

THE ROLE OF SOFTWARE PROCESS IMPROVEMENT INTO TOTAL QUALITY MANAGEMENT: AN INDUSTRIAL EXPERIENCE

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I. Background / Abstract

NEC do Brasil – NDB is a telecommunication company that encompasses Brazilian and Latin America markets by providing products and solutions to its customers. With its business, NDB has four areas, which are concerned in the software development: Switching, Wireless, Transmission and Radio. NDB software teams perform customization of systems developed by other companies as well as the complete development of software systems. These are real time systems and they control the functionality of the telecommunications equipment, operate in commercial computers and in embedded systems.

NDB has been developing since 1996 a specific program for Software Process Improvement. This R&D program is a partnership with University of Sao Paulo – USP and has been the first Brazilian Telecommunication Company to apply the model SW-CMM and achieving Level 2 in 1997.

The aim of this paper is to present NDB's experience in the implementation of Software Quality Management – SQM, by applying the experience, culture and successful practices already institutionalized in an environment of Total Quality Management – TQM. The paper also proposes to answer doubts of implementation, problems faced in development of activities as well as the found solutions, lessons learned and SQM benefits.

SW-CMM is an application of TQM concepts to software development [1,2] and the success of TQM has inspired the software process improvement [2]. NDB's experience shows that a Management structure established with TQM concepts is applicable and tailored, in many aspects and features, for a SQM establishment.

In spite of this experience and knowledge have great relation with SW-CMM, some practices and the general concept can be applied in any of current

models or standards for software process improvement like ISO/IEC 15504 – SPICE; ISO 9000-3 and TL 9000.

II. A way for the Excellence

A. Organizational approach and deployment

One of the best definitions of the term excellence was given by Aristotle's (384 – 322 BC.) "*Excellence is an ability acquired through the training and practice. We are what we make continuously. Excellence, then, is not an act, but a habit.*" This habit, for organizations, with clear business directions, cannot be applied only for specific areas or processes, but must be a systematic model including innovative management and continuous evolution. Moreover, this model needs to be established or institutionalized in the entire organization [2].

B. Origins and Evolution of Software Quality

During the last years, many organizations have been working towards an evolutionary way regarding excellence in quality concepts. During the twenties the main focus of the quality management was on the product. In the fifties the focus was on manufacturing process and people, it was the TQC - Total Quality Control. In the eighties, we observed the beginning of the TQM – Total Quality Management era whose focus was on the customer and market needs.

All these quality concepts evolution had been developed and demonstrated successfully by the effort and work of important quality specialists [1,2]. Table 1 summarizes the milestones of quality evolution and tracks the origins of the software process movement.

In this evolution two outstanding models, developed in 1987, have been worldwide disseminated and therefore they should be mentioned: ISO 9000 series of quality assurance standards and MBNQA – Malcolm Baldrige National Quality Award Criteria

[3] or its similar PNQ in Brazil [4].

Walter Shewhart 30's	⇒ Promulgated the principles of statistical quality control and propose PDCA cycle for quality improvement.
Edwards Deming Joseph Juran 50's	⇒ Further developed and successfully demonstrated the Shewhart principles.
Phil Crosby 80's	⇒ Developed a quality maturity grid
Edwards Deming 1986	⇒ Based on the experience and lessons learned the 14 Deming's Principles are published (Out of the Crisis)
Watts Humphrey 1986	⇒ Adapted Crosby's maturity grid to software process and added the concept of maturity levels.

Table 1 – Quality milestones and software movement

In the approach of Software process and its improvement, the Software Engineering Institute – SEI has been doing, since 1987, an important contribution to maturity framework and evaluation methods - SPA, CBA (SCE/IPI)^(a), and other management structures like - SW-CMM, SE-CMM, P-CMM, CMMI [1,2]^(b). A strong correlation between SQM and TQM could be demonstrated when Humphrey combined Deming's principles, Juran's improvement approach and Crosby's maturity grid, and applied their underlying principles to the software development process [2].

^(a) → Software Process Assessment, Capability Based Appraisal (Software Capability Evaluation / Internal Process Improvement).

^(b) → Software CMM; Software Engineering CMM; People CMM; CMM Integration

C. Motivations in NDB

Currently, the trustworthy development of the product, fulfilling customer's requirements of delivery, costs and quality represents a great challenge for organizations. For some of them software is an important part of overall project, product and services affecting its functionality, quality, cost and time to market, becoming a key business factor.

In 1995 NDB identified the necessity that something should have be done to improve its software products and services.

Usually business solutions have three main aspects: technology, people and process. [2] – See Figure 1.

The necessary technology has been developed internally or in the NEC Co. and people had been already engaged in quality culture due to several activities, mainly ISO-9001 certification in 1993. However, the third important aspect – the software process should be improved at NDB. This process was in ISO 9000 certification scope, but without continuous improvement approach and funds/resources, costs and delivery features management.

These factors, in addition to the challenge to tailor the Software Quality to TQM concepts and the need of people qualification in software quality best practices, had motivated NDB to develop its SQM.



Figure 1 – Three aspects to implement business solutions [2]

III. The process evolution in NDB

A. The Quality Evolution

In the last few years Quality Management development in NDB has followed an evolutionary approach. At the end of 80's its focus was on the product. From 1990 to 1995 the focus was on the process and people with ISO 9001 certification and the establishment of training structure to develop the skills and knowledge of the individuals. In 1995, with the approach of TQM, the concept IPE⁽¹⁾-Enterprise Process Innovation was created with the customer and market focus. There were some goals in management concept of IPE. One of these goals was the SPI - Software Process Improvement deployment. Then, the study and analyses of a method to improve software quality began in 1996.

In November 1999 there was an evolution from IPE to QDC⁽²⁾ – Customer Driven Quality with the improvement in criteria like leadership, people management and performance metrics management, keeping the good practices previously implemented.

^{(1) (2)} Note: IPE and QDC are acronyms in Portuguese meaning.

B. QDC Concept and Structure

QDC is the concept of the Total Quality, which NDB will develop a culture where all employees understand the Customer Satisfaction, thinking and acting with the customer desires in mind.

In its structure QDC has 4 (four) Components and each component has specific Attributes as showed on Table 2.

The structure and concept of QDC is the result of studies, research, deployment of good practices and IPE's evolution and improvement. [1,3,4,5,7]

Components	Attributes
Leadership	<ul style="list-style-type: none"> ▪ Directions and Goals establishment ▪ Customer and Market Management ▪ Management framework
People	<ul style="list-style-type: none"> ▪ Communication ▪ Motivation ▪ Skill and knowledge
Innovation & Continuous Improvement	<ul style="list-style-type: none"> ▪ President award ▪ Benchmarking ▪ Software Quality – SW-CMM ▪ Lean system ▪ Customer Information System
Systems	<ul style="list-style-type: none"> ▪ Quality Mg. - ISO 9000 / TL 9000 ▪ Environmental Mg. – ISO – 14000 ▪ Metrics Mg.

Table 2 – Components and attributes of QDC

Software Quality – SW-CMM is one of the QDC attributes aiming Innovation & Continuous Improvement, but the QDC's Management concepts are integrated and dynamic. The activities and requirements of SW-CMM Model are not separately applied but integrated with QDC to have inputs and also to provide outputs to the major QDC attributes. This integration of dynamism will be detailed later.

C. Why SW-CMM

The decision in 1996 of the management structure to be adopted for Software Process Improvement had been done after the analysis of three (03) models. It has been analyzed ISO 9000-3 – Guidelines for the application of ISO 9001 to the development, supply and maintenance of software, SPICE - Software Process Improvement and Capability dEtermination or the current ISO/IEC15504 and SW-CMM.

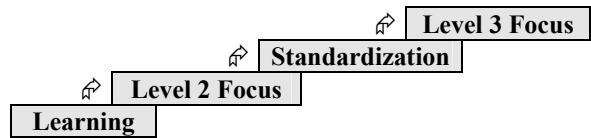
The reasons to apply SW-CMM were:

- Nomenclature and language applicable and known by the software developers;
- Maturity grid to software process and the concept of maturity levels aligned to QDC concepts;
- Model recognized worldwide;
- Material available for guidance;
- Correlation with some items and activities of the ISO-9001 and NDB Certified System [1,5,7,9];
- Correlation with MBNQA or PNQ that was the basis of IPE management model, current QDC [1,4,5,6].

D. The Software Quality Management and QDC.

1) Software Quality Evolution

Since the decision to implement the SW-CMM model, four stages can be identified in NDB that shows the software process evolution.



Learning → In 1996 it was established the partnership with University of São Paulo and the creation of the group SEQT – Software Engineering Quality Team responsible for the Software Process Improvement in corporate level. This stage also included the study and analysis of the best model to be applied, correlation with the institutionalized Quality System and the self-assessment of the software process.

Level 2 Focus → The self-assessment has provided data and information to establish the action and improvement plan aiming Level 2 as the first target. Before the official appraisal, pre-appraisals and SCE – Software Capability Evaluation training had been done to provide conditions and more information regarding the software process. The Maturity Level Rating was achieved according to the Table 3.

Software area	Level 2 achievement date
Radio	November, 1997
Switching	April, 1998
Transmission	November, 1998

Table 3: Dates of Maturity Level 2 achievement

Standardization → This stage, started in 1998 with the approach of the Organization Standard Software Process that was established in the MQS⁽³⁾ – Software Quality Manual that was tailored from the SW-CMM Model and aligned with internal procedures and QDC management structure.

⁽³⁾ Note: MQS is an acronym in Portuguese meaning

Level 3 Focus → After MQS establishment, the next step is its institutionalization as the main requirement to achieve Level 3 in the organization.

2) Software Quality Management and MQS

NDB's Software Quality Management – SQM is defined and documented in MQS, which goals are:

- To describe methods for the improvement opportunities identification and
- To describe methods to plan and oversight the activities of development and software process improvement.

To achieve these goals, the MQS defines the OSSP - Organization Standard Software Process and the SPI - Software Process Improvement methods that take care of:

- Tailoring from the SW-CMM to NDB software process;
- Correlation with QDC practices; and
- Definition of responsibilities, activities, roles and interfaces.

Organization Standard Software Process for NDB

The NDB Standard Software Process was tailored from OSSP established in SW-CMM and defines:

- Descriptions of applicable software life cycles;
- Guidelines for projects' tailoring of the MQS (OSSP);
- Software process database with definitions of access, maintenance and entered data methods;
- Software process related documentation Library;
- Measurements/Metrics applicable for NDB and for each software development area;
- Verifications to ensure that activities are performed in compliance with established process – Internal and External (independent) verification;
- Structure; functions and activities of SEQT and SEPG workgroups responsible for definition, maintenance and improvement of software process in NDB and development areas; and
- Software process structure tailored from each KPA – Key Process Area of SW-CMM and the guidelines to implement in each development area.

The Software Process Improvement at NDB

Despite the development approach of SEI, applied for Software Process Improvement, is based on IDEAL cycle - Initiating / Diagnosing / Establishing / Acting / Leveraging [10], the Software Process Improvement established for NDB had been based in the Deming or PDCA Cycle - Plan / Do / Check / Act. The reasons to use of PDCA Cycle were:

- PDCA Cycle is aligned with the continuous improvement structure established in the concept of QDC Quality Management;
- The practical application of PDCA Cycle as well as its nomenclature have been already institutionalized within NDB; and
- Most of the requirements and goals of the IDEAL were covered by the PDCA concept [2,10].

Based on the study, analysis and tailoring of IDEAL and PDCA, the Software Process Improvement had been structured and has the following stages: (Table 4 and Figure 2).

Information and Data Input	Information and data <u>sources</u> that should be used for the improvement process. Can be used information of SW-CMM evaluation process or management processes of QDC.
Improvement Planning P	Groups SEQT and SEPG's review data/information, establishing and documenting actions plans in the corporate level and its deployment in each areas.
Improvement Execution D	Groups SEQT and SEPG's are responsible for the execution, tracking and oversight of the action plans. In this stage, necessary information are sending to review.
Verification and Review C	Reviews are executed in some levels involving and integrating the Leadership (Corporate and Areas Quality Committees) and SEQT/SEPG groups.
Acting A	Implement systems changes and fulfillment of the goals after reviews, process standardization for its institutionalization and MQS maintenance.

Table 4 – PDCA Cycle for SPI

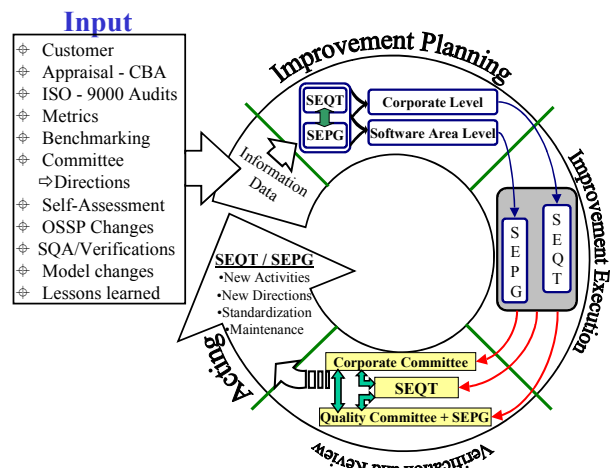


Figure 2 - NDB's Software Process Improvement SPI

IV. Institutionalization of integrated process
A. QDC and SQM integration

The necessary effort to implement and maintain the SPI – Software Process Improvement would be very great without tailoring and integration with management methods already practiced. Moreover, it would not have a perfect correlation with the company strategies and goals with the establishment of different management structures.

To avoid unnecessary effort and also to apply the good practices that have already institutionalized in the organization, the SPI have been built on the bases of QDC. It has been done by reviewing the QDC components and its attributes and by establishing the integration between the practices in a corporate level and the activities needed to SPI. This integration is presented in the Table 5.

QDC Component	Integration with SPI
Leadership	<ul style="list-style-type: none"> ▪ The Leadership is the SPI sponsor; ▪ Directions (Mission, Policies) are established and committed in corporate level; ▪ The structure already formed by the Directive and Quality Committees has incorporated the activities and software process reviews. ▪ Customer's data, information and requirements are input to the SPI Cycle - (see also figure 2)
People	<ul style="list-style-type: none"> ▪ Education and Training practices to built knowledge and capabilities are applicable for the entire NDB including SPI needs; ▪ People communication media (Intranet, Handouts, etc) divulge software improvement activities for all the organization and vice versa
Innovation & Continuous Improvement	<ul style="list-style-type: none"> ▪ President Award involves and recognizes people and papers from SPI; ▪ The benchmarking method is applicable as an input to SPI – (see also figure 2); ▪ Customer Satisfaction System sends software information regarding customers' reported problems. (TI)
Systems	<ul style="list-style-type: none"> ▪ ISO 9000 Quality Management is the base for the improvement and maintenance of procedures in the organization, including the relative ones to software. There is a great relationship between ISO items and KPA's of the SW-CMM (see also table 6); ▪ Metrics Management Systems will include in its structure a database including Software measurements.

Table 5 – Integration and correlation of QDC and SPI

ISO 9001 Items	Contribution / Integration ISO and SPI
4.1 Management responsibility	<ul style="list-style-type: none"> ▪ Quality Management structure and its review method institutionalized. ▪ Quality Policy applicable for the entire organization ▪ Roles, responsibilities and functions defined and documented ▪ Relationship with Commitments, Verifications and Activities of SW-CMM.
4.2 Quality System	<ul style="list-style-type: none"> ▪ Structure to establish procedures already institutionalized; ▪ Existence of Quality culture; ▪ Relationship with Commitments and Verifications of SW-CMM.
4.4 Design control	<ul style="list-style-type: none"> ▪ Great relationship with the KPA RM – Requirements Management of SW-CMM
4.5 Document control	<ul style="list-style-type: none"> ▪ Documented procedures for creation, review, control, access and spread already institutionalized.
4.9 Process control	<ul style="list-style-type: none"> ▪ Some software process procedures already defined, documented, followed and practiced.
4.14 Corrective action	<ul style="list-style-type: none"> ▪ The corrective action procedures and records have been applied for software.
4.16 Quality records	<ul style="list-style-type: none"> ▪ Procedures for identification, collection, indexing, filing, storage, maintenance and disposition of quality records have been applied completely
4.18 Training	<ul style="list-style-type: none"> ▪ Education and training procedures already institutionalized; ▪ Great relationship with the Abilities to performance and the KPA TP – Training Program of SW-CMM.

Table 6 – Contribution and integration ISO and SPI

B. Achieved Results

The most important result until today is the Level 2 achievement – Repeatable Level of SW-CMM. However, other important topics should be mentioned as:

- Skill and knowledge of Quality Management Models for Software and Evaluation Methods to NDB and USP people;
- Integration between different software development areas to develop practices and procedures as a common goal;

- Establishment of Corporate Workgroup – SEQT to define, maintain and improve software process as well as to motivate the people involved.
- Establishment of a tailored and integrated SQM based in TQM.

C. Difficulties and Solutions

In the stages presented for the establishment of the SQM, the main difficulties and its solutions had been:

- Comprehension of SW-CMM model and its requirements. People didn't know the model approach and requirements in the beginning of implementation activities. Solution: Research, study and analysis by people of NDB and USP in the materials, literature and resources available [7,9],
- The method of evaluation – Appraisal. The criteria and procedures of SEI-SCE were very different from the evaluation method of ISO 9000. Solutions: Training in the SCE method and execution of pre-appraisals [9]; and development of Self-assessment procedures
- Tailoring the SW-CMM. The difficulty was the number of human resources hours needed to develop the MQS and the associated studies. Solution: To focus previous studies, analysis and jobs at the corporate coordination area;
- Establishment of Corporate Training Program. Because different levels of knowledge in the software development areas, it was difficult to define just one Training Program. Solution: It will be necessary to review and establish new training procedures;
- Establishment of Applicable Metrics. The definition of metrics in Corporate and Software Development Areas levels is still a difficult. Solution: To study material available, including TL 9000 (Telecommunication Handbooks from QuEST Forum www.questforum.org)

V. Conclusion

This paper is an experience of how to structure and to apply SQM in an environment of TQM and the contributions, benefits and results achieved. Furthermore, it can be noticed the great contribution for an organization to integrate the Quality Management and implement it as a whole with the commitment of everybody involved.

This experience is a part of NDB activities in Continuous Improvement path for the Software Process and represents the skill and knowledge acquired in the researches and studies of vast material focusing the SW-CMM. However, some practices and lessons can be applied in any of current models

or standards for Software Process Improvement like ISO/IEC 15504 – SPICE; ISO 9000-3, TRILLIUM and TL 9000. It means that, if an organization has already established a Quality Management structure, all the knowledge and practices acquired should be applied in the tailoring of a SQM.

The next steps of this work must have the focus on tailoring the MQS - Software Quality Manual to the specific needs of the process in each software development area. Among the difficulties that are being faced, for the effective implementation and institutionalization of process improvements, this is the most complex and critical factor to get the success in SQM.

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VII. References

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