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Maturity of verification and validation in ICT companies

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Abstract: This paper examines the maturity of Verification and Validation (V&V) activities in the different phases of new product development (NPD) chain. A CMMI-based Verification Validation Maturity Model (V2M2) is utilised for the analysis. In this study, the maturity of V&V activities is analysed based on interviews conducted in major Scandinavian telecom companies. The study highlights how the maturity of V&V in production is higher than in the earlier NPD phases. The overall maturity of V&V activities is found to require significant improvement.

Keywords: verification; validation; testing; innovation; new product development; learning; maturity model.

1 Introduction

Increasing product complexity, time-to-market pressures, changing requirements and the decrease in physical dimensions in electronics cause pressures for improving the efficiency of NPD processes. It has been argued that it is impossible to design and manufacture information and communications technology (ICT) products without defects (e.g. Woodward and Hennell, 2005). Therefore, assuring quality is a critical success factor (e.g. Hauser et al., 2007). Verification and validation activities have become increasingly important and have been estimated to take between 40 to 80 percent of high-technology product development resources (e.g. Cartwright and Shepperd, 2000; Myers, 2004; Hailpern and Santhanam, 2002). Studies also indicate that in practice all companies have problems with their V&V processes. (e.g. Andersson and Runeson, 2002; Runeson et al., 2003; Perttula 2007).

Verification and validation have typically not been considered sufficiently over the entire new product development chain. However, there are studies that consider improving V&V within a single phase, or with a different perspective (e.g. Cheng et al., 2007; Engel and Last, 2007). In this study V&V has been studied as an integral part of the NPD chain. This has been done by analysing V&V activities in different NPD phases, namely: applied research, platform development, productisation, production and after-sales (Figure 1).

Figure 1 The phases of NPD chain



The terminology used in this paper includes, verification, validation and testing. The purpose of V&V, in a broad sense, is to supply information concerning the product design to the management, and other stakeholders for their decision-making (Perttula, 2007). V&V can be divided into technical (verification) and customer-related (validation) elements (e.g. Mooz et al., 2003; Raghavendra and Subrahmanya, 2006; Suikki, 2007). The term ‘testing’ is used in this paper broadly as a synonym for verification and validation activities.

Maturity models are management tools that can also be used for assessing the performance of NPD chain (e.g. Tiku et al., 2007; Lee and Chang, 2006). However, companies often find maturity models somewhat abstract and difficult to perceive. A simple matrix was derived in this study to aid maturity analysis, and to ease the initial adoption of these models. This can help in sharing the knowledge over maturity models within companies.

This study utilises a V&V specific maturity model, the verification validation maturity model (V2M2), for analysing the maturity of V&V activities. However, as the very extensive original V2M2 is not directly applicable as a management tool, a simple matrix is constructed in this study for simplification, and to aid the analysis. The analysis is conducted for the different phases of the NPD chain. This paper presents a viewpoint on managing V&V activities throughout the chain, from applied research to after-sales. The empirical part of the paper describes the current status of managing V&V activities across the NPD chain. The scope of the empirical study covers V&V activities within the telecommunications industry.

The above-mentioned can be summarised in the following research questions:

(RQ 1) What are the features of the Verification Validation Maturity Model (V2M2) that can be utilised to provide valuable information for management purposes?

(RQ 2) At what level of maturity are the V&V activities in telecom companies?

This paper aims to derive a practical tool of the V2M2 model and applies it to interviews conducted in major Scandinavian telecom companies.

2 Maturity of verification and validation

One way of measuring process improvement is to utilise various types of maturity models. Processes cannot be improved before they are well understood, or it is very difficult (e.g. Daghfous, 2007). Examples of maturity models include, the Capability Maturity Model Integration (CMMI) (e.g. CMU/SEI, 2006; Lee and Chang, 2006), and its application specific variants such as the ones for testing and V&V (e.g. Burnstein, 1996; Ham et al., 2001; Tiku et al., 2007; Farooq and Dumke, 2007). These frameworks have been considered as an approach for implementing a management viewpoint and have a great potential to be used as a guiding tool for managing V&V activities.

Whereas the maturity models enable assessing organisational maturity and allow identifying priorities for improvement, maximising their potential may require utilising some supporting techniques. Dayan and Evans (2006) see knowledge management (KM) and CMMI to be supporting, and dependent of, each other. KM and CMMI both take different approach to achieving competitive advantage, but may together make the organisation more efficient and effective. Also, according to Bellini and Lo Storto (2006), maturity models can effectively support and address knowledge management and learning. In addition, KM is an important systemic function for modern telecom organisation for improving organisational performance, however there are some deficiencies in understanding and guidance of KM within organisations (e.g. Wei et al. 2006; El-Korany, 2007; Lin and Kuo, 2007). A focus on processes is not enough to guarantee the effectiveness, but organisations must ensure they have functional measurement and management systems in place as well. (Tan and Hung, 2006).

Capability maturity models incorporate the essential elements of effective processes for diverse applications. As an example, the SW-CMM has become a de facto standard for assessing and improving software processes (e.g. Leung et al., 2007). The CMMI was developed to provide an enterprise-wide framework for improving and evaluating capability maturity across both software and systems engineering. The purpose of CMMI is to provide guidance for improving organisations' processes and their ability to manage important functions (e.g. Dayan and Evans 2006). However, CMMI does not cover all the activities that may be relevant for different practitioners, or explicitly address issues specific to their main functions (see e.g. McCaffery and Coleman, 2007; Beecham et al., 2005a; Beecham et al., 2005b). Testing and verification and validation have the need for their own application specific maturity models, such as Testing Maturity Model (TMM) (Burnstein, 1996) and Verification Validation Maturity Model (V2M2) (Ham et al., 2001; Jacobs and Trienekens, 2002).

Testing maturity model (TMM) was developed for the purpose of guiding the software testing process (Burnstein, 1996). However, TMM is seen to overlook the fact that improvement actions at higher levels cannot be carried out without considering the organisational aspects (e.g. Jacobs and Trienekens 2002).

Verification and validation maturity model (V2M2) (e.g. Ham et al., 2001; Jacobs and Trienekens, 2002; Farooq and Dumke, 2007) is a comprehensive model that has potential, because V2M2 is not geared towards any specific type of business, such as

software engineering. Therefore, the verification validation maturity model allows a wider scope for V&V process assessment. V2M2 model also has CMMI like structure, allowing better compatibility with any enterprise-wide maturity assessment interests. Additionally, V2M2 also takes the organisational aspects into consideration at higher levels.

The vast majority of industrial organisations spend considerable resources to promote product quality by using sub-optimal verification, validation and testing processes (e.g. Engel and Last, 2007). If a company improves its performance on the scale of a maturity model by one level, it can significantly reduce the share of development budget spent on fixing errors (e.g. Engel and Last, 2007; Houston and Keats, 1998). Therefore, it is vital to understand whether these models can provide improvement in practice.

In this paper, V2M2 maturity levels and process areas are combined into a single matrix outlining the core of the verification validation maturity model (Table 1). The information is combined into this matrix by utilising sources publicly available (Ham et al., 2001; Jacobs and Trienekens, 2002) to have a practical enough tool for assessing V&V maturity. This is done as the maturity models have a tendency to seem virtually complicated, making them less attractive to be used as tools for analysis.

Practitioners have found the maturity models complicated and difficult to perceive, without taking substantial amount of time to obtain the required understanding (e.g. Whittaker and Voas, 2002; Maatta et al., 2007). In practice, this effort is only undertaken when forced to by customers or competition. Therefore, in this study, the most vital factors for starting maturity assessment with V2M2 model are combined into a matrix (Table 1) that provides a softer landing for the use of the actual model itself. The applicability of the matrix is tested in the empirical part, where it is used as an aid for analyses.

Table 1 Maturity level matrix – based on Metric based Verification Validation Maturity Model (V2M2)

Level 1 Initial	Level 2 Repeatable	Level 3 Defined	Level 4 Managed and Aligned	Level 5 Optimising
Main objective of V&V: <i>To show in an ad-hoc way that products work</i>	Main objective of V&V: <i>Defect detection</i>	Main objective of V&V: <i>Are based on the requirements</i>	Main objective of V&V: <i>To provide quantitative measures to allow visibility for management</i>	Main objective of V&V: <i>To act as a total product quality control, to result in low risk products</i>
Purpose of the level: N/A	Purpose of the level: <i>The establishment of a basic verification and validation process</i> <i>By the introduction of basic practices, basic V&V process emerges</i>	Purpose of the level: <i>To further organise V&V and to embed it into the development life-cycle</i> <i>A defined and repeatable process is in place, documented standards and procedures</i>	Purpose of the level: <i>The establishment of V&V as a real quality measurement</i> <i>By aligning the way-of-working with other organisational entities</i>	Purpose of the level: <i>To fine-tune and optimise the V&V process on a continuous and structured basis</i>
V&V is finding and correcting problems Lack of tools, resources and properly trained staff	V&V is performed in a systematic and planned way Work products are documented Tests are conducted in a dedicated V&V environment	Activities start already at the requirements phase and continue through the entire life-cycle A V&V organisation is in place and testing is recognised as a profession	Quantitative measurements, statistical techniques and methods control the process	Costs, efficiency and effectiveness are quantitatively measured Defect causal analysis and defect prevention is a common practice The V&V process is continuously monitored and improved
Process areas: None	Process areas: 1. V&V policy and goals 2. V&V project planning 3. V&V monitor and control 4. V&V design methodology 5. V&V environment	Process areas: 1. Organisation embedding 2. Training program 3. V&V life-cycle embedding 4. Peer reviews	Process areas: 1. Organisational alignment 2. Quality measurement and evaluation 3. Quantitative process management	Process areas: 1. Defect prevention 2. Quality management 3. Process optimisation

The levels in the V2M2 model are (1) initial, (2) repeatable, (3) defined, (4) managed and aligned, and (5) optimising. The matrix (Table 1) combines the factors that are most essential for an analysis, including the main objectives for each maturity level. The matrix also combines the explanations for the purposes of each level and lists the related process areas. The details of each process area, or any other deeper information, are not included in the matrix for simplicity. This is because the available materials regarding the V2M2 model provide perfect reference for understanding the deeper details, and table 1 was merely constructed to ease the initial conceptualisation and act as a tool to aid analyses.

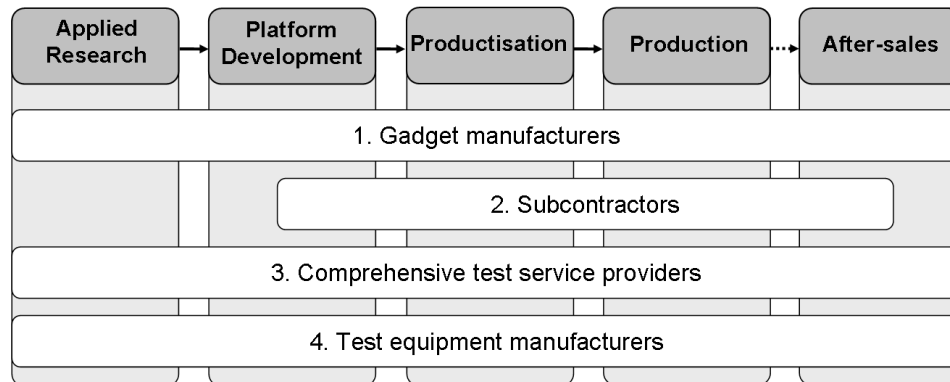
To be at a certain maturity level requires, (1) conformance to some, but not necessarily all of the requirements at that level, and (2) conformance to all of the lower level requirements. For example, activities cannot be said to be at level two, unless they are also in conformance with all the level one requirements. Nevertheless, activities can also have elements that conform to some of the higher level requirements. However, the non-conformance issues at lower levels must be addressed, and solved, before the activities can be said to be at a higher level.

4 Empirical study

4.1 The research process

The empirical study was conducted to obtain data for maturity analysis over the V&V activities through the entire NPD chain. The studied phases included applied research, platform development, productisation, production and after-sales. The study concentrated in examining companies within the telecommunication industry. The empirical study consisted of twenty interviews, comprising a representation from different phases of the NPD chain. Interviews were conducted informally allowing the interviewees to explain and clarify the cases and topics as entities. Appendix A includes the interview form. All the individual interview results were analysed separately for each phase of the chain by using V2M2 model as a tool for analysis.

The companies that participated in the interviews can be divided into four categories (Figure 2): The first company type is the 'gadget' manufacturers that sell their products globally. These companies provide products for both business-to-customer and for business-to-business markets. The second type of companies can be seen as subcontractors, whose products are inputs into the first category. The third category is companies who provide comprehensive test services, including test equipment, know-how and consulting services. The fourth category comprises of companies developing and selling test equipment, which can be used to solve testing problems in high technology product development, manufacturing and after-sales. Therefore, these interviews represent the V&V activities in a versatile manner and provide understanding over managing diverse issues.

Figure 2 Interviewed companies in the NPD chain

The participants interviewed were selected carefully on the basis of their professional background and expertise. Selected participants hold responsible positions in the field of V&V. The experience and the current interests ensured the high motivation among the participants and up-to-date knowledge with respect to the discussed topics. The total work experience of the interviewed is between 8 to 23 years, out of which they have spent a significant part with V&V activities, but have also held other positions. The job titles of the respondents include: Quality Manager, Quality Controller, Competence Area Manager, Senior Test Manager, Product Development Manager, Director (R&D), Engineering Manager, Manager (After-Sales), Group Manager, and Senior Developer. The selected participants were among the top-professionals in the field of V&V and testing.

4.2 Maturity analysis (V2M2)

The interview material was analysed by using the matrix presented earlier (Table 1). The comments of the interviewees were analysed separately for each phase of product development (applied research, platform development, productisation, production and after-sales). The created matrix (Table 1) enabled the practical application of V2M2 model for the analysis. Deeper analysis was conducted by using the available material on the V2M2 model. The results obtained were then analysed as a whole, resulting in conclusions over the current state of V&V activities in telecommunications industry.

Another issue that may influence the observed maturity is at which level the company's organisational issues will influence the conformance. This is, whether the NPD chain is observed as a whole, instead of viewing a single NPD phase as a sole 'organisation'. Examples of this consideration are, the level two process area one "V&V policy and goals", and level four process area one "organisational alignment". It is clear that the level four process area one considers the company level issues. However, the way the organisational aspects of the "V&V policy and goals" should be interpreted is not clear (see the process area details e.g. Jacobs and Trienekens, 2002). In this study, we have assumed that the company level organisational aspects are not to be considered before level four, but have brought this issue up in the later analyses for each NPD phase.

Tables 2-6 present extracted interviewee comments, which reflect the way the interviewees view V&V activities in the discussed NPD phases. The interview data was the base on which the more in depth analysis was conducted. However, the tables do not directly indicate which elements are missing of conformance towards different maturity

levels. Also, the obtained maturity levels may be slightly different for single companies, when analysed as single entities, and compared to the results presented later. This study has intentionally included the entire chain that has influence on the emergence of products to the markets.

4.2.1 Applied Research

The interviewee comments, supporting, or being against conformance towards each maturity level are presented in table 2. When comparing the comments of the interviewees against the V2M2 model (e.g. table 1), it can be concluded that the interviewee comments fully support the V&V activities to level one requirements, but only partially conforming to level two. Nevertheless, some issues were brought up that do contribute towards higher level requirements, yet it was evident that V&V in this phase is at most at level two. Common view across the organisation was not fully reflected as per level two process area one “V&V policy and goals” (see process area details e.g. Jacobs and Trienekens, 2002), and therefore the maturity of this phase cannot be any higher than level two. In addition, the goals of V&V in this phase are not clear due to uncertainty as per level two process area one “V&V policy and goals”. Our conclusion on the level of V&V maturity on applied research is based on the interviewee comments (see Table 2), and on a more in depth analysis of the process areas. The maturity of verification and validation activities in applied research, within the telecommunications industry, is at level two.

Table 2 Extracted interviewee comments for V&V in applied research

Maturity level	Interviewee comments
Level 1 conformance	+ “The purpose of V&V is to do more than finding and correcting problems”
	+ “Testing during applied research aims to explore and to find the technological boundaries”
	+ “Results are merely directional, but are enough to base the decisions for continuations”
Level 2 conformance	+ “Taking testing into account already during this phase is important”
	+ “Analytical testing, which includes studying the existing blueprints and formulas, or algorithms and assessing their validity”
	+ “Assessed whether the pre-set hypothesis are valid”
	+ “self-testing attributes, testing their own functionality”
	+ “This phase is especially sensitive as later everything is based on this”
	+ “Planning and defining testing activities is important”
	+ “Sound documentation important”
	+ “Small test environments for V&V”
Level 3 conformance	- “Test methods in applied research are not systematic enough as every project differs from previous ones”
	- “Rarely there are clear courses of action in applied research, when studying new phenomena”
Level 3 conformance	+ “The ability to place testing activities in applied research as a part of the entire value chain is the core know how of testing”
	+ “To assure detailed fulfilment of the requirements set by the new products or systems”

	+ “Testing activities should be started as early as possible”
	+ “It is important to consider and understand the role of V&V throughout the product life-cycle
Level 4 conformance	+ “Clear enough and measurable parameters with defined requirements serve testing in the following phases the best”
	+ “Co-operation with measuring equipment manufacturers and with test software houses is important”
Level 5 conformance	N/A

[(+) = supports conformance (-) = against conformance]

4.2.2 Platform development

The interviewee comments over the conformance issues obtained are presented in table 3. This phase is fully conforming to level one requirements, and clearly is at maturity level two. Nevertheless, platform development is not fully conforming to the level two requirements. Some issues also contribute towards higher levels than two. Common view across the organisation was not fully reflected as per level two process area one “V&V policy and goals”. Also, it can be seen how the goals of V&V in this phase are not clear due to uncertainty as per level two process area one “V&V policy and goals” (see process area details e.g. Jacobs and Trienekens, 2002). The maturity of verification and validation activities in platform development phase is at level two.

Table 3 Extracted interviewee comments for V&V in platform development (early product development)

Maturity level	Interviewee comments
Level 1 conformance	+ “Testing at the early product development is mainly exploring the limitations, a learning curve”
	+ “The technical skills and knowledge required for testing are available”
Level 2 conformance	+ “Testing in platform development starts from making a test plan”
	+ “Explicit plans of what should be tested and of the required test environments are desired in this phase”
	+ “Testing activities vary from creating test solutions for mobile device functionalities, such as tracking function, for which test environments are developed”
	+ “It is important to prioritise what is really important, as there is infinite possibilities for faults, many of which will never be faced by customers”
	+ “The aim is to rule out the errors the end-user can become aware of during the intended use”
	+ “Planning testing activities and defining the focus is vital, as once this has been well documented, the same subjects do not need to be tested repeatedly in the future phases”
	- “Defining testing in this phase is difficult as there are multiple possibilities of using the subject in later phases”
	- “Too often testing is conducted by the inexperienced employees”

Level 3 conformance	<ul style="list-style-type: none"> + “Testing in the hierarchy of early product development is verifying the requirements specifications and reviews, which are then utilised to create product specifications” + “The core know-how in this phase is testing against technological solutions and requirements” + “DFT is an example of a technique to anticipate the test activities, later phases in mind” + “This is fundamental work that everything is based on later, as all the faults and errors remaining after this phase will accumulate to the final product” - “Testing <u>should</u> be viewed more as a natural element of the product creation process” - “Tight schedules cause some prioritisation, making some of the internal wishes secondary”
Level 4 conformance	<ul style="list-style-type: none"> + “Testing in this phase is quality assurance, where testing and the faults, or error correction, are visible as error costs” + “Co-operation is important to be able to specify and develop test methods and equipment”
Level 5 conformance	N/A

[(+) = supports conformance (-) = against conformance]

4.2.3 Productisation

Table 4 presents the interviewee comments for V&V in productisation. It can be clearly seen how the interviewee comments indicate full conformance to level one, when compared to the verification validation maturity model. Productisation is fully conforming also with the level two requirements and process areas. However, V&V activities in productisation are only partially conforming to level three requirements, and cannot therefore be at a higher maturity level. Nevertheless, some evidence does contribute towards higher levels. As examples of non-conformance with all the level three requirements can be seen the “organisation embedding” and “V&V life-cycle embedding” (see Table 1) not fully being reflected as per level three process areas one and three (see process area details e.g. Jacobs and Trienekens, 2002). Therefore, the maturity of verification and validation activities in productisation is at level three.

Table 4 Extracted interviewee comments for V&V in productisation (late product development)

Maturity level	Interviewee comments
Level 1 conformance	+ “Testing in this phase is quite straightforward set of activities, but the actual challenge is with the systematic scrutinising of the product”
Level 2 conformance	<ul style="list-style-type: none"> + “One needs to understand the development history of the product in this phase, so that the testing activities can be planned in a meaningful way” + “Once faults, or errors, are discovered, the people involved in testing must be capable of analysing their causes and making the required changes” + “It is essential to know how the test results are obtained” + “Testing in this phase is expected to find faults and errors on the product being developed, and to provide information on how the

	specifications can be filled”
	+ “The output of this phase is proficiently verified product, including the test equipment and required software, which is all ready to be moved into production”
Level 3 conformance	+ “Testing activities in the following phase, production, are also considered in this phase, as it is important to understand which tests are to be covered before releasing the product to the markets”
	+ “There are norms against which the tests will be conducted to have them approved”
	+ “Any changes in this phase, even small ones, will cause the product having to be tested thoroughly from scratch, to make sure it is functioning as previously defined”
	+ “The purpose of testing in productisation is to assure that the product fulfils the specifications set in the applied research”
	- “It is impossible to conduct product development project in an ideal way from the testing viewpoint”
Level 4 conformance	+ “From the viewpoint of quality, testing activities and correcting the found errors are error costs”
	+ “One of the aims of testing is to minimise the expenses, while keeping the coming production process in mind”
	- “Internal functions do not always understand the requirements of the internal customer well enough, to accommodate the next phase in the process”
	- “Different activities <u>should</u> be directed more based on the requirements set by testing activities”
Level 5 conformance	N/A

[(+) = supports conformance (-) = against conformance]

4.2.4 Production

The evidence in the form of extracted interviewee comments is presented in Table 5. Verification and validation in production can be seen to clearly conform to the level one and two requirements, when production phase is observed as a separate entity. Should the entire chain be observed as a single assessment, one should pay special attention on how the common view across the organisation is reflected as per level two process area one “V&V policy and goals”. V&V activities in production are only partially conforming to the level three requirements. However, production phase has evidence indicating conformance to higher levels, which shows an orientation towards even higher levels. No clear non-conformance issues were discovered directly from the interviewee comments for any of the levels. However, a closer analysis clearly indicates how all the requirements are fully conforming to, only until level three, but not beyond. The interviews indicate how “organisation embedding” and “V&V life-cycle embedding” (see table 1) are not fully reflected as per level three process areas one and three (see process area details e.g. Jacobs and Trienekens, 2002). Should the interviewee comments be compared to higher levels, it can be seen how organisational alignment is not fully reflected as per level four process area one, or the process area three. Also, “quantitative process management” with regards to V&V is insufficiently covered. Additionally, if ‘integrated and standard V&V processes would be defined to deploy the process, and to

coordinate and facilitate the organisation's V&V activities', as per "organisation embedding", level three process area one content, production phase would be very close to being at level four. However, the maturity of V&V production is at level three.

Table 5 Extracted interviewee comments for V&V in production

Maturity level	Interviewee comments
Level 1 conformance	+ "Normally the tests a product must pass have been considered already during product development"
	+ "Testing in this phase is assuring the compatibility and the intended functioning of the product"
Level 2 conformance	+ "The role of production is to duplicate the designed product. Therefore, there should not be any other forms of testing than testing for the errors caused by the production process itself"
	+ "All the results obtained in testing are recorded into a database with the details of any repair actions"
Level 3 conformance	+ "The interaction between testing activities in production and R&D is strong"
	+ "The source information for testing in production includes the information on how testing should be performed"
	+ "Sufficient planning of the testing activities prior to production is of paramount importance to be able to detect any anomalies as early as possible"
	- "In some instances, there is overlapping with previous test phases, causing unnecessary repeat of tests in production"
Level 4 conformance	+ "Testing in this phase is tangible in the form of different test equipment, which are utilised to measure the quality of the product"
	+ "Statistical methods, such as SPC (statistical process control), are utilised to analyse the measured results. The results are observed for possible trends, which may predict possible errors"
	+ "Separate test equipment is compared to each other's results, so that any test equipment based errors will be detected"
	+ "Automatic alarms give warnings, when the set values are being exceeded"
Level 5 conformance	+ "Testing activities in this phase are optimising and verifying that the product, or assuring a part of the product is functional"
	+ "Once the production is up and running, and the most essential tests have been recognised, testing activities can be optimised"

[(+) = supports conformance (-) = against conformance]

4.2.5 After-sales

Table 6 presents the evidence extracted from the interviewee comments for the after-sales phase. After-sales can be seen to fully conform to level one requirements, but only partially to conform to level two requirements. A noteworthy factor is that no evidence was found that would indicate contribution towards any higher levels than two. It can be clearly seen how common view across the organisation is not fully reflected as per level two process area one "V&V policy and goals" (see process area details e.g. Jacobs and Trienekens, 2002). In addition, no dedicated V&V environment for after-sales only are

indicated through the evidence. The maturity of V&V activities in after-sales functions is at level two.

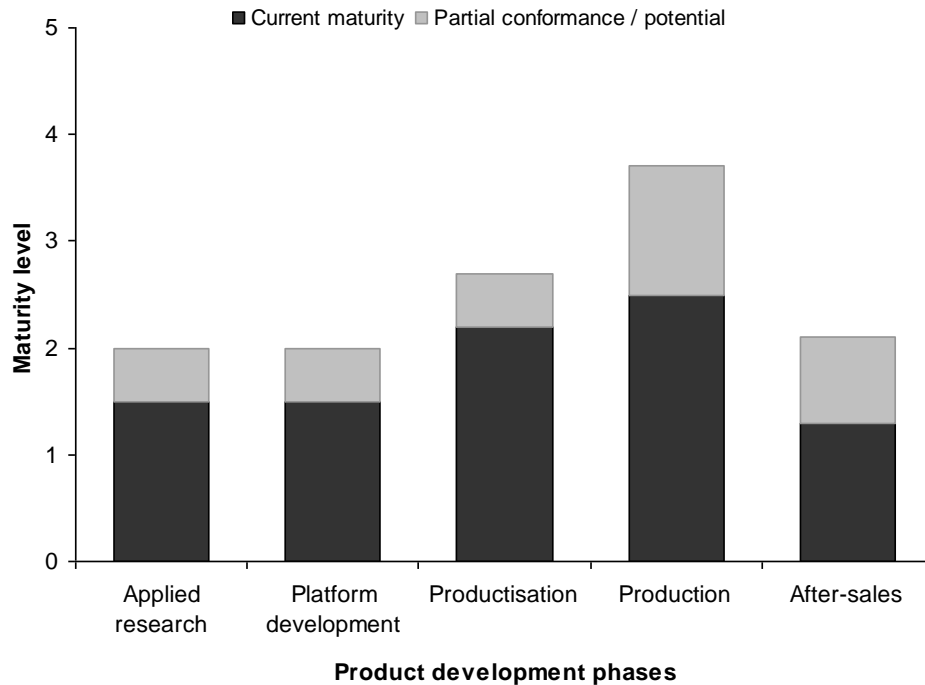
Table 6 Extracted interviewee comments for V&V in after-sales

Maturity level	Interviewee comments
Level 1 conformance	+ “Testing in this phase can be considered as ramp-ups, customer education and maintenance testing”
Level 2 conformance	+ “Testing in after-sales is hunting for faults” + “The product type, or different business-based motivations, may influence the customer care in different ways” + “Customer feedback and test data is collected into electric databases, which can later be utilised as an input for next generation products” - “Test environments in this phase are a challenge, as using the same test environments as in production may cause the error not being revealed”
Level 3 conformance	- “Typically an extensive customer feedback system does not exist, so that all the information would be analysed and be later available and utilised”
Level 4 conformance	N/A
Level 5 conformance	N/A

[(+) = supports conformance (-) = against conformance]

4.2.6 Summary of the phase-wise analysis

Figure 3 presents the current levels of maturity for V&V activities in each NPD phase. Verification and validation in applied research, platform development and after-sales services are all at level two maturities, according to the conducted analysis. Productisation and production phases indicate clearly higher level three maturity for V&V activities. However, the analysis undoubtedly revealed that the V&V activities in production are at the highest level, even if the maturity ‘classification’ according to V2M2 model is the same for productisation phase.

Figure 3. Current maturity levels in each NPD phase of telecommunications industry

The congruent areas in Figure 3 that fill the maturity levels completely indicate which level requirements the particular NPD phase fully conforms to. However, the congruent area filling a maturity level only partially indicates that the V&V in that particular NPD phase is at that level of maturity according to the analysis. For example, if the congruent area is between levels one and two, V&V in that phase is at level two maturity. The shaded, light grey, areas indicate how the phase is not conforming to all the requirements at a level, but also indicate if there is strong potential for improvement.

The greatest dilemma for the entire analysis was set by the first process area of maturity level two; “V&V policy and goals” (see details e.g. Jacobs and Trienekens, 2002). If this process area was taken literally, “V&V policy is necessary to attain a common view on V&V between all relevant stakeholders within an organisation”, none of the phases studied would have a higher level of maturity than two. Only if every single phase is studied as an entity of its own right, the maturity level can be seen to be higher than two. This is when the above statement is taken literally to indicate the company level ‘organisation’. The other similar ‘obstacles’ for higher maturity levels can be found on levels 3 and 4, where the first process area in both relate to organisational aspects in the same manner as above mentioned (“organisation embedding and organisational alignment”). One possibility is to see each NPD phase as a separate ‘organisation’ until maturity level four ‘organisational embedding’

5 Managerial implications

Verification and validation activities have become a very important factor for new product development in ICT. However, V&V have been managed sub-optimally in the

NPD chain, and the overall coordination has been deficient. Also, the emphasis of these activities has traditionally been too late in the development chain (e.g. Blackburn et al., 1996; Pinheiro, 2003).

Maturity models can help in understanding V&V through the NPD process, and the prevailing practices better. These models also provide the management with tangible indicators for their process improvement efforts. The matrix developed in this study is a concrete way to share knowledge more easily within an organisation, over an issue that is challenging to perceive initially.

Potential reason for V&V activities being managed sub-optimally is the fact that the maturity of these activities has not been high enough throughout the NPD chain. It is not possible to consider V&V comprehensively before the “organisational alignment” is taken care of and the activities are at the maturity level four of V2M2. Once the V&V maturity is high enough in all the phases, the processes can be dealt with organisation-wide. Only this will truly allow the early consideration of V&V activities, and remove overlapping.

Maturity level being high means that an organisation is capable of reacting rapidly to external changes. This type of agility has been brought up strongly, especially with software related projects. At the level three, V2M2 model has the purpose of embedding V&V into the development chain, which will help with the capability to react. However, this cannot be accomplished fully unless the V&V activities are at least at level four maturity. This also includes developing V&V related competencies continuously.

6 Conclusions

The large scale of verification and validation activities requires a comprehensive understanding. Estimating the maturity of the V&V processes is a necessity to be able to develop the NPD phases in a well-balanced manner. Maturity models are generally seen as good and effective tools for continuous process improvement. The CMMI-based V2M2 model being a V&V specific maturity model is a potential tool for developing V&V processes. However, the practitioners have experienced these models, including V2M2, somewhat abstract and difficult to perceive. To alleviate this difficulty, a simple matrix was derived in this study to enable a quick initial analysis (see Table 1). The main benefit of this created matrix is that it enables a straightforward start of maturity evaluations. The matrix also allows discussion within a company and sharing the knowledge promptly over maturity models and acts as a first step for a deeper analysis. The matrix was tested for analysing data and was found suitable for a quick ballpark estimate on the state of V&V process maturity. A deeper analysis was then conducted by utilising the available V2M2 material. (rq1)

Previous studies have indicated how the V&V activities in the ICT industry have deficiencies due to not managing V&V in an ideal manner (e.g. Runeson et al., 2003; Andersson and Runeson, 2002). In this study, the maturity of V&V activities was analysed in companies involved in telecommunications. Each phase of the NPD chain was first studied separately, after which the entire chain was considered. The V&V maturity was found to be the highest in production. The maturity of V&V activities in the other NPD phases are lower and therefore are preventing production from rising higher. This study thus confirms the findings of previous studies, indicating late emphasis of V&V. Reaching a higher maturity level requires the entire chain to improve their V&V maturity. (rq2)

The influence of maturity of V&V activities requires further research. This is, for example, how the overall maturity of the company affects the maturity of V&V.

Knowledge management consideration is also an interesting viewpoint as an addition to maturity models, thus is worth further research.

The number of interviews was not especially extensive, thus by having a wider set of organisations to be reviewed, the obtained results would have yielded a somewhat different analysis of the maturity of V&V. This study, however, strengthens the view on V&V maturity and demonstrates how it is worthwhile to dissect it in a phase-wise manner.

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APPENDIX A

QUESTIONNAIRE

Background information:

Name of the Interviewee:

Work title:

Start in the current role:

Previous work experience

Company:

Company Turnover:

Number of employees:

Number of employees working in NPD:

1. Which phase of the NPD chain do you represent (applied research, platform development, productisation, production, after-sales, entire chain)?
2. What type of activities do you consider as V&V (or Testing,)?
3. Describe typical V&V (Testing) activities within the phase you represent.
4. What do you expect of the previous phase?
5. What types of problems created in the previous phase/s arise here?
6. What type of actions in this phase could serve the following phase/s the best?
7. Are there any V&V related bottlenecks in this phase?
8. How can the V&V activities be improved in your view?
9. Other comments on V&V activities

(The details of the interviewee or the company will not be disclosed in any published material.)