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Guidelines for Testing Maturity

Erik van Veenendaal of Improve Quality Services BV in the Netherlands has both involved in test process improvement projects at a large number of industrial organizations. For the past years he has been using the Test Maturity Model (TMM) as his reference model. In this paper the author provide an overview of the model, its background and guidelines for achieving TMM level 2.

For the past decade, the software industry has put substantial effort in improving the quality of its products. This has been a difficult job, since the size and complexity of software increases rapidly while customers and users are becoming more demanding. Despite encouraging results with various quality improvement approaches, the software industry is still far from zero defects. To improve product quality, the software industry has focused on improving their development processes. A guideline that has been widely used to improve the development processes is the Capability Maturity Model. The Capability Maturity Model (CMM) is often regarded as the industry standard for software process improvement. Despite the fact that testing often accounts for 30-40% of the total project costs only limited attention is given to testing in the various SPI models such as the CMM, and it's recently released successor CMMi. As an answer, the testing community has created its complementary improvement models. This paper focuses on the Test Maturity Model (TMM). TMM[SM1] is a model for test process improvement and positioned as being complementary to the CMM(i). The ISEB practitioner syllabus also identifies test process improvement as one of the key areas within the testing profession and identifies TMM as one of the major models.

History and background

The TMM framework has been developed by the Illinois Institute of Technology as a guideline for test process improvement and is positioned as a complementary model to the CMM (Brunstein *et al*, 1996a, 1996b). Just like the CMM(i), the TMM also uses the concept of maturity levels for process evaluation and improvement. Furthermore process areas, maturity goals and key practices are identified. For defining the maturity levels, the evolutionary testing model (Gelperin and Hetzel, 1988) has served as a starting point. The evolutionary testing model reflects the testing phases that an organisation will go through, from a debugging and detection oriented period to ultimately a prevention-oriented period. Furthermore, various industrial best-practices have contributed to the TMM development providing it with its necessary foundation and the needed level of practicality.

Whereas some models for test process improvement focus only on high-level testing or address only one aspect of structured testing, e.g. test organisation, the TMM addresses static *and* dynamic testing. With respect to dynamic testing both low-level and high-level testing are within the TMM scope. Studying the model more in detail one will learn that the model addresses all four cornerstones for structured testing (life cycle, techniques, infrastructure and organisation).

TMM overview

The structure of the TMM is partly based on the CMM and the staged version of the Capability Maturity Model-Integrated (CMMi). This is a major benefit for organisations that are already

[1] TMM is a servicemark of the Ilinois Institute of Technology

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familiar with the CMM(i). The TMM consists of 5 maturity levels that reflect a degree of test process maturity. For each maturity level, a number of process areas are defined. A process area is a cluster of related activities within the test process, e.g. test planning or test training. When these activities are performed adequately, they will contribute to an improved test process. The five levels of the TMM will support an organisation to determine the maturity of its test process and to identify the next improvement steps that are necessary to achieve a higher level of test maturity.

The five maturity levels and related process areas of the TMM are (figure 1):

- Level 1: Initial
  No process areas are identified at this level
- Level 2: Definition
  Process areas: Test Policy and Goals, Test Planning, Test Techniques and Methods and Test Environment
- Level 3: Integration
  Process areas: Test Organisation, Test Training Program, Test Life Cycle and Integration, and Control and Monitor
- Level 4: Management and Measurement
  Process areas: Peer Reviews, Test Measurement and Software Quality Evaluation
- Level 5: Optimisation
  Process areas: Defect Prevention, Quality Control and Test Process Optimisation

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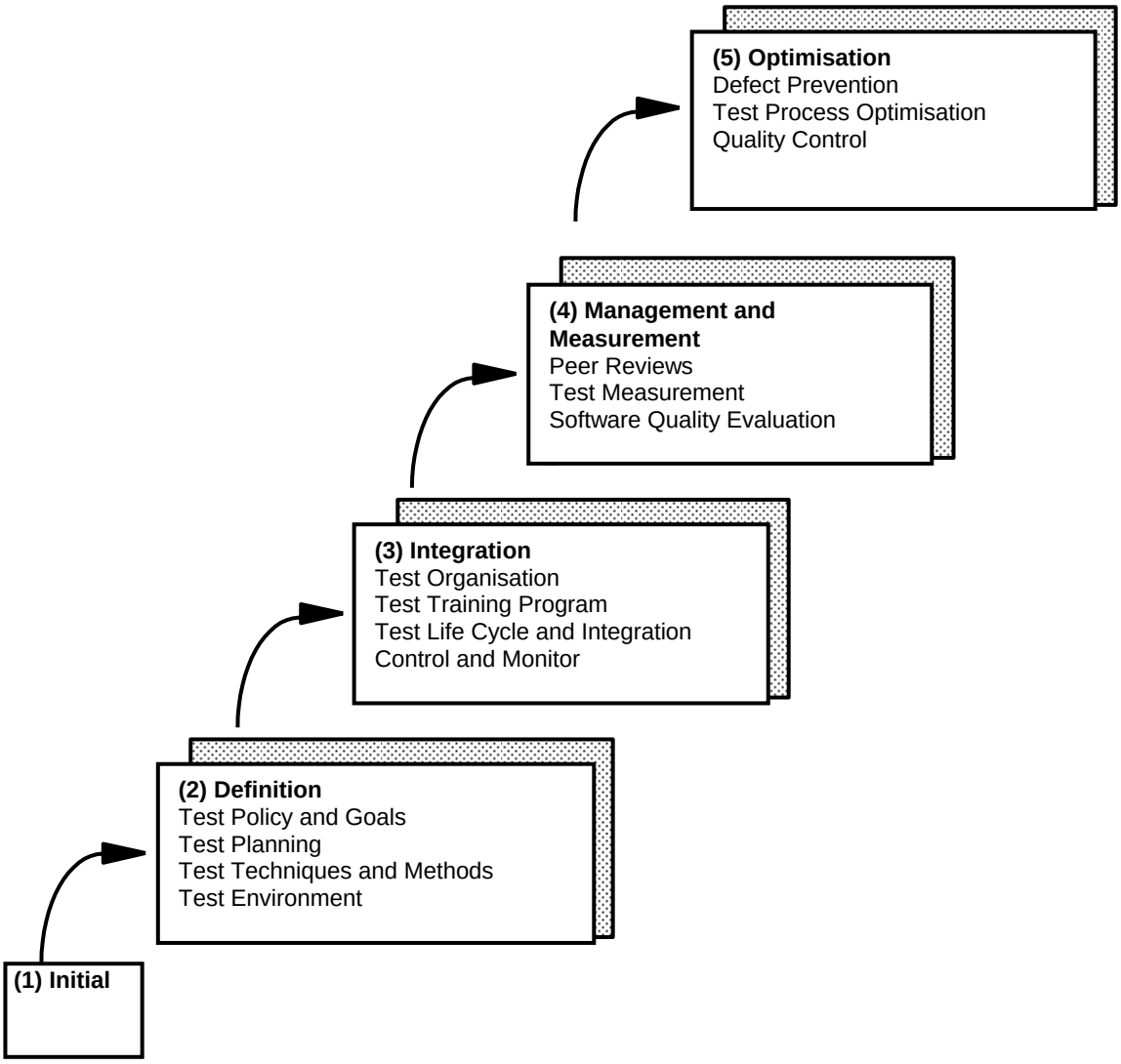

Figure 1: TMM maturity levels and process areas

Maturity Levels

As can be seen in figure 1, the TMM consists of five maturity levels. In this paragraph, the maturity levels are characterised.

The five maturity levels show an evolution from a chaotic, undefined test process to a controlled and optimised test process and largely reflect the five evolutionary periods that are described by Gelperin and Hetzel. TMM level 1 is related to the “debugging-oriented” period, level 2 to the “demonstration-“ and “destruction-oriented” periods, level 3 to the phase “evaluation-oriented” and level 4 and 5 to the “evaluation-“ and “prevention-oriented” periods. The five maturity levels are also strongly related to the CMM levels. In fact in many cases, a given TMM level needs specific support from key process areas in its corresponding CMM level

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and the CMM level beneath it. An overview of support from the CMM level required for the TMM level achievement is shown in table 1 (Suwannasart, 1996). Note that a similar table is also available for support from CMMi.

TMM	CMM	Supporting CMM Key Process Areas
2	2	Requirements Management, Software Project Planning, Software Configuration Management
3	2	Software Project Tracking and Oversight, Software Quality Assurance
3	3	Organisation Process Focus, Organisation Process Definition, Training Program
4	3	Intergroup coordination, Peer Reviews
4	4	Quantitative Process Management, Software Quality Management
5	5	Defect Prevention, Technology Change Management, Process Change Management

Table 1: Support for TMM maturity levels from CMM key process areas

Level 1: Initial
At level 1, testing is a chaotic, undefined process and is considered as a part of debugging. The objective of testing at this level is to show that the software runs without major failures. Software products are released without adequate visibility regarding the quality and risks. In the field, the software does not often fulfil needs, is not stable, or is too slow to work with. Within the test project there is a lack of resources, tools and well-educated testers. There are no process areas at this level.

Level 2: Definition
At level 2, testing is a defined process and is clearly separated from debugging. In the context of structuring the test process, test plans are established containing a test strategy. For deriving and selecting test cases from requirement specifications, formal test design techniques are applied. However, testing still starts relatively late in the development life cycle, e.g. during the design or even during the coding phase. The main objective of testing is to verify that the software satisfies the specified requirements.

Process areas at level 2 are:
- Test Policy and Goals
- Test Planning
- Test Techniques and Methods
- Test Environment

Level 3: Integration
At level 3, testing is fully integrated in the software life cycle. It is recognised at all levels of the V-model. Test planning is done at an early project stage by means of a master test plan. The test strategy is determined using risk management techniques and is based on documented requirements. A test organisation exists, as well as a test training program and testing is perceived as being a profession. Reviews are carried out, although not consistently and not

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according to a documented procedure. In addition, to verify that the software satisfies the requirements, testing is very much focused towards invalid testing.

Process areas at level 3 are:
- Test Organisation
- Test Training Program
- Test Life Cycle and Integration
- Control and Monitor

Level 4: Management and Measurement
Testing is a thoroughly defined, well-founded and measurable process. Reviews and inspection are taking place throughout the software life cycle and are considered to be part of testing. Software products are evaluated using quality criteria for quality characteristics such as reliability, usability and maintainability. Test cases are gathered, stored and managed in a central database for re-use and regression testing. A test measurement program provides information and visibility regarding the test process and product quality. Testing is perceived as evaluation; it consists of all life cycle activities concerned with checking software and software-related work products.

Process areas at level 4 are:
- Peer Reviews
- Test Measurement
- Software Quality Evaluation

Level 5: Optimisation
On the basis of all results that have been achieved by fulfilling all the improvement goals of the previous levels, testing is now a completely defined process and one is capable of controlling the costs and the testing effectiveness. At level 5 the methods and techniques are optimised and there is a continuous focus on test process improvement. Amongst others “Defect Prevention” and “Quality Control” are introduced as process areas. The test process is characterised by sampling based quality measurements. A procedure exists for selecting and evaluating test tools. Tools support the test process as much as possible during test design, test execution, regression testing, test case management etc. Testing is a process with the objective to prevent defects.

Process areas at level 5 are:
- Defect Prevention
- Quality Control
- Test Process Optimisation

TMMi Foundation
To further develop and market the TMM, the TMMi Foundation has recently been founded (www.TMMiFoundation.org). This is a non-profit making organisation that will play the role of an anchor point regarding TMM in the near and distant future. The TMMi Foundation aims at providing:
- A standard TMM Model that can be used in isolation or in support of other process improvement models and is either staged or continuous.

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- An independently managed data repository to support TMM assessment method accreditation, assessor and assessment certification/validation and validated assessment data and certificates.
- Assessment Method Accreditation/Audit Framework for TMM in accordance with ISO15504 and the process to certify commercial assessment methods against the standard model.
- Certification and training/examination process, procedures and standards for formal, public accreditation of Assessors and Lead Assessors and the on-going management.

TMM level 2 in detail

For TMM level 1 organisations the TMM level 2 maturity goals as described in this paper should be the focus of their test improvement process activities. A short quick scan questionnaire is included in this paper for those who want to quickly score their test processes against the TMM reference model. As with CMM, if you exist you're level 1. Recent studies have shown that almost 90% of the companies are still at TMM level 1. The level 2 guidelines therefore reflect the test improvement areas for most companies and projects. Within TMM level 2, four key areas can be distinguished:

- Test policy and goals
- Test planning
- Test techniques and methods
- Test environment

Except for the first key area "Test Policy and Goals", all improvement goals are very much test project focused. A test planning process, the usage of test designs and procedures and a well-controlled test environment are the basics for any test project. "Test Policy and Goals" addresses the management commitment and involvement that comes as a pre-requisite for successful test process improvement.

Test Policy and Goals

The purpose of Test Policy and Goals is to develop and establish a test policy and an overall test approach containing test goals, responsibilities and main tasks for each test level.

When an organisation wants to improve its test process, it should first clearly define a test policy. The test policy defines the organisation's overall test objectives, viewpoints regarding testing and the level of independence. It is important that the test policy is aligned with the overall business (quality) policy of the organisation. A test policy is necessary to attain a common view on testing between all relevant stakeholders within an organisation. This common view is indispensable to align further test process improvement activities.

Within the test policy the objectives of test process improvement should be stated. These objectives should be translated into a set of high-level key test performance indicators. The establishment of performance objectives and indicators provides clear direction and communication of expected and achieved levels of performance.

Within this process area an overall test approach is also defined. The overall test approach is a high-level test process description. The overall test approach can be based on existing generic overall test approaches for example: the V-model or the incremental model. Within the overall test approach, test levels are identified, for example: unit, integration, system and acceptance test. In addition, goals, responsibilities and main tasks for each test level are defined. The overall test approach serves as a starting point for the test projects. Test projects are set up according to the overall test approach. When an overall test approach is defined and followed, less overlap between the test levels is likely to occur leading to a more efficient test process.

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Maturity goals of the Test Policy and Goals process area are:
- A test policy, aligned with the business (quality) policy, is defined and agreed upon.
- An overall test approach is defined and deployed, identifying the test levels including goals, responsibilities and main tasks for each test level.
- A set of test process performance indicators is defined and deployed.

Test Planning
The purpose of Test Planning is defining a committed test strategy and approach, and to establish well-founded plans for performing and managing the test. Planning is essential for a process that is to be repeatable defined and managed.

After confirmation of the test assignment, a general study is made of the system to be tested, the project, the functional and quality requirements, and the organisation of the development process. As part of test planning, the test strategy is defined by means of a risk assessment. Depending on the risks, it is decided which properties of the system will be tested, and in what depth. For it is impossible to test the entire system, as test techniques providing 100% coverage exists only in theory. Moreover, no single company would be willing to afford the resources required for this purpose. The objective is to provide the best possible degree of coverage in the right place. Such matters are, of course, agreed specifically with the stakeholders. Testers should not take these decisions themselves. Within test planning, the test organisation is also set up, the test deliverables that are to be provided are identified, and aspects relating to infrastructure and management are defined. Finally, the test plan is prepared and agreed upon.

Maturity goals of the Test Planning process area are:
- A project's test strategy is defined and agreed upon.
- Test project activities and commitments are planned and documented.
- Estimates are documented for use in planning and monitoring the test project.

Test Techniques and Methods
The purpose of Test Techniques and Methods is to improve test process capability during test design and execution by applying basic test techniques and methods.

Well-founded testing means that formal techniques and methods are applied, supported (if possible and useful) by tools. Test design techniques are used to derive and select test cases from requirements and development documentation. A test case consists of the description of the starting situation (including the test input), the change process, and the expected result. The test cases are documented in a so-called test design. At a later stage, as more information becomes available on the actual implementation, the test designs are translated into test scripts. In a test script, the specific test actions and checks are arranged in an executable sequence. The tests can subsequently be executed using these test scripts. The test design and execution follow the predefined test strategy in the test plan.

During the test execution test incident reports are documented and tracked until closure. Incidents are logged using an incident management system and a clear communication about the incidents with the stakeholders is realised.

Maturity goals of the Test Techniques and Methods process area are:
- Test design techniques are evaluated, recommended and consistently applied throughout test design.
- Test execution is performed using formal test scripts.
- Supporting tools are evaluated, recommended and consistently applied where possible for test design and test execution.
- Incidents found during testing are managed and reported.

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Test Environment
The purpose of Test Environment is to establish and maintain an integrated software and hardware environment in which it is possible to execute tests in a manageable and repeatable way.

A test environment is needed to obtain test results under conditions which are as close as possible to the "real-life" situation; at least as far as high level testing is concerned. Furthermore, at any test level the reproducibility of test results should not be endangered by undesired or unknown changes in the test environment.

Specification of the test environment is carried out early in test projects. Specifications are reviewed to ensure their correctness, suitability, feasibility and its representativeness towards the "real-life" environment. Early specification has the advantage that there is more time to develop any special simulators, like stubs or drivers.

Availability of a test environment encompasses a number of issues, which need to be dealt with: Is it necessary for testing to have an environment per test level? A separate test environment can be very expensive. It must therefore be decided how to use them as efficiently as possible. Maybe it is possible to have the same environment shared between testers and developers. But then strict management and control is necessary as both testing and development activities are done in the same environment. When poorly managed, this situation can cause many problems ranging from conflicting reservations to people finding the environment in an unknown or undesired state when starting one's activities. Reconfiguring an environment to reach a known initial state can take days, depending on its size and complexity. Another approach for test environments is to let them 'grow' in parallel with the test levels. For example, one can decide to test a certain requirement at a higher test level to prevent the development of stubs that are needed to simulate specific subsystems that *are* available at higher levels.

Throughout the project the test environment is subject to changes due to for example hardware changes, incremental test environment development and changes in the test object. Thorough (configuration) management on the test environment is needed to cope with these changes.

Maturity goals of the Test Techniques and Methods process area are:
- Test environments are specified and their availability is ensured on time in projects.
- For higher test levels the test environment is as much as possible "real-life".
- Test environments are managed and controlled according to documented procedures.

Conclusion

Software systems play an increasingly important role in the society, making it necessary to link quality both to the process and the product. TMM is focused on the test process as a complementary model to CMM(i). It has been developed to support software organisations at evaluating and improving their test process. Within the TMM, testing evolves from a chaotic, ill-defined process with a lack of resources, tools and well-educated testers to a mature and controlled process that has defect prevention as its main objective.

Practical experiences are positive and show that TMM supports the process of getting a more effective and efficient test process. Testing becomes a profession and a fully integrated part of the software development process. The focus will change from defect detection to defect prevention.

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*For a more detailed description of TMM level 2, including the key testing activities, examples and literature references sent an email request to Erik van Veenendaal (**eve@improveqs.nl**) or visit **www.improveqs.nl**.*

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TMM level 2 Quick Scan

Read the statements and tick to show whether your organisation follows these testing rules, set by the Test Maturity Model at level 2.

Test policy and Goals
- A documented test policy exists and has been approved by management
- A V-model is unambiguously defined, stating the goals, activities, deliverables and responsibilities for each test level.
- The test policy and defined V-model clearly separate (module) testing from debugging activities.
- The test and software engineers are informed on the policy and defined V-model; the documents are distributed to the people involved.
- A basic set of test process performance indicators is defined and deployed

Test Planning
- A project test plan describing objectives, test strategy, answering the “what to test” and “how to test” questions is developed.
- A documented procedure and template exist for test planning.
- Test managers are specifically trained on test planning.
- A documented technique and procedure is consistently applied to determine the test strategy. This technique deals with risk-analysis and prioritisation of parts of the system and quality characteristics to be tested.
- A documented technique and procedure is consistently applied for test estimation and scheduling.

Test techniques and methods
- Software engineers apply test coverage techniques for module testing.
- Test engineers apply structured test design techniques such as Equivalence Partitioning and C/E graphing, for system and acceptance testing.
- Engineers are specifically trained on test design techniques.
- Tests are executed using documented test procedures or test scripts.
- An incident management procedure is documented and followed throughout the (test) project.
- Supporting tools are applied during test design and execution, e.g. incident management, coverage analysis and record & playback.

Test Environment
- A detailed specification of the test environment is documented in the test plan
- Test environments are managed and controlled according to documented procedures for configuration management
- An adequate back-up and restore procedure exists for the test environment and it’s databases
- For higher level tests, the test environment is as much as possible real-life

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