) process capabilities in seven maturity levels, from G to A, as presented in Table II.

TABLE III: MPSBR–MATURITY LEVELS [16]

Level	Related process
A	(no new processes are added)
B	Project Management (new outcomes)
C	Decision Management Risk Management Development for Reuse
D	Requirements Development Product Design and Construction Product Integration Verification Validation
E	Human Resources Management Process Establishment Process Assessment and Improvement Project Management (new outcomes) Reuse Management
F	Measurement Configuration Management Acquisition Quality Assurance Project Portfolio Management
G	Requirements Management Project Management

To support the relationship of software engineering process, the MPSBR model provides the actual sustainability of quality programs in organizations that develop software to build their quality programs based on processes improvement.

As CMMI, the MPSBR model consider the continuous process improvement characteristics, which contribute to support the assertion that quality is linked to continuous process improvement and also related to the modern era of quality in a view supported by the approach of quality assurance that by [5] is related to quality construction.

Considering eight maturity levels, the Brazilian model has been used by several national companies that develop software. Trainings had been conducted by the association that developed the model, either for the companies, for the consultants or for the auditors to increase the use and application of the model. However there are also companies that seek the CMMI model in order to implement it in their software development organizations.

The growing use of these models in Brazil is presented in Table IV for CMMI and Table V for MPSBR. For both models is possible to observe the appraisals for the period of 2010-2013.

TABLE IV: CMMI APPRAISALS IN BRAZIL (2010-2013) [19]

Year	# of Appraisals
2010	11
2011	27
2012	25
2013	36

TABLE V: MPSBR APPRAISALS IN BRAZIL (2010-2013) [20]

Year	# of Appraisals
2010	71
2011	71
2012	83
2013	107

The results observed on Table IV and Table V are restricted to this period because it was a consolidation period of MPSBR Program in the Brazilian software market. It is possible to observe that the use of MPSBR program has increased, probably because it was designed to be used, not only, but preferably by small and medium companies. It is also possible to note, if considered just the year of 2012, that the MPSBR model was more used than the CMMI, at least 200% of appraisals more than the CMMI. As well, if is considered only the CMMI model, it is possible to see an increase on their use, if is compared the years of 2010 and 2011 and that their adoption is maintained by the local industry.

Although, the implementation of quality programs sometimes are not supported by a strategic planning designed to meet the organization needs. Therefore, the next section, considers mechanisms focused on strategy and relates this mechanisms to the software quality in a movement that favors a strategic planning aimed to quality.

VI. STRATEGIC ISSUES RELATED TO SOFTWARE QUALITY

In a contemporary view, many approaches of strategies for quality are increasing and being considered by the companies from different segments, and also by software industry. In this sense, collaboration is obtained from the quality eras proposed by [5] and innovations should be considered with the intention of leveraging strategic principles to improve software quality.

This is, perhaps, the main point that companies should focus on now, especially those that need to produce software with better quality, either for their internal or external clients, with the assistance of an insightful strategic planning. This corresponds to the current era of the precepts of quality for many big industries worldwide, especially software industry.

People within organizations deal with this feature on product development, many studies are developed related to this area and also the influences of continuous process improvement are considered to offer better software products

[12], since they also permit qualitative advances.

The specific models that can be applied, whether they are to project management, corporative governance activities or more specifically for software engineering and software quality [15], [20], are based on a process structure in order to define organizational processes for increase quality.

In many cases, organizations believe that the adoption of specific quality models or standards is sufficient to guide them to achieve the quality they are looking for. Only the adoption of models or standards is not sufficient, because the results obtained do not reach their objectives compared with the realized investments [21]. This situation reflects the absence of the strategic planning for the software quality program.

The strategic actions correspond to the actions that have direct impact on the survival of organizations, and in this approach the following dimensions should be considered: 1) spatial that considers the organization as a whole and the environment where it is inserted and 2) time that considers changes over time, such as those related to technological progress [22].

The concept of strategy is relevant to be used in all organizational activities and it is also necessary to the organizations that produce a complex product as software [23]. Strategies can provide basic criteria for the organization to measure the results achieved with the implementation of a Quality Program, or a Quality Management System in accordance with their previously defined objectives [22].

Thus, the strategic planning should map the quality and define elements that collaborate to build and manage it. The strategies are a broadly view and the tactical and operational processes are associated to support its implementation [23].

As verified in specific references as models, standards and regulations issued by many authors and associations such as [7], [15], [16], there is a lack of explicit strategic concepts that should permeate the quality engineering. Some specifically elements designed for strategies of software quality are identified in [9].

For reference [9] "SPI (Software Process Improvement) does not occur overnight, and it cannot be implemented on a 'fad of the week'". It involves the development of an overall strategy, requiring commitment by the parts involved: managers, developers and all stakeholders.

A strategic plan is crucial to determine the actions related to implementing a program of continuous process improvement, to enable it and to promote the construction and verification of quality by developers and especially by their end-users or clients.

In developing a strategic plan for quality, relevant elements must be considered, such as: investment, people, infrastructure (hardware, software support, specific tools, etc) [9], [21].

Reference [12] considers that for an implementation with success of a SPI (Software Process Improvement) Program, it must be aligned with the organization's business objectives.

This plan can be well developed if it is considered some kind of self-evaluation that favors *a priori* understanding of the situation and determine a macro action plan, which is an important input element for strategic planning.

Some strategic drivers are presented as proposed by reference [9, p. 335] as an approach to determine the strategic actions for SPI (Software Process Improvement) that refers to:

- Develop process improvement proposals;
- Evaluate the proposals;
- Rank the proposed projects;
- Estimate the implementation schedule; and
- Obtain management commitment.

These strategic drivers also consider that this type of planning should:

- Have a strong linkage to the business processes;
- Involve the right people;
- Use proven business planning methods;
- Facilitate productive communication, share ideas among all participants;
- Have an approach that does not lose sight of the big picture.

Another possibility is a set of strategic guidelines for quality supported by actions that reflect the Strategic Planning for Software Quality Improvement (SPSQI) that is proposed in order to promote the strategic direction for quality. It suggests that the organization has to consider a set of drivers to improve its ability to develop software and provide products with better quality.

The SPSQI drivers are relevant to the quality strategic movement for organizations that seek to implement quality management, as presented below:

- Conceptualization of Quality for the organization;
- Definition and purpose of the Quality Program;
- Alignment of Quality Program and Business Objectives;
- Definition of SPI Approach;
- Evaluation and adoption of frameworks to support Quality Program;
- Involvement of people and tools;
- Definition of expected results;
- Measurement Program; and
- Allocation of financial resources (investments).

These strategic drivers for software quality management, which permeate a strategic planning, may be aligned with other organizational strategic goals, promoting better results and defining future actions.

The strategic planning of quality should direct the movements necessary to move the organization to a leadership position, where it is possible to consider that quality is an important feature that drives organizations to be leaders in their segments.

The conceptualization of quality by the organization directs the actions relevant to other drivers, for example: 1) adopting models, standards and guides that favor the implementation of a tactical plan quality, 2) influencing considerably the process improvement program. Also, accordingly to [22] the conceptualization of quality can generate value to the business organization. For [24], a quality management program is strongly supported by people who really understand what real quality means.

The drivers move the organization to require considerations, for example, on the quality setting for the organization, their desires and how it should be considered and evaluated, either internally or externally. It is relevant to consider quality as a factor of change and a positioned market

leadership [22].

People should be involved to the extent that it was strategically planned, and therefore it may involve a change of organizational culture that has different impacts in accordance with the strategic definitions. These constraints drive the organization and its movement in relation to quality. The influence of people in this movement can make it extremely progressive as it can also divert strategic actions initially planned.

Results should be measured regularly and a program of measurement should be linked to a set of strategic actions [6]. The indicators may arise in a simplified manner, but they are of vital importance to the directions for the movements that will occur. They should start together with the first actions taken and their partial or final results should be considered periodically to support decision making.

The measuring systems are of vital importance in a move to quality management supported by strategic planning from the beginning, ie, defining strategic actions to implement and measure activities that improve operational processes in a continuous improvement approach aiming to present better results.

The funds and investments focused on the quality program are another relevant driver. It should be checked strategically and should be spent as the program evolves and offers good relations between what was predicted and what the proposed indicators are showing.

Thus, the strategic actions related to implementing and maintaining a quality program should be guided by some feasible strategic drivers that favor the 'think' quality strategically.

VII. Conclusion

As software quality nowadays is a feature on continuous expansion that evolves constantly, it is possible to note these expansions observing specific indicators presented in section five. The presentation of these indicators are restricted to the period 2010-2013 because it reflects the consolidation period of the MPSBR Program, so the indicators related to CMMI are presented for the same period. These indicators and the presentation of the MPSBR Program are capable to show the situation of Brazilian software market.

The studies focus was aimed to present the aspects of software quality in Brazilian industry, specifically the association between quality and process engineering. As observed by the brief presentation of MPSBR Program and its models, especially the Reference Model (MR-MPS), it is possible to conclude that the Brazilian Program for Software Process Improvement followed this premise as well as follows the vision of international standards for software quality which also consider process engineering as a key to quality.

As for the specific purpose related to the strategic planning for the implementation of quality program in software development organizations, it was found that there are few reflections on the subject in [9] and that quality models usually do not refer to the practices of strategic vision.

Some directions to software quality strategy and a set of drivers that favor a strategic planning for software quality were encapsulated in the SPSQI that drives to strategic management of quality.

The application of SPSQI by any software organization can create the option of an important future work related to the application of these drivers and the possibility of reporting this case study. Although, as it is a macro view, more studies should be conducted in order to provide greater visibility on strategic issues for the software industry.

Strategic planning should be directed to support the software quality program and move actions for continuous improvement of software product in the short, medium and long term.

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