ISO 9000 FOR SOFTWARE QUALITY SYSTEMS

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SUMMARY

This paper outlines some key elements of quality system standards ISO 9000 and their application to Information Technology and software development. Emphasis is put on the need for closed feedback loops in the organization which will provide a stable framework for effective quality management.
Application of the generic ISO 9000 standards to software development has to take into account the specific characteristics of this process. Additional guidelines are described in ISO 9000-3.

Implementation of a quality system in practice should be based on the existing process and where necessary add improvements. The objective is not to impose rules, but to improve the process.
Finally the paper describes audit and certification of quality systems. In the Information Technology Sector a number of initiatives have been taken to promote the general acceptance and international harmonization of IT quality system certificates.

1 PRINCIPLES OF QUALITY MANAGEMENT

The objectives of quality management are twofold:
- improvement of customer satisfaction, and at the same time
- improvement of the internal processes.

The realisation of these objectives in an organization requires a systematic approach, supported by a quality system. In working out the details of a quality system a few key-questions have to be considered:
- What are the objectives of an organization?
  What do we want to accomplish?
- Which activities and processes do we need in order to achieve the objectives?
- How can we manage and control these activities?

The principles of customer oriented quality-management are in the expression: Tell what we will do, and do what we have told!

2 QUALITY MANAGEMENT BASED ON FEEDBACK LOOPS

Engineering principles learn us that a stable process has to be based on a closed control loop, which provides feedback between the stated objectives and the actual results. The same principle applies to quality-management. We need a number of closed feedback loops.

First of all we need communication and feedback between the different levels in the organization. Management has to define the objectives and to translate these objectives into targets and results which can be understood by the staff carrying out the activities. Vice-versa management should have an open mind for the practical experiences of their staff and the bottlenecks encountered. Such bottlenecks should be solved by improvement of the working method and/or by adjustment of the objectives.
To be able to determine whether improvement has actually occurred we have to formulate the objectives in a concrete and measurable way. And we have to measure our results, keeping some formal records and comparing measurements made at different time intervals.
Quality management involves also documentation of the procedures and working methods throughout the organization. Here again a process of careful communication and feedback is required to ensure that the actual working methods follow the documented procedures and that these documents are kept up-to-date when changes occur in practice.
The various feedback loops provide a framework for the quality management, in which a number of elements are put together:

- ***Management Responsibility***
  Management will define the quality policies and objectives
- ***Quality System***
  The quality system implements the procedures and working methods in the organization which are necessary to achieve the objectives
- ***Measurements***
  Measuring and recording methods keep track of actual results and performance
- ***Internal audits***
  Internal audits will show whether the quality systems works in practice and how effective it is
- ***Management review***
  Management will review and analyze the results of quality measurements and internal audits and compare these with their objectives
- ***Preventive and corrective action***
  The performance-analysis will lead to actions for improvement of the quality system.

The essential requirements for a quality system are specified in a series of internationally accepted standards: the ISO 9000 standards. Implementing these requirements enables an organization to manage and control its quality processes and the "quality-level" of its products or services.

3 CHARACTERISTICS OF SOFTWARE DEVELOPMENT

The ISO 9000 standards are generally applicable. However in their application to software development we have to take into account the special characteristics of this process.

- In a software quality system a great deal of emphasis is put on design and development activities. As soon as these activities have resulted in a first operational product which meets the stated requirements, this product is delivered.

Reproduction of software seems rather trivial. As a consequence we have to pay much attention to planning and control of the development process.

- Software is intangible and often very complex which makes it difficult to determine its quality. It is therefore important to use design reviews and verification and validation in order to prevent errors or detect them as early as possible.
- The intangible nature of software makes it also difficult to distinguish one version from another version. This makes it necessary to have a rigorous configuration management system.
- Software development involves strong interaction and cooperation with the customer, whether this is external customer or an internal customer. It is necessary to ensure a complete set of specifications and a clear understanding thereof before the development is started.
- Software development is project oriented. Before a project is started the availability has to be ensured of the capabilities and resources necessary to complete the project successfully.
- In addition project planning and control are important in all phases of the project.
- In many instances it is to be recommended to work according to formalized methods, using supporting tools and techniques. However such methods and techniques should not become an end in themselves and become an obstacle for the quality objectives.

4 ISO 9000-3 FOR SOFTWARE DEVELOPMENT

To give guidelines for the application of the general requirements of ISO 9001 to software development, an additional guidance standard has been drawn up: ISO 9000-3. This guidance document describes a software quality system in three layers.
The main layer comprises the life-cycle activities, covering the software development process from specification to maintenance. The life-cycle activities are project-specific: they have to be carried out for each separate project in a way which takes into account the specific requirements of the project.
In the life-cycle activities we can distinguish two phases:

- The planning phase, in which we complete a contract, agree the specifications and prepare a workplan.
- The implementation phase which comprises the actual development activities.

The second layer of a software quality system consists of elements which support the life-cycle activities. In many cases software projects will be carried out using an existing system environment and using existing supporting procedures and tools which are not project specific. Some of these supporting elements are software oriented, such as configuration management and development tools. We have also supporting elements which are more general and not software specific, e.g. document control or purchasing procedures.

Finally a software quality system needs a management framework to bring all elements together and to create the general organization and conditions for control over the process and for achieving quality. This framework is highly similar to other sectors of industry and has to provide the feedback loops as described previously in section 2 of this paper.

5 OTHER STANDARDS AND MODELS FOR SOFTWARE QUALITY

In addition to the ISO 9000 series we have also other standards and models available aiming at improvement of software quality, e.g.:

- IEEE has published a whole series of standards, technical oriented and defining detailed specification of working methods.
- The Software Capability Maturity Model (CMM) defines five levels of quality and productivity and it provides a road map for a step by step implementation of the requirements.
- The SPICE initiative (Software Process Improvement and Capability Determination) develops a series of standards based on similar principles and approach as CMM.

The various standards and models have a common objective: to assist and enable an organization to achieve better quality management of the software process.
They have also in common that quality improvement is not merely a technical issue. It is primarily a management issue and requires a systematic approach in the organization.
A key element in quality improvement in all cases is good control and management of the activities and processes; this is strongly supported by ISO 9000, which can therefore be considered as a series of base standards. How can we possibly achieve improvement of our process if we do not have control over the process?

6 IMPLEMENTATION OF ISO 9001 REQUIREMENTS

ISO 9001 is a generic standard. For each process in an organization all relevant clauses of the standard apply. There is no simple one-to-one relation between the clauses of the standard and the processes in the organization, especially not in software development. For example the clause on Design Control does not apply only to the "Design Department" but is applicable to all processes where design activities take place. The requirements of this clause may be implemented in a different way for different processes, depending on specific conditions and circumstances. Key requirement in all cases is to provide adequate control of the process.

Implementation of a quality system should take the existing process as a starting point. This will enable us to use as much as possible existing knowledge and experiences, even if we know that it is not perfect. Therefore the start is to document the various activities in our existing process, e.g. in a flowchart or process diagram. This will enable us to analyze what are the objectives, which inputs do we use, what outputs do we have and how can we control the process.
Following this we can map the requirements of ISO 9001 on the process. This will clarify where we already satisfy the standard and where we need additional controls or procedures.
We should not take ISO 9001 as a starting point and force our organization or our process into the structure of the standard. This would mean major changes in our process and would make existing knowledge and experience useless.
In a similar way it is very difficult to take over the existing quality system of another organization and import that into our own organization. The differences between the two organizations in goals, working methods and culture etc. will lead to difficulties.

Throughout the implementation process we have to remember that the objective of a quality system is not to impose rules, but to improve our process. The improvement should be visible to the people directly involved in the activities.
Also we have to be careful about the paperwork. A thin quality manual is preferable to a thick one. A thick manual will not be read and it will certainly not be observed in practice.
Finally we have to bear in mind that a software quality system involves more than just a documented development method. This method is important. However, let us be aware that development is one section of the standard and that there are 19 other sections dealing with other processes.

From practical experience we can identify some issues which are specific for software development, e.g.:

- In internal software departments or in development of embedded software we often see confusion over who is "the customer" (as referred to in ISO 9000). In such cases the customer is the part in the organization that approves the software specifications and the budget. When the specifications change also a change may be needed in the budget and the time-schedule.
- Configuration management has to be applied to the development project. But also to the environment which supports the development, e.g. the computer network, compilers, test sets etc.
- ISO 9001 requires a clear distinction between internal release by the supplier and acceptance by the customer. These activities should not be merged into a single test.
- Many organizations carry out already project-audits. Such an audit will consider: have we completed the project on schedule, or what went wrong? In addition to project-audits we also need internal system-audits, i.e. an audit of the quality system as a whole in order to consider e.g.: are our development method and other working methods adequate and how can we improve our process?

7 AUDIT AND CERTIFICATION

A third party audit means a formal investigation whether a quality system satisfies the requirements of ISO 9001. A successful audit may result in the certification of the organization's quality system.
A quality system audit may be carried out for several reasons, e.g.:

- ***Present a challenge***
  The implementation of ISO 9001 presents a clear and challenging goal to the internal organization which will help to stimulate and focus the quality activities.
- ***Provide a benchmark***
  An audit of the quality system provides a clear and objective comparison with other organizations.
- ***Customer confidence***
  Audit and certification of the supplier's quality system can provide confidence to the customer.

Especially in software development, where the customer is depending on the supplier's quality system for successful completion of an unique product made to the customer's specifications.

An audit involves a number of activities. In preparation of an audit a detailed audit-plan will be prepared based on an analysis of the supplier's activities and organization in relation to the requirements of the standard.
The actual audit starts with an appraisal of the documented quality system, i.e. the quality manual and associated quality procedures and work instructions. All procedures as required by the standard have to be in place, for instance for contract review, for development planning, for the use of tools, for document control etc.
The next step is the verification of the practical application of all procedures and work instructions in the organization. This involves interviewing staff and inspection of project files, test records and other quality records.
The third important element is an audit of the feedback loop for internal control and management of the quality system, by means of internal audits, management reviews and corrective actions.

A third party audit will be based as much as possible on objective evidence. The supplier will be asked to demonstrate that the required procedures and work instructions are available and followed in practice. Of course all information collected by the auditors will be treated fully confidential.

After a successful audit a Certificate can be issued for the supplier's quality system. This means formally that the quality system complies with the requirements of the standard. In practical terms it means that the supplier is able to deliver a product as specified and has effective control procedures for this purpose.
Certification of a quality system will be followed by periodic surveillance audits.

8 ITQS

A number of certification bodies cooperate in ITQS: the Agreement Group for Assessment and Certification of Quality Systems in the Information Technology Sector. The objective of ITQS is to promote the general acceptance and international harmonization of IT quality system certificates based on ISO 9000 standards.
Currently ITQS has 10 certification body members, located in 9 European countries: AENOR(ES), AFAQ(FR), AVI(BE), BSI-QA(GB), CETECOM(DE), DELTA(DK), IMQ(IT), KEMA(NL), NSAI(IR), TÜV-Bayern(DE).
Contacts have been established with candidate members outside Europe.
ITQS was established in 1992 with support from the Commission of the European Union, in response to a growing market perception of significant difference in the quality and depth of audits in the IT-sector, as carried out by different bodies. ITQS offers an open platform for international harmonisation of competent and consistent audit and certification.

ITQS members offer a number of benefits to their clients:

- *Accredited and high level services*
  All members offer audit and certification services with a high level of integrity. Their operation is verified and monitored by national accreditation authorities.
- *Competent and consistent auditing*
  The audit and certification methods and procedures are harmonised among the ITQS members. The harmonisation includes:
  * common auditor qualification criteria
  * the use of a common European IT Quality System Auditor Guide
  * a continuous program of mutual audit observation.
- *Mutual recognition*
  The mutual recognition agreement among the ITQS members enables an IT company to avoid multiple assessments and to obtain a quality system certificate that will be endorsed by all ITQS members.
- *Central register of certificates*
  ITQS maintains a central register of quality system certificates issued by its members. This register is published regularly and currently lists over 2000 certificates.

An important element in the harmonisation is the European Quality System Auditor Guide. The guide identifies IT-related aspects in a quality system which needs to be verified in an audit. However, it does not give additional requirements. The auditor guide is based on ISO 9001 and on the implementation guidance as given in ISO 9000-3. The use of the guide makes it possible for auditors from different certification bodies to reach equivalent results. The auditor guide has been developed in close cooperation between ITQS and TickIT, the UK sector scheme for software quality system certification. As a result the same auditor guide is used in ITQS and in TickIT.

9 INTERNATIONAL HARMONISATION

As described before ITQS is a cooperation of a number of certification bodies. In the UK the TickIT scheme has been established. In addition also in other countries proposals have been developed for software specific certification schemes.
The possible emerging of a number of certification schemes presents confusion to the market regarding the meaning and the value of certificates and may create barriers to the general acceptance of certificates.
To avoid theses risks a User Forum Meeting on International Harmonisation of IT Quality System Certification was organised in September 1995 (The Hague, NL). In this event representatives of Information Technology suppliers, users and certifiers from 17 countries on four continents discussed the market requirement for international harmonisation between ISO 9000 certification bodies.
Also representatives of accreditation bodies attended.
The meeting expressed the opinion that international harmonisation is needed to allow one-stop audit and general acceptance of quality system certificates.

This should be achieved through agreed auditor competency criteria, auditor qualification procedures, and equivalent and consistent audit and certification practices.
Certification must be based only upon conformity with the ISO 9001/9002 standard; no additional requirements for IT supplier quality systems shall be formulated. Up-to-date guidance should bridge the gap between every day practice and the high level of abstraction in the standard.

The meeting installed a Task Force with the mission to ensure that:
- IT users and suppliers obtain optimum benefit from implementation of ISO 9000
- Certifiers deliver a consistent, reliable and relevant certification service that is recognised worldwide.

This task force is now considering further proposals.

10 CONCLUSIONS

After a period of initial development clear patterns are now established for the application of ISO 9001 to the Information Technology Sector and especially to software development. It is important to bear in mind the objectives and the principles of quality management:
- quality management is aimed at improvement of customer satisfaction and of the internal processes
- effective quality management will be based on a number of feedback loops in the organization.

Implementation of a quality system takes considerable effort. A number of essential conditions can be summarized as follows:
- we need Commitment; without clearly visible commitment from management the rest of the organization will not move
- we need Communication; top-down and bottom-up throughout the organization
- we need Consultation; the people who carry out the activities know where improvements in the process can be made
- it means a change in Culture; working methods will have to change and quality will become an important consideration in our decisions.

Finally an organization should consider an audit and certification of the quality system following internationally harmonized practices. However, certification should not be the main objective but will be an added benefit. The primary objective and benefit of a quality system lies in the improvements which will result from a successful implementation of ISO 9001.

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He was involved in drafting of ISO 9000-3 and participates in its current revision. He is chairman of the Agreement Group ITQS.