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Evaluating Software Process Assessment Methods Based On Engineering Design Principles

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***Abstract*—Software Process Assessment (SPA) is an effective method used to understand organizations' software processquality. Assessment methods are tools used to identify the possible software process improvement opportunities. This paper studies the design process of the SPA methods from an engineering viewpoint and uses Vincenti's classifications of engineering design knowledge as an analytical tool. The analyses end up with the necessary pieces of knowledge that the SPA methods' designers bring with them before starting the design process of the SPA method. These pieces of knowledge provide useful guidelines, mainly for less experienced designers, to start SPA methods design. For the already developed SPA methods, these pieces of knowledge can be used as evaluation criteria that disclose the strengths and weaknesses of theses SPA methods.**

Keywords— Software, Process, Assessment, Evaluation, Design, Engineering, Criteria

I. INTRODUCTION

Software Process Assessment (SPA) is an effective method used by software organizations to understand software process quality and to identify issues to be resolved to achieve higher maturity [1]. In the past two decades, various assessment methods have been developed. These assessment methods varies from comprehensive SPA methods, such as SCAMPI method of CMMi [2] and SPA methods compliant with ISO 15504 [3], to lightweight assessment methods, see for example [4-12]. The effectiveness of any assessment method is affected by the size of the organization, i.e. for small and very small organizations, and the comprehensive SPA methods are considered to be difficult to implement [13-17]. Accordingly, the effective SPA method for large organizations will not be effective for small or very small organizations.

The increasing numbers of assessment methods available, the ISO 15504 standard that sets out the requirements for process assessment, and the popularity of

the CMMI model, illustrate the relevance of software process assessment for the software development industry. The increasing numbers of assessment methods encouraged several researchers to study the differences between various SPA methods and compare between them using different approaches - see for example [18-22].

The same requirements for conducting successful assessments are common to all SPA methods [1], The requirements consists of a set of high-level design criteria for developing, defining, and using assessment methods [23]. Usually, the design criteria for comprehensive assessment methods are well defined, while for tailored lightweight methods the design of the assessment methods interferes with the designers' experience and opinions. Such expertise and opinions are normally in the designers' mind. Accordingly, identifying and explicitly coding the design criteria to design SPA methods would help in standardizing the design process of lightweight SPA methods. Moreover, aligning the design knowledge of SPA methods (both comprehensive and lightweight methods) with the engineering design knowledge would help improve the maturity of the SPA methods' design. This paper studies the design knowledge of the SPA methods from an engineering viewpoint using Vincenti's classifications of engineering design knowledge as an analytical tool. The initial and incomplete results of this research has been introduced to the SPI community in [24]. This paper continues what has been started in [24] aiming at providing a complete list of evaluation criteria to evaluate the SPA methods as well as providing guidance to the design of new SPA methods.

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This paper presents in section IIthe details of developing the evaluation method. Section IIIpresents the conclusion and the future work.

II. DEVELOPING THE EVALUATION METHOD

The target for the proposed evaluation is the SPA methods. Building a new SPA method is not the goal of this paper. This paper aims at evaluating the design and implementation of SPA methods based on engineering design principles. The evaluation wouldshow the strengths and weaknesses of the evaluated SPA method allowing for improvements to increase the probability of having a successful software process assessment and therefore a successful process improvement initiative.

Building the evaluation method based on engineering design principles would help improve the maturity of the SE, mainly the SPA field, as an engineering discipline.

Vincenti in his book [25] provided a detailed discussion of engineering design knowledge where he classified engineering design knowledge into six classes. These classes are used in this paper as the bases to build the evaluation criteria.

The work done by Vincenti in defining the anatomy of engineering design knowledge, based on a long experience in the aeronautical field, forms a good framework to study the design process in the SPA field. Vincenti stated that "a complicated technology can often be regarded as a device". Today, the software products, which are used as standalone products or as embedded in very complex systems, as well as the development process producing them, are obviously complex technologies and can be regarded as devices performing certain functions. Therefore, Vincenti's classifications should be applicable and adaptable to the software domain. In this paper, we try to adapt Vincenti's classifications to study the SPA methods' design from an engineering viewpoint. This research is vital to align software engineering field in general with the engineering principles and theories.

Using Vincenti's terms and concepts in the SPA context, designing a new SPA method(especially lightweight methods) is mostly based on a vicarious model. The common vicarious models used in the SPA field are ISO 15504 and CMMI, which have been adapted to fit the needs of such organizations. Such a vicarious means of selection is preferred as a cost and time saving alternative of building a full assessment model.

In his book, Vincenti discusses the anatomy of design knowledge in the engineering discipline and provides a classification of engineering design knowledge. This classification could also be used as an analytical tool to study the coverage of different engineering topics with other domains such as software engineering, for example.Modeling Vincenti's classifications and how to use Vincenti's categories as constituting criteria for investigating software engineering from an engineering perspective has been discussed in [26].

Accordingly, to investigate the SPA methods using Vincenti's classifications, it is useful to see to what extent the design of these methods is aligned with engineering design principles.

Vincenti stated that this classification is not specific to the aeronautical engineering domain only, but can be transferred to other engineering domains. This transfer to the software engineering field in general and software process assessment and improvement in particular, is challenging in the sense that this field is not mature enough to apply such a classification.

As stated by Vincenti, the defined six main classifications, whose breakdown graph is shown is Fig. 1, are not entirely exclusive since some items of knowledge can embody the characteristics of more than one category. Vincenti also stated that these categories are complete while the details and contents for each of them are not. The contents depend on the domain where this classification is applied. Hence, Vincenti's classifications should be studied in the context of SPA to define the contents relevant to each point in the classification to end up with a form more suitable to be used for evaluating lightweight SPA methods.

The breakdown graph shown in Fig. 1 would serve as an evaluation criteria tree. In the following sub sections each of these criteria will be discussed in detail.

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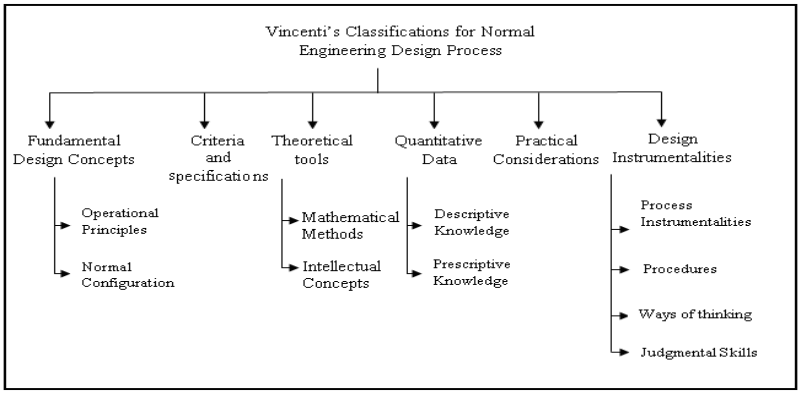

Figure1 Vincenti's classifications breakdown graph

1) Fundamental design principles evaluation criteria:

Usually, the designers planning to start a project to build a certain device using a normal design process bring with them some fundamental concepts about the devices. These concepts may exist only in the designers mind implicitly or stated explicitly somewhere else: "they are givens for the projects, even if unstated" [25]. As stated by Vincenti, the fundamental design concepts can be derived from two main sources:

a) Operational principles:These principles specify how the different parts of the designed device fulfill special functions in combination with overall operation to achievethe purpose. In other words "how the device works. The operational principles also, in effect, define a device" [25].

The main principle to design an SPA method – the proposed device – is that the designer keeps in mind that the software development process should be divided into a set of distinct processes. For each process a clear definition of purpose and outcomes is provided; this is formally known as a process reference model. The designer also keeps in mind that these processes should have indicators which are used to assess the achievement of process attributes. This is formally known as the software assessment model; hence the process reference model and the process assessment model form the main operational principles for SPA methods. Consequently, when evaluating the SPA methods based on the operational principles the following two criteria should be considered:

- Identify the process reference model which the SPA method is based on.
- Identify the process assessment model which the SPA method is based on.

b) Normal configuration:The normal configuration of a device means "the general shape and arrangement that are commonly agreed to best embody the operational principles"[25]; that is to say, any device or product to be produced, usually, consists of a set of sub-devices or sub-products, the interaction and arrangement of these sub-products is what concerns a normal configuration.

To study the normal configuration in an SPA context, the set of the sub-products and their arrangement should be identified. The best way to do this is by identifying the different phases for conducting an assessment method, and be able to identify the set of sub-products and their arrangements for each phase.

Loon in his book [27] has defined a generic assessment procedure for the assessment process, Loon's generic procedure is summarized in Fig. 2. Despite the fact that this generic procedure is based on an ISO 15504 conformant assessment method for the assessment of the space software processes SPICE for SPACE, this method is general enough to be used for any assessment. A summary of Loan's procedure follows:

Initiate Assessment

Assessment starts by sponsor commitment and definition of the input data: Business needs, reports from previous assessment, organizational documents, assessment tools and industry benchmarking.

Planning

Assessment team creates a plan describing all activities to be performed in conducting assessments. Planning produces other work products which include: confidentiality statement, pre-assessment questionnaire and assessment initiation file which records all assessment inputs.

Briefing

The assessment team presents an overview of the assessment method to the organizational unit.

Data Acquisition

Assessment team collects and produces as work product the evidence of process performance either by interviews or by reviewing the organizational documents.

Data Validation

Actions are taken to ensure that the data is accurate and sufficiently covers the assessment scope.

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Process Rating

A rating is assigned for each process attribute up to and including the highest capability level defined in the assessment scope.

Report Results

The assessment team documents the assessment results with any analysis and reports them to the participants and the sponsor. This phase produces also the assessment record which summarizes the whole assessment process and includes: assessment input, assessment method, tools, ratings and results, proposals.

For SME organizations, this generic procedure is still applicable although some details of this procedure can be overlooked for SME organizations. These details include "select the assessment team leader" which gives the impression of having a large assessment team to be lead, whereas the assessment in SME organizations is carried out by one assessor or by an assessor with one assistant assessor only. Another example is related to "select the local assessment coordinator". Usually such a coordinator is needed when assessing large organizations where the product of one department or unit is interrelated with other departments or units. Hence, to conduct an assessment, the coordination among the participants from these related units should be maintained by the coordinator which is not the case in SMEs: the needed assessment logistics in SMEs can be done via the sponsor or one of the participants without the need to assign an employee to play this role. The cost in time is one of the obstacles facing the SMEs; unnecessary roles should be reduced or eliminated.

Consequently, when evaluating the SPA methods based on the configuration management the following criteria should be considered:

- Define the business need before the assessment.
- Make use of previous assessment reports.
- Refer to the organizational documents and reports while preparing for the assessment.
- Make use of assessment tools through different phases of the assessment.
- Produce a pre-assessment questionnaire.
- Produce an assessment initiation file.
- Produce an assessment plan.
- Track evidences of process performance and capability.
- Produce an assessment report.
- Produce an assessment record.
- Produce an assessor record.

2) Criteria and specifications evaluation criteria:

Vincenti stated that "to design a device embodying a given operational principle and normal configuration, the designer must have at some point specific requirements in terms of hardware". When designing a new device, the designer translates the general qualitative goals into specific quantitative goals. The designer must have knowledge of technical criteria appropriate to the device and its use; the designer must also assign numerical values or limits to the characteristics of the appropriate criteria, which is essential for the design.

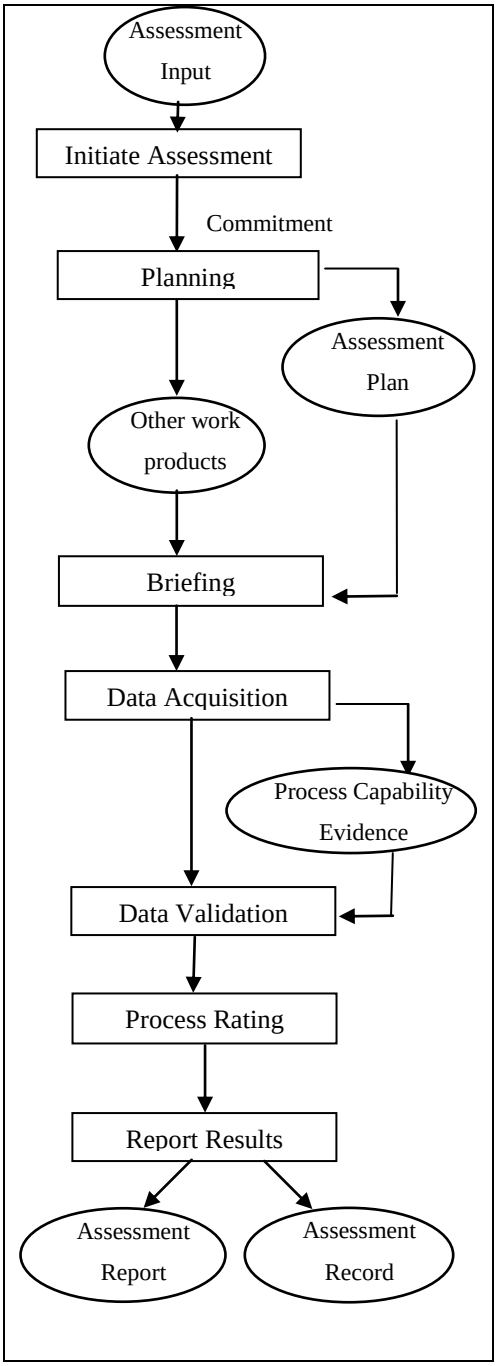

FIGURE- 2: LOON'S ASSESSMENT PROCEDURE SUMMARY

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When talking about the criteria and specifications in an SPA context where the device to be produced is a new proposed assessment method, one can define several requirements in terms of the operational principles and the normal configuration incorporated in the design of the intended device.

One of the main models that the SPA process is based upon, as mentioned in the operational principles section, is the software process reference model. The process reference model usually defines the purposes and outcomes of a list of processes. When adopting a certain process reference model to build an assessment method for SME organizations, the designer should decide on the number of processes to be assessed and how they are selected. This selection of processes is important since SMEs are usually interested in some processes but not all of them. Therefore, the following evaluation criteria emerge from this discussion:

- Specify the number of processes to be assessed.
- Specify the processes to be assessed.

The other model, which the SPA method is based upon, is the software assessment model. When choosing the process assessment model to build the new assessment method for SME organizations, the designer keeps in mind that the criteria used to assess each process and what scale is used for measurement and the limits or range of this scale. The designer also keeps in mind the criteria that should be used to assess the organization as a whole if the intent is to assess the whole organization, and keep in mind the scale and its limits to be used for making the measurement. The following evaluation criteria emerge from this discussion:

- Specify the criteria for assessing the process.
- Define the scale and its limits used to assess the process.
- Define the scale and its limits used to assess the organization

3) Theoretical tools evaluation criteria:

Vincenti stated "To carry out their design function, engineers use a wide range of theoretical tools. These include intellectual concepts for thinking about the design as well as mathematical methods, theories and formulas which can be simple or complex formulas for making design calculations" [25].

Accordingly and as stated previously, when designing an SPA method the designer should specify the set of processes to be assessed and the mechanism that should be used to rate each process. The designer in order to answer the firstpart uses intellectual concepts to specify which processes to assess and for the second part the designer specify a mathematical method to rate these processes. Thus, the following evaluation criteria emerge from this discussion:

- Specify the theoretical tools used to select the processes to be assessed.
- Specify the mathematical methods to define the rating process

4) Quantitative data evaluation criteria*:*

Vincenti focused on the importance of quantities and other data for other physical properties required in the formulas during the design process. Vincenti also stated that "other kinds of data may also be needed to lay out details of the device or to specify manufacturing processes for production" [25]. Such data is usually obtained empirically and sometimes calculated theoretically and are typically represented in tables or graphs. The quantitative data can be divided into two types of knowledge, descriptive and prescriptive [25].

Descriptive knowledge is the knowledge of how things are. It includes physical constants as well as properties of substances and physical processes. Descriptive data occasionally deal with operational conditions in the physical world.

Prescriptive knowledge is knowledge of how things should be to attain a desired end – it says, in effect, "in order to accomplish this, arrange things this way" [25].

The quantitative data in the SPA context is greatly related to the rating process. When designing an SPA method, the designer should specify the descriptive data needed to perform ratings either for the process or for the organization. The questions therefore are:

- What data is used to determine the scale/rate for each process?
- What data is used to determine the scale/rate for the organization?

5) Practical considerations evaluation criteria:

In addition to theoretical tools and quantitative data, Vincenti stated that "Designers also need for their work an array of less sharply defined considerations derived from experience in practice" [25]. Usually, practical considerations are difficult to define and are rarely documented. Sometimes the practical considerations become well codified. In such cases, these practical considerations are moved to another category.

When designing the assessment method for SME organizations, the designers select the set of processes to be assessed either based on their own experience or by applying certain selection methods. When rating the organization with reference to an assessment model, designers also specify the maximum target scaling level to be used based on his experience and according to the needs of the SME organization. The designer also should decide whether to build an action plan or not at the end of the assessment process. Hence, the following criteria emerge from this discussion:

- How are the processes to be assessed selected?
- What is the target scaling level for the organization?
- Does the assessment method build an action plan at the end of the assessment?

6) Instrumentalities evaluation criteria:

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"Besides the analytical tools, quantitative data and practical considerations required for their tasks, designers need to know how to carry out those tasks" [25]. As part of the engineering design knowledge, the instrumentalities of the design process should be determined which contain the procedures, judgmental skills and ways of thinking by which the process is done.

Vincenti mentioned that "designers doing normal design call upon a number of well-organized, more or less structured procedures"; Vincenti also mentioned that "the division of an overall system into subsystems is fundamental. In the terms of the SPA method, the assessment process is divided into sub-divisions, or phases using Loon's terms [27]. The arrangement and configuration of each sub division is defined by the designer, these sub divisions are executed sequentially when conducting the assessment method which defines the assessment procedure. Examples of such sub-division are the assessment phases defined by Loon and presented in Fig. 2. These divisions may vary from one assessment method to another and should be evaluated by the evaluation framework. The criterion related to this issue is:

- Define the sub divisions of the assessment method during the assessment design process.

Another design instrumentality that the designer of a SPA process usually uses are the judgmental skills to define which process should be included in the assessment process; the processes to be assessed are determined based on the organizational objectives and usually, the designer uses his experience and practical considerations to specify these processes. Hence, the context on which the assessment is conducted varies from one organization to another and the criterion that should be addressed here is:

- What are the judgments related to which processes should be taken by the designer?

Vincenti stated that one of the design procedures that can be used to improve the proposed design is the use of iterative techniques, such as successive improvement of a design based on analytical or test experience with earlier versions. Hence, another evaluation criterion emerges:

- What procedure is used to improve the designed SPA method?

III. Conclusion and Future Work

This paper studied in detail the design criteria of SPA methods from an engineering perspective. Aligning the design of SPA methods with the engineering design knowledge helps improving the maturity of software engineering field in general as an engineering discipline. The resulted evaluation criteria,summarized in Table I, are classified based on Vincenti's classifications of engineering design knowledge.

Vincenti's classification consists of six main classes that cover the different aspects of the engineering design process. The resulted design criteria are vital for designing SPA methods and can be used by designers of new SPA methods as guidelines to direct the design process of the new SPA method.

During the design phase of the SPA method, the designer should take these criteria into consideration. Failing to take one or more of these criteria into consideration would be considered a weakness point in the design process that may cause an ineffective implementation of the SPA method.

Authors are currentlydeveloping a questionnaire based on the defined criteria and are using it to evaluate a couple of currently available lightweight SPA methods, especially those lightweight SPA methods that lack unbiased third party evaluation, showing their strengths and weaknesses. Such evaluation is vital for the designers of these methods to make necessary amendments as well as practitioners who implement them. Results of this evaluation will be published in the near future.

TABLEI: SUMMARY OF THE SPA METHOD EVALUATION CRITERIA

Criteria Based on Fundamental Design Principles
Identify the process reference model.
Identify process assessment model.
Identify business needs.
Use of previous assessment reports.
Refer to the organizational documents and reports while preparing for the assessment.
Use of assessment tools through different phases of the assessment.
Produce a pre-assessment questionnaire.
Produce assessment initiation file.
Produce assessment plan.
Track evidences of process performance and capability.
Produce assessment report.
Produce assessment record.
Produce assessor record.
Criteria Based on Criteria and Specifications
Identify the number of processes to be assessed.
Identify processes to be assessed.
Identify the bases for assessing the process.
Identify scale and limits used to assess the process.

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Identify scale and limits to assess the organization.
Criteria Based on Theoretical Tools (TT)
Identify theoretical tools to select the processes to be assessed.
Identify mathematical methods to define the rating process.
Criteria Based on Quantitative Data
Collect data used to determine the scale for each process.
Collect data used to determine the scale for the organization.
Criteria Based on Practical Considerations
Select the processes to be assessed.
Identify scaling level for the organization.
Build an action plan.
Criteria Based on Instrumentalities
Identify the sub divisions of the assessment process.
Identify any designer judgments related to which processes to be assessed.
Identify the procedure used to improve the designed SPA process.

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