A Process Assessment Model for Very Small Software Entities

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Abstract

A new standard for very small software producing entities is emerging. The standard describes processes for project management and software implementation, and assumes that conformance assessments or process assessments are performed. This paper describes development of a novel process assessment model. The work includes analysis of the prospective standard, which provides the basis for definition of a process reference model. The results of this research may be of benefit to process assessors, assessment tool developers, and future development of the standard.

1. Introduction

This paper follows the development of an international standard for small software organizations. The standard is titled ISO/IEC 29110 Software Engineering — Lifecycle Profiles for Very Small Entities (VSEs). The standard has been modeled in our earlier work [10] and described in various papers, e.g. [9, 10].

The prospective ISO/IEC 29110 standard presents a process life cycle model for very small entities (VSEs) that produce software. Here, VSE denotes an organization of up to 25 people and it can be an enterprise, organization, department or project. The standard is best suited for a team that produces software as a contracted project.

The 29110 draft standard is now in its final development phase before publication that is likely to happen in the end of 2010. The draft standard consists of 5 parts as shown in Figure 1 [5].

The original 29110 development strategy was to construct the standard from subsets of existing standards, like ISO/IEC 12207, 15289 and 15504, and ISO 9000. This approach produces a Profile that is a subset of one or more standards. To complement the source standards and make their application easier, 29110 standards will provide more detailed information to support software processes in VSEs. From the viewpoint of a VSE, the Part 5 Management and Engineering Guide is the most practical one. For a model developer or an assessor Part 4 Specifications of VSE Profiles provides useful information about the mapping to the source standards. To comprehend Part 4, Part 2 Framework and Taxonomy presents the concepts needed.

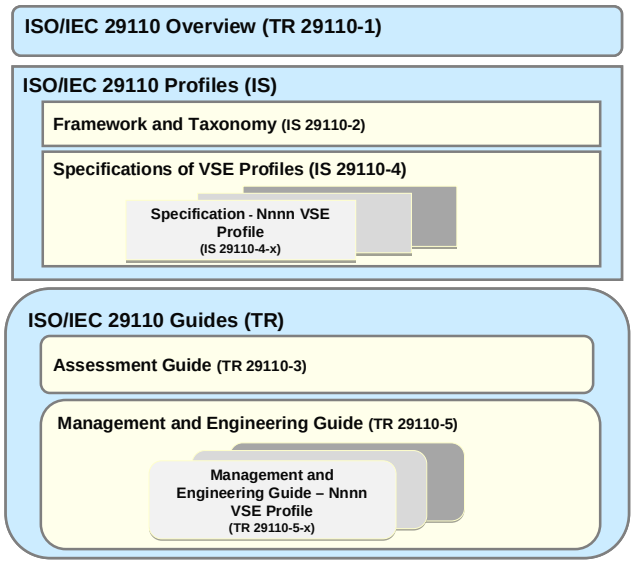

Figure 1. ISO/IEC 29110 Set of Documents [29110-1].

The VSEs can benefit of process assessments in two ways. First, an assessment provides objective information for process improvement. Second, the assessments can support in claiming conformance to the standards.

The purpose of this paper is to present an analysis of the mapping included in the 29110 draft standard and an approach for the development of a process assessment model based on the elements available in the ISO/IEC systems and software engineering standards. Process assessment models are instrumental for reliable and repeatable process assessments. A process capability assessment studies individual processes and their attributes, while a conformance assessment can study e.g. fulfillment of a standard's requirements.

This paper is targeted to an audience that considers providing assessment services for small organizations or is interested in promoting the VSE Profiles. The outcome of this study should benefit the developers of the

international standards in ensuring the quality of the standards.

The second chapter describes our design-science research framework. The third chapter defines the requirements related to process capability assessments. In chapter four, we present the results of the 29110 analysis and some implications of the results. Chapter five describes our method in creating a process assessment model for the VSEs, and chapter 6 presents the developed model. The conclusion of the study and eventual next steps are discussed in chapter seven. The three annexes provide supplementary material of the analysis and a sample of the developed assessment model.

2. Research framework

Our research is in the scope of design science in software engineering (SE) or more specifically SE process, following SWEBOK [1]. We have two research questions:

1. What is the assessment model for the Basic VSE Profile like?
2. How are assessment models for VSE profiles constructed?

In this section, we describe our research approach according to the seven guidelines stated by Hevner et al. [2]. They discuss design science in the context of information systems (IS) research. Although our context is different, the guidelines seem to be applicable and very relevant. Hevner's guidelines are presented as quotations below with a corresponding comment relating it to our research.

1. Design as an Artifact

"Design-science research must produce a viable artifact in the form of a construct, a model, a method, or an instantiation." The primary out-come of this research is an exemplar assessment *model* for very small software entities. As the second research outcome, we reveal our *method* for constructing such assessment models.

2. Problem Relevance

"The objective of design-science research is to develop technology-based solutions to important and relevant business problems." Before now, there was no assessment *model* related to the Basic VSE Profile. The assessment model is required in an assessment that is applied in the determination of process capability, improving processes [4], and demonstrating conformance against international standardized profiles [6]. The *method* is required when assessment models are constructed in the context of Lifecycle Profiles for VSEs. In the future, 29110-4 will contain other profiles in addition to the Basic VSE Profile. Every time a new profile has been developed, the assessment model for it can be generated utilizing the method.

3. Design Evaluation

"The utility, quality, and efficacy of a design artifact must be rigorously demonstrated via well-executed evaluation methods." The method is evaluated by constructing the exemplar assessment model, which is qualitatively evaluated using the intended use cases of assessment as the evaluation criteria. The empirical evaluation of the assessment model has been left out of the scope of this paper, but it is identified as a topic for future work.

4. Research Contributions

"Effective design-science research must provide clear and verifiable contributions in the areas of the design artifact, design foundations, and/or design methodologies." Although assessment models are common practice, the process to construct them for international standardized profiles is not generally known. In this paper, we identify three ways for building an assessment model. One of them is utilized in the construction of the exemplar assessment model.

5. Research Rigor

"Design-science research relies upon the application of rigorous methods in both the construction and evaluation of the design artifact." The procedure for building the exemplar assessment model is described in section 5. The qualitative evaluation of the model is discussed in section 6.

6. Design as a Search Process

"The search for an effective artifact requires utilizing available means to reach desired ends while satisfying laws in the problem environment." The design is limited to the application of selected international standards to ensure wide acceptance of the developed model within the domain of systems and software engineering standardization. Adequate knowledge has been obtained through long-term experience in standards and model development.

7. Communication of Research

"Design-science research must be presented effectively both to technology-oriented as well as management-oriented audiences." Our focus knowledge area is SE process. We classify our audience into practical performers, e.g. process engineers or assessors, and researchers. This paper is a research report. There is a separate publication that includes the complete description of the exemplar assessment model and related assessment method [11].

This research is related to two on-going research projects at our Centre of Software Expertise (CoSE) in Tampere University of Technology, Pori. One is aimed to integrate process assessment and modeling and another

to identify factors related to micro SE enterprise growth. Both projects are funded by Tekes – the Finnish Funding Agency for Technology and Innovation.

In addition, CoSE is a member of the international Network of VSE Support Centers. The results of this study will be published through this network and CoSE will also set up a web-site that offers the developed models for VSE assessors and researchers.

3. Requirements for performing a capability assessment

According to 15504-2, process capability is used to indicate the ability of a process to meet the business goals of an organization. Process assessments are performed to understand the capability of an organization's implemented process by determining the extent to which the processes achieve the process purpose [4].

Process models are essential in supporting reliable and repeatable process assessments. In the context of international standards we can refer to the 15504-2 requirements for both Process Reference Models (PRM) and Process Assessment Models (PAM).

A Process Assessment Model is related to one or more Process Reference Models [4]. In addition, a PAM requires a Measurement Framework to characterize process capability. The 15504-2 standard defines a Measurement Framework that uses a six point ordinal scale i.e. capability levels 0-5.

A Process Reference Model provides the process descriptions. According to 15504-2 the process descriptions shall meet the following requirements:

- *a process shall be described in terms of its purpose and outcomes;*
- *the set of process outcomes shall be necessary and sufficient to achieve the purpose of the process;*
- *process descriptions shall contain only aspects related to process performance (i.e. capability level 1).*

Furthermore, 15504-2 specifies that a process outcome describes one of following:

- *Production of an artefact;*
- *A significant change of state;*
- *Meeting of specified constraints, e.g. requirements, goals etc.*

Also, the requirements for the scope of the PAM are defined in 15504-2:

A Process Assessment Model shall declare its scope of coverage in the terms of:

a) the selected Process Reference Model(s);

b) the selected processes taken from the Process Reference Model(s);

c) the capability levels selected from the Measurement Framework

A PAM must contain assessment indicators *that explicitly address the purposes and outcomes, as defined in the selected PRM*. Also, A PAM shall provide an explicit (complete, clear and unambiguous) mapping from its elements to the processes of the PRM and the process attributes of the Measurement Framework. The indicators of the PAM need mapping to the purposes and outcomes of the PRM. [4]

Generally, process assessments can be performed to support process improvement or to determine process capability. A process assessment provides an objective basis for an organization to understand its processes and improve them effectively. Capability determination is often more formal evaluation of the applicability of the process for specific requirements. Process assessment could also provide a way to evaluate conformance to a standard like 12207 or 29110, when we consider the standards as a set of requirements.

Process assessment models can be constructed in various ways. Conformance assessment approach may utilize process reference models in evaluating achievement of the process outcomes. Process capability approach combines process reference models and a measurement scale into a model, which may be a combination or a subset of an existing process assessment model including the relevant indicators, or built upon a process reference model or a profile with new indicators.

4. VSE Process Model

Specifications of VSE Profiles (29110-4) provide profiles based on subsets of other standards [2]. The first developed profile for VSEs, 29110-4-1, is named Basic VSE Profile and it contains project management and software development processes. The processes and related activities are summarized in their context in Figure 2.

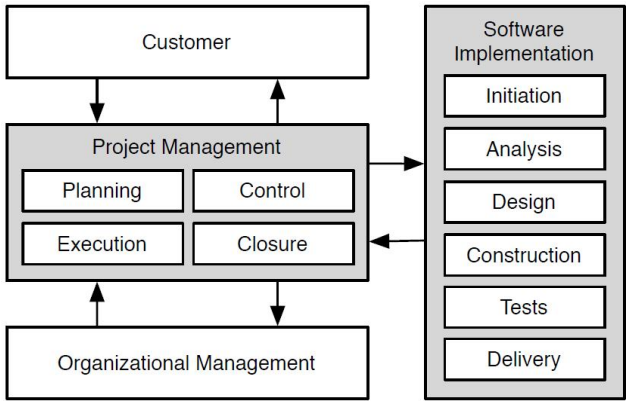

Figure 2. 29110-4-1 Basic VSE Profile processes.

The profile elements include processes, process objectives, work products, activities and tasks. Work products are defined as inputs or outputs for activities. The elements of the Basic Profile and their relations are depicted in Figure 3. For conformity assessment purposes, all processes, objectives, activities and work products are defined as mandatory (exposed with grey shading in Figure 3). Additionally, output work products are mandatory for activities.

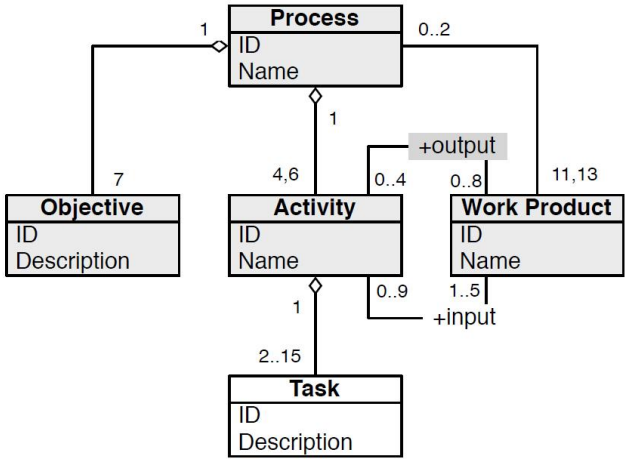

Figure 3. Elements of the Basic VSE Profile.

A more detailed analysis of the Basic Profile element relationships is presented in Annex II of this paper. It shows among other things that 29110-4-1 links the work products to processes (29110-4-1, clause 6.5) differently to how they are linked through activities input & output specifications (29110-4-1, clause 7.5). Yet the activities belong to only one process.

The purpose of 29110-4-1 is to provide the normative and informative links to the subset of ISO/IEC 12207:2008 and ISO/IEC 15289:2006 [7]. Figure 4 illustrates the references to the source standards.

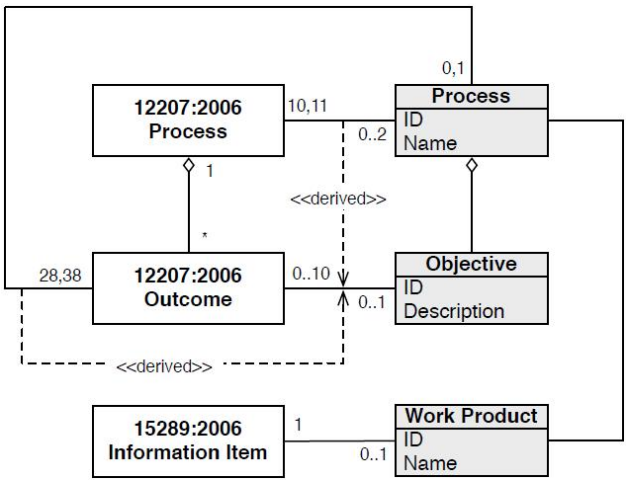

Figure 4. IS 29110-4-1 References.

In 29110-4-1 there is a normative annex (Annex A: Process Reference Model for Basic VSE Profile Assessment) that states:

For the purpose of capability assessments as defined in ISO/IEC 15504, process objectives specifications shall be used as the process reference models, using 29110 objectives as 15504 outcomes.

As a normative part of the standard this annex must be significant. On the other hand, the content of the annex is confusing and inaccurate, and does not provide a PRM as the title indicates. Next, we try to construct a PRM based on 29110-4-1.

We can notice several issues, when we analyze the 29110-4-1 process descriptions against the requirements presented in section 3. First, 29110-4-1 does not describe the processes in terms of process purpose and outcomes. Second, the processes contain aspects beyond process performance requirements, e.g. quality assurance objective in project management process, validation activities in software implementation process, and measurement in general. Third, the process objectives do not meet the requirements for process outcomes as they describe process goals. Therefore, the 29110-4-1 cannot be considered as a PRM.

It is also questionable, whether the 29110-4-1 meets the definition of a Profile (conforming subset of base standards). For instance, some of the defined objectives or activities cannot be mapped to the base standards. Obviously, the purpose of 29110-4-1 needs clarification: if it is not a PRM, nor a Profile, then what is it?

The present state of the 29110 standards as process models is mainly due to lack of architectural design in creating the standards. The 29110 standards were created with bottom-up approach, which made it difficult to provide precise mapping to the source standards. More

detailed analysis of the mapping is presented in Annex I of this paper. Creating profiles as subsets of existing standards would benefit of a top-down approach. The present deficiencies noted in the 29110-4-1 standard might impose a risk for the acceptance of 29110 to be applied in process capability or conformance assessments.

5. How to construct a VSE PAM

Our goal is to build a PAM for the VSE. According to 15504-2 a PAM is two-dimensional and requires indicators for both process performance and process capability. For the moment, 29110 does not specify any process capability related elements beyond process performance, so we can limit to the capability level one process attribute: Process Performance. Hence, our VSE PAM will contain only process performance indicators. Later on, the VSE PAM can be extended using the capability level 2-5 process attributes of 15504-2 and corresponding process capability indicators of 15504-5.

First issue is to identify a suitable PRM. As concluded in the previous chapter, the 29110-4-1 is not applicable as a process reference model. On the other hand, the mapping provided can be used to identify a plausible PRM. Based on the identified PRM, an applicable PAM could be constructed.

Although the process purposes have not been defined in 29110-4-1, they are included in 29110-5-1. The process purposes are [8]:

- *The purpose of the Project Management process is to establish and carry out in a systematic way the tasks of the software implementation project, which allows complying with the project's objectives in the expected quality, time and costs.*
- *The purpose of the Software Implementation process is the systematic performance of the analysis, design, construction, integration and tests activities for new or modified software products according to the specified requirements.*

It is debatable, whether the process objectives correspond to the process purposes in either of the processes. Nevertheless, we have now processes and their purposes.

In the mapping, most of the process objectives are linked to 12207 process outcomes (Annex I). The 12207 process outcomes meet the requirements for outcomes set in 15504-2 - this is implied by an existing PAM, the 15504-5 An exemplar Process Assessment Model. If we accept a subset of outcomes from various 12207 processes for the 29110-4-1 processes, we can constitute a PRM for the VSEs.

By selecting the 12207 process outcomes as the basis for the PRM, we can now construct the VSE PAM based on a subset of assessment indicators in 15504-5. The 15504-5 PAM utilizes the 12207 process purposes and outcomes, and provides Base Practices and Work Products as assessment indicators for capability level 1. The 15504-5 PAM includes mapping of the Base Practices to 12207 process outcomes. Using this mapping, we can create a corresponding subset of Base Practices for the VSE PAM.

The remaining issue is the Work Products. The 29110-4-1 draft standard specifies work products as mandatory elements for conformance. The work products are explicitly mapped to ISO/IEC 15289. An analysis of work product usage in the processes and their activities is documented in Annex II. There are many work products that are defined as output only. How do these work products help a VSE to improve its processes? On the other hand, there are two work products that are input only, i.e. they are not created by any process. Does it mean that without these work products a project cannot be started, since they are mandatory?

The 15504-5 PAM considers work products as 'objective guidance for potential inputs and outputs' [4]. Using this more permissive interpretation, we can include the Work Products as assessment indicators in the VSE PAM. The work products are grouped under processes and the input/output division is obtained through the activities.

The interpretation of the work products in an assessment depends on the nature of the assessment. A formal or conformance assessment might concentrate on checklist type of interpretation of the work products. An improvement oriented assessment might look for the purpose of the work product related information in their process context.

The next chapter presents an alternative for a VSE PAM including base practices and work products as assessment indicators.

6. Exemplar VSE PAM

As a result of this study we have constructed an exemplar VSE PAM (Annex III) that corresponds to the Basic Profile defined in 29110-4-1. It is based on the following principles, also depicted in Figure 6:

- Processes are from 29110-4-1
- Process purposes are from 29110-5-1
- Process outcomes are from 12207 based on the mapping in 29110-4-1
- Base Practices are from 15504-5 and based on the mapping to 12207 outcomes

- Work product input/output lists are based on the 29110-4-1 profile specification

Some minor consistency issues in Base Practices are due to the on-going revision of the source standards. 29110-4 refers to 12207:2008 and 15504-5 refers to the preceding 12207 version. This can be amended as soon as the revised 15504-5 PAM is published, latest in 2011.

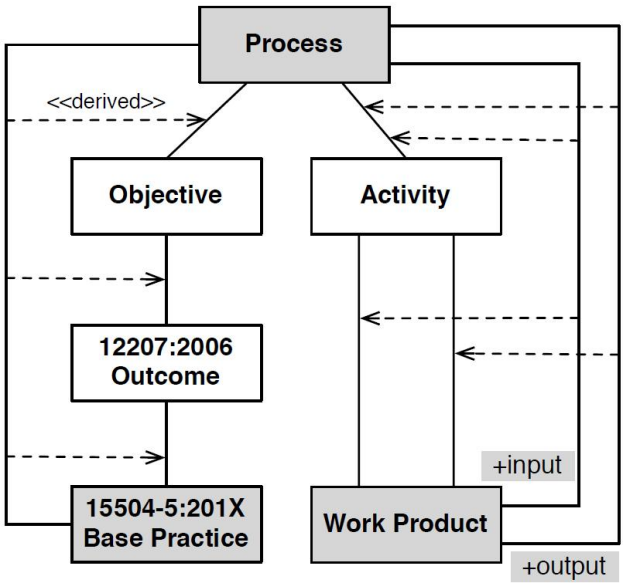

Figure 5. Derived process indicators of VSE PAM.

The presented VSE PAM fully satisfies the needs of a PAM for process improvement purposes. To meet more formal process capability assessment needs, an explicit PRM would be needed. This requires that the proposed 29110-4 standard should, at minimum, be corrected to include elements required for PRMs. A more professional solution would be to use 12207 as the PRM and provide an explicit mapping to it. This would also imply revision of the 29110-5-1 guide.

The presented VSE PAM does not support conformance assessment for 29110. The main reason is that the model does not cover the mandatory 29110 activities. The relationships between objectives and activities are too complex and the mapping to 12207 is inadequate to enable concluding the fulfillment of the standard based the presented Base Practice and Work Product assessment.

7. Conclusions

The main results of this study are a PRM for VSEs and a PAM for VSEs. The model development method is described in detail. Furthermore, a comprehensive analysis of the 29110-4-1 mapping was performed.

When constructing the PRM we noticed that the 29110-4-1 does not provide all the necessary information. The developed PRM combines elements of 12207 and 29110-5-1.

The VSE PAM design is based on the VSE PRM and s an existing software process assessment model, 15504-5. We limit the assessment model to process performance indicators of the identified process outcomes. The VSE PAM is a subset of the base practices from 15504-5 and the work products of 15289.

There are several limitations to this work. First, the analyzed 29110 standard is not yet approved or published; obviously some alterations are still needed. Second, the created PRM does not fully meet the requirements; especially the relation between the process purposes and selected outcomes is open to discussion. Third, the activities are mandatory elements of 29110-4-1, but are excluded of the PAM. And, at the moment the assessment indicators are limited to process performance level.

However, we believe that the 29110 standard will in the future provide valuable guidance to VSEs. The developed VSE PAM is the first step to integrate the Basic VSE Profile into systematic process improvement of VSEs.

Our future plans include publication of the VSE PAM on the web and evaluation of the model in VSE assessments. Furthermore, new VSE Profiles will most likely create a need to expand the VSE PAM with capability indicators.

8. References

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Annexes

Annex I. 29110 Basic VSE Profile process objectives mapping to 12207 process outcomes.

PM - Project Management		Included Outcomes							Omitted	Outcome	
12207 Process	PM	PM.O1	PM.O2	PM.O3	PM.O4	PM.O5	PM.O6	PM.O7	Outcomes	Coverage	
Project Processes (4/7)											
Project Planning		a c e f							b d	4 / 6	L
Project Assessment and Control			a c d						b	3 / 4	L
Risk Management						c			a b d e f	1 / 6	P
Measurement		a	d e						b c f g	3 / 7	P
Technical Processes (1/11)											
Software Acceptance Support			a						b c d	1 / 4	P
Software Implementation Processes (1/7)											
Softtware Requirements Analysis				g					a b c d e f h	1 / 8	N
Software Support Processes (4/8)											
Software Configuration Management							a b c d g		e f	5 / 7	L
Software Quality Assurance								a b c d	-	4 / 4	F
Software Review					a c d	e			b	4 / 5	L
Software Problem Resolution			b e						a c d f	2 / 6	P
Σ Outcomes / Σ Processes:	28 / 10	5 / 2	8 / 4	1 / 1	3 / 1	2 / 2	5 / 1	4 / 1			

SI - Software Implementation		Included Outcomes							Omitted	Outcome	
12207 Process	SI	SI.O1	SI.O2	SI.O3	SI.O4	SI.O5	SI.O6	SI.O7	Outcomes	Coverage	
Agreement Processes (1/2)											
Supply							d e f		a b c	3 / 6	L
Technical Processes (1/11)											
Stakeholder Requirements Definition			a						b c d e f	1 / 6	P
Software Implementation Processes (6/7)											
Software Requirements Analysis			a b f h						c d e g	4 / 8	L
Software Architectural Design				a b c					-	3 / 3	F
Software Detailed Design				a b c					-	3 / 3	F
Software Construction				a	b c d				-	4 / 4	F
Software Integration						c d e f			a b g	4 / 7	L
Software Qualification Testing						a b c			d	3 / 4	L
Software Support Processes (3/8)											
Software Documentation Management							a c e		b d f	3 / 6	L
Software Verification								a b c d e	-	5 / 5	F
Software Validation								a b c d f	e	5 / 6	L
Σ Outcomes / Σ Processes:	38 / 11	0 / 0	5 / 2	7 / 3	3 / 1	7 / 2	3 / 1	10 / 2			

Annex II. 29110 Basic Profile processes and actives, and their related work products.

		PM Activity					Project Management	SI Activity							Software Implementation	Σ
		PM.1 ... Planning	PM.2 ... Execution	PM.3 ... Control	PM.4 ... Closure	Σ		SI.1 ... Initiation	SI.2 ... Analysis	SI.3 ... Design	SI.4 ... Construction	SI.5 ... Tests	SI.6 ... Delivery	Σ		
	Work Product															
1	Acceptance Record				0,1	0,1	1									0,1
2	Change Request		1,1	0,1		1,2	1		0,1	0,1				0,2		1,4
3	Correction Register			0,1		0,1	1									0,1
4	Maintenance Documentation												0,1	0,1	1	0,1
5	Meeting Record		0,1			0,1	1									0,1
6	Product Operation Guide											0,1		0,1	1	0,1
7	Progress Status Record		0,1	1,0		1,1	1									1,1
8	Project Plan	0,1	1,1	1,0	1,0	3,2	1	1,0	1,0	1,0	1,0	1,0	1,0	6,0		9,2
9	Project Repository	0,1			0,1	0,2	1									0,2
10	Project Repository Backup		0,1			0,1	1									0,1
11	Requirements Specification								0,1	1,0				1,1	1	1,1
12	Resources	1,0				1,0										1,0
13	Software											0,1		0,1	1	0,1
14	Software Component										0,1	1,1		1,2	1	1,2
15	Software Configuration				1,0	1,0			0,1				1,1	1,2	1	2,2
16	Software Design									0,1	1,0			1,1	1	1,1
17	Software User Documentation								0,1			1,1		1,2	1	1,2
18	Statement of Work	1,0				1,0	1									1,0
19	Test Cases and Test Procedures									0,1	1,0	1,1		2,2	1	2,2
20	Test Report											0,1		0,1	1	0,1
21	Traceability Record									0,1	1,1	1,1		2,3	1	2,3
22	Verification Results						1		0,1	0,1		0,1	0,1	0,4	1	0,4
23	Validation Results						1		0,1					0,1	1	0,1
	Legend: 1,0 - input; 0,1 - output; 1,1 - input/output	2,2	2,5	2,2	2,2	6,8	11	1,0	1,6	2,5	4,2	5,8	2,3	8,14	13	12,21

Annex III. A sample of an Exemplar VSE Process Assessment Model with ISO/IEC 15504-5 base practices.

1. Process Assessment Model for Very Small Entities

1.1 Project Management (PM) process

1.1.1 PM purpose

The purpose of the Project Management process is to establish and carry out in a systematic way the tasks of the software implementation project, which allows complying with the project's objectives in the expected quality, time and costs.

1.1.2 PM objectives

PM.O1. The Project Plan *for the execution of the project is developed according to the* Statement of Work *and reviewed and accepted by the Customer. The tasks and resources necessary to complete the work are sized and estimated.*

6.3.1 Project Planning Process
a) the scope of the work for the project is defined;
c) the tasks and resources necessary to complete the work are sized and estimated;
e) plans for the execution of the project are developed; and
f) plans for the execution of the project are activated.

6.3.7 Measurement Process
a) the information needs of technical and management processes are identified.

[ISO/IEC 12207, 6.3.1, 6.3.7]

Base Practices	**PM.O1.BP1: Define the scope of work**. Identify the project's objectives, motivation and boundaries and define the work to be undertaken by the project. [Outcome: 1a]
	PM.O1.BP2: Define project activities and tasks. Identify project activities and tasks according to defined project lifecycle, and define dependencies between them. [Outcome: 1c]
	PM.O1.BP3: Define project schedule. Allocate resources to activities and determine the sequence and schedule of performance of activities within the project. [Outcome: 1e]
	PM.O1.BP4: Allocate responsibilities. Identify the specific individuals and groups contributing to, and impacted by, the project, allocate them their specific responsibilities, and ensure that the commitments are understood and accepted, funded and achievable. [Outcome: 1e]
	PM.O1.BP5: Establish project plan. Define and maintain project master plan and other relevant plans to cover the project scope and goals, resources, infrastructure, interfaces and communication mechanisms. [Outcome: 1f]
	PM.O1.BP6: Implement the project plan. Implement planned activities of the project, record status of progress and report the current status to affected parties. [Outcome: 1f]
	PM.O1.BP7: Identify measurement information needs. Identify the measurement information needs of organizational and management processes. [Outcome: 7a]