A CMM-Based Evaluation of the V-Model 97

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Abstract. The V-Model 97 is a widely used process model in Germany and Europe. It is the development standard for IT-Systems of the Federal Republic of Germany and the basis of Austria's and Switzerland's corresponding standards. Software process assessment and improvement efforts world-wide are based on the Capability Maturity Model (CMM) for Software. We present a detailed evaluation of the V-Model 97 based on the key practices of the CMM. For each key process area of the CMM we identify the strengths and weaknesses of the V-Model 97. While project-related issues are covered well by the V-Model 97, organizational aspects leave room for improvement. The algorithm specified by the CMM Appraisal Framework sees the V-Model 97 at level 1 whereas a BOOTSTRAP-based algorithm results in a more appropriate rating of level 2.

1 Motivation

During the last 15 years different groups published – official or de-facto – standard software process models. More and more commercial software development organizations use one of these process models as the foundation of their development process. Increasingly, these organizations are faced with the need to assess and improve their development processes. Here, too, a number of standards exist. To select the appropriate standard process model, to prepare for a standardized process assessment, and to improve their development process organizations need to know the strengths and weaknesses of their process and the expected performance in an assessment. The maintainers of a standardized process model can also use this information as input for further versions of the standard.

In Germany and Europe the V-Model 97 (V-Model[1]) is a widely used process model. It is the current version of the development standard for IT-Systems of the Federal Republic of Germany. Its use is compulsory in IT-projects with the German federal administration. The Capability Maturity Model for Software (CMM), developed by the Software Engineering Institute (SEI), is the root of

[1] In this paper, "V-Model" is used to refer to the V-Model 97 and "CMM" is used to refer to the Capability Maturity Model for Software Version 2.0 Draft C.

most efforts for software process assessment and improvement. Many of the organizations working with the V-Model have started software process assessment and improvement efforts or are awaiting them. An evaluation of the V-Model process based on the CMM, the world's de-facto standard for software process assessments and improvements, can generate valuable input for both, users and maintainers of the V-Model.

The term "evaluation" is used instead of "assessment" throughout this paper. An assessment as defined in [1] appraises the state of the software process in an organization and is usually based on questionnaires and interviews. This evaluation determines the state of a software process as described in a set of documents without considering an organizational implementation. It is based on a mapping between the elements of a process model (the V-Model) and a reference model (the CMM). However, the purpose of both, assessment and evaluation, is the same: to identify strengths and weaknesses of a process and to generate input for improvement.

In this paper, we present a detailed evaluation of the V-Model. The evaluation is based on the practices of the CMM. We briefly describe the relevant characteristics of the V-Model and the CMM in Sect. 2. Next, in Sect. 3 we explain the approach taken for the evaluation. General aspects of the V-Model and the CMM, that are not covered by that approach, are compared in Sect. 4. Then, in Sect. 5 the strengths and weaknesses of the V-Model are identified and compliance of the V-Model with the CMM is evaluated for key process areas, key practices common to key process areas, and maturity levels. The results are validated with the CMM-based assessment procedure of Siemens AG. Finally, the results are discussed in Sect. 6 and a conclusion is drawn in Sect. 7.

The evaluation [2] was carried out in a cooperation with the Institut für Informatik (Dept. of Computer Science) at Technische Universität München and the corporate technology division of Siemens AG, Munich.

2 Background

In this section we give an introduction to the V-Model 97, the Capability Maturity Model for Software, and Siemens Process Assessments. Due to space considerations the introduction can only be brief. For additional information please refer to the literature given in the references.

2.1 The V-Model 97

The V-Model 97 [3] is the second released version of the standard for carrying out IT-projects with the German federal government authorities. Austria's IT-BVM [4] and Switzerland's HERMES [5] standards are based on the V-Model as well. Mappings to other standards (ISO 9000 family [6][7], ISO 12207 [8], MIL-STD-498 [9]) are provided. The V-Model covers software development and optional software/hardware co-development. The V-Model is available in German and English versions from the official web site of the V-Model [10].

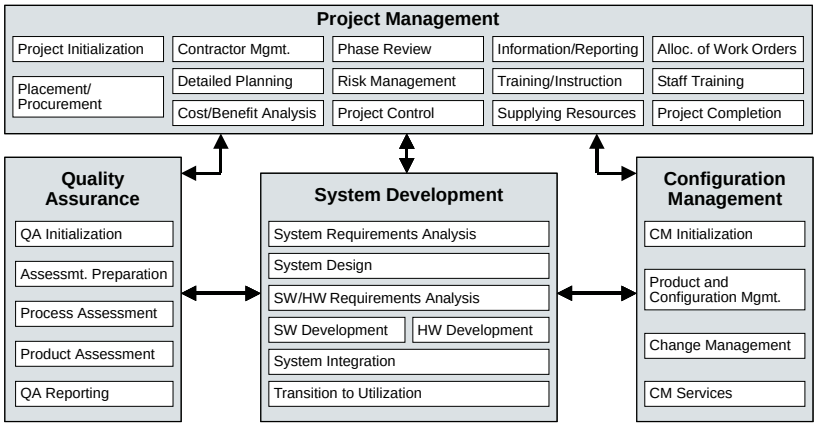

Fig. 1. Submodels and selected activities of the V-Model

The standard consists of three parts. The first part describes the *activities* to be performed and the *products* resulting from these activities. A *collection of manuals* provides information on selecting an appropriate life cycle model, process tailoring, assignment of roles, etc. The second part describes the *methods* to be used to perform the activities. *Functional tool requirements* are contained in the third part.

Activities and products are arranged in four *submodels*. Development is performed according to the submodel *system development*. Both, *quality assurance* and *configuration management* activities are grouped into submodels of their own. *Project management*-related activities and products are contained in the fourth submodel. Figure 1 shows the submodels and selected activities of the V-Model.

2.2 The Capability Maturity Model for Software

The Capability Maturity Model for Software [1] is a well-known reference model for assessing and improving the software development process. Its first version was developed by Watts Humphrey at the SEI in 1987. The latest version available is version 2.0 draft C [11]. Work on version 2.0 has been stopped to integrate several capability maturity models into a coherent framework, the Capability Maturity Model Integration (CMMI). Draft 0.2 [12] was released in August 1999. Nevertheless, CMM version 2.0 draft C is being widely used for software process assessments and improvements. Therefore, that draft was used as the basis of this evaluation.

In the CMM, five *maturity levels* characterize the *process capability* of an organization. With the exception of the first (the lowest) maturity level, a number of *key process areas* describe what is expected at a certain level. Some key process areas are concerned with organizational issues, others are relevant for

individual projects. Each key process area contains several *goals*. How these goals can be reached is explained in *key practices*. The key practices are grouped into five *common features*. While some key practices are unique to the relevant key process area, others are common to most or all of the key process areas. The unique practices guide the implementation of activities to reach the goals of a key process area. The common practices are concerned with their lasting institutionalization.

2.3 Siemens Process Assessments

The importance of processes in software development was recognized early within Siemens AG. As a result a company-wide "Software Initiative" [13] was founded and Siemens corporate technology division started assessing and helping to improve the software development processes within the business units at Siemens AG. For this purpose, a standardized assessment procedure, a questionnaire, and an associated set of templates for the resulting documents were developed. Siemens Process Assessments [14] are based on the CMM and the BOOTSTRAP algorithm [15]. The focus of Siemens Process Assessments is the identification of improvement measures.

Siemens AG adapted the source models to suit its needs. For this purpose, additional questions were introduced regarding, for example, hardware development or patents. The questions are grouped into 15 process areas. Each question is assigned to a maturity level from two to five. The questions are answered and evaluated using the four-point scale and rating algorithm of the BOOTSTRAP approach.

While there is no one-to-one relationship between process areas of the Siemens Process Assessment and key process areas of the CMM, the assignment of questions to maturity levels is the same. Questions that go beyond the CMM are clearly marked.

3 Approach

The scope of this evaluation is the process as it is described in the original documentation of the V-Model [3]. Organizational implementations of the V-Model are not rated.

In most process assessments the compliance of the assessed process with some kind of reference model is investigated. Often, process assessments are based on questionnaires. These questionnaires are used as a guideline to cover the important aspects of the underlying reference model and enable an experienced assessor to come up with a qualified judgement on the strengths, weaknesses, and the maturity of the process in the assessed organization. However, there is a danger that the structure and some details of the reference model are hidden by the questionnaire. To grasp all details and retain the structure of the CMM, its key practices, and, if applicable, their sub-practices are selected as the basis for the evaluation in Sect. 5.

However, some aspects of the V-Model cannot be covered by an evaluation based on the key practices of the CMM. These are more general aspects like, for example, origin or life cycle-independence. These are compared on a qualitative basis in Sect. 4 rather than evaluated quantitatively.

In the evaluation, for each key practice or sub-practice the corresponding elements of the V-Model (i. e., activities, products, manuals, methods, and functional tool requirements) are documented. On this basis, the compliance of the V-Model with each key practice or sub-practice is rated. The original questionnaire used for assessments at the SEI employs a two-point rating scale. While two-point scales seem to have advantages in interrater agreement [16], four-point scales allow for a more detailed judgement. In assessments for selecting a contractor, interrater agreement is an important criterion. However, the focus of this assessment is on the identification of strengths and weaknesses of the V-Model. For this purpose a four-point scale seems more appropriate. Therefore, the four-point scale of the BOOTSTRAP algorithm (weak or absent $\hat{=}$ 0 %, basic or fair $\hat{=}$ 33 %, significant or strong $\hat{=}$ 67 %, extensive or complete $\hat{=}$ 100 %) is used in the rating process. Aggregated ratings are calculated as the average of the individual ratings to avoid artificial weightings.

The key practices in the CMM can be divided into two groups: those unique to a certain key process area and those common to a number of key process areas. The key practices in the "activities to perform" common feature are – with the exception of the first key practice – unique to the relevant key process area. All other key practices are common to all, the organizational or the project-related key process areas. This is used to structure the ratings of the key practices. The ratings of key practices unique to a key process area are grouped by key process area (i. e., one group per key process area). The ratings of key practices common to all key process areas are grouped by key practice (i. e., one group per key practice). This way, commonality between key process areas can be exploited in the assessment whereas their specific characteristics are preserved.

4 Comparing general aspects of the V-Model and the CMM

In this section general aspects of the V-Model and the CMM are compared qualitatively that cannot be covered by the quantitative evaluation in Sect. 5.

4.1 Origin, Approach, and Scope of Application

The first versions of both the V-Model and the CMM were created to attack time, budget, and quality problems in large military software projects. The approach taken is different. The V-Model is a prescriptive process model – contractors of the German federal administration generally have to follow that model. The CMM on the other hand is to be used as a guide for assessing government contractors. There is no binding minimum maturity level for contractors, the results of the assessment are one of several selection criteria [17].

Much supporting material is available for software process assessment and improvement with the CMM. Although the V-Model was not designed for that purpose and does not provide any support, user surveys indicate that it is being used for continuous process improvement [18].

The focus of the V-Model is an individual project. Only few organizational aspects are covered by the V-Model. The CMM focuses on project issues at level 2 but at level 3 and above organizational aspects are at least equally important.

The V-Model is an integrated process model for developing hardware/software systems. The CMM covers only software-related aspects. Other capability maturity models exist for systems development (see [19]) but are less comprehensive for software issues.

Safety and security play an important role in the V-Model. The CMM does not provide any support for these aspects. Specialized capability maturity models were created for developing security systems [20] but are separate and not in conjunction with the CMM.

4.2 Features

In the V-Model, submodels can be exchanged in part or as a whole with so-called *operative modules* described in the collection of manuals. In a reengineering project the system development submodel would probably be replaced by a submodel for reengineering. In the CMM, the exchange of key process areas might compromise the validity of the maturity level rating resulting from an assessment [21].

The descriptions of the activities and products in the V-Model are generic, i. e. they are described once but implemented as often as they are performed or produced. In the CMM key practices which are to be performed in several key process areas are described separately in each key process area. Templates are used for these descriptions. The current draft 0.2 of the CMMI makes use of generic activities.

Both models are life cycle-independent. The V-Model favors incremental development. The collection of manuals also contains information on other life cycles.

Neither the V-Model nor the CMM imply a specific organizational structure. The CMM suggests some organizational units, for example a software engineering process group.

The CMM and the V-Model define a number of roles performing the software engineering process. Only in rare cases does the CMM specify which role should perform a specific task. The concept of the V-Model is more elaborate. A separate manual assigns roles to all activities. Participation of a role can be responsible, cooperating or advising.

The CMM gives some advice on the content of work products. The V-Model specifies all products resulting from the activities including their structure and contents.

5 Results of the Evaluation

In this section the assumptions and the results of the quantitative evaluation of the V-Model are described. General aspects of both models are compared in Sect. 4.

5.1 Assumptions

External support for the V-Model is available in many ways. A change control board for the V-Model is institutionalized by the German federal authorities. A web site provides an introduction, an electronic version and a list of frequently asked questions (FAQ) on the V-Model. A mailing list answers questions not covered by the FAQ. Training and consulting is offered by various vendors. The V-Model even has a user group, called ANSSTAND e. V. [22], which, for example, organizes annual meetings to share experiences among V-Model users. But because the V-Model has no activities performing or roles responsible for process management this support is not guaranteed to take effect in an organization. Therefore, these activities are not taken into account in this evaluation.

Descriptions of activities and products in the V-Model are generic. Planning, for example, is described once but done for all activities performed in the V-Model. To avoid rating of institutionalization of activities that are not implemented properly, upper limits are defined for the ratings of common key practices. If the average rating of the unique key practices of a certain key process area is below 50 %, the common key practices are rated at most strong (67 %). If the rating of the unique key practices is less than 25 %, the rating is limited to basic (33 %).

5.2 Strengths and Weaknesses at Key Process Areas

This section lists the key findings of the evaluation grouped by key process areas. A general statement indicates strength or weakness of the V-Model with respect to a key process area. Key practices that deviate significantly in their rating from that of the key process area are stated. The detailed results can be found in [2].

Most key practices of the *requirements management* key process area are covered well by the V-Model. Weaknesses in the V-Model are reviews of requirements and of the effects of changes to the requirements by those affected.

A good correspondence between V-Model and CMM can be seen in *software project planning*. Coordination of planning, metrics, and estimates of computer resources are the only weak points in the V-Model.

Coverage of the key practices of *software project control* is split. Whereas project progress is reviewed and risks are monitored, there is no tracking of size estimates in the V-Model. Furthermore, the weaknesses of the previous key process area continue here.

In *software acquisition management*, the CMM is more detailed than the V-Model. The coverage is the weakest at level 2. There are no reviews of technical

or management issues with the supplier nor periodic evaluations of the supplier's performance in the V-Model.

A separate submodel results in good coverage of *software quality assurance* in the V-Model. The products and methods of the V-Model go beyond the CMM. However, no regulations for resolving deviations in the performance of activities exist in the V-Model. In addition, deviations detected during product or process assurance activities that cannot be resolved locally are not escalated.

For *software configuration management* there is a separate submodel in the V-Model as well. Apart from software configuration management audits, the V-Model shows no weaknesses here. The rating is second-best of all key process areas.

Organization process focus is weak in the V-Model. There are no software process assessment or improvement activities nor an organizational learning process. Only the deployment of software process assets is covered to some extent.

Some of the sub-practices in the *organization process definition* key process area are concerned with activities for creating and managing a process model. The V-Model is the result of such activities but that process itself is not covered in the V-Model. Therefore, only those sub-practices for which the coverage can be determined by inspecting the result of the process can be fulfilled by the V-Model. The key practices regarding the organization's process model, software life cycles, and process tailoring are moderately covered. A software measurement database and a library with software process related documentation are mentioned in the functional tool requirements of the V-Model but no detailed regulations are found.

In the V-Model there is only one activity related to the *organization training program* key process area. Training is provided as needed by the project team but training requirements for roles do not exist. Additional, more advanced criteria of the CMM are not fulfilled.

The key practices regarding the project's software process and project risks in the *integrated software management* key process area are covered well by the V-Model. In contrast, coordination of the project with the rest of the organization is weak, as is management of training project staff.

Software product engineering is performed in the system development submodel (with some complements in the quality assurance and configuration management submodels). CMM and V-Model match well in the early phases. Later, both models have some weaknesses. The V-Model gives no details on user documentation and product support is only mentioned briefly while the CMM does not state integration as a separate task.

V-Model and CMM have different views on *project interface coordination*. The scope of the V-Model is the project as a whole whereas the CMM sees itself as the software part of a larger project. Therefore, the CMM emphasizes coordination and communication aspects where the V-Model provides little guidance. This leads to a weak coverage in this key process area.

Peer reviews are among the most important quality assurance methods in the V-Model. The result is the best rating of all key process areas.

Although the V-Model provides some support for reuse the CMM goes far beyond that in the *organization software asset commonality* key process area. Reuse of components is considered in the system architecture in the V-Model's system engineering submodel. However, there are neither activities for evaluation of the components on their potential for reuse nor for feedback on the use of common software assets.

In the V-Model, basic metrics on effort, schedule, cost, errors, and changes are collected. But no advanced metrics are derived and no quantitative models of process performance are built. Accordingly, the rating of the *organization process performance* key process area is relatively poor.

In this key process area the CMM expects the use of the data and models of the previous key process area for *statistical process management*. The weaknesses of the previous key process area continue here. Process management is performed only as a comparison between planned and actual figures. Historical data or quantitative models are not used. The rating of this key process area is slightly better than that of the previous one.

Defect prevention is performed regularly in the quality assurance submodel of the V-Model. But because the translation of suggestions into practice is not required by the V-Model, the analyses might have no effect. Furthermore, the effects of measures are not tracked.

Neither *organization process & technology innovation* nor *organization improvement deployment* are covered by the V-Model.

Figure 2 illustrates the average ratings of the V-Model for the unique key practices of each key process area.

5.3 Strengths and Weaknesses at Common Key Practices

This section lists the key findings of the evaluation grouped by common key practices. Again, a general statement indicates strength or weakness of the V-Model; key process areas that deviate significantly in their rating are stated. For details please refer to [2].

In general, no *policies* are given in the V-Model as are required by the CMM for each key process area. Only in rare cases can products fulfill some of the relevant criteria.

Sponsorship only applies to organizational key process areas. The V-Model does not contain any corresponding regulations.

Activities which are prescribed by the V-Model are also *planned*. Therefore, this key practice is usually covered as far as the coverage of the specific key practices of the relevant key process area allows for (cf. Sect. 5.1).

Funding, people, and tools are provided for the activities in the V-Model. As a result, the requirements of the *resources* key practice are fulfilled as far as possible.

The same applies for the assignment of *responsibilities*. The V-Model has a separate manual detailing the assignment of roles to activities. Project members are assigned to their roles during project planning.

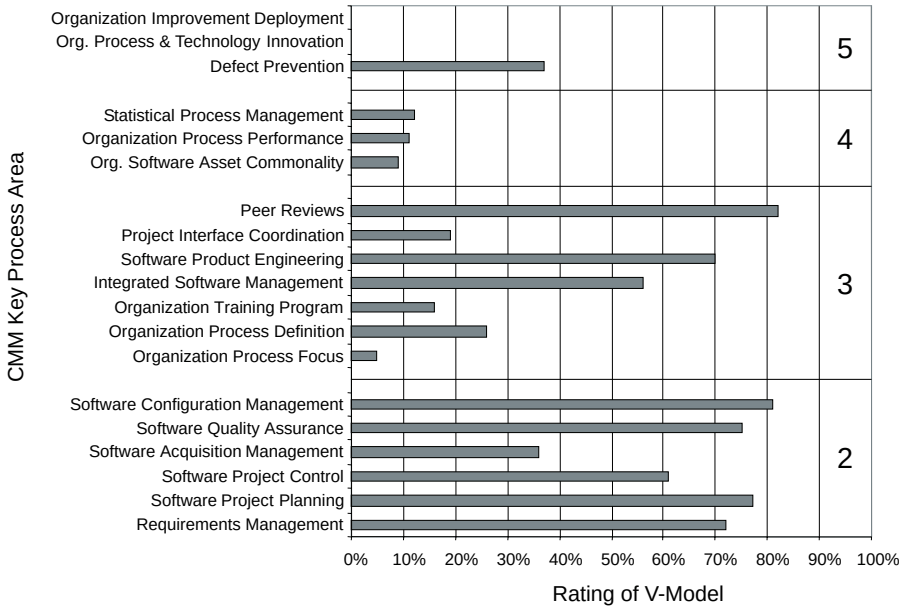

Fig. 2. Average ratings of the V-Model for the unique key practices grouped by key process areas

Training is provided as needed by the project members. No required training is defined.

A *perform* key practice emphasizes the practical implementation of each key process area. As stated in Sect. 3, this key practice is not rated.

Basic metrics to gain *insight* into the process performance are collected and analyzed with simple tools in the V-Model. However, because of its well-designed structure the V-Model is ideally suited for the introduction of additional metrics and analysis methods.

How *process assurance* is done is assessed in the software quality assurance key process area. What activities are subject to process assurance is stated in this key practice. In the V-Model, process assurance is mandatory only in rare cases. The requirements of the CMM are not fulfilled here, but this could be changed easily.

A further key practice states what products should undergo *product assurance*. While for products of the system engineering submodel quality assurance is obligatory, it is optional for most other products in the V-Model. Therefore, the rating here is not as good as it could be.

Senior management reviews and *project manager reviews* are held in the V-Model. The project is assessed technically and economically. Not covered are conflicts and issues escalated and appropriate corrective action.

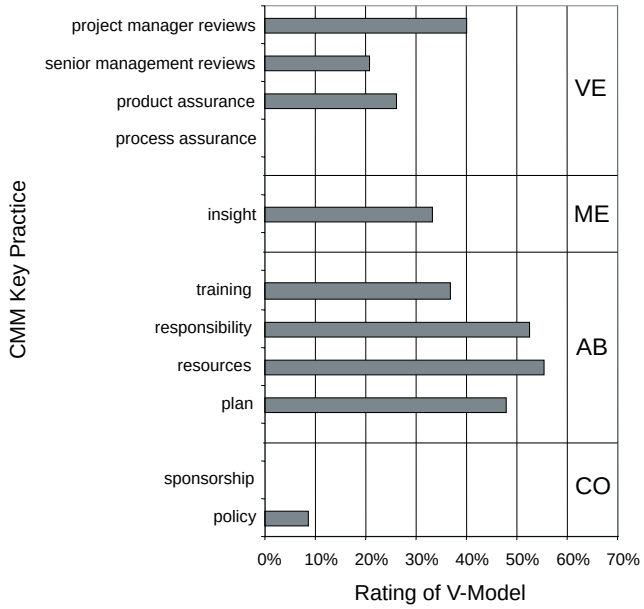

Fig. 3. Average ratings of the V-Model for the common key practices

Figure 3 illustrates the average ratings of the V-Model for the key practices common to several key process areas. The perform key practice is not rated and, therefore, not shown in the figure.

5.4 Aggregation into Ratings for Maturity Levels

By aggregation of the ratings of all key process areas in each maturity level we can obtain ratings for the maturity levels of the CMM. At level 2, 62 % of the criteria of the CMM are fulfilled by the V-Model. At level 3 the rating is 32 %. Level 4 is weakest at 10 % with level 5 being slightly better at 12 %. The ratings of the V-Model for the maturity levels are shown in Fig. 4.

The algorithm for calculating the overall maturity level of a process specified by the SEI in the CMM Appraisal Framework (CAF) [23] is rather strict. To reach a certain maturity level, the goals of the key process areas at that and all lower levels must be satisfied. As the V-Model shows weaknesses at level 2 (for example, in the software acquisition management key process area) it is rated a level 1 process by this algorithm.

5.5 Validating the Results with the Siemens Process Assessment

For the validation of the results obtained by rating the key practices of the CMM, all questions of the questionnaire used for Siemens Process Assessments which relate directly to the CMM are answered for the V-Model. Additional

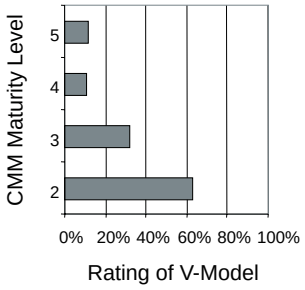

Fig. 4. Ratings of the V-Model for the maturity levels

questions specific for the Siemens approach (regarding, for example, hardware development or patents) are not rated and thus do not influence the results. The questions were rated and evaluated using the four-point scale and rating algorithm of the BOOTSTRAP approach.

As stated in Sect. 2.3 there is no one-to-one relationship between process areas of Siemens Process Assessments and key process areas of the CMM. Therefore, the ratings of the process areas are not given here. However, the assignment of questions to maturity levels is the same as in the CMM. Here, a comparison makes sense.

The results are encouraging. In general, the same strengths and weaknesses are identified in the V-Model. Moreover, the aggregated ratings of the maturity levels correlate well with those stated in Sect. 5.4. At level 2 the rating is 68 %. At level 3 it goes down to 38 %. Level 4 is weakest again at 8 % and level 5 is at 11 %.

The BOOTSTRAP-based algorithm used for Siemens Process Assessments gives an overall maturity level of 2 for the V-Model.

6 Discussion

The V-Model was created as a development standard for individual projects. Separate submodels for system development, quality assurance, configuration management, and project management are provided.

Accordingly, here are the strengths of the V-Model. In the CMM key process areas requirements management, software project planning, software project control, software quality assurance, software configuration management, integrated software management, and software product engineering the V-Model can achieve ratings above 50 %, often above 70 %. Reviews are rated best at more than 80 %.

Among the project-related key process areas at levels 2 and 3 of the CMM, only software acquisition management and project interface coordination are weak.

Organizational aspects are hardly covered by the V-Model. The reason is that the V-Model was designed to be included in contracts for projects and not as a process model for an organization.

Having said this, external support for some organizational issues is available (see Sect. 5.1). If the V-Model included a role and activities for process management in an organization, the external support would be guaranteed to take effect in the organization and ratings in the organization process focus and organizational process definition key process areas would improve.

Other organizational issues like training, reuse or quantitative modeling of processes require more effort for improvement in the organization.

The focus on projects is reflected in the ratings of maturity levels as well. Level 2 of the CMM contains project-related key process areas only. The V-Model can fulfill more than 60 % of the requirements. At level 3 focus shifts to a coherent standard process for the organization with the projects tailoring that standard process according to their needs. Here, the V-Model is rated only slightly above 30 % but with good potential for improvement. Statistical process control is the main theme at level 4 of the CMM. While the V-Model does not use metrics extensively its structure is well suited for that purpose. Quantitatively controlled process improvement which is the level 5 focus of the CMM is not covered at all by the V-Model. The non-zero rating of level 5 results only from the defect prevention key process area.

The algorithm of the CAF rates the V-Model a level 1 process. The CMM characterizes a level 1 process as being "ad-hoc" and "chaotic" with few processes defined and project success depending on individual project members [1].

Carrying out a project according to the V-Model should ensure a smooth running with repeatable success. At DaimlerChrysler Aerospace, Defense and Civil Systems division, an integrated development process based on the V-Model was introduced in cooperation with Siemens corporate technology division. All four piloting projects were in time and below budget. A positive return on investment is expected in the second year of the improvement project [24].

However, it is not guaranteed by the V-Model as is that this success is taken to the organizational level. This is the typical characteristic of a level 2 process.

Therefore, the level 2 rating calculated by the BOOTSTRAP-based algorithm of the Siemens Process Assessment seems to be more adequate than that of the CMM Appraisal Framework.

This confirms earlier results [25] of a less detailed evaluation of the V-Model 92 with a questionnaire based on version 1 of the CMM.

7 Conclusion

The V-Model provides a strong basis for carrying out software development projects but leaves much room for improvement in organizational aspects. Although CMM and V-Model have different cultural backgrounds, there are no regulations in the V-Model contrary to the CMM.

Siemens AG plans to specify modifications to the V-Model based on these results. These modifications could be included in organizational implementations of the V-Model or might even find their way into a future version of the standard V-Model. This would be one step further on the way to making the V-Model a CMM-compliant process.

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References

1. Paulk, M., Weber, C., Curtis, B., Chrissis, M. (eds.): The Capability Maturity Model: Guidelines for Improving the Software Process. Addison-Wesley Publishing Company, Reading, Massachusetts, 1995
2. Schuppan, V.: Das V-Modell 97 als Softwareentwicklungsprozeß aus der Sicht des Capability Maturity Models (CMM) für Software. Master's thesis. Institut für Informatik, Technische Universität München, Munich, August 16, 1999
3. Bundesministerium des Inneren, Koordinierungs- und Beratungsstelle der Bundesregierung für Informationstechnik in der Bundesverwaltung (ed.): Entwicklungsstandard für IT-Systeme des Bundes. Bonn, June 1997
4. Freitter, Michael: Bundesvorgehensmodell IT-BVM Vorgehensmodell für die Entwicklung von IT-Systemen des Bundes Version 1.0. Available in Internet: URL: http://www.bv-modell.at/set_info.htm [as of September 15, 1999]
5. Bundesamt für Informatik: HERMES Führung und Abwicklung von Informatikprojekten Ausgabe 1995. Bern, 1995
6. International Organization for Standardization: International Standard ISO 9001 Quality systems – Model for quality assurance in design, development, production, installation and servicing. ISO Copyright Office, Geneve, 1994
7. International Organization for Standardization: International Standard ISO 9000-3 Quality management and quality assurance standards – *Part 3:* Guidelines for the application of ISO 9001:1994 to the development, supply, installation and maintenance of computer software. ISO Copyright Office, Geneve, 1994
8. International Organization for Standardization; International Electrotechnical Commission: International Standard ISO/IEC 12207 Information technology – Software life cycle processes. ISO/IEC Copyright Office, Geneve, 1995
9. Department of Defense: Military Standard: Software Development and Documentation MIL-STD-498. US Department of Defense, 5 December 1994
10. IABG: Das V-Modell. In Internet: URL: http://www.v-modell.iabg.de/ [as of September 15, 1999]
11. Software Engineering Institute: Draft C of the Software Capability Maturity Model (SW-CMM) v2.0. Software Engineering Institute, Carnegie Mellon University, Pittsburgh, Pennsylvania, October 22, 1997. Available in Internet: URL: http://www.sei.cmu.edu/cmm/draft-c/c.html [as of September 15, 1999]
12. Software Engineering Institute: Capability Maturity Model – Integrated – Systems/Software Engineering CMMI-SE/SW Staged Representation Version 0.2. Software Engineering Institute, Carnegie Mellon University, Pittsburgh, Pennsylvania, August 31, 1999

13. Gonauser, M., Paulisch, F., Völker, A.: Siemens' Experience with People / Process / Technology: Lessons Learned. In: Proceedings of The third annual Software Engineering Process Group Conference 1998 (European SEPG '98), London, United Kingdom, June 8–11, 1998.
14. Mehner, T., Messer, T., Paul, P., Paulisch, F., Schless, P., Völker, A.: Siemens Process Assessment and Improvement Approaches: Experiences and Benefits. In: Proceedings of The Twenty-Second Annual International Computer Software & Applications Conference (Compsac 98), Vienna, Austria, August 19–21, 1998. IEEE Computer Society, Los Alamitos, California, 1998
15. Haase, V., Messnarz, R., Cachia, R.: Software Process Improvement by Measurement BOOTSTRAP/ESPRIT Project 5441. In: Mittermeir, R. (ed.): Shifting Paradigms in Software Engineering, Proceedings of the 7th Joint Conference of the Austrian Computer Society (OCG) and the John von Neumann Society for Computing Sciences (NJSZT), Klagenfurt, Austria, 1992, pp. 32–41. Springer Verlag, Wien, 1992
16. El Emam, K., Briand, L., Smith, B.: Assessor Agreement in Rating SPICE Processes. European Software Institute, July 1, 1996
17. Newberry, G.: The Relationship Between the SEI's CMM Levels and Source Selection. In: CrossTalk 9 (1996) 5
18. Steinmann, C.: Verwendung des V-Modells (387). Mail to the V-Model mailing list, July 26, 1999. Archived in Internet: URL: http://www.v-modell.iabg.de/maillst.htm [as of September 15, 1999]
19. Bate, R., Kuhn, D., Wells, C. et al.: A Systems Engineering Capability Maturity Model, Version 1.1. CMU/SEI-95-MM-003. Software Engineering Institute, Carnegie Mellon University, Pittsburgh, Pennsylvania, 1995
20. Members of the SSE-CMM project team: Systems Security Engineering Capability Maturity Model SSE-CMM Model Description Document, Version 2.0, April 1, 1999. Available in Internet: URL: http://www.sse-cmm.org/SSEdocs/TheModel/SSECMMv2Final.pdf [as of September 15, 1999]
21. Paulk, M.: Questions and Answers on the CMM Issue #1, April 5, 1994. Available in Internet: URL: http://www.sei.cmu.edu/activities/cmm/docs/q-and-a.1.html [as of September 15, 1999]
22. ANSSTAND: ANSSTAND e. V. Homepage. In Internet: URL: http://www.ansstand.de/ [as of September 15, 1999]
23. Masters, S., Bothwell, C.: CMM Appraisal Framework, Version 1.0. Technical Report, CMU/SEI-95-TR-001. Software Engineering Institute, Carnegie Mellon University, Pittsburgh, Pennsylvania, 1995
24. Rußwurm, W., Kranz, W.: An Integrated System Development Process for Software, Hardware, and Logistics: Definition, Implementation, and Experiences. In: Proceedings of The European Conference on Software Process Improvement (SPI 99), Barcelona, Spain, November 30–December 3, 1999
25. Ehlting, J.: Konformität des V-Modells der Bundesbehörden mit den Prinzipien des Total Quality Management Konzeptes in der Softwareentwicklung unter Einbeziehung des CMM. Master's thesis. Universität zu Köln, Cologne, 1994