Transactions on Information and Communications Technologies vol 8, © 1994 WIT Press, www.witpress.com, ISSN 1743-3517

Management models for software development

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ABSTRACT

In the experience of the authors, many Companies base their approach to Quality Management Systems on just one, or at best two, standard models. For example ISO 9001/ISO 9000-3 (TickIT), SEI and TQM.

Expert groups such as ISO TC176, DISC, ABCB discuss the detail and application of the ISO approach. Other groups and projects such as SEI, ESPRIT etc. concentrate on the SEI CMM approach.

The Authors propose that little formal effort has been devoted to exploring the potential substantial advantages of developing an optimum approach by way of a combination of the models. Indeed sadly, on a number of occasions, the emphasis appears to have been to try and discredit all approaches other than the one adopted, by the use of biased argument.

The purpose of this paper is to analyse current approaches to Management Systems for software development via three models: ISO 9001/ISO 9000-3 (TickIT), SEI and TQM. Many overlaps between the approaches are apparent, it is also recognised at the same time that each model has its own advantages and disadvantages.

This paper will compare and contrast the various approaches. The subject of TQM will be included throughout, by identifying the key principles of TQM and applying it to both the SEI and TickIT models to identify the parallels.

INTRODUCTION

There are many approaches to Quality Management/Improvement. Fundamentally, they are all aiming to achieve the same objective i.e. a well run organisation following defined repeatable processes within which the employees contribute positively by following the processes and suggesting improvements. Management demonstrate commitment to improvement by following defined processes themselves, supporting Project Teams in difficult times and providing the resources for analysis of process effectiveness and subsequent improvement.

4 Software Quality Management

There are many gurus with their own formula on how to implement a TQM programme, they all have the following underlying principles:-

- Management Commitment is essential
- Everyone in the organisation contributes to the quality of the output.
- A mechanism for Quality improvement is needed.

Some TQM consultants like to maximise the differences between an ISO 9000 systems oriented approach to Quality and the TQM approach, in doing this they 'play down' the standard. However, in order for TQM to work, there must be defined repeatable processes within an organisation, such that each individual knows what they are aiming to achieve and have a basis for improvement. This is a quality system, similar to that required by implementation of ISO 9001[1].

The above three principles are also fundamental to the successful implementation of an ISO 9000 compliant Quality System.

- Management commitment - an ISO 9000 compliant Quality System cannot be effective without the driving force of the management to ensure all within the Company implement it. ISO 9001 para 4.1.1 requires that the "management shall define and document its policy and objectives for, and commitment to, quality." Also that the management shall "ensure that this policy is understood, implemented and maintained at all levels in the organisation."
- Everyone in the organisation contributes to the quality of the output from the organisation - ISO 9001 para 4.1.2.1 requires that the "responsibility, authority and interrelation of all personnel who manage, perform and verify work affecting quality shall be defined". It is difficult to argue that this doesn't cover everyone within the organisation. Indeed the standard as a whole can be applied to departments such as Sales and Marketing or Accounts.
- A mechanism for Quality improvement is needed. - this is a fundamental requirement of ISO 9001 para 4.14 "Corrective Action" and para 4.1.3 "Management Review" which together require that the Quality System is reviewed regularly in the light of experience and based on results. Any necessary improvements are thus identified and implemented.

The Software Engineering Institute's CMM describes a process infrastructure for software engineering and management practices. With it a company can organise itself in such a way that the technical, administrative and human factors affecting quality of its products and services will be under control. A major premise of the CMM is that as a software organisation gains in software process maturity, it institutionalises its software process through policies standards and organisational structures. i.e. an infrastructure and corporate culture are built to support the methods, practices and procedures even after their champions have gone.

The CMM was designed to guide software development organisations in selecting process improvement strategies by determining its current process maturity and identifying the few issues most critical to that improvement. Essentially then, the CMM has as its overriding structure or framework the concept of process with the other management and technical practices supporting process improvement and subsequent maturity.

A TQM approach is thus fundamentally similar to an ISO 9000 Quality Systems approach and the CMM approach. So why do Organisations opt for one approach or another and why are some consultants so insistent that the methods they implement or the guru they follow are the only way? (other than for the obvious commercial reasons).

Even professional groups such as CAC-JTC/SC7 [2] can demonstrate considerable bias rather than to examine all methods and approaches to obtain the best workable system to suit each individual situation. The two approaches examined in detail in this paper are ISO 9000/TickIT [3] and the Software Engineering Institute Capability Maturity Model.[4,5]. The benefits, content and assessment approaches are compared and contrasted in order to identify strengths and weaknesses and propose how either or both models and assessment methods may be improved by learning from experience with the other.

BENEFITS BROUGHT ABOUT BY IMPLEMENTATION OF AN ISO 9000/TickIT COMPLIANT QUALITY SYSTEM

There is currently very little substantiated evidence on the financial rewards derived by way of less waste, increased profits or increased business. There is a real need in fact for research in this area to be conducted at a National or International level. There are many perceived benefits derived on a more subjective basis. For example the DTI Survey of Quality Consultancy Scheme Clients [6] indicates that :-

- "89% of clients surveyed believed that the introduction of Quality Management Systems had a positive affect on their internal operating efficiency"
- "48% of firms claimed increased profitability, 76% improved marketing and 26% improved export Sales"

The projected savings indicated in the TickIT Guide are of the order of £150k - £300k per year for a Company with a turnover of £3m. These savings being brought about by more efficient processes and less rework. This of course accounts only for the savings within an organisation, there are further benefits to customers in that there will be less down time and less time investigating problems.

Experience at Bull Information Systems, UK [7], revealed a factor of 8 - 10 reduction in defects found during acceptance tests from the start of quality system implementation, 2 years pre-registration to 2 years post registration. Due largely to a reduction of costs brought about by less support needed during the warranty period, an accompanying increase in profits from 25% to 33% was also achieved.

There is further evidence from the Chemical Industry [8]. DuPont reported "one chemicals plant saved $2.4 million/year, mainly by reducing the production of non-conforming material; a quality control lab reduced costs by $750,000/year by eliminating unnecessary tasks, reducing overtime, and clarifying job responsibilities; and another plant identified $1 million in obsolete or excess inventory." The time taken to achieve a return on investment for the costs of developing and implementing the QMS and for the registration costs was also researched. The longest payback time for investment - according to a DuPont study is three years.

The authors note it has been interesting to watch Companies grow in their awareness of Quality within their own organisations and their knowledge of how to influence it. Many organisations have adopted the principles wholeheartedly and become more aware of the quality of the products and services they deliver to their customers and what their customer perceptions of them as an organisation are. They also enjoy the benefits of better planning, more reliable estimates, fewer cost and time scale overruns.

There are now so many companies registered to ISO 9000/TickIT that with time it is not so much a question of what are the benefits of implementing the Quality System and seeking registration as what are the drawbacks of not seeking registration. Many companies have, as part of their procurement policy, the requirement that for eligibility

to bid for certain contracts, contractors shall be registered. The effect of this is to force Companies to develop and implement Quality Systems and seek registration. This has some counter-productive side-effects. See paragraph on "Problems with TickIT Certification" below.

BENEFITS OF FOLLOWING THE CMM

It has been six years since the ideas of software process maturity and systematic efforts to improve it have spread in the U.S. During that time some organisations have collected and tracked data that allow a calculation of their return on investment to software process improvement. They are the Software Engineering Division of Hughes Aircraft Company in California [9], Raytheon's Equipment Division [10] based in Massachusetts and the U.S Air Force Air Logistics Centre in Oklahoma [11]. Their data shows an ROI of 5, 6, or 7-to-1. A spectacular achievement.

Schlumbergers' corporate wide process improvement effort counted its results using other metrics [12]. For example, one Schlumberger group improved its on-time deliveries from 51% to 94% in two years by installing a formal process for project planning. Another group implemented formal SQA procedures over two years from 1989 to 1991 and reduced the percentage of defects discovered after shipment from 25% to 10%.

There are some common themes that emerge from published reports and other accounts of the use of the CMM. Among them are:-

- An improved understanding of how the organisation develops software;
- Increased control of costs and ability to predict development cycle time and costs;
- Reduced re-work;
- Increased predictability and control of software quality

These results are just those to be expected from successful TQM efforts in software. What differences does the CMM make? We claim that they are the following;

- the effectiveness of assessment as the impetus to start on the CMM road map;
- the wedding of the phased goals of the CMM and the techniques for organisational development and cross-functional teams;
- the rapid spread of CMM based improvement efforts and the associated exchange of lessons learned among improvement groups.

It will be evident that these benefits are generated as much from the context of use of the CMM as from the CMM itself.

One can argue that the greatest benefit of the CMM, as a framework for process improvement, is that an organisation using it learns how to manage its own change. This learning, which depends heavily on an organisation's ability to take a process view of itself, is crucial for competitive advantage in a world of rapidly re-aligning markets. Following the CMM road map thus gives an organisation practice in guiding its own change, a sense of the priorities and leverage points for improving processes and a realistic sense of how much and how fast effective changes can be accomplished. At higher maturity levels, this kind of learning enables organisation to take calculated risks for innovation and perhaps seize the initiative from competitors.

COMPARISON OF SUBJECT CONTENT ISO 9000 Vs CMM

The subject content of the CMM is entirely consistent with that of ISO 9001/TickIT, the method of expressing requirements is quite different however. ISO 9001 is a set of high level requirements with which an organisation must conform. The twenty paragraphs cover the main areas of concern with operating a well run organisation. The standard is totally non-prescriptive giving freedom of choice on the method of implementation.
The twenty paragraphs cover the following subject areas:-

Management Responsibility
Quality System
Contract Review
Design Control
Document Control
Purchasing
Purchaser Supplied Product
Product Identification and Traceability
Process Control
Inspection and Testing
Inspection, Measuring and Test Equipment
Inspection and Test Status
Control of Non-Conforming Product
Corrective Action
Handling, Storage, Packaging and Delivery
Quality Records
Internal Quality Audits
Training
Servicing
Statistical Techniques

The CMM model has five layers of maturity. Each has associated with it a number of key practices, broad groupings of software engineering or management practise that are considered to define the level. The description of each level is very broad. A summary is given below[4]:-

- Level 1 - Initial - The starting point for many companies, at the pre Quality System stage. Some projects are successful, but rely on the skills of individuals. The success of a project may not be predicted with any degree of certainty
- Level 2 - Repeatable - effective management is institutionalised, successful practices may be repeated, realistic commitments are based on the results observed on previous projects.
- Level 3 - Defined - A standard process for software development is documented within the organisation. A software engineering process group SEPG has been established. Both software engineering activities and management practices are stable and repeatable.
- Level 4 - Managed - Quantitative goals are set for software products and processes. The risks whilst learning in a new application domain are known and managed. Product and process quality trends are quantitatively predicted. When the limits are exceeded, corrective action is taken. Software products are of predictably high quality.
- Level 5 - Optimising - The entire organisation is focused on continuous process improvement. Defects are analysed to determine their causes. Software processes are evaluated to eliminate known types of defects and lessons learned extrapolated to other projects. Improvement occurs both by incremental advancements in the existing process and by innovations using new technologies and methods.

There are eighteen key process areas in all. These are as follows:-

Level 2	Level 3
Requirements Management	Organisation Process Focus

Software Project Planning
Software Project Tracking and Oversight
Software Sub-contract Management
Software Quality Assurance
Software Configuration Management

Organisation Process Definition
Training Program
Integrated Software Management
Software Product Engineering
Inter-group co-ordination
Peer Reviews

Level 4
Quantitative Process Management
Software Quality Management

Level 5
Defect Prevention
Technology Change Management
Process Change Management

Key practises for each process are grouped into 5 categories which provide a framework for use either in appraisals or as improvement goals. The categories are "common features" considered necessary for a practise to be effectively implemented and are:

Commitment to perform
Measurement and analysis
Ability to perform

Activities performed
Verifying implementation

The framework of common features presupposes that for a practise to be fully in-place and a part of the routine for conducting business, a policy mandates its use (Commitment to perform); adequate resource will be allocated (Ability to perform), appropriate engineering or management tasks will be carried out (Activities performed); a means of determining the status of the tasks performed will be effected (Measurement and analysis). Task reviews will take place (Verifying implementation).

None of these practices are inconsistent with adoption of an ISO 9001/TickIT Quality System. There have been attempts to determine where on this maturity scale an ISO 9001/TickIT Quality System sits. Various figures have been suggested as around level 2 or level 3 or between level 3 and 4. Defined, documented, repeatable processes as required by levels 2 & 3 are implicit within ISO 9001. The discussion arises more at levels 4 and 5. These are consistent with the requirements of ISO 9001 para 4.14 "Corrective Action" and 4.1.3 "Management Review". Para 4.14(a) states that the supplier shall "investigate(ing) the cause of non-conforming product and the corrective action needed to prevent recurrence". Software with bugs in is non-conforming product, therefore within an ISO 9001 compliant system, we are expected to determine causes of bugs and improve our processes to ensure that similar types of bugs don't occur in the future. How would we know if they did? We need to know how many we have in existing products, what changes had been made to the quality system and whether or not these had been successful by comparison with bug levels in software pre and post improvement to the quality system. The other sections of paragraph 4.14 give more 'food for thought' on this subject. Therefore implementation of this paragraph of the standard implies the use of metrics, analysis of trends and improvement of processes which is also the requirements of the CMM level 5.

One major difference between the ISO approach and that of the CMM is that in order to achieve the various levels of maturity, an organisation must be implementing a number of "key practices". For example on the subject of estimating and planning, the

requirements within ISO 9001 that are of direct relevance are para 4.3 "Contract Review" which states that contracts shall be reviewed to ensure:-
"a) the requirements are adequately documented, b) any requirements differing from those in the tender are resolved, c) the supplier has the capability to meet contractual requirements". Further, paragraph 4.4.2.1 "Activity Assignment" states that, "The design and verification activities shall be planned and assigned to qualified personnel equipped with adequate resources"

Neither of these requirements mentions that there should be a formal procedure for estimating and records of previous estimates on which to base future ones. It would seem sensible that in order to conform to these requirements, formalised estimating procedures and records are the way to implement this element of the quality system. However, there is no actual requirement to do so.

The CMM on the other hand states that a characteristic of a level two organisation is that realistic commitments are based on the results observed on previous projects. A key practice in achieving this is deemed to be the use of estimating procedures and records. For each level of maturity therefore there are certain processes or key practices that must exist and be effectively implemented. The CMM is therefore more prescriptive than ISO 9001, although the method of implementation of the key practices is at the discretion of the implementing organisation.

Other differences in subject content are that implementation of statistical methods, definitions of standards and implementation of technology are all addressed in more detail in the CMM than in ISO 9001. Purchaser supplied product (4.7), packaging, handling, storage and delivery (4.15), and quality records (4.16) are not so fully covered in the CMM as in ISO 9001.

Due to these differences in content between the two models, an organisation demonstrating an advanced level of maturity with the CMM will be well organised and managing its business effectively. This company may not pass an ISO 9001 assessment however. Conversely, an organisation which has passed ISO 9001, may be evaluated at level 1 - initial - on the CMM due to the lack of key processes that are not a requirement of ISO 9001. This organisation also will have a stable Quality System, be managing its business effectively, able to recognise problems with product or service and apply corrective action to prevent recurrence. It is clear therefore that there is more than one way to achieve good management practices and an effective Quality System.

It may be seen from the above analysis that it is meaningless to make direct comparisons between companies that have achieved certification to ISO 9001 and their corresponding level of maturity on the CMM.

There are also important key areas of agreement in the requirements of the two models. These are as follows:-

- independent audits of development activities
- corrective action
- employee training
- detailed process and life-cycle definition.

THE ASSESSMENT APPROACH - ISO 9001/TickIT

This section presents, in overview, the sequence of events for a TickIT assessment.

TickIT Assessments are conducted by trained auditors having a strong background in the IT Industry. Attributes of Auditors are summarised in Appendix A of

the TickIT Guide. Organisations authorised to carry out these assessments are accredited Certification Bodies (CBs) who are assessed themselves for competence (accredited) in conducting TickIT assessments, by the National Accreditation Council of Certification Bodies (NACCB). The NACCB acts as agent on behalf of the DTI.

The process is in two stages. First is the review of the documented Quality Management System QMS, to establish if it covers all requirements of ISO 9001 and activities within the scope of registration. Often termed the "system audit", it may involve several iterations and discussions between auditor and client. System audits may or may not be carried out on the auditee company site. On successful conclusion, the second stage, the compliance audit is conducted.

At the auditee company, the compliance audit begins with an opening meeting at which the process of the audit is described to the auditee management by the Lead Auditor. The scope of assessment is confirmed and any logistical arrangements made.

The main body of the audit is then conducted. Audit team members separate to interview the management and staff, according to a pre-arranged schedule. Auditors aim to interview a representative sample of managers, developers administrators etc., also a representative sample of projects and support functions covering all activities defined on the scope of assessment. The auditors are looking for compliance with ISO 9001 and the company QMS. The guidance in ISO 9000-3 and the Auditor Guide (both in the TickIT Guide) is used to aid to this process. Non-compliances are identified, and discussed with the auditee to ensure the auditor has the correct facts. Non-compliance reports are then written up, usually later in the day.

The team meet frequently throughout the audit to review their findings. They consider them for the last time in an audit team only pre-closing meeting. They examine evidence presented on non-compliances to decide if any of them are major, or if a combination of those raised indicates a major non-compliance. A major non-compliance is defined as the absence or total breakdown of a quality procedure requirement [3]. The company cannot be recommended for registration until any major non-compliance has been cleared. Depending on the number and extent of major non-compliances raised, and the time taken to clear them, this could require either limited or full re-assessment.

A closing meeting chaired by the lead auditor is held with the company management, . A summary of the main findings of the assessment are presented along with the decision on recommendation for registration. This decision is made by the lead auditor after taking into account the views of the team members. The recommendation is then reviewed by the certification body in the light of the evidence presented in the non-compliances.

A company, though recommended and ratified for registration, may be required to undertake corrective action on non-compliances before a certificate is issued. This depends on whether all the non-compliances were addressed during the assessment, and the practice of the individual certification bodies.

THE ASSESSMENT APPROACH - SEI CMM

The CMM in Assessments and Evaluations

There are two ways of using the CMM to appraise an organisations' software process maturity, evaluation of contractors by the government and assessment of organisations for their own use..

In the software capability evaluation (SCE), the appraisal style is one of audit. An external team determines the suitability of a contractor on a specified project having a large software cost or importance. A questionnaire consisting of 85 questions (in the 1987 version, still in use as of January 1994, but intended for replacement by the SEI) on software practise in their projects, is completed by 4 to 6 leaders of current or recent projects. The projects selected for evaluation would be those related to the applications domain for which the buyer seeks bidders. The audit team would require verification for each "yes" answer since each amounts to a claim that a particular key practise is in place. The verification sought would be in the form of meeting minutes, build lists, test records etc. showing past and continuous use of a practise.

The audit team interviews project leaders who completed the questionnaire to probe the "yes" or "no" answers. Other interviews are with staff from various engineering and support functions in software development, such as quality assurance or systems engineering. The number and kinds of these interviews are at the discretion of the SCE team.

The on-site period for an SCE is around 3 days. The outcome is a determination of the risk of contracting with the bidder for the system in question and may include a rating of the maturity level of the software practise at the site. For example, the audit team may report to the site only that it is above maturity level 1. Since the audit is used to qualify bidders, this report means that the customer will consider bids from companies at level 2 or higher. Practise varies as to whether the team reports to the site which key practises were found to be deficient. The same audit team can be making 3 or more visits to different bidders in successive weeks and will have no time to prepare a diagnostic briefing.

Past performance and maturity levels of bidders would be considered by the customer to be an indicator of software process capability. In making the final selection of bidder, this would be examined along with price and technical features of the proposed system.

The CMM in Appraisals/Assessments

In the Software Process Assessment, the appraisal has a collaborative rather than an audit style. Unlike the SCE, the purpose of the SPA is to highlight areas of software process, especially key practises, that are deficient at the maturity level of the site and which could be improved by a program of managed change. Unlike the SCE, the findings are treated as proprietary information and belong to the site exclusively.

The on-site period of the SPA is 8 days and is in two parts. The first, (Response Analysis Period), lasts 3 days. The team leader briefs all participants, on the background and purpose of assessment and the plans for the rest of the eight days. It is crucial to the success of the process improvement activity that the Site Manager attends this meeting and states his or her support for the assessment with the message to the participants that the assessment is the beginning of a collaboration between all levels, to improve the way work is done. The improvement should have a business objective, perhaps staying in the market because process improvement is a customer requirement, or improved efficiency and cost competitiveness, or shipping fewer defects. The focus is not the failings of the workers but the way work is organised.

The leaders of from 4 to 6 representative projects complete the maturity questionnaire. In the rest of the 3 day Response Analysis Period, the team analyse questionnaire responses and develop appropriate exploratory questions which will be used to structure coming interviews with the project leaders .

In the final five days on-site, is the assessment proper . Each project leader is interviewed for about one and a quarter hours. One team member called the facilitator, conducts the interview according to a prescribed formula designed to be relaxing and non-threatening [13]. All assessment interviews are conducted within a formal undertaking of confidentiality as to the source of information. Thus the findings on process deficiencies finally briefed on day eight will be aggregate for the site as a whole. No project leader or interview group will be associated with specific findings.

The other type of assessment interview is called practitioner discussions. These are free wheeling, informal sessions with groups of 6 to 10 engineers. Each session is devoted to one of four "functional areas": Quality assurance and release, Software integration and test, Code and unit test, requirements and design.

After two full days of interviews, the next two days are spent compiling the information into draft process findings. The validity of these initial findings are tested first in feed-back sessions with each project leader separately (by asking the formula questions: does this finding apply to your project and to the organisation as a whole?).

Three dry runs or rehearsals of the draft findings briefing are then held. The team leader presents the first to the team alone . This allows the team leader to become comfortable with the breifings structure and pacing It follows a format supplied in electronic and hard copy form in the kit of assessment materials. The second dry run is conducted with all the practitioners together, (perhaps 20 to 40 people). There are no managers present. The third dry run is presented to those project leaders who filled out questionnaires and were interviewed.

A good findings briefing will describe the 8 to 10 most serious process issues, state their business consequences, outline process and human strengths on which the organisation can build for improvement, preserve assessment confidentiality and represent a consensus of the participants (senior manager, project leaders, practitioners and team).

The findings briefing is presented on the final assessment day to all participants and other personnel who work in the senior manager's organisation and who wish to attend. The audience may number 50 or more.

There is inevitably a negative atmosphere when deficiencies are announced, therefore, no managers higher than the site senior manager are present. This ground rule is to guard against the assessment finding being seen as a report card on the performance of the senior manager. Assessments identify process problems, they do not evaluate the people carrying out the process.

To conclude the briefing, closing remarks are usually made by the senior manager. These acknowledge the validity of the assessment results and commit the organisation to address them. They may also reaffirm the motivation for the improvement to follow. At this time the improvement baton passes from the assessment team to the senior manager responsible for the allocation of resources to the follow-up improvement actions.

It should now be apparent that the assessment is really a "social ritual" [14]. For the typical level 1 organisation, it is likely to be the first time a systematic step towards long-term improvement has occurred.

The CMM as a Road Map

Just as the CMM's use in assessment requires an assessment framework, its use in a program of long-term process improvement requires a context for process improvement, of which the assessment itself is one part.

The context consists of a cycle of commitment to improve the software process, appraisal of the maturity of that process, providing the infrastructure and action plans needed and then implementing those plans over a long term. There is no magic in the CMM. It calls for an organisation to undertake systematic improvement over the long term and for strategic business reasons. Successful process improvement is not an activity added on to the normal business but a new and permanent core competency of the business. Hence the need to build an infrastructure, directed towards process improvement, that is (frequently) a new facet of the organisation . Hence, also the need for a commitment phase in which the motivation for improvement permeates the whole organisation. Also the need for an appraisal phase to identify process deficiencies with which people are struggling. All of these features require management commitment and sponsorship.

ANOMALIES WITH THE APPLICATION OF THE ISO 9001/TickIT CERTIFICATION PROCESS

This section is not intended to denigrate the ISO 9001/TickIT certification process in any way. TickIT is a very successful scheme that has brought enormous benefits to the industry. The scheme has now been fully operational for approaching three years however, and it is of value to reflect on what we have learned.

ISO 9001 is Not Software Specific

This is both a strength and a weakness at the same time. As ISO 9001 is not software specific it may be applied across all functions of a company. Thus where an organisation carries out hardware design in addition to software, offers consultancy services and training, ISO 9001 may be applied directly. Within the TickIT scheme, ISO 9000-3 is used by auditors and by implementors of the quality system as guidance. This results in tailoring of ISO 9001 for the software industry.

Where a standard is software specific, depending on the size of the software company and the type of software they develop, the requirements of the standard could be too arduous or too lax. Further, it is difficult to ensure that all critical activities are addressed within the standard. To illustrate this point, we can consider ISO 9000-3 itself. It is a very useful standard, it is certainly more intelligible to those in the software industry who are not familiar with ISO 9001. The standard was developed by a team of experts from many countries. Yet on analysis, there are many important aspects of management within a software development environment that can be raised as non-compliances against ISO 9001, but are not covered in ISO 9000-3, even by repetition of the ISO 9001 requirement. For example:-

- problem reporting
- indication of test status
- virus control
- security, back-up, disaster recovery.

It is probable that ISO 9000-3 will improve, with future versions and cover these omissions, but it serves to demonstrate how difficult it is in one specific standard to address all eventualities of good management practice, that will be appropriate for every software development company .

The emphasis of ISO 9001 on the manufacturing industry also produces anomalies from time to time, in purchasing for example. This is a critical activity in a manufacturing environment, but much less so in most software development companies. Many organisations are left confused, the bulk of their purchases are for stationery etc., they understandably object to spending a lot of effort doing vendor selections etc. on suppliers of these consumables. There are other products that may potentially have a considerable effect on the quality of output of their organisation, software test suites for example. These are often available as 'shrink wrapped' packages and the purchasers of these packages are often at a loss as to how to begin with their evaluation. It would certainly help to have the purchasing requirements of ISO 9001 more favourably worded for the IT industry. These anomalies result in auditors applying their own interpretations of what is required of the purchasing activity for those seeking registration under the TickIT scheme. This of course can add to problems brought about by inconsistencies between auditors.

There are other similar anomalies also with the application of ISO 9001 to software, it is difficult to see how para 4.11, "Inspection, measuring and test equipment" applies. Also, it is difficult to get a clear idea of the requirements for configuration management systems from the standard. A base standard that is less firmly rooted in the manufacturing industry would therefore be advantageous. (This is likely to be the case with the rewrite of the standard as part of 'Vision 2000').

Consistency Between Auditors

There are many factors that can give rise to inconsistency between auditors. One such problem has been highlighted earlier where inconsistencies arise due to different interpretations of ISO 9001.

The varying background and knowledge of the auditors may also contribute. An auditor who is very familiar with a certain technology may be less likely to be blinded by science and not raise non-compliances where they exist, or to raise them in error. Although auditors are carefully selected so as to have appropriate background and experience, it is unlikely that they will know about all technologies, methods etc. that may be encountered. This is further exacerbated by fast moving technology. It is easy to get into the mind set of traditional software development following the waterfall model. The development process is speeding up, using more tools, becoming more advanced and reliable. It is not always appropriate for traditional life-cycles and methods to be in use. It can be quite difficult for full-time auditors to keep up with these diverse advances in technology.

Further problems arise due to the length of time it takes to conduct an assessment of a company. The certification bodies enter into competitive tender for a certification contract. For reasons of commerciality, the tendency is to minimise the time spent on an assessment. However all the accredited certification bodies are professional organisations, so commercial pressure to keep bids low is countered by the auditors who strive to ensure only credible companies are registered. If insufficient time is made available for an assessment, there may be insufficient time to gather evidence of non-compliance. A major non-compliance may exist, in companies that are 'borderline cases' but is not found purely due to time constraints. Major non-compliances are readily found in poor companies, it is usually fairly clear when one is auditing a well organised company also.

There are guidelines defined by the NACCB on how long it takes to audit companies, however, these guidelines are not industry specific and are considered inadequate for the software industry.

Continuous Improvement

There are no levels of compliance with ISO 9001. A company is registered once it has demonstrated compliance with the standard. This means it is organised, follows defined repeatable procedures and has the mechanism in place to identify problems with processes, products and services in order to analyse them and improve the system such that these problems should not recur. However, there is no route map for improvement or any new targets that may be externally assessed. It is one thing to write a procedure to say that root causes of problems will be analysed and corrective action applied, and quite another to effectively carry out this procedure. Most companies at their initial certification assessment have only recently implemented this part of the quality system and have very little history on effective implementation.

Some companies lose the momentum post registration and struggle along only just maintaining their certificate. Others treat the registration as the beginning and make enormous improvements based on the results of their company performance. All of these companies are on the same register. There is no public recognition of the advances of the more pro-active companies.

Commercial Pressure for Registration

Many companies have set deadlines either internally or for their sub-contractors to achieve registration by certain dates. In some cases this has achieved the objective of a well produced QMS effectively implemented and the registered organisation producing a better service. In some cases however, it has put severe pressure on individuals within the organisation to implement new systems quickly on projects that are already part way through their life-cycle and still achieve the delivery dates. These pressures can be counter-productive. Firstly, in the short term, in projects that are already started, no allowance has been made in the schedule for writing procedures, or reading and implementing new procedures by changing existing practices. Project team effort is therefore diverted from technical activities to one of implementing the QMS. If the end date for delivery of the project is not allowed to move, effort may be diverted from activities such as testing etc., with the result of reduced quality of output.

The morale of individuals put under so much pressure can also be seriously affected which can result in a negative reaction to the QMS. Commercial pressure for registration can be positive, but only if sensibly managed, tied in with business and product quality objectives and with due regard for morale of the staff.

Quality of Product or Process

As already mentioned in this paper, there are more ways of achieving the right culture within an organisation such that quality products are produced. Some companies have generated a culture through careful selection of employees, intensive training programmes, research into new technologies and other methods. As a result, consistently high quality products have been produced over an extended period. Within these companies there is a fear that implementation of an ISO 9001 compliant QMS may damage that culture.

We must not lose sight of the purpose of developing quality systems. The quality of the process is far less important than the quality of the products and services produced as a result.

ANOMALIES WITH THE APPLICATION OF THE CMM APPROACH

Anomalies in use and their remedies

Having seen an outline of how the CMM is used in assessment and as a goal for process improvement, we can look at some issues that have arisen during its use and see how they can be overcome. To cite these anomalies is not to deprecate the CMM's value but to indicate some of the pitfalls that can be avoided if forewarned.

Focus on the maturity level as a score

Though the assessment is intended to be the first organisation-wide step towards improvement, it is sometimes regarded by management as a "rating" having intrinsic value. A senior manager who expects to achieve a level 2 or 3 can suffer severe disappointment when the site is assessed as level 1. His or her response can be "aren't we even level 1.75?" (Though the method does not allow for fractional assessment).

Sometimes the entire site experiences disappointment at a perfectly justifiable level 1 rating. This can occur when a site has made successful technical improvements such as using more powerful development platforms. When isolated, they may be laudable but irrelevant without systematic and organisation wide continuous improvement.

The assessment in most cases generates an enthusiasm for improvement: a valuable asset which the astute manager will use to advantage.

Improvement and Business Strategy

Achievement of the next higher maturity level can become a goal in itself rather than for a sound commercial reason. Under such conditions there is a danger that the improvement programme will be abandoned either at the first crisis or worse, as a result of apathy.

An objective of reasonable improvement of CMM key practices together with adequate motivation towards the objective will help to largely avoid this anomaly. For example a reasonable (and cost effective) objective could be to reduce late deliveries (exceeding schedule) by having more realistic project estimates (planning and tracking practices). The improvement can be steady and well within the company capability with the likelihood of encouraging statistics.

Assessments are Assumed to be Surveys

Sometimes organisations misunderstand the purpose of the CMM as a guide to improvement and assume that the assessment consists simply of having a few project leaders complete the questionnaire. Maturity level is then merely a computation based on the answers. There will be no interviews, no participants briefing, no demonstration of management sponsorship for continuous improvement. There is also a phenomenon characteristic of level 1 organisations. Here the project leaders and managers tend to have a more sanguine view of the maturity of their site software practices than do the engineers who carry out the practices. Frequently the engineers must make allowances for poor configuration management, poor software quality assurance, unrealistic schedules and inaccurate manning estimates. Thus survey results disguised as full assessments result in maturity levels, inappropriately inflated, and devoid of credibility.

A remedy is to appreciate that assessment can give impetus to process improvement because of the force of its impact on an organisation. The large management investment necessary for process improvement both demonstrates its sponsorship and solicits workforce support.

Differences in Assessment and Evaluation Methods of Appraisal with the CMM

Cases have occurred whereby assessment and evaluation on the same company by different teams and at different times have produced different maturity results.

The explanation is due to several factors. Differences between SPA and SCE methods (number of interviews, scope of projects, number of participants). Differences in purpose (qualifying suppliers versus process improvement). The user of the results (3rd party reviewers of bids, senior manager of the organisation). Personal approach of team (inquisitorial versus collaborative).

There are also apparent differences between the results of an audit conducted under ISO 9000-3 and an assessment with the CMM in the improvement context. When an organisation is TickIT certified for a software scope and then shortly after is assessed as ML1., does this indicate a problem in the two kinds of standard? Is ISO 9000-3 certification equivalent to ML 1, 2 or 3? or should the two standards be regarded as applicable for different purposes and therefore potentially reinforcing each other.

In such cases it seems reasonable to put each standard to best effect by applying each for its intended purpose. There is no reason why the same site should not use both standards properly and effectively. For instance, circumstances may require an ISO 9000-3 audit for an organisation to be an approved supplier. At the same time, the organisation may see production and commercial benefits from long-term improvement with the CMM as a guide and elect to make the organisational arrangements necessary to meet both standards.

CONCLUSIONS

Benefits

Companies that have adopted either the ISO or CMM approach have achieved demonstrable benefits. A significant contribution towards software quality has been achieved in the UK and the USA as a result of these initiatives.

The Value of Comparison

We conclude that a purely textual comparison of ISO 9001/ISO 9000-3 and CMM standards, while necessary for introduction, is not very helpful. It is necessary to see how the standards are applied in appraisals and how the companies who use them to guide changes post-assessment apply them to achieve improvement. Consultants who apply them should be cross-trained in each standard and its method - comparisons issued by experts in only one or the other are bound to be one-sided.

Product/Service or Process Quality

Both the ISO 9001 and CMM approaches suffer when commercial pressures concentrate organisations more on 'registration' or the 'maturity level' than on the quality of output of the organisation. Quality system standards that companies are evaluated against should be more firmly linked to product and service quality and business objectives. For ISO 9001/TickIT assessments, a route map post registration should be established, companies should be required to set targets for product and service quality, and demonstrate

improvement consistent with business objectives. Some practices from the CMM could be useful in establishing this, however, maturity levels within the CMM are based on the types of key practices in place rather than the improvements made in product/service as a result of implementing those practices. The emphasis therefore still appears to be too strongly on process quality without demonstrable evidence that these processes improve the quality of products, services, profits or other business objectives. Research into how to achieve this link, and into the actual benefits achieved by implementation of quality systems, is clearly needed.

Consistency of Audits/Evaluations

Inconsistency in the outcome of assessment or evaluation has occurred in both the CMM and TickIT approaches, the main reason for these appears to be the training/background of the auditors, the project sample taken and with the case of TickIT, the number of assessor days devoted to the audit.

To overcome these problems, the following proposals are made:-

- For the more popular new technologies and design approaches introduced into industry, training courses for auditors should be arranged to ensure their knowledge does not become outdated. These courses should be biased towards the potential quality problems of adopting various approaches, and the suitability of approaches in various project types/circumstances.
- For TickIT assessments, research into estimating techniques and the development of guidelines for certification bodies to follow.

ACKNOWLEDGEMENT

The authors would like to express their grateful thanks to Tony Morgan, Jeff Perdue and Tim Kasse for their invaluable comments and efforts in reviewing this paper.

REFERENCES

[1] ISO 9001, Model for Design/Development, Production, Installation and Servicing, 1987
[2] John Harauz, CAC-JTC1/SC7/CAC-TC176 Draft Position Paper July 1993
[3] DTI, TickIT Guide, issue 2.0, Feb 1992
[4] Software Engineering Institute, Capability Maturity Model, Version 1.1, Feb 1993
[5] Software Engineering Institute, Key Practices of the Capability Maturity Model, Vers 1.1.
[6] DTI Survey of Quality Consultancy Scheme Clients, 1992
[7]A. Morgan, Honeywell Bull Ltd, Systems Division, Application for the British Quality Award 1988
[8] Chemical Week, 22 September 1993
[9] Humphrey, Snyder and Willis; IEEE Software; July 1991
[10] Dion, IEEE Software; July 1992; July 1993
[11] Lipke and Butler; Crosstalk; Nov 1992
[12] Wohlwend and Rosenbaum; Proceedings of the International Conference on Software Engineering 1993
[13] SPA Team Members Guide, ISPI; April 1992, p5.
[14] Presentation by Ron Radice, 4th EFDPMA Conf; Washington D.C. 4 Nov.1993.