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DEPENDENCIES OF PROCESSES' CAPABILITY LEVELS[1]

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Abstract. Staged and continuous representations of process capability maturity models have different architecture and focus. Staged representation includes a straightforward process improvement path by defining certain key process areas. Continuous representation does not imply a defined order of processes for the process improvement. Conventional approach to the software process improvement path establishment is based on software process assessment and processes capability profile gained as input for improvement informal decision-making. This work introduces new approach to definition of software process improvement skeleton based on hierarchy of dependencies of capability levels of processes on other processes' capability. The approach has been applied for the capability level 2 in ISO/IEC 15504 model: the dependencies between process capability level 2 and supporting/organizational processes have been analyzed and the processes and practices that must exist to achieve capability level 2 of Primary life cycle processes have been determined.

1. Indroduction

Software process improvement (SPI) has become a driving force in the global software industry. However, it has not become a popular topic of rigorous research, especially at universities [12]. Each software process model and methodology is supported by different groups of people and research groups, which makes it difficult for practitioners, university teachers, and researchers to be able to understand, teach, adopt, and apply those best practices for the development and maintenance of software and systems [13].

Another major problem facing research and evolution in SPI is the separation of work and research in industry and researchers in academia. Most SPI work and development of methodologies in the last years have been driven by the industry. Academia and university researchers have had almost no impact [13].

This paper represents an attempt to address software process improvement path definition problem analyzing internal properties [16] of most promising continuous representation capability maturity model.

The research is based on processes capability level dependencies idea introduced in SE-CMM [2]. SPI research targeted to priorities definition in software process improvement [14] addresses the same problem. The underlying principle is that organization's needs and business goals determine the software process improvement goals [15]. The process improvement actions must be determined according to the improvement goals. Process capability improvement actions are dependent and the processes capability profile is insufficient input to determine the path for the improvement. This work demonstrates the dependence of process capability level on presence and capability of other processes in the case of capability level 2 - the process will reach the Managed capability level only if the required Supporting and Organizational life cycle processes are implemented in an organization.

Software process improvement path definition problem is raised by software process capability maturity models evolution.

One of the first software process capability maturity models SW-CMM [1] has introduced staged software process capability model which explicitly defines the roadmap to the process improvement but it is not flexible enough to provide the tool to create detailed process profile. The first process model of continuous representation SE-CMM [2] was created in 1994 and now the continuous architecture can be treated as more promising and the most influencing process capability models, such as ISO/IEC 15504 [3] and CMMI [4], employs it.

Definition of software process improvement steps according to continuous representation models is a complex task because of dependencies between processes and their capability levels. Capability of a particular process depends on the process performance

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environment composed by other processes [2]. Process can't reach targeted capability without support of other processes performed at suitable level.

This paper is devoted to investigation of dependencies between process capability level 2 and supporting processes in ISO/IEC 15504 [3] to leverage model knowledge for software process improvement.

2. Assessment model based software process improvement

There are three major approaches (or paradigms) to software process improvement, which can be used independently or in combination [10, 18, 19, 20]. These include:

- Model-Based Improvement;
- Bottom-Up Process Improvement;
- Business Process Reengineering.

Conventional model-based SPI scheme [3, 11, 17] includes software process assessment as a step in SPI framework and devotes the role of process profile composition to it. SPI decisions are made based on profile obtained during assessment. During software process assessment a detailed assessment model is used and this model plays an essential role in software process improvement providing insight for detailed SPI steps.

Process capability levels are defined by providing process attributes. According to [3, 5], process attributes are used to determine whether a process has reached a given capability. Each attribute measures particular aspect of the process capability.

Following the definition of each process attribute, the assessment model provides a set of management practices that enable achievement of characteristics of the attribute. Management practices are activities of generic type and are intended to be applicable to all processes. In fact, management practices are implemented by compositions of activities from organizational and supporting processes categories.

Even if assessment of a software process produces process profile, which provides capability level for each process separately, this does not mean that processes are not related to each other and, therefore, it is hardly possible to improve one process without improving associated processes [2].

3. The roadmap to SPI

Let's analyze how primary, supporting and organizational life cycle processes (as defined in [3, 9]) are related to each other.

A lot of organizations tend to improve their primary life cycle processes (customer-supplier and engineering process categories), but this can not be done without having appropriate supporting structure to operate in. We will review how other processes must be improved to have mature primary life cycle processes.

Each organization must create software product, therefore it is natural that primary life cycle processes are performed, even if other processes are not executed (Figure 1).

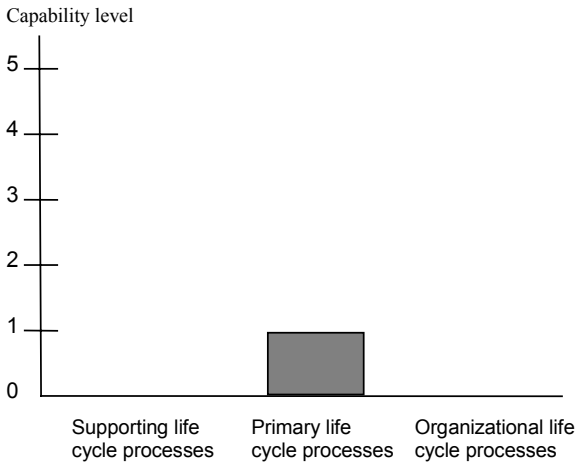

Figure 1. Performed process

To achieve Managed capability level for Primary life cycle processes, an organization needs to perform project management (part of organizational life cycle processes) and support processes (documentation, audit, review, configuration management, quality assurance, problem resolution). Therefore, if Primary life cycle processes reach capability level 2, then Organization life cycle and Supporting life cycle processes must be performed (capability level 1) (Figure 2).

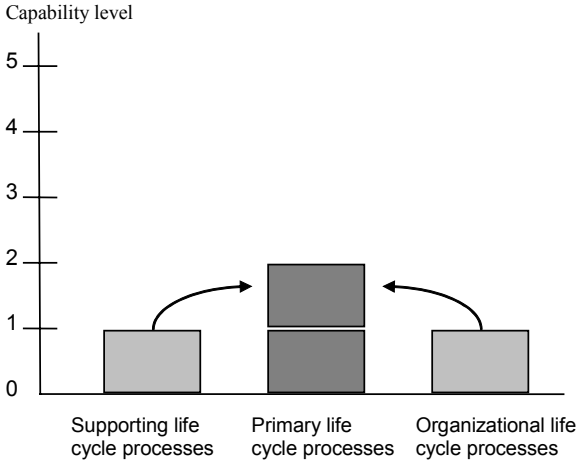

Figure 2. Managed process

To achieve Established capability level of Primary life cycle processes, an organization needs to start performing organizational processes, which are responsible for organization-wide establishment of Primary life cycle processes. Project management should be at Managed level, therefore Organizational life cycle processes reach capability level 2 (Figure 3).

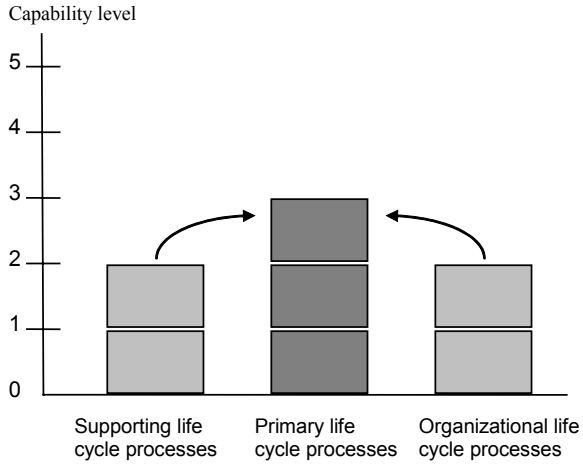

Figure 3. Established process

Primary life cycle processes can be measured and quantitatively controlled (capability level 4) only if all other processes are well defined and established at organizational level (capability level 3) (Figure 4).

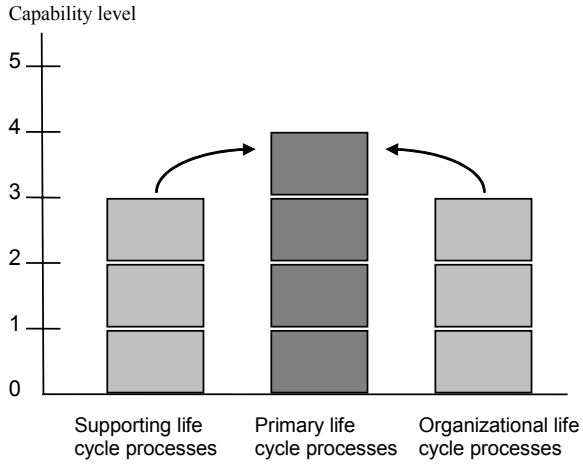

Figure 4. Predictable process

Optimizing capability level of Primary life cycle processes can be achieved only if other processes are of Predictable level (capability level 4) (Figure 5).

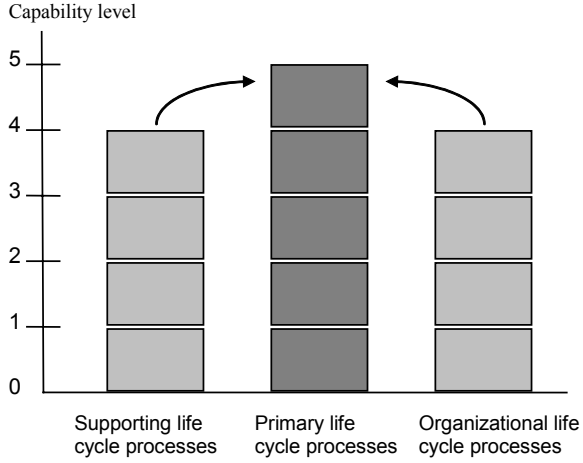

Figure 5. Optimizing process

4. Path to process capability level 2 – Managed process

As stated by ISO/IEC 15504 [3], managed process must deliver work products according to specified procedures, process execution must be planned and tracked. Work products must be delivered with fulfillment of expressed quality requirements and within defined timescales and resource needs.

4.1. Capability level 2 process attributes

Capability level 2 in ISO/IEC 15504 [3] is expressed by two process attributes: Performance Management Attribute and Work Product Management Attribute.

Performance Management Attribute is achieved if the performance of the process is managed to produce work products that meet the defined objectives: quality, time-scale, cycle time and resource usage.

Work Product Management Attribute is achieved if the performance of the process is managed to produce work products that are appropriately documented, controlled and verified.

4.2. Management practices and associated processes

ISO/IEC 15504 [3] informative part (5) defines management practices that address the implementation or institutionalization of process attributes provided.

Each management practice is described by its performance characteristics, resource and infrastructure characteristics and a list of associated processes.

References to associated processes specify processes that support implementation of management practices.

Table 1 lists all management practices from capability level 2 as they are defined in [3] together with their associated processes.

This table provides the start point for investigation of two-dimensional relations in continuous representation capability maturity model and allows to identify, which processes support the implementation of management practices under investigation.

4.3. Processes supporting Capability level 2

Let's point out which processes appear in the Table 1. Those processes support implementation of capability level 2 in Primary life cycle processes (Figure 6).

Table 2 lists associated processes and number of times they appear in Table 1. Highlighted are names of processes that are essential for Managed process establishment as they support capability of nearly every Primary life cycle process.

Table 1. Management practices and their associated processes

PA 2.1. Performance management attribute		
	MP 2.1.1. Identify the objectives for the performance of the process	
		MAN.1 Management process
		MAN.2 Project management process
		CUS.3 Requirements elicitation process
		MAN.4 Risk management process
		SUP.6 Joint review process
	MP 2.1.2. Plan the performance of the process according to the identified objectives by identifying the activities of the process, the expected time schedule and allocation of resources for each activity	
		MAN.1 Management process
		MAN.2 Project management process
		MAN.3 Quality management
		ORG.3 Human resource management
		ORG.4 Infrastructure
	MP 2.1.3. Plan and assign the responsibility and authority for developing the work products of the process	
		MAN.1 Management process
		MAN.2 Project management process
		SUP.3 Quality assurance
		ORG.3 Human resource management
	MP 2.1.4. Manage the execution of the activities by continued tracking and re-planning to produce work products that meet the defined objectives	
		MAN.1 Management process
		MAN.2 Project management process
		MAN.4 Risk Management
		SUP.3 Quality Assurance
		SUP. 7 Audit
		SUP.8 Problem resolution
PA 2.2. Work product management attribute		
	MP 2.2.1. Identify the requirements for the work products, including both functional and non-functional aspects	
		CUS.3 Requirements elicitation
		SUP.2 Configuration management
		SUP.3 Quality assurance
	MP 2.2.2. Manage the documentation, configuration management and change control of the work products	
		SUP.1 Documentation
		SUP.2 Configuration management
		SUP.3 Quality assurance
	MP 2.2.3. Identify and define any work product dependencies	
		CUS.3 Requirements elicitation
		SUP.1 Documentation
		SUP.2 Configuration management
		SUP.3 Quality assurance
	MP 2.2.4. Manage the quality of work products to ensure that they meet their functional and non-functional requirements	
		MAN.3 Quality management
		SUP.3 Quality assurance
		SUP.4 Verification
		SUP.5 Validation
		SUP.7 Audit
		SUP.8 Problem resolution process

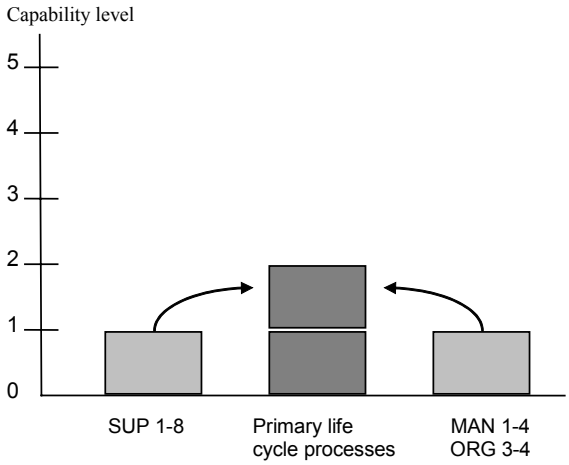

Figure 6. Processes supporting capability level 2

4.4. Management practices performance characteristics and related base practices

ISO/IEC 15504 [3] does not define, which base practices from processes associated with management practices, are essential for management practice implementation. Let's investigate which base practices support management practice performance characteristics.

Table 2. Involvement of processes supporting Capability level 2

Process	#
SUP.3 Quality assurance	**6**
MAN.1 Management process	**4**
MAN.2 Project management process	**4**
CUS.3 Requirements elicitation	**3**
SUP.2 Configuration management	**3**
MAN.3 Quality management	2
MAN.4 Risk Management	2
ORG.3 Human resource management	2
SUP.1 Documentation	2
SUP.8 Problem resolution	2
SUP. 7 Audit	2
ORG.4 Infrastructure	1
SUP.4 Verification	1
SUP.5 Validation	1
SUP.6 Joint review process	1

Table 3. Practice performance characteristics and supporting base practices for MP 2.1.3

MP 2.1.3. Plan and assign the responsibility and authority for developing the work products of the process	
Practice performance characteristics	Base practices
Tasks and work products are allocated to resources	MAN.1.BP3: Plan and allocate resources and infrastructure. Plan and allocate the resources and infrastructure required to perform the identified activities and tasks according to a defined time schedule.
	MAN.2.BP6: Identify infrastructure requirements. Identify and select the environmental and human resource elements needed to support the project strategy and performance.
Responsibility and authority are agreed and documented	MAN.2.BP8: 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.
	ORG.3.BP9: Define project teams. Define the teams, which will be needed to perform the work of the project, defining the structure and operating rules for the team, required knowledge and skills.
	ORG.3.BP10: Empower project teams. Empower teams to perform their job, by ensuring that they have possess: an understanding of their job; a shared vision or sense of common interest; appropriate mechanisms or facilities for communication and work; support from the appropriate management for what they are trying to accomplish.
Work products availability milestones are defined	MAN.2.BP10: Establish and implement project plans. Provide a mechanism to ensure that project plans are formally developed, implemented and maintained, and available to those involved with the project. Document the results of the activities in this process within the project plans, and ensure that the plans are published to all those involved.
Verification responsibility is defined and allocated	SUP.3.BP1: Develop quality assurance strategy. Develop, implement and maintain quality policy, scope of assurance and responsibilities for quality.
	SUP.3.BP2: Establish quality standards. Establish quality standards for each process and work product.
	SUP.3.BP3: Define quality records. Define quality records that demonstrate conformance of process and work products to quality standards.

When table 1 provides processes level associations, the following table indicates more detailed associations – shows how management practice performance characteristics are implemented by base practices:

In the Table 4, all base practices that support implementation of management practices of capability level 2 are collected. The table suggests the conclusion that associated Support and Organizational life cycle processes (particularly, SUP 1-8, MAN 1-4, ORG 3-4) should be implemented to large extent in order to achieve level 2 in Primary life cycle processes.

Table 4. Level 2 management practices and their supporting base practices

PA 2.1.	MP 2.1.1.	MAN.1	BP1, BP2
		MAN.2	BP1, BP2
		CUS.3	BP1
		MAN.4	BP1, BP2, BP4, BP5
		SUP.6	BP2
	MP 2.1.2.	MAN.1	BP2, BP3
		MAN.2	BP1, BP2, BP4, BP5, BP6, BP7
		MAN.3	BP1, BP2, BP3
		ORG.3	BP1
		ORG.4	BP1, BP2
	MP 2.1.3.	MAN.1	BP3
		MAN.2	BP6, BP8, BP10
		SUP.3	BP1, BP2, BP3
		ORG.3	BP9, BP10
	MP 2.1.4.	MAN.1	BP5, BP6, BP7, BP8
		MAN.2	BP10, BP11, BP12
		MAN.4	BP5, BP7, BP8
		SUP.3	BP6, BP7
		SUP.7	BP1, BP2, BP3, BP6, BP7, BP8
		SUP.8	BP1
PA 2.2.	MP 2.2.1.	CUS.3	BP1, BP2, BP3, BP4, BP5, BP6
		SUP.2	BP1, BP2, BP3
		SUP.3	BP1, BP2, BP3
	MP 2.2.2.	SUP.1	BP1, BP2, BP3, BP4, BP5, BP6, BP7
		SUP.2	BP4, BP5, BP6, BP7, BP8, BP9
		SUP.3	BP6, BP7
	MP 2.2.3.	CUS.3	BP1, BP2, BP3
		SUP.1	BP3, BP4, BP5, BP6
		SUP.2	BP3, BP4
		SUP.3	BP3
	MP 2.2.4.	MAN.3	BP4, BP5, BP6, BP7, BP8
		SUP.3	BP4, BP5, BP6, BP7
		SUP.4	BP1, BP2, BP3, BP4
		SUP.5	BP2, BP3, BP4
		SUP.7	BP3, BP4, BP5, BP6, BP7, BP8
		SUP.8	BP4, BP5, BP6

5. Conclusions

This paper contributes to the software process improvement in several aspects:

- demonstrates the validity of general idea on dependence of process capability level on presence and capability of other processes, i.e. process capability level can not be raised independently from surrounding processes;
- provides the dependence of process capability level 2 on the presence of set of processes performed at level 1;
- introduces the need to complement process model by the hierarchy of processes capability levels;
- maps management practices and supporting base practices of associated processes.

Further investigation can be motivated by:

- performance characteristics of management practices are expressed mainly in terms similar to work products. Therefore mapping of input and output work products at the base practice level would be desirable, as it would allow more precise definition of the activities supporting achievement of processes capability levels attributes;
- hierarchy diagram of dependencies of capability levels of processes on other processes' capability should be constructed in order to predefine SPI skeleton.

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