The Evolution of the Continuous Representation for Process Capability

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Abstract

A continuous representation model characterizes a set of processes by a structured set of process attributes, typically organized into six Capability Levels. The continuous representation is a flexible and easily extended architecture, so understanding its evolution can be helpful to those wishing to use a continuous representation model or to adapt it for different environments. The reference model in ISO/IEC 15504 includes a "continuous" process capability dimension that has evolved to address conflicting requirements and that has been adapted for a variety of other improvement frameworks, including the Systems Engineering Capability Maturity Model (SE-CMM), the Software CMM, and CMM Integration (CMMI). The evolution of the continuous representation in ISO 15504, and the variants developed for other frameworks, capture a tradeoff between reliability and usability that remains a challenge for model developers today. The purpose of this paper is to describe the evolution and the important variants of the ISO 15504 continuous representation with a discussion of the objectives and tradeoffs associated with each.

Keywords: capability index, continuous representation, generic practices, process capability, staged representation

The international standard for process assessment, ISO/IEC 15504 (Process assessment) uses a continuous representation architecture for characterizing process capability [ISO 2003]. A continuous representation model characterizes a set of processes by a structured set of process attributes, typically organized into six Capability Levels. The continuous representation is also used by other process management models, e.g., Capability Maturity Model Integration (CMMI) [Chrissis 2003]. This approach to measuring process capability is therefore widely used; it is also a flexible and easily extended architecture, so understanding its evolution can be helpful to those wishing to use a continuous representation model or to adapt it for different environments.

ISO/IEC 15504 is a suite of standards for process assessment, which was developed by an ISO software engineering working group (JTC1/SC7/WG10) established by the International Organization for Standardization (ISO) and the International Electrotechnical Commission (IEC). WG10 was established as the result of a study group on process management proposed by Alec Dorling and Peter Simms (UK), based on the ImproveIT report [Dorling 1991], which described 25 process management frameworks for improving IT capability. The initial set of requirements for this effort

was agreed to at a November 1991 ISO meeting in Turin. The product suite included a reference model for harmonizing other frameworks and for measuring process capability called the Baseline Practices Guide (BPG). Al Graydon (Canada) and I were the initial project editors for the BPG. The group drafting the work products was called SPICE (Software Process Improvement and Capability dEtermination); the distinction between SPICE and WG10 was to encourage the participation of individuals and organizations who did not normally participate in standards work.

The proposed architecture of the BPG, from the June 1993 Tokyo ISO meeting, included a set of 30 process attributes, derived from the practices in the Common Features of the Capability Maturity Model for Software [Paulk, 1995]. This evolved to a set of 26 Generic Practices, organized according to 12 Common Features and assigned to one of six Capability Levels when the BPG was published in 1995 as a working draft [ISO, 1995]. When the reference model was published as a type 2 technical report by ISO in 1998, the continuous representation had shifted to nine process attributes, still assigned to one of six Capability Levels; the ISO standard, ISO/IEC 15504-2, published in 2003 was similar.

The BPG set of Generic Practices was used essentially unchanged in the Systems Engineering CMM [Bate 1995] and was the basis for the templates in the draft of Software CMM v2C [Paulk, 1997]. Variants of the continuous representation similar to the 1998 ISO version were used in the Systems Engineering Capability Assessment Model [INCOSE 1996], EIA 731 (Systems Engineering Capability Model) [EIA 1998], and CMMI.

This evolution in the continuous representation diverged and converged as conflicting requirements for a comprehensive measure of process capability and a capability dimension usable in assessments were balanced. Although variants of the continuous representation have been used in a variety of process management models, the evolution within the core ISO/IEC 15504-2 model captures the tradeoff between reliability and usability.

1. Background

The basic premise underlying the work on software process improvement is that the quality of a software product is largely determined by the quality of the software development and maintenance processes used to build it. The Software Engineering Institute (SEI) defined a five-level framework for how an organization matures its software process [Humphrey 1987a], which was formalized as the Software CMM [Paulk 1995]. The five maturity levels describe successive foundations for continuous process improvement and define an ordinal scale for measuring the maturity of an organization's software process.

The staged structure of the software process maturity framework was first inspired by Crosby's quality management maturity grid [Crosby 1979]. Crosby's maturity grid

applies five stages to six measurement categories in subjectively rating an organization's quality operation. The five stages are:

- *uncertainty*, where management is confused and uncommitted regarding quality as a management tool
- *awakening*, where management is beginning to recognize that quality management can help
- *enlightenment*, when the decision is made to really conduct a formal quality improvement program
- *wisdom*, where the company has the chance to make changes permanent (things are basically quiet and people wonder why they used to have problems)
- *certainty*, where quality management is considered an absolutely vital part of company management

Crosby's maturity grid was adapted to the software process by Ron Radice and his colleagues working under the direction of Watts Humphrey at IBM [Radice 1985]. They identified twelve process stages, which were characterized by eleven attributes measured on a five point scale. The process stages were stages in the life cycle: requirements, product level design, component level design, module level design, code, unit test, functional verification test, product verification test, system verification test, package and release, early support program, and general availability. The eleven attributes were process, methods, adherence to practices, tools, change control, data gathering, data communication and use, goal setting, quality focus, customer focus, and technical awareness. The five-point scale consisted of traditional, awareness, knowledge, skill & wisdom, and integrated management system.

Humphrey brought these concepts to the Software Engineering Institute in 1986 and revised it to define maturity levels [Humphrey 1987a, Humphrey 1987b, Humphrey 2002]. His book, Managing the Software Process, elaborated the maturity framework [Humphrey 1989]. Appendix A of the book expressed his thoughts on improving process capability in a form reminiscent of the continuous representation.

In formalizing Humphrey's maturity framework, several approaches were prototyped, including representations called software process domains and the normative model. The 1988 "software process domains" provided a partial ordering of practices in an evolutionary path, but the domains spanned maturity levels, and there were interdependencies between different domains. This was especially problematic for practices at different maturity levels in different domains.

In 1989 an orthogonal representation of maturity in terms of "the normative model" was prototyped that applied stability factors and maturity indices to unit operations. Stability factors were entities such as resources, training, tools, plans, policies, and responsibility. Maturity indices were attributes such as existence, review, selection, metrics, analysis, and monitoring. The unit operations were activities such as staffing, committing, planning, tracking, executing, documenting, and verifying. While this approach led to some significant insights affecting the later development of the CMM, it was difficult to

explain. Neither of these approaches was found satisfactory for formalizing the maturity framework in more detail than the original reports [Paulk 1995c].

Although these initial attempts at characterizing the software process maturity framework were at their heart variations on the continuous representation concept of applying process attributes to a profile of processes, the intent of the maturity framework was to drive organizational transformation. The Software CMM is sometimes characterized as a *staged* model because it describes organizational capability in terms of maturity levels that represent evolutionary stages of capability. A *staged* model, such as the Software CMM, can be described as:

- an *organization-focused* model, since its target is the organization's process capability,
- a *descriptive* model, because it describes the processes of organizations at different levels of achieved capability, and
- a *prescriptive* or normative model, since it prescribes how an organization should improve its processes.

The Software CMM was rapidly adopted by the software community, beginning with its initial release in 1991, to the release of version 1.1 in 1993, and the publication of version 1.1 as a book in 1995 with additional supplemental information. Similar efforts in software process improvement, as described in the ImproveIT report, were occurring in parallel, although the Software CMM was the most prominent of the frameworks. The genesis of ISO/IEC 15504, and the continuous representation, derives from this context.

2. The 1995 SPICE Baseline Practices Guide

The Baseline Practices Guide (BPG) [ISO 1995] defined, at a high level, goals and activities that are essential to good software engineering. The practices comprising the guide were architected in a two-dimensional matrix. The X axis consisted of processes, along with the base practices necessary for performing the process. The Y axis characterized the capability of each process by capability levels, common features, and generic practices. Generic practices are generally stated practices that are "universally" applicable and can be used to describe increasing capability as higher level practices incrementally build on the capability established at the lower levels.

The Process Dimension

The BPG categorized processes into five process categories.

- The *Customer-Supplier* process category consisted of eight processes that directly impact the customer, support development and transition of the software to the customer, and provide for its correct operation and use.

- The *Engineering* process category consisted of seven processes that directly specify, implement, or maintain a system and software product and its user documentation.

- The *Project* process category consisted of eight processes that establish the project, and coordinate and manage its resources to produce a product or provide services which satisfy the customer.

- The *Support* process category consisted of five processes that enable and support the performance of the other processes on a project.

- The *Organization* process category consisted of seven processes that establish the business goals of the organization and develop process, product, and resource assets which will help the organization achieve its business goals.

A process in the BPG could be described in terms of *base practices*, which were its unique software engineering or management activities. Process categories, processes, and base practices provided a grouping by type of activity. These processes and activities characterized the performance of a process, even if that performance was not systematic. Performance of the base practices may be ad hoc, unpredictable, inconsistent, poorly planned, and/or result in poor quality products, but those work products are at least marginally usable in achieving the purpose of the process. Implementing only the base practices of a process may be of minimal value and represent only the first step in building process capability, but the base practices represented the unique, functional activities of the process when instantiated in a particular environment.

The Process Capability Dimension

Evolving process capability was expressed in terms of capability levels, common features, and generic practices in the BPG. A *capability level* is a set of common features (sets of activities) that work together to provide a major enhancement in the capability to perform a process. Each level provides a major enhancement in capability to that provided by its predecessors in the performance of a process. They constitute a rational way of progressing through the practices, which can be used to harmonize most of the different approaches to rating software processes.

Capability levels provide two benefits: they acknowledge dependencies among the practices of a process, and they help an organization identify which improvements it might perform first, based on a plausible sequence of process implementation. There were six capability levels in the BPG:

Table 1 The Capability Levels in the BPG.

Capability Level	BPG Description of Capability Levels

Capability Level	BPG Description of Capability Levels
Level 0 *Not-Performed*	This level has no common features. There is general failure to perform the base practices in the process. There are no easily identifiable work products or outputs of the process.
Level 1 *Performed-Informally*	Base practices of the process are generally performed. Work products of the process testify to its performance.
Level 2 *Planned-and-Tracked*	Performance of the base practices in the process is planned and tracked. Performance according to specified procedures is verified. Work products conform to specified standards and requirements.
Level 3 *Well-Defined*	Base practices are performed according to a well-defined process using approved, tailored versions of standard, documented processes.
Level 4 *Quantitatively-Controlled*	Detailed measures of performance are collected and analyzed. This leads to a quantitative understanding of process capability and an improved ability to predict and manage performance. The quality of work products is quantitatively known.
Level 5 *Continuously-Improving*	Quantitative process effectiveness and efficiency goals (targets) for performance are established, based on the business goals of the organization. Continuous process improvement against these goals is enabled by quantitative feedback from performing the defined processes and from piloting innovative ideas and technologies.

A *common feature* in the BPG was a set of practices (called *generic practices*) that addressed the some aspect of process institutionalization. The words "common" and "generic" are intended to convey the idea that these features and practices should be applicable to any process, with the goal of enhancing the capability to perform that process. As an example, "planning' is a feature common to improved management of any process.

The ordering of the common features stems from the observation that some features benefit from (are enabled by) the presence of others. For example, the provision of a well-defined, usable process for an entire organization to tailor and use should follow from some experience in managing the performance of that process at the level of individual projects. An example of this is that prior to institutionalizing a specific estimation process for an entire organization, the organization first attempts to use the estimation process on a project.

Also, some aspects of process implementation and institutionalization should be considered together (not one ordered before the other) since they work together toward enhancing capability. That is why some generic practices are grouped together, and likewise, common features.

The common features and generic practices characterize good process management that results in an increasing process capability for any process. A planned, well-defined, measured, and continuously improving process is consistently performed as the common features are implemented for a process. This process capability is built on the foundation of the base practices that describe the unique, functional activities of the process. The generic practices in the BPG are listed in Table 1, along with the associated common features and capability levels.

Table 1. The Generic Practices in the BPG.

Capability Level 1: Performed-Informally	
Common Feature 1.1: Performing Base Practices	
GP 1.1.1 Perform the process.	Perform the base practices of the process to provide work products and/or services to a customer.
Capability Level 2: Planned-and-Tracked	
Common Feature 2.1: Planning Performance	
GP 2.1.1 Allocate resources.	Allocate adequate resources (including people) for performing the process.
GP 2.1.2 Assign responsibilities.	Assign responsibilities for developing the work products and/or providing the services of the process.
GP 2.1.3 Document the process.	Document the approach to performing the process in standards and/or procedures.
GP 2.1.4 Provide tools.	Provide appropriate tools to support performance of the process.
GP 2.1.5 Ensure training.	Ensure that the individuals performing the process are appropriately trained in how to perform the process.
GP 2.1.6 Plan the process.	Plan the performance of the process.
Common Feature 2.2: Disciplined Performance	
GP 2.2.1 Use plans, standards, and procedures.	Use documented plans, standards, and/or procedures in implementing the process.

GP 2.2.2 Do configuration management.	Place work products of the process under version control or configuration management, as appropriate.
Common Feature 2.3: Verifying Performance	
GP 2.3.1 Verify process compliance.	Verify compliance of the process with applicable standards and/or procedures.
GP 2.3.2 Audit work products.	Verify compliance of work products with the applicable standards and/or requirements.
Common Feature 2.4: Tracking Performance	
GP 2.4.1 Track with measurement.	Track the status of the process against the plan using measurement.
GP 2.4.2 Take corrective action.	Take corrective action as appropriate when progress varies significantly from that planned.
Capability Level 3: Well-Defined	
Common Feature 3.1: Defining a Standard Process	
GP 3.1.1 Standardize the process.	Document a standard process or family of processes for the organization, which describes how to implement the base practices for the process.
GP 3.1.2 Tailor the standard process.	Tailor the organization's standard process family to create a defined process which addresses the particular needs of a specific use.
Common Feature 3.2: Performing the Defined Process	
GP 3.2.1 Use a well-defined process.	Use a well-defined process in implementing the process.
GP 3.2.2 Perform peer reviews.	Perform peer reviews of appropriate work products of the process.
GP 3.2.3 Use well-defined data.	Use data on performing the defined process to manage the defined process.
Capability Level 4: Quantitatively-Controlled	
Common Feature 4.1: Establishing Measurable Quality Goals	
GP 4.1.1 Establish quality goals.	Establish measurable quality goals for the work products of the organization's standard process family.
Common Feature 4.2: Objectively Managing Performance	
GP 4.2.1 Determine process capability.	Determine the process capability of the defined process quantitatively.

GP 4.2.2 Use process capability.	Take corrective action as appropriate when the process is not performing within its process capability.
Capability Level 5: Continuously-Improving	
Common Feature 5.1: Improving Organizational Capability	
GP 5.1.1 Establish process effectiveness goals.	Establish quantitative goals for improving process effectiveness of the standard process family, based on the business goals of the organization and the current process capability.
GP 5.1.2 Continuously improve the standard process.	Continuously improve the process by changing the organization's standard process family to increase its effectiveness.
Common Feature 5.2: Improving Process Effectiveness	
GP 5.2.1 Perform causal analysis.	Perform causal analysis of defects.
GP 5.2.2 Eliminate defect causes.	Eliminate the causes of defects in the defined process selectively.
GP 5.2.3 Continuously improve the defined process.	Continuously improve process performance by changing the defined process to increase its effectiveness.

The continuous representation architecture does not prescribe any particular organizational improvement path. Improvement priorities are left up to the software organization, as determined in the context of its business objectives. Individual processes, at either the organization or project level, can be measured using this "continuous improvement" architecture for rating processes.

Some Reflections on the Capability Dimension in the BPG

The term *continuous* is not a strictly accurate description. Other descriptive terms that could be used include:

- a *process-focused* model, since its target is process capability,
- a *terrain* model, from the analogy to a description of the software process terrain, and
- a *reference* model, since its primary use is in assessment as the reference for rating processes.

One of the objectives of ISO/IEC 15504 is to create a way of measuring process capability, while avoiding a specific approach to improvement such as the SEI's maturity levels, so that many different kinds of assessment, model, and their results, can be meaningfully compared to one another. The approach selected is to measure the implementation and institutionalization of specific processes; a process measure rather than an organization measure.

Maturity levels can be viewed as sets of process profiles using this approach [Paulk94, Paulk96]. This addresses one of the deficiencies in the staged approach: key process areas in the Software CMM capture snapshots in the evolution of individual processes that are representative as a gestalt of organizational capability. Key process areas are not processes. A process is dynamic: it changes over time and hopefully matures. A key process area is a static description of essential attributes of a process when that process is fully realized, and it does not tell how the process is performed. Some processes are "invisible" in a staged model, until the point that focusing on their improvement becomes critical to organizational maturity. Engineering processes, for example, are not a focus of maturity level 2, so they "suddenly appear" at maturity level 3. This is intrinsic to the way the maturity levels are defined: the critical problems for maturity level 1 organizations are managerial, not technical, so the improvement focus is not on the engineering processes at maturity level 2.

3. The 1998 Type 2 Technical Reports

ISO/IEC 15504 became a set of five type 2 technical reports in 1998. Type 2 technical reports are an intermediate step in standardization; they are broadly available for trial but do not yet have the status of standards. In the 1998 product suite, the reference model architecture remains two dimensional, but the 1995 SPICE product suite evolved as it moved through the ISO standardization process.

The 1998 Process Capability Dimension

The 1998 *process dimension* is characterized by process purpose statements, which are the essential measurable objectives of a process. The *process capability dimension* is characterized by a series of process attributes, applicable to any process, which represent measurable characteristics necessary to manage a process and improve its capability to perform. Each process attribute describes an aspect of the overall capability of managing and improving the effectiveness of a process in achieving its purpose and contributing to the business goals of the organization. There are nine process attributes, which are grouped into capability levels, one at capability level 1 and two each at levels 2-5. Capability levels constitute a rational way of progressing through improvement of the capability of any process. The six capability levels described in Table 3 are essentially equivalent to the capability levels in the BPG with some nomenclature and wording changes.

Table 2 The Capability Levels in ISO/IEC 15504-2:1998

Capability Level	ISO/IEC 15504-2 Capability Level Description
Level 0 *Incomplete*	There is general failure to attain the purpose of the process. There are little or no easily identifiable work products or outputs of the process.

Capability Level	ISO/IEC 15504-2 Capability Level Description
Level 1 *Performed*	The purpose of the process is generally achieved. The achievement may not be rigorously planned and tracked. There are identifiable work products for the process, and these testify to the achievement of the purpose.
Level 2 *Managed*	The process delivers work products according to specified procedures and is planned and tracked. Work products conform to specified standards and requirements.
Level 3 *Established*	The process is performed and managed using a defined process based upon good software engineering principles. Individual implementations of the process use approved, tailored versions of standard, documented processes to achieve the process outcomes.
Level 4 *Predictable*	The defined process is performed consistently in practice within defined control limits, to achieve its defined process goals.
Level 5 *Optimizing*	Performance of the process is optimized to meet current and future business needs, and the process achieves repeatability in meeting its defined business goals.

Process Attributes in the 1998 Capability Dimension

The process attributes are defined in ISO/IEC 15504-2 by process indicators, which are similar to the generic practices in the BPG, although the rating component is the attribute. Table xxx includes the ISO/IEC 15504-2:1998 process attributes and short, descriptive tags for the process indicators, along with the related BPG generic practices.

Capability Levels and Process Attributes	ISO/IEC 15504-2:1998 Description of Capability Dimension	Similar BPG Generic Practice
Level 0 *Incomplete process*	The process is not implemented, or fails to achieve its defined process outcomes.	**Level 0** *Not-Performed*
Level 1 *Performed process*	The implemented process achieves its defined process outcomes.	**Level 1** *Performed-Informally*

Capability Levels and Process Attributes	**ISO/IEC 15504-2:1998 Description of Capability Dimension**	**Similar BPG Generic Practice**
PA 1.1 Process performance attribute	The extent to which the process uses a set of practices that are initiated and followed using identifiable input work products to produce identifiable output work products that are adequate to meet the defined process outcomes.	GP 1.1.1 Perform the process.
	a. process requirements	
	b. work products	
	c. outcomes	
Level 2 *Managed process*	The previously described Performed process now delivers work products that fulfill expressed quality requirements within defined timescales and resource needs.	**Level 2** *Planned-and-Tracked*
PA 2.1 Performance management attribute	The extent to which the performance of the process is managed to produce work products within defined time and resource requirements.	
	a. resources	GP 2.1.1 Allocate resources.
	b. time-scale	
	c managed (planned, tracked and adjusted)	GP 2.1.6 Plan the process. GP 2.4.1 Track with measurement. GP 2.4.2 Take corrective action.
PA 2.2 Work product management attribute	The extent to which the performance of the process is managed to produce work products that are documented and controlled and that meet their defined functional and non-functional requirements.	

Capability Levels and Process Attributes	ISO/IEC 15504-2:1998 Description of Capability Dimension	Similar BPG Generic Practice
	a. work product requirements	
	b. integrity requirements	
	c. work product dependencies	
	d. configuration control	GP 2.2.2 Do configuration management.
	e. quality of work products	GP 2.3.2 Audit work products.
Level 3 *Established process*	The previously described Managed process now performs using a defined process that is based upon good software engineering principles and capable of achieving its defined process outcomes.	**Level 3** *Well-Defined*
PA 3.1 Process definition attribute	The extent to which the performance of the process uses a process definition based upon a standard process to achieve the defined process outcomes.	
	a. process documentation, tailoring	GP 3.1.1 Standardize the process. GP 3.1.2 Tailor the standard process.
	b. perform in accordance with defined process	GP 3.2.1 Use a well-defined process.
	c. historical process performance data	GP 3.2.3 Use well-defined data.
	d. experience	

Capability Levels and Process Attributes	ISO/IEC 15504-2:1998 Description of Capability Dimension	Similar BPG Generic Practice
PA 3.2 Process resource attribute	The extent to which the process draws upon competent human resources and suitable process infrastructure that is appropriately allocated to deploy the defined process.	
	a. roles	
	b. competent human resources	
	c. process infrastructure	
Level 4 *Predictable process*	The previously described Established process now performs consistently within defined limits to achieve its defined process outcomes.	**Level 4** *Quantitatively-Controlled*
PA 4.1 Process measurement attribute	The extent to which process and product goals and measures are used to ensure that performance of the process supports the achievement of the business goals.	GP 4.1.1 Establish quality goals.
	a. process and product measures collected	
	b. trends in performance	
	c. process capability	GP 4.2.1 Determine process capability.
PA 4.2 Process control attribute	The extent to which the process is controlled through the collection and analysis of product and process measures to correct, where necessary, the performance of the process to reliably achieve the defined process goals.	
	a. analysis and control techniques	
	b. in-process measures	
	c. performance within the defined limits	GP 4.2.2 Use process capability.

Capability Levels and Process Attributes	ISO/IEC 15504-2:1998 Description of Capability Dimension	Similar BPG Generic Practice
Level 5 *Optimizing process*	The previously described Predictable process now dynamically changes and adapts to effectively meet current and future business goals.	**Level 5** *Continuously-Improving*
PA 5.1 Process change attribute	The extent to which changes to the definition, management and performance of the process are controlled better to achieve the business goals of the organization.	GP 5.1.2 Continuously improve the standard process.
	a. impact of proposed changes	
	b. disruption within defined limits	
	c. effectiveness of process change evaluated	
PA 5.2 Continuous improvement attribute	The extent to which changes to the process are identified and implemented to ensure continuous improvement in the fulfillment of the defined business goals of the organization.	
	a. improvement goals support business goals	GP 5.1.1 Establish process effectiveness goals.
	b. sources of problems and opportunities	GP 5.2.1 Perform causal analysis.
	c. improvement opportunities identified	GP 5.2.2 Eliminate defect causes.
	d. implementation strategy	GP 5.2.3 Continuously improve the defined process.

Some Reflections on the Model Changes Between 1995 and 1998

Although one can always debate nomenclature and wording, the 1998 process capability dimension is in most ways very similar to the 1995 version. Usability was an issue in the trials of the BPG when 26 generic practices were rated on the capability dimension. This led to over 1,000 rating decisions during an assessment, and early trials indicated that assessments of a process instance could be quite lengthy [Woodman96]. The solution to this problem was to "raise the level of abstraction" in rating to process attributes.

For Software CMM v2, we proposed addressing this concern via a goal for each key process area to capture the institutionalization of the process. The institutionalization goal would have captured the topics addressed by ISO/IEC 15504 process attributes via key practice templates for planning, training, tailoring, etc., as appropriate for the maturity level. This would have clarified that institutionalization is a critical part of satisfying a key process area and separated institutionalization and implementation for purposes of rating key process areas. CMMI retained this solution, in somewhat different forms, in both its continuous and staged representations.

Several generic practices were lost in this evolution:

- GP 2.1.2 Assign responsibilities.
- GP 2.1.3 Document the process.
- GP 2.1.4 Provide tools.
- GP 2.1.5 Ensure training.
- GP 3.2.2 Perform peer reviews.

Peer reviews are simply lost. It can be argued that process documentation is implied in PI 2.1c, and tools are implied in PI 2.1a, but the other three generic practices are not addressed even by implication at the same capability level. Responsibility and training are implied by roles and competence in PA 3.2, but it is a level 3 rather than a level 2 solution.

A more interesting difference between the 1995 and 1998 reference models is that the organization versus project distinction is no longer crisply captured. Common Features 3.1, 4.1, and 5.1 focus on organizational issues, and Common Features 3.2, 4.2, and 5.2 focus on project-level issues in the BPG. Whether this distinction is a useful one can be debated; it has been retained in CMMI.

4. The 2003 ISO/IEC 15504-2 International Standard

The reference model was published as an international standard in 2003. The process capability dimension remains very similar to that in the 1998 technical report, but the processes are intended to be adapted from other frameworks, such as ISO/IEC 12207 (Software life cycle processes) and ISO/IEC 15288 (Systems life cycle processes).

Capability Levels and Process Attributes	ISO/IEC 15504-2:2003 Description of Capability Dimension	Similar 1998 Practice
Level 0 *Incomplete process*	The process is not implemented, or fails to achieve its process purpose.	**Level 0** *Incomplete process*
Level 1 *Performed process*	The implemented process achieves its process purpose.	**Level 1** *Performed process*
PA 1.1 Process performance attribute	The process performance attribute is a measure of the extent to which the process purpose is achieved.	PA 1.1 Process performance attribute
	a) process outcomes	c. outcomes
		a. process requirements
		b. work products
Level 2 *Managed process*	The previously described *Performed process* is now implemented in a managed fashion (planned, monitored and adjusted) and its work products are appropriately established, controlled and maintained.	**Level 2** *Managed process*
PA 2.1 Performance management attribute	The performance management attribute is a measure of the extent to which the performance of the process is managed.	PA 2.1 Performance management attribute
	a) objectives	
	b) planned and monitored	c managed (planned, tracked and adjusted)
	c) performance adjusted to meet plans	
	d) responsibilities and authorities	
	e) resources and information	a. resources
	f) interfaces between parties	
		b. time-scale

Capability Levels and Process Attributes	ISO/IEC 15504-2:2003 Description of Capability Dimension	Similar 1998 Practice
PA 2.2 Work product management attribute	The work product management attribute is a measure of the extent to which the work products produced by the process are appropriately managed.	
	a) requirements	a. work product requirements
	b) requirements for documentation and control	b. integrity requirements
	c) work products controlled	d. configuration control
	d) work products reviewed	e. quality of work products
		c. work product dependencies
Level 3 *Established process*	The previously described *Managed process* is now implemented using a defined process that is capable of achieving its process outcomes.	**Level 3** *Established process*
PA 3.1 Process definition attribute	The process definition attribute is a measure of the extent to which a standard process is maintained to support the deployment of the defined process.	PA 3.1 Process definition attribute
	a) standard process, tailoring guidelines	a. process documentation, tailoring
	b) sequence and interaction	
	c) competencies and roles	
	d) infrastructure and work environment	
	e) methods for monitoring	

Capability Levels and Process Attributes	ISO/IEC 15504-2:2003 Description of Capability Dimension	Similar 1998 Practice
		d. experience
PA 3.2 Process deployment attribute	The process deployment attribute is a measure of the extent to which the standard process is effectively deployed as a defined process to achieve its process outcomes. As a result of full achievement of this attribute:	PA 3.2 Process resource attribute
	a) a defined process deployed, tailored	PI 3.1b. perform in accordance with defined process
	b) roles, responsibilities	a. roles
	c) personnel competent	b. competent human resources
	d) resources and information	
	e) infrastructure and work environment	c. process infrastructure
	f) data collected, analyzed	PI 3.1c. historical process performance data
Level 4 *Predictable process*	The previously described *Established process* now operates within defined limits to achieve its process outcomes.	**Level 4** *Predictable process*
PA 4.1 Process measurement attribute	The process measurement attribute is a measure of the extent to which measurement results are used to ensure that performance of the process supports the achievement of relevant process performance objectives in support of defined business goals.	PA 4.1 Process measurement attribute
	a) process information needs	

Capability Levels and Process Attributes	ISO/IEC 15504-2:2003 Description of Capability Dimension	Similar 1998 Practice
	b) process measurement objectives	
	c) quantitative objectives for process performance	
	d) measures defined	
	e) measures collected, analyzed	a. process and product measures collected
	f) measurement characterizes process performance	
		b. trends in performance
		c. process capability
PA 4.2 Process control attribute	The process control attribute is a measure of the extent to which the process is quantitatively managed to produce a process that is stable, capable, and predictable within defined limits.	PA 4.2 Process control attribute
	a) analysis and control techniques	a. analysis and control techniques
	b) control limits	c. performance within the defined limits
	c) special causes of variation	
	d) corrective actions	
	e) control limits re-established	
		b. in-process measures
Level 5 *Optimizing process*	The previously described *Predictable process* is continuously improved to meet relevant current and projected business goals.	**Level 5** *Optimizing process*

Capability Levels and Process Attributes	ISO/IEC 15504-2:2003 Description of Capability Dimension	Similar 1998 Practice
PA 5.1 Process innovation attribute	The process innovation attribute is a measure of the extent to which changes to the process are identified from analysis of common causes of variation in performance, and from investigations of innovative approaches to the definition and deployment of the process.	PA 5.2 Continuous improvement attribute
	a) improvement objectives support business goals	a. improvement goals support business goals
	b) common causes of variation	b. sources of problems and opportunities
	c) opportunities for innovation	c. improvement opportunities identified
	d) opportunities from new technologies	
	e) implementation strategy	d. implementation strategy
PA 5.2 Process optimization attribute	The process optimization attribute is a measure of the extent to which changes to the definition, management and performance of the process result in effective impact that achieves the relevant process improvement objectives.	PA 5.1 Process change attribute
	a) impact of changes assessed	a. impact of proposed changes
	b) disruption to performance understood	b. disruption within defined limits
	c) effectiveness of process change evaluated	c. effectiveness of process change evaluated

5. Looking Back

The continuous representation of process capability is a logical and simple depiction of how processes systematically improve in capability. The basic idea has been used for decades, including in Humphrey's work at IBM that preceded the development of the Software CMM, which used a staged model focused on organizational transformation.

The simplicity of the continuous representation is intuitively appealing, and it is easily extensible to new domains. The drawback is that it easily explodes into a large set of attributes that must be assessed when its flexibility is exercised in investigating the complexities of modern organizations. This has led to many simplifications of the original approach with generic practices organized according to capability levels. The additional complexity simplifies the assessment task, albeit with some risk of hiding useful detail. Whether these issues are better addressed within the model architecture or within the method for using the model is an ongoing discussion, and the SPICE trials (as well as related CMMI work) have led to changes in both the continuous representation and the assessment method to balance the reliability and consistency supported by the model architecture and the usability requirements for the assessment method.

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