A Measurement Approach Integrating ISO 15939, CMMI and the ISBSG

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Abstract

In recent years, a number of well-known groups have developed sets of best practices on software measurement, but from different perspectives. These best practices have been published in various documents, such as ISO 15939, the CMMI model and the ISBSG data repository. However, these documents were developed independently and for a software engineering organization initiating a measurement program. As a result, it is a challenge to work out a strategy to leverage the benefits of each, while at the same time offsetting gaps. First, although ISO 15939 (Software Measurement Process) is an international standard which defines the activities and tasks that are necessary to implement a software measurement process, because its activities and tasks are defined at a very high level, additional support is necessary for ease of implementation. Second, while CMMI (Capability Maturity Model Integration) is a model which contains the essential elements of an effective software engineering process, it is now strongly measurement-oriented, which means that it provides guidance on which elements need measurement, but does not provide specific guidelines for defining specific measures and does not support an international repository of project measurement results. Third, the International Software Benchmarking Standards Group (ISBSG) provides a repository of project data which may be used for benchmarking and development of estimation models. This paper proposes an approach to integrating resources such as ISO 15939, CMMI and the ISBSG data repository in support a software engineering measurement program.

1. Introduction

Software engineering, like any other engineering discipline, can benefit from continuous improvements. This requires that the actual performance of a software engineering process be objectively evaluated and assessed against a baseline, that an improvement program be designed and implemented, and, finally, that the impact of any improvement made be objectively evaluated. A body of best practices has been published in various documents, such as ISO 15939 [1,2], CMMI [3] and the International Software Benchmarking Standards Group (ISBSG) [4] data repository and related glossary, data collection questionnaire and releases. However, these documents were developed independently and for a software engineering organization initiating a measurement program. It is therefore challenging to work out a strategy to leverage the benefits of each, while at the same time offsetting gaps. But, where does one begin when starting up a new organization measurement program?

ISO 15939 is a must when the time comes to implement a software measurement program, as it covers all the activities and tasks necessary for a successful implementation. However, this international standard is not sufficient by itself, and additional knowledge coupled with considerable expertise is still needed. For instance, this international standard clearly states that it "*does not catalogue software measures, nor does it provide a recommended set of* *measures to apply on software projects*" [1]. Instead, it provides guidance for "*defining a suitable set of measures that address specific information needs*" [1]. It remains, however, that these information needs must be worked out and measures found to help meet these needs [2].

CMMI defines goals and practices covering multiple maturity levels and multiple process areas. These goals and practices may be used to provide more guidance about which elements of a software engineering process need measurement and to identify some of the information needs. The major part of this paper presents an analysis of CMMI in order to assess whether or not this model could be used, along with ISO 15939, as a starter kit for planning a software measurement process. However, neither ISO 15939 nor CMMI provides detailed data which can be of immediate use to organizations for benchmarking or guidance purposes.

Such data is, however, available from the ISBSG [3], which provides benchmarking standards based on ISO 15939, as well as a repository of over 3,000 projects, as of early 2006. Could the ISBSG be used as a turnkey solution when the time comes to implement a software measurement process? This paper looks into this question as well.

Section 2 presents ISO 15939 and section 3 a mapping between ISO 15939 and CMMI. Section 4 presents the measurement view incorporated in the CMMI model, and section 5 the ISBSG. Finally, our conclusions are presented in section 6.

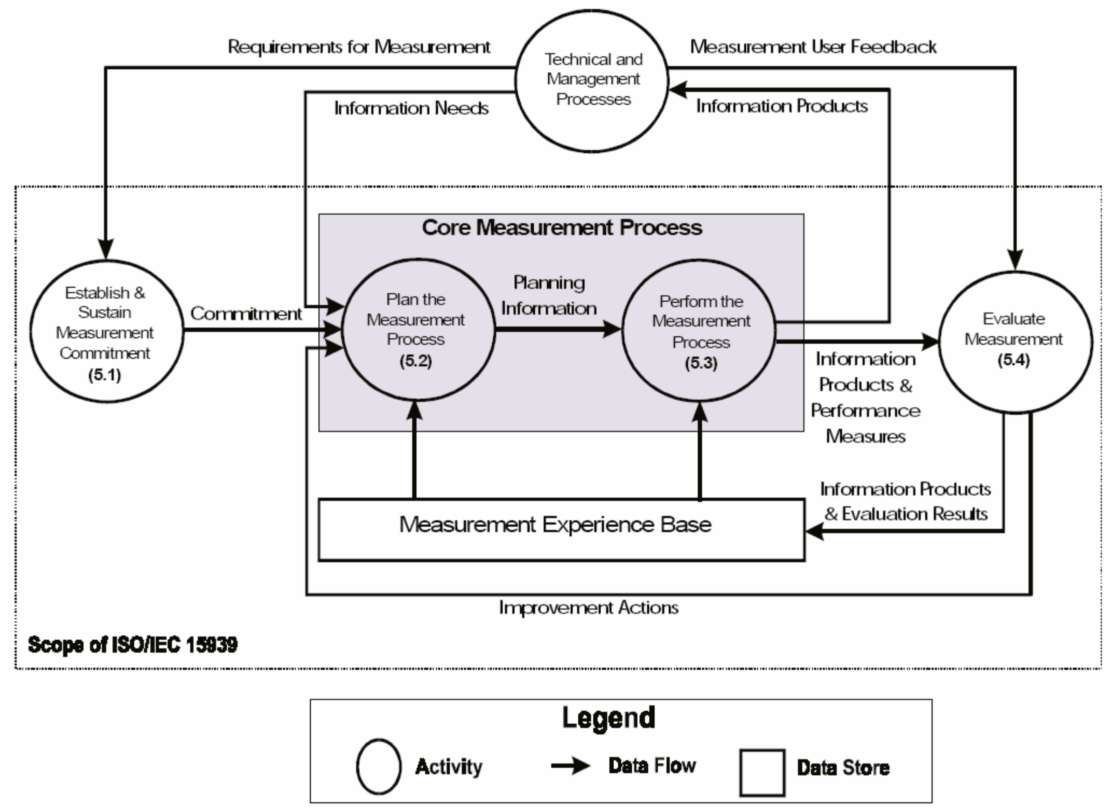
2. ISO 15939 – An Overview

The ISO 15939 international standard documents the required components of a software measurement process and includes a number of appendices for additional guidance. The software measurement process is described in terms of activities and tasks only; properties such as entry criteria, exit criteria and work products are not defined. The appendices provide useful information, such as a measurement information model, examples of specific measures using the model, the work products that may be produced by the process and examples of criteria for evaluating some work products.

2.1. Software Measurement Process

The software measurement process consists of four activities (Figure 1):

- "**Establish & sustain measurement commitment**": Scope is defined, necessary commitment is established and resources are assigned.
- "**Plan the measurement process**": Information needs are identified, information products are defined, measurement procedures are defined and supporting technologies are acquired.
- "**Perform the measurement process**": Data are collected, meaningful information products are produced and results are communicated.
- "**Evaluate measurement**": Information products are evaluated and potential improvements of the measurement process are identified.


Requirements for Measurement
Technical and Management Processes
Measurement User Feedback
Information Needs
Information Products
Core Measurement Process
Establish & Sustain Measurement Commitment (5.1)
Commitment
Plan the Measurement Process (5.2)
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Information Products & Performance Measures
Evaluate Measurement (5.4)
Information Products & Evaluation Results
Measurement Experience Base
Improvement Actions
Scope of ISO/IEC 15939
Legend
Activity
Data Flow
Data Store

Figure 1: Software Measurement Process Model [1]

Only the second and third activities are considered to constitute the "core measurement process", which is itself driven by the information needs as input and producing information products as output. These information products will be used by measurement users as an objective basis for communication and decision-making.

2.2. Information Needs & Products

For each information need, there is a corresponding information product that satisfies it. An information product comprises one or more indicators and their associated interpretations. But information products are not close to the measured entities; this is why a detailed measurement information model needs to be defined (Figure 2). From the measured attributes, there are measurement methods, measurement functions, algorithms and criteria that are applied before actual values can be assigned and interpreted. However, in order to stay within the scope of this paper, only the information needs and products (indicators and interpretations) are considered.

In [2], the hierarchy of concepts in the Measurement Information Model illustrated in Figure 1 has been subdivided into three sets for ease of understanding – see Figure 3:

- **data collection**: includes the measurement methods and the base measures;
- **data preparation**: includes the agreed-upon mathematical formula and related labels (e.g. measurement functions and derived measures);
- **data analysis**: includes the analysis models, indicators and interpretation.

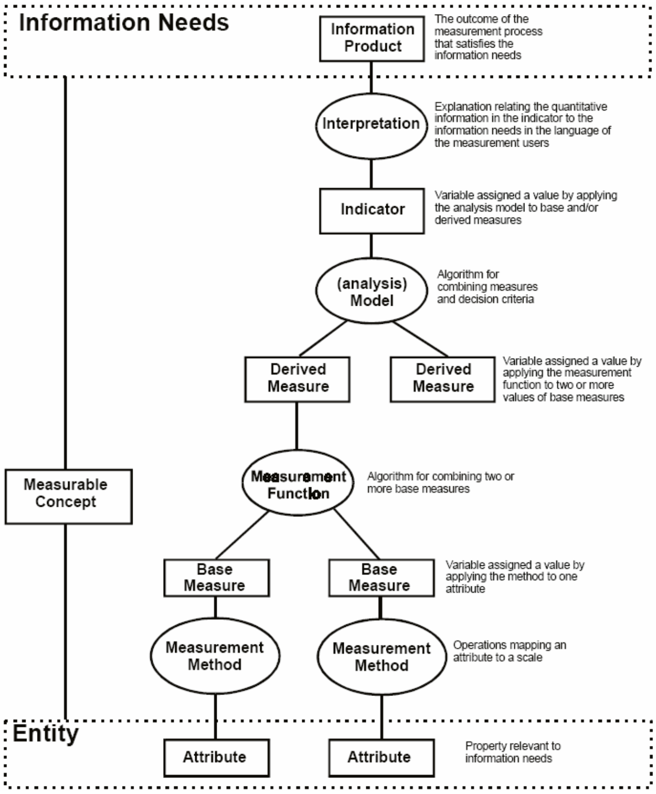

Information Needs
Information Product
The outcome of the measurement process that satisfies the information needs
Interpretation
Explanation relating the quantitative information in the indicator to the information needs in the language of the measurement users
Indicator
Variable assigned a value by applying the analysis model to base and/or derived measures
(analysis) Model
Algorithm for combining measures and decision criteria
Derived Measure
Derived Measure
Variable assigned a value by applying the measurement function to two or more values of base measures
Measurable Concept
Measurement Function
Algorithm for combining two or more base measures
Base Measure
Base Measure
Variable assigned a value by applying the method to one attribute
Measurement Method
Measurement Method
Operations mapping an attribute to a scale
Entity
Attribute
Attribute
Property relevant to information needs

Figure 2: ISO 15939 Measurement Information Model [1]

3. ISO 15939 vs. CMMI

ISO 15939 defines a software measurement process which takes information needs as input in order to produce useful information products as output. But is it possible to obtain guidance about those information needs? What if the measurement users, especially managers, do not know about software measurement and, consequently, about their own information needs?

3.1. Using Both

Fortunately, it is possible to create a starter kit by using both ISO 15939 and CMMI. Indeed, **CMMI,** version 1.2 [3], offers guidance about which elements of a software engineering process need measurement, and, because it is a software engineering process model applicable to both the software and the systems engineering domains, this model is used extensively as a process improvement model.

Hence, it is possible to extract information needs from CMMI and use them as input for the core software measurement process defined in ISO 15939. This new information flow (see Figure 4) may be particularly useful for an emerging business that does not have personnel with the substantial knowledge and expertise required to drive a software measurement process. The new information flow would be used during task "*5.2.2.1 Information needs for measurement shall be identified*" [1].

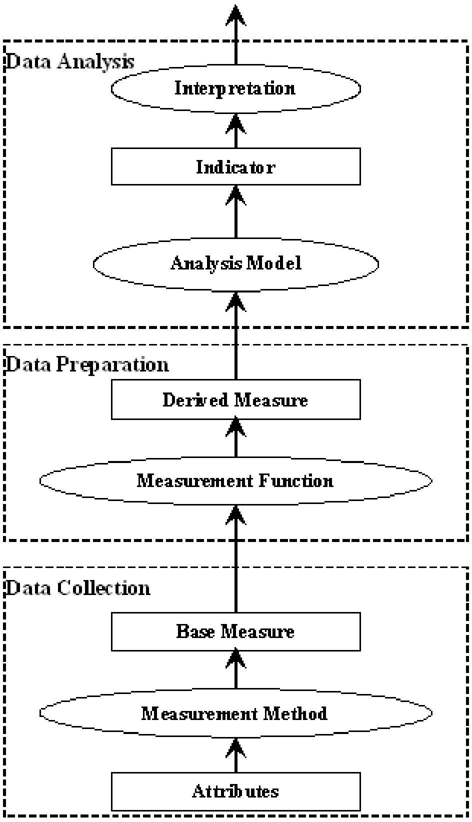
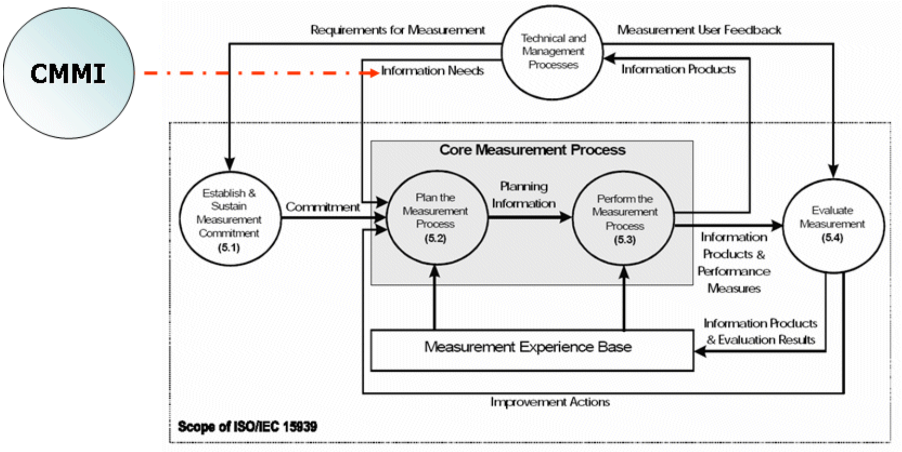


Figure 3: Hierarchy of concepts in the Measurement Information Model [2]


CMMI
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Measurement Experience Base
Improvement Actions
Scope of ISO/IEC 15939

Figure 4: CMMI and the Software Measurement Model

3.2. Methodology

ISO 15939's task 5.2.2.1 states that the "information needs are based on: goals, constraints, risks, and problems (which originate from the technical and management processes" [1]. In a context where CMMI is used, some of the information needs will be based on the goals and practices defined in that context. Within the scope of this paper, a CMMI goal or practice related to measurement is considered to be a goal or practice which:

- generates data that could be analyzed in order to produce an objective basis for communication or decision-making;
- involves decision-making that would benefit from objective information;
- explicitly requires measurement as part of the measurement process.

Unfortunately, the first and second criteria may generate many information needs that do not have the same relevance. Hence, it is important to identify the following levels of relevance:

- "**mentioned**" when the information need is based on the first and/or second criterion;
- "**recommended**" when the information need is expressed in terms of measurement without being explicitly required as a part of the measurement process;
- "**required**" when the information need is based on the third criterion.

3.3. Measurement Interest Areas

To organize the extracted information needs, it is important to classify the information needs. Here, the concept of "*measurement interest areas*" is used. This makes it possible to take a snapshot of each maturity level defined in CMMI without going into too much detail. The following measurement interest areas are based on combining the process group classifications from ISO 12207 and CMMI (see Figure 5):

- "**Requirements**": a software life cycle area which involves requirements development, requirements analysis and requirements acceptance;
- "**Analysis**": a software life cycle area which involves risk analysis and decision analysis;
- "**Design & Implementation**": a software life-cycle area which involves software design and software coding;
- "**Verification & Validation (V&V)**": a software life cycle area which covers both verification and validation throughout the project life cycle, including testing activities, related to the verification of internal and external quality (e.g. quality models from ISO 9126);
- "**Project Management**": a supporting area which covers project planning and monitoring, and control for the whole life cycle;
- "**Configuration Management**": a supporting area which covers versioning and baseline for the whole life cycle;
- "**Quality Assurance**": a supporting area which covers evaluation of activities and work products against a managed or defined process with the purpose of improvement for the whole life cycle;
- "**Training**": a supporting area which covers training for the whole life cycle and other supporting areas.

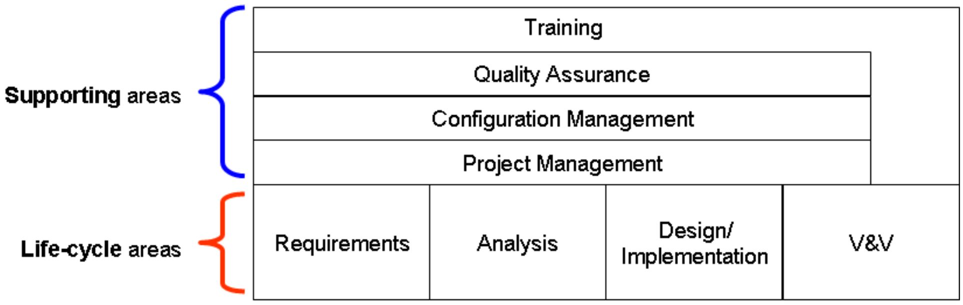

Figure 5: Measurement Interest Areas – using the CMMI structure of software processes

3.4. QA vs. V&V

It is important to explain the distinction between Verification/Validation (V&V) and quality assurance (QA). This distinction is not always clear to practitioners.

Verification and validation constitute a set of activities that evaluates the quality of a specific software product. In the scope of a software measurement process, verification and validation activities measure the quality of a specific software product in order to support decision-making surrounding improvement (correcting bugs, re-factoring) of this specific software product.

Quality assurance looks at a longer perspective and is not specific to a particular software product. Within the scope of a software measurement process, quality assurance makes use of the measures with a view to evaluating actual process performance against the managed or defined process in order to support decision-making surrounding improvement of the organization as a whole. Since the organization's mission is to deliver software products with built-in quality, quality assurance and verification/validation are both aimed at improving software product quality, but from significantly different points of view.

4. CMMI – An Analysis

For this paper, the staged representation of CMMI has been chosen: "*The staged representation prescribes an order for implementing process areas according to maturity levels, which define the improvement path for an organization from the initial level to the optimizing level*" [3]. In the following sub-sections, Maturity Levels (MLs) 2 to 5 are analyzed in terms of information needs for a software measurement process. Since all organizations are considered to be at least at ML1 by default, the first level is not defined and not analyzed. Because these sub-sections are like snapshots, a detailed analysis of each level is documented in four tables (see Tables 1 to 4) at the end of this paper.

4.1. Level 2 – Managed

At the Managed level, an organization does not yet have a defined set of processes. Instead, it has processes that are planned, performed, measured (with some beginner measures) and controlled. At this level, there is an emphasis on requirements management and project management to ensure that the software products satisfy the specified requirements and that they are delivered according to plan (cost and time).

At this level (ML2), "Measurement & Analysis" is already a central concern. Hence, the answer to the question "When to begin?" is "As soon as possible". CMMI does not explicitly require any information needs to be satisfied at ML2; however, some information needs are mentioned, with particular attention paid to project estimates (cost and time). At least some of these information needs should be addressed by the soon-to-be software measurement process.

Some of the extracted information needs among measurement interest areas of ML2 are listed next and summarized in Figure 6. Note that one information need may give rise to multiple indicators and measures, which may, in turn, satisfy other information needs.

- **Requirements**:
  - Need to know the degree of compliance of the requirements with established criteria;
  - Need to evaluate the impact of requirements for commitment;
  - Need to know the consistency of other work products vis-à-vis the requirements.
- **Analysis**:
  - Need to evaluate the risk associated with a project.
- **Configuration management**:
  - Need to evaluate the impact of change requests;
  - Need to know the integrity of the baselines.
- **Project management**:

- Need to collect data about project effort, project cost, work product attributes and task attributes;
  - Need to estimate effort and cost using models and/or historical data;
  - Need to track the actual project performance;
  - Need to know the effectiveness of corrective actions when taken on identified issues.
- **Quality Assurance**:
  - Need to evaluate the process as performed against the applicable process descriptions;
  - Need to evaluate the work products against applicable descriptions.

References to more information needs from CMMI practices and sub-practices are listed in Table 1.

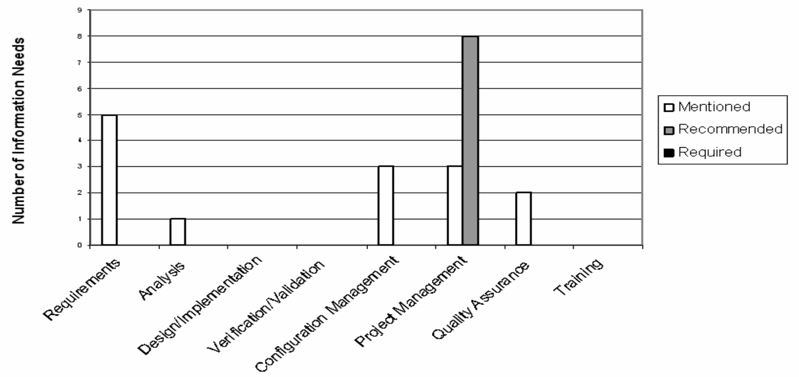

Figure 6: Distribution of information needs at ML2

4.2. Level 3 – Defined

The Defined level is reached when an organization has a defined set of processes that are improved over time. *"[...] at maturity level 3, processes are typically described more rigorously than at maturity level 2*" [3]. Moreover, at Maturity Level 3 (ML3), processes are managed using detailed measures of the processes and work products.

At ML3, information needs cover all measurement interest areas. However, most of the information needs (60%) come from "quality assurance" and "verification and validation".

Some of the extracted information needs among measurement interest areas of ML3 are listed next and summarized in Figure 7. Note that one information need may give rise to multiple indicators and measures, which may, in turn, satisfy other information needs.

- **Requirements:**
  - Need to know the functional size of the requirements;
  - Need to know the completeness, feasibility and verifiability of the requirements;
  - Need to track technical performance requirements during development effort.
- **Analysis:**
  - Need to evaluate the risk associated with the requirements;
  - Need to evaluate, categorize and prioritize identified risks using established criteria;
  - Need to trigger a risk mitigation plan when an unacceptable level or threshold is reached;
  - Need to compare alternative solutions using established criteria in order to select the best solution.
- **Design and implementation:**
  - Need to know the degree of compliance of the design with established criteria;
  - Need to know the consistency of the design vis-à-vis the requirements;

    - Need to evaluate the completeness and coverage of all product component interfaces;
    - Need to know the degree of compliance of the code with the design.
- **Verification and validation:**
    - Collect data from peer reviews on the code;
    - Collect results from unit testing;
    - Collect data from peer reviews on the documentation;
    - Need to evaluate assembled product components following product integration;
    - Need to confirm correct operation at the operational site;
    - Need to identify corrective actions by analyzing verification and validation data;
- Project management:
    - Need to estimate the project's planning parameters using the measurement repository;
    - Need to manage the project using a set of specific measures.
- **Quality assurance:**
    - Need to appraise processes, methods and tools periodically to identify strengths and weaknesses and to develop recommendations;
    - Collect data from peer reviews on the common set of measures and procedures for storing and retrieving measures.
- **Training:**
    - Collect data about training activities;
    - Collect data about test results.

References to more information needs from CMMI practices and sub-practices are listed in Table 2.

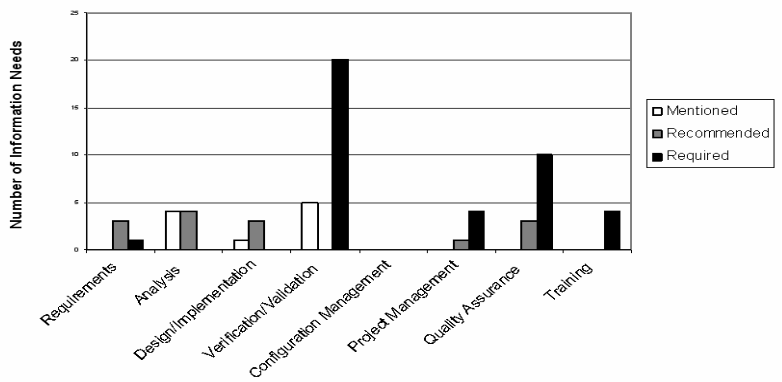

Figure 7: Distribution of information needs at ML3

4.3. Level 4 – Quantitatively Managed

The Quantitatively Managed level is reached when detailed measures of quality and process performance are collected and statistically analyzed. "*Quantitative objectives are based on the needs of the customer, end users, organization, and process implementers*" [3]. Project management is achieved by establishing quantitative objectives and then by composing a project process that should reach these objectives, given the measured performance history of sub-processes composing the project process.

At Maturity Level 4 (ML4), information needs come only from "project management" and "quality assurance". At this level, these two measurement interest areas are closely related, since project management is totally based on process performance, which is the object of quality assurance.

It is outside the scope of this paper to list the advanced information needs of ML4 (Figure 8). References to more information needs from CMMI practices and sub-practices are listed in Table 3.

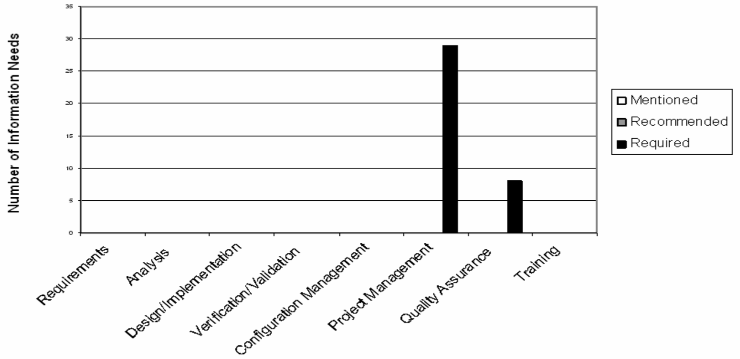

Figure 8: Distribution of information needs at ML4

4.4. Level 5 – Optimizing

The Optimizing level is reached when "*processes are continually improved based on a quantitative understanding of the common causes of variation inherent in processes*" [3]. "*Maturity level 5 focuses on continually improving process performance through both incremental and innovative technological improvements*" [3].

At Maturity Level 5 (ML5), information needs come only from "quality assurance", since the aim is only to improve processes.

It is outside the scope of this paper to list the advanced information needs of ML5 (Figure 9). References to more information needs from CMMI practices and sub-practices are listed in Table 4.

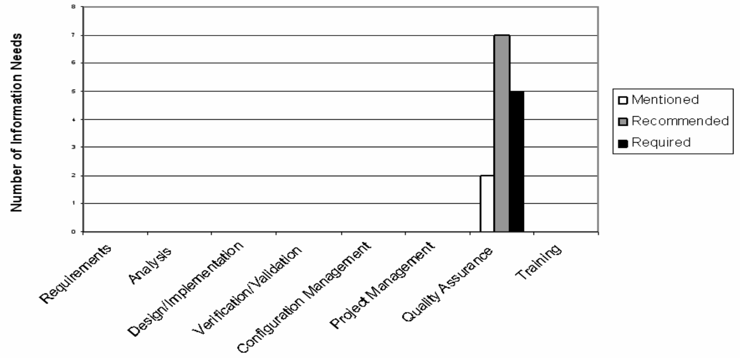

Figure 9: Distribution of information needs at ML5

4.5. Overview

An overview of the information needs from all maturity levels may help in understanding the scope of a software measurement process (Figure 10)[1].

[1] Readers must take into account that a number of information needs overlap one another.

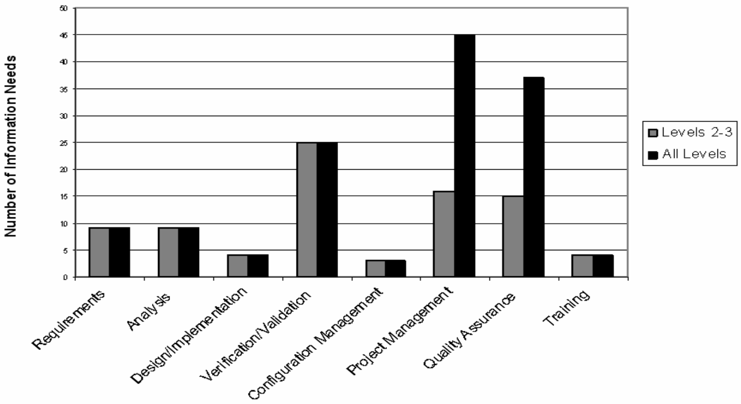

Figure 10: Distribution of information needs in all maturity levels

Initially considering only ML2 and ML3 as the target for process improvement, the most significant measurement interest areas are, in order of importance, “verification and validation”, “project management” and “quality assurance”. This gives a good idea of which information needs should be given the most consideration when initiating the implementation of a software measurement program.

Why is it better to consider ML2 and ML3, rather than ML2 only? The answer is that it would be irresponsible to ignore a measurement interest area like “verification and validation” when implementing a software measurement process. An emerging business needs to verify and validate the quality of its software products, and this is, in most organizations, a key concern to be addressed through a software measurement process. In addition, a few studies have investigated the maturity level equivalence for those organizations already ISO 9001:2000-certified and implementing CMMI processes between ML2 and ML3 [5,6]; for instance, an ISO-certified organization must – to be certified – demonstrate that a process is in place to identify and eliminate the causes of non conformities. This means that, for these organizations, there should be documented evidence of some measurement-intensive process areas (PAs), such as *Causal Analysis & Resolution (CAR)*, which corresponds to *Decision Analysis & Resolution (DAR)* at ML3.

For this analysis, the staged representation of CMMI was chosen because CMMI was easier to analyze. In the staged representation, process areas are categorized under maturity levels. Consequently, some process areas are ignored in the earlier stages of that representation. However, in the continuous representation, the maturity levels also exist within each process area. Consequently, all process areas that are relevant for a given business may be considered in the earlier stages if the continuous representation is chosen.

To end the discussion on the information needs that may be extracted from CMMI, it is important to keep in mind that CMMI only offers guidance, and that information needs should, above all, be business information needs.

5. ISBSG – As a Turnkey Solution

5.1. Introduction

The ISBSG is a not-for-profit organization created in 1994 “*to develop the profession of software measurement by establishing a common vocabulary and understanding of terms”* [4, 7, 8]. It groups together national software measurement associations, currently representing 13 different countries. The ISBSG software project repository provides “*software development practitioners with industry output standards against which they may compare their aggregated or individual projects, and real data of international software development that can be analysed to help improve the management of IT resources by both* *business and government*" [8]. To achieve these goals, the ISBSG makes available to the public a questionnaire [8] designed to help in collecting data about projects, including software functional size measured with any of the measurement standards recognized by the ISO (COSMIC-FFP functional size – ISO 19761, etc.). The ISBSG assembles this data in a repository and provides a sample of the data fields to practitioners and researchers in an Excel file, referred to below as the ISBSG MS-Excel data extract. The ISBSG data collection questionnaire available at www.isbsg.org includes a large amount of information about project staffing, effort by phase, development methods and techniques, etc. Moreover, the ISBSG provides a glossary of terms and measures to assist in the collection of project data into the repository and to standardize the way the collected data is analyzed and reported [7].

The ISBSG data collection questionnaire includes 7 sections, subdivided into several subsections (Figure 11).

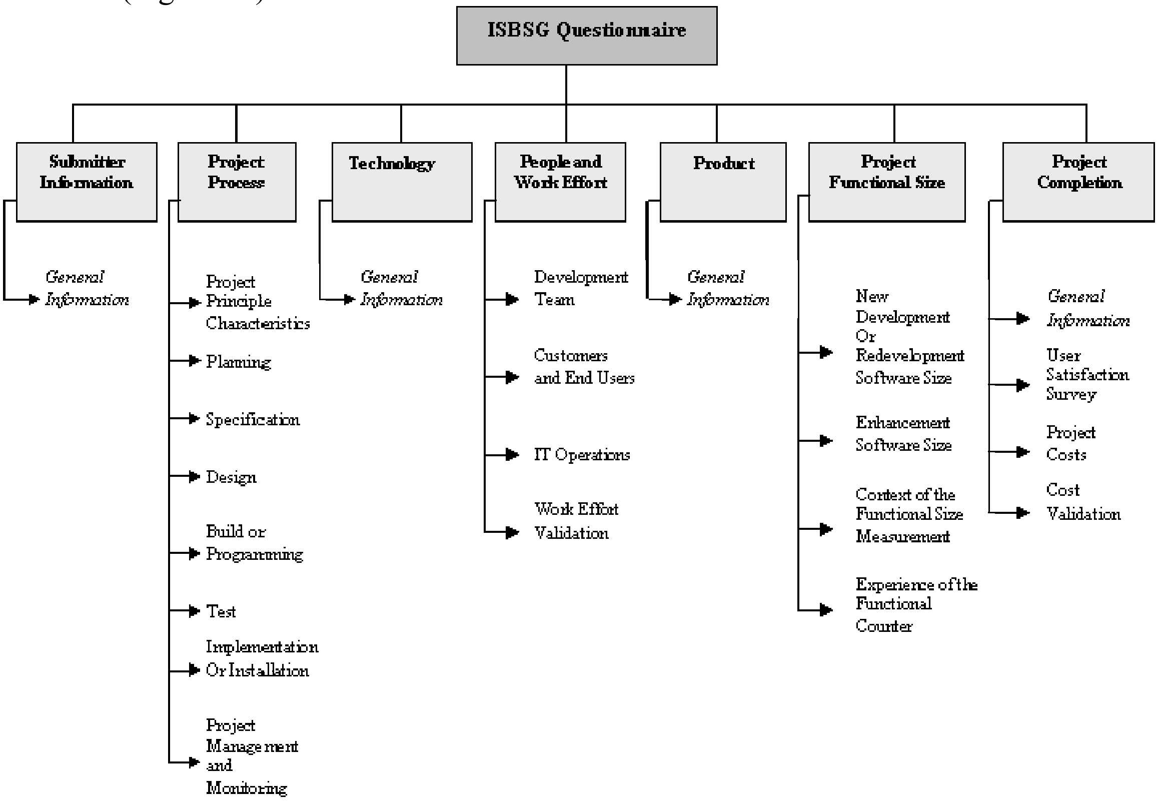

Figure 11: Structure of the ISBSG Data Collection Questionnaire

The ISBSG project repository is mostly used for project productivity benchmarking and for building effort estimation models. In addition, Cheikhi, Abran and Buglione have investigated in [9] the extent to which the current ISBSG repository can be of use for benchmarking software product quality characteristics on the basis of ISO 9126. They also identify the subset of quality-related data fields made available by the ISBSG to industry and researchers, and illustrate its use for quality analysis.

Therefore, even though the ISBSG data collection repository does not necessarily address the totality of the information needs of an organization, there are advantages to taking the ISBSG as a reference solution for initiating a software measurement program:

- The ISBSG offers an existing measurement framework that can facilitate faster implementation of the software measurement process with industry-standardized definitions of base and derived measures throughout the project life cycle phases. This will align the internal project database repository with this international repository.

- The ISBSG offers a database repository with data from over 3, 000 projects, which means that it already contains valuable data.

5.2. Analysis

The ISBSG data collection questionnaire is divided into multiple sections containing, in all, one hundred and thirty one (131) questions (some with a number of sub-questions). The analysis was made by categorizing each question based on the measurement interest areas defined in this paper. The detailed analysis may be found in Table 5 at the end of the paper.

Briefly, the most important measurement interest areas in the ISBSG are "project management" and "quality assurance" (Figure 12). This is understandable, since the ISBSG mostly focuses on project cost and effort, identifying project types, allowing for the identification of the more productive practices and processes, etc.

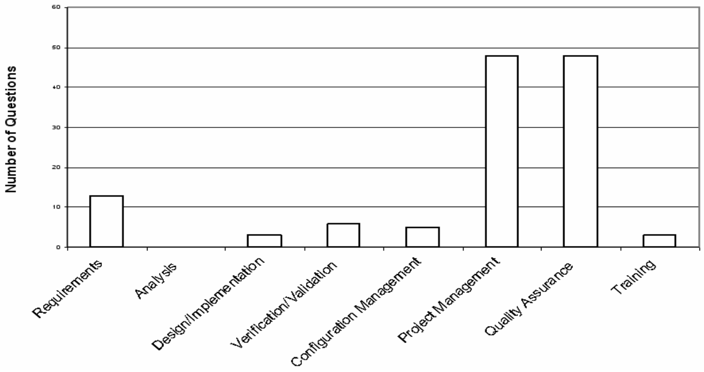

Figure 12: Distribution of questions in the ISBSG Questionnaire

5.3. Comparison with CMMI

Since there is no documented one-to-one relationship between CMMI practices and ISBSG questions, our comparison has been made on the basis of the percentage of interest given to each measurement interest area (Figure 13).

The highlights of this comparison are the following:

- The ISBSG focuses strictly on "project management" and "quality assurance".
- The ISBSG lacks "verification and validation" data.
- The ISBSG does not consider "analysis" at all, not even risk analysis.

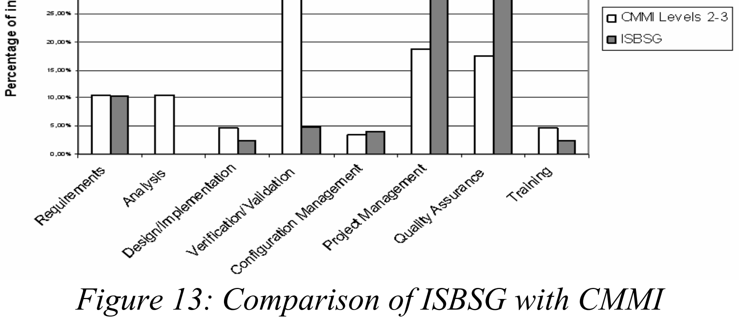

Figure 13: Comparison of ISBSG with CMMI

6. Conclusions

The analysis of CMMI, from the perspective of a software measurement process, illustrates that information needs from ML2 and ML3 can provide guidance in identifying business information needs. As a consequence, ISO 15939 and CMMI may be used together as a starter kit when planning a software measurement program and related processes.

However, even though CMMI particularly stresses “verification and validation”, it does not refer to, nor does it recommend, a specific a quality model or a specific set of verification and validation measures. Therefore, the design and selection of one or more quality models (and related measures) is left to the organizations themselves. As a consequence, the information needs concerning verification and validation are stated in CMMI only at a very high level. To address this issue, ISO 9126[2] proposes and defines detailed quality models for both internal quality, external quality and quality in use. Furthermore, ISO 9126 proposes an inventory of over 200 measures about software quality, but it is left to the organizations to select from these, which is, of course, a challenging task.

Furthermore, the ISBSG was identified as a candidate turnkey solution for a software measurement process. Organizations at a lower maturity level should, however, select only the subset of ISBSG measures that can be realistically collected in an organization initiating a measurement program, including measures concerning “project management” and “quality assurance”. Organizations interested in implementing the full set of ISO 9126 quality models (internal quality, external quality and quality in use) must select and add the relevant measures proposed in ISO 9126, parts 2 to 4. A possible joint usage of the three elements (ISO 15939, CMMI and ISBSG) is presented in Figure 14.

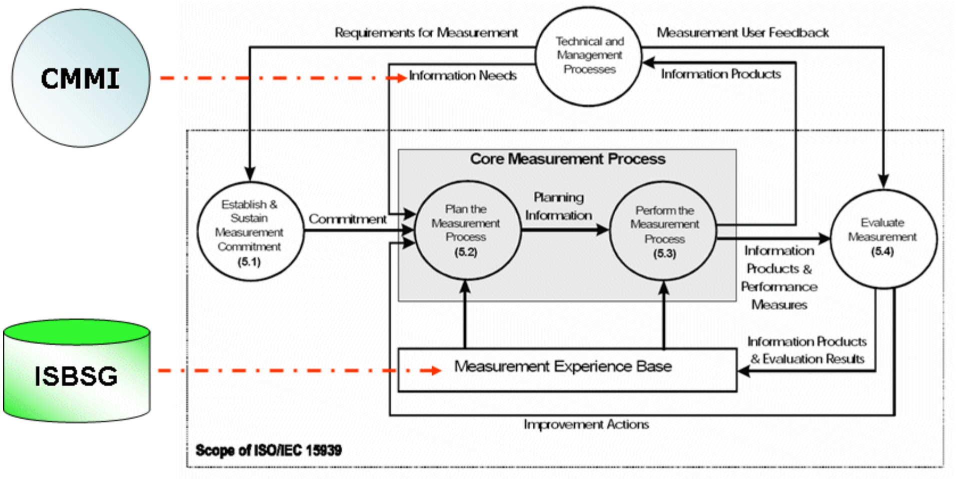
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Figure 14: CMMI, ISBSG and the Software Measurement Model

Finally, even if ISO 15939 and CMMI could be used as a starter kit and the ISBSG is used as a turnkey solution, it is important to keep in mind that information needs must be identified both by and for the business.

[2] The ISO is currently working on the next release of ISO 9126, which will be published as part of the ISO 25000 series.

7. References

[1] ISO, *IS 15939:2002, Information technology – Software engineering – Software measurement process*, International Organization for Standardization, Geneva, 2002.

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8. Appendix A - Tables

Information Needs CMMI Level 2	Measurement Interest Areas							
	Requirements	Analysis	Design/ Implementation	Verification/ Validation	Configuration Management	Project Management	Quality Assurance	Training
Requirements Management								
Mentioned	1.1.3, 1.2.2, 1.3.1, 1.3.3, 1.5.1							
Recommended								
Required								
Project Planning								
Mentioned		2.2.3				3.3		
Recommended						1.2.2, 1.4.1, 1.4.3		
Required								
Project Monitoring and Control								
Mentioned						2.1.1, 2.3.2		
Recommended						1.1.1 to 1.1.5		
Required								
Supplier Agreement Management	This process area has not been considered in the analysis since the information needs extracted from all other process areas may also be applied to the suppliers.							
Measurement and Analysis	This process area has not been considered in the analysis since it takes the software measurement process and formulates it in terms of goals and practices. This process area is fully compatible with ISO 15939.							
Process and Product Quality Assurance								
Mentioned							1.1.3, 1.2.3	
Recommended								
Required								
Configuration Management								
Mentioned					2.1.1, 2.1.2, 3.2.1			
Recommended								
Required								
Generic Goals								
Mentioned							2.8.1, 2.9	
Recommended								
Required								

Table 1 – Detailed analysis of CMMI Maturity Level 2 practices

Information Needs CMMI Level 3	Measurement Interest Areas							
	Requirements	Analysis	Design/ Implementation	Verification/ Validation	Configuration Management	Project Management	Quality Assurance	Training
Requirements Development								
Mentioned		3.5.1						
Recommended	3.2.1, 3.3.1, 3.3.4							
Required	3.3.5							
Technical Solution								
Mentioned		1.3.1		3.1.3, 3.1.4, 3.2.5				
Recommended			2.1.3, 2.1.4, 3.1.2					

Information Needs CMMI Level 3	Measurement Interest Areas							
	Requirements	Analysis	Design/ Implementation	Verification/ Validation	Configuration Management	Project Management	Quality Assurance	Training
Required								
Product Integration								
Mentioned			2.1.1	3.4.6				
Recommended								
Required				3.3.1, 3.3.2				
Verification								
Mentioned								
Recommended								
Required				2.2.2 to 2.2.7, 3.1.1, 3.1.2, 3.2.1 to 3.2.5				
Validation								
Mentioned				2.1				
Recommended								
Required				2.2.1 to 2.2.5				
Organizational Process Focus								
Mentioned								
Recommended							1.2.5, 1.2.6, 2.4.6	
Required							2.4.5	
Organizational Process Definition								
Mentioned								
Recommended								
Required							1.4.1 to 1.4.8	
Organizational Training								
Mentioned								
Recommended								
Required								2.2.1 to 2.2.4
Integrated Project Management								
Mentioned								
Recommended						1.3.7		
Required						1.2.2, 1.3.2, 1.4.3, 1.5.2		
Risk Management								
Mentioned								
Recommended		2.2.1 to 2.2.3, 3.1.1						
Required								
Decision Analysis and Resolution								
Mentioned		1.5.1, 1.6						
Recommended								
Required								
Generic Goals								
Mentioned								
Recommended								
Required							3.2.1	

Table 2 – Detailed analysis of CMMI Maturity Level 3 practices

Information Needs CMMI Level 4	Measurement Interest Areas							
	Requirements	Analysis	Design/ Implementation	Verification/ Validation	Configuration Management	Project Management	Quality Assurance	Training
Organizational Process Performance								
Mentioned								
Recommended								
Required							1.2.1 to 1.2.4, 1.4.1, 1.4.2, 1.5.1, 1.5.2	
Quantitative Project Management								
Mentioned								
Recommended								
Required						1.1.3 to 1.1.5, 1.2.3, 1.3.4, 1.4.1 to 1.4.4 2.1 to 2.4		

Table 3 – Detailed analysis of CMMI Maturity Level 4 practices

Information Needs CMMI Level 4	Measurement Interest Areas							
	Requirements	Analysis	Design/ Implementation	Verification/ Validation	Configuration Management	Project Management	Quality Assurance	Training
Organizational Innovation and Deployment								
Mentioned								
Recommended							1.2	
Required							2.3	
Causal Analysis and Resolution								
Mentioned							1.1, 1.2	
Recommended								
Required								

Table 4 –Detailed analysis of CMMI Maturity Level 5 practices

Information Types ISBSG	Measurement Interest Areas							
	Requirements	Analysis	Design/ Implementation	Verification/ Validation	Configuration Management	Project Management	Quality Assurance	Training
Project Process								
Process Infrastructure						7	8, 9, 10, 11	
Planning						12, 14, 15, 16, 17, 18, 19	13	
Specification	22, 24, 25					24, 26	21, 23	
Design	31		29		30	29, 32	27, 28	
Build or Programming			35		36	35, 37	33, 34	
Test				40	41	40, 42	38, 39	
Implementation or Installation				46	44, 47	46, 48, 49	43, 45	
Project Management and Monitoring							50, 51, 52	
Technology								
General Information							53, 54, 55, 56, 57, 58, 59	

Information Types ISBSG	Measurement Interest Areas							
	Requirements	Analysis	Design/ Implementation	Verification/ Validation	Configuration Management	Project Management	Quality Assurance	Training
People and Work Effort								
Development Team						60, 65, 66	61, 62, 63, 64	
Customer and End Users						67, 68, 69, 70, 71		
IT Operations						72, 73		
Work Effort Validation						77, 78	74, 75, 79, 80, 81	
Product								
General Information						83, 84, 85, 86, 87, 88		
COSMIC Project Functional Size								
New Development or Redevelopment Software Size	92, 93					92, 93	89, 90, 91	
Enhancement Software Size	98, 99, 100, 101, 102						94, 95, 96, 97	
Context of the Functional Size Measurement	105, 106			109		107	108, 110, 111, 112	
Experience of the Functional Counter							114, 115	113, 116, 117
Project Completion								
General Information			124	123		118, 119, 120		
User Satisfaction Survey				125, 126				
Project Costs						128		
Cost Validation						129, 130, 133, 134	131	

Table 5 – Detailed analysis of the ISBSG questionnaire