

Configuration Management Measures in CMMI

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Abstract

Configuration management is an important activity throughout the software development lifecycle (SDLC). Configuration management is a managerial discipline that aims at providing consistency and accuracy of product knowledge throughout its lifecycle. Configuration management plays a vital part in both the system's and product life cycle to provide visibility and control. Our research will set common measures for the three specific goals and related seven specific practices of configuration management Process Area in Capability Maturity Model Integration (CMMI). The CMMI is a frame for assessment and improvement of software systems. The process we used to set the measures is to implement the Goal Questions Metrics (GQM) model on the three specific goals and related seven specific practices of configuration management Process Area in CMMI.

Keywords: Configuration, Management, Measures, CMMI, GQM.

INTRODUCTION

Configuration Management (CM) is a primary activity throughout the software development lifecycle (SDLC). CM becomes essential if any of the artefacts is to be changed during the life cycle. There are many methods which can be used in configuration management to streamline the work and produce the quality to the software development process. For this purpose, most of the software development companies also adopt configuration management practices with larger teams to implement these practices [21].

This research will classify general measures for the specific goal and its specific practices of Configuration Management Process Area (PA) in Capability Maturity Model Integration (CMMI). CMMI is produced by Software Engineering Institute (SEI) at Carnegie Mellon University in the USA. The CMMI is a framework for development and evaluation of information systems. The method we used to set the measures, is to apply the Goal Questions Metrics (GQM) paradigm to the specific goals and its specific practices of Configuration Management Process Area in CMMI.

Configuration management is an administrative discipline which is aiming at providing accuracy and consistency of

product information during its lifecycle and for the same purpose, it is being used in different extents in many of the organizations. The main purpose of CM is to be sure that in all the stages of the product lifecycle, changes to product components such as requirements, design, and information of both software and hardware aspects are confirmed and assessed before being implemented and recorded and then followed after implementation. Configuration management ensures that products and instruments including all components are precisely described all the time [34].

It is written by many researchers that executing effective configuration management processes not only increase the safety in organizations, but also has clear positive effects on return on investment, costs of the product, deliveries dates and product quality [34].

Software configuration management activities have been considered the entry point to stringent software development, where multiple organizations collaborate in a decentralized process to save resources, guarantee the quality of the variety of software products, and manage mutual information to get a better financial return [8]

Configuration management (CM) is an active way for project managers to use a formal process in order that they can manage changes and status during the lifecycle [2]. Configuration management of software is a way of getting control of the software development process and is known as a correlative part of quality-oriented product development regardless of the methodology of development [9]

Configuration management is an important process in product development. The objective of configuration management is to set and maintain the integrity of work products using configuration identification, configuration status accounting, configuration control, and configuration audits [39].

Configuration management (CM) can be defined as “a management activity for establishing and maintaining consistency of performance of products, functional, and physical attributes of requirements, design and operational information during its life”. Configuration management plays an important part in both the system development and product life cycle to provide control and visibility on levels of status and performance [1].

Measures help us to be sure that the project is under control.

Measures of a software system implement to processes, products, and people [10]. Software measures support us to control, understand, and assess the processes, products, and software systems from the aspect of controlling, understanding, assessing, tracing, and forecasting [14]. Measurements help projects to achieve objectives in software development [19] and [11].

Measures are helpful for project management [29]. Measures are necessary for effective management of processes. The measurement is a way for assessing and predicting software processes and products [3]. For developing a software process we should define related attributes of the process, and then set relevant metrics of these attributes, and then use the set of the determined metrics to enhance the process. Measurement practices perform an important role in recognizing and controlling processes and products in software projects [28].

“During software measures, we attach numbers or symbols to attributes of the selected objects in the real life in such a way to identify the attributes by some determined rules” [13]. Measures are essential for project process understanding, managing, and change [12]. Measurement is used to conclude status in respect to plans, to judge accomplishment of goals, and to reach an agreement of processes and products, and to support process improvement [35] and [32].

Software measures are in a level which specification, policies, and practices are yet being defined and combined. We don't think that we will reach quantitative rules that are essentially reliable and ready and hold the same consistency and accuracy as the rules of physics. The description of relevant metrics which are sound may be long-dated research and analysis object, which cannot be achieved in the nearer future [7]. Precise metrics such as velocity and voltage are rare in the software measures area. Software measurements are usually subject to argument [37]. We need to establish a structure of effectiveness metrics [15].

A study started by the Software Engineering Institute (SEI) in the mid-1980s to verify the capability of software developers. The result of the research was the construction of Software Capability Maturity Model for Software (CMM/SW) [36]. Software Engineering Institute (SEI) and other software companies from the related field are joining to produce the Capability Maturity Model Integrated (CMMI) framework. The CMMI is a comprehensive structure that used extensively for enhancing the processes of projects to produce qualified products [38].

CMMI framework provides professional practices to reach a definite quality level for process development. The important objective of CMMI is to enhance the software products to be accepted by the users and satisfy system requirements. Using CMMI model to enhance and evaluate software quality is an important need for organization's continuity and strategy [33].

While processing using CMMI, we attempt to arrive the

following goals: enhancing project management, improving the quality of the product, developing productivity, and improving the estimation of the project budget and schedule [30] and [44].

CMMI model covers a number of processes associated with software development. CMMI describes several software development Process Areas (PA). Every process area holds general goals, general practices, specific goals, specific practices, and some related work products. After appraisal CMMI decides the satisfaction of a process area. CMMI clearly defines its practices and activities in a well-structured and easy way [20].

Every chosen process area in CMMI framework has general goals and related general practices, specific goals and related specific practices. The specific goal describes what must be done in the process area to be satisfied. The specific practice is a central action for the associated specific goal to be realised. In CMMI, specific practices are recognized as goals rather than the way to realise the goal [41] and [43].

CMMI assists process improvement and enhance process quality. The CMMI includes all activities in the software development and affects many processes and products in software life cycle [42]. Capability maturity model integration (CMMI) grows and becomes a well-known accepted standard of software process enhancement as it covered a suitable level of details [40].

Goal-Question-Metric (GQM) is a way for specifying metrics. Basili and Weiss [5] developed GQM for identifying effective metrics for software development activities. GQM proved that it is a usefull strategy for identifying and executing metrics.

This paper names measures for the three specific goals and seven specific practices related to configuration management process area which is in level 3 in CMMI-SW (Staged Representation) model. The define measures will be issued by applying the Goal-Question-Metrics method to the three specific goals and related seven specific practices in configuration management process. We evaluate and control products and processes in configuration management using the set of the defined measures.

The remainder of our paper is structured as the following: next section explains the related work for both CMM/SW and CMMI, section three and section four explain a summary of the CMMI/SW and GQM, section five presents the applying of the GQM to the three specifig goals and seven specific practices of configation management resulted in the definition of measures, section six proves the validity and reliability of the defined measures, and section seven presents conclusions.

RELATED WORK

Various researches in measuring the software process have been suggested, including: [6] [16] [18] [22] [23] [24] [25] [26] [27] [31] and [36]. The most related to our work are [6] [31] [36] [22] [23] [24] [25] [26] and [27]. Baumert and McWhinney research [4] specifies a collection of notices that are helpful to measure the practices (general characteristics) defined in the Capability Maturity Model for CMM/SW. The specified notices include thirteen classes, which are not happen in all maturity levels. The work of Baumert and McWhinney don't concentrate on a definite process. Their effort was regarding to CMM not CMMI.

A collection of patterns of metrics (one of the common features) were determined by Paulk and others [36] which are related to the Capability Maturity Model for Software (CMM/SW) in Key Process Areas (KPAs). In their effort, they named some patterns involved with requirements management KPA. Their effort don't concentrate on a definite process. Their effort was regarded to (CMM/SW) not (CMMI/SW). Loconsole researches [28] specified a collection of measures for the Requirements Management Key Process Area in CMM/SW. Her effort was regarded to (CMM/SW) but not (CMMI/SW). Khraiweh searches [22] [23] [24] [25] [26] and [27] determines a collection of measures for Risk Management, Project Planning, Project Monitoring and Control, Requirements Validation, and Process and Product Quality Assurance processes in CMMI/SW.

Our paper describes a collection of general measures for the Configuration Management process in CMMI/SW. The measures we determined are relevant to the three specific goals and their relevant seven specific practices in Configuration Management Process.

OVERVIEW OF THE CMMI-SW

CMMI/SW (Staged Representation) includes five levels of maturity: Initial, Managed, Defined, Quantitatively Managed and Optimizing. Each of the five levels have several process areas excluding level1 [39].See Figure 1.

A process area possesses general goals with related general practices and one or more specific goals with related specific practices. The specific goal controls the characteristics that specify what must be done to perform the process area. A practice is an action that need to be performed to achieve the related specific goal [39]. A generic goal holds proper institutionalization exercises; because the one goal associated to different processes they called generic, as shown in figure 2.

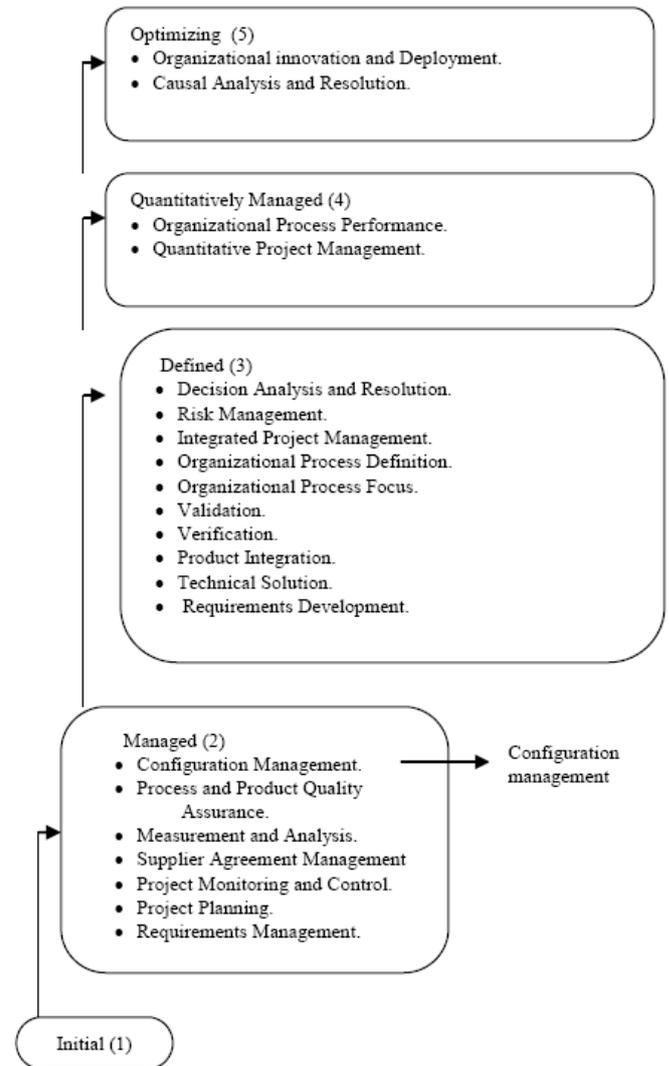


Figure 1: The five levels of maturity in CMMI with related Process Areas

Building and managing the integrity of work products is purpose of Configuration Management (CM) by applying configuration identification, control, status accounting, and audits [39].

The specific goals and the specific practices related to each specific goal for Configuration Management process are:

1 - Establish baselines:-

- 1.1 Identify configuration items.
- 1.2 Establish a configuration management system.
- 1.3 Create or release baselines.

2 - Track and control changes.

- 2.1 Track change requests.
- 2.2 Control configuration items.

3 - Establish integrity.

- 3.1 Establish configuration management records.
- 3.2 Perform configuration audits.

OVERVIEW OF THE GQM

Organizations use Goal/Question/Metric (GQM) paradigm to concentrate on the measures of their objects. An organization should determine goals before gathering data when using GQM model [3]. If the process is experienced then it is clear and easy to be measured. After defining goals a set of quantifiable questions related to the goals are defined then a set of measures associated to the questions are defined next gather data that lead to realizing the goals.

Three steps in GQM model:

1. Defining a set of goals linked to the requirements of projects in the organization [4].
2. Generating a set of quantifiable questions, so the set of defined goals is led to quantifiable questions and focusing on measurement. Various sets of instructions to analyze questions linked to products or processes were defined by Basili and Rombach [3].
3. Generating a set of measures that are fit to the quantifiable questions. This step specifies measures that present information to answer the quantifiable questions. Many measures may be specified for the goal. The measure may refer to various questions.

implemented to the GQM model.

Configuration Management process has the following seven specific practices:

1. Identify configuration items: Identify configuration items, components, and related work products to be placed under configuration management.
2. Establish a configuration management system: Establish and maintain a configuration management and change management system for controlling work products.
3. Create or release baselines: Create or release baselines for internal use and for delivery to the customer.
4. Track change requests: Track change requests for configuration items.
5. Control configuration items: Control changes to configuration items.
6. Establish configuration management records: Establish and maintain records describing configuration items.
7. Perform configuration audits: Perform configuration audits to maintain the integrity of configuration baselines.

We will apply the seven specific practices as goals on the first step of the GQM. In GQM the next step is to produce a collection of quantifiable questions associated to the seven goals (specific practices). In the third step we define a set of measures that provide the required quantitative data to satisfy the produced questions. We will take into account the work products and sub-practices which are proposed in each of the seven specific practices when we determine the measures.

The following tables describe a set of questions and measures, table 1 to table 7. Every of the tables describes a specific practice (a goal). The questions and measures there are interfering. One measure can provide information to clarify more than one question.

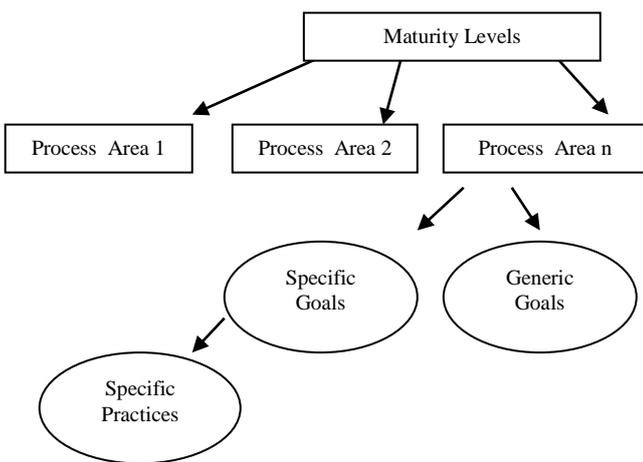


Figure 2: Specific and generic goals

APPLYING GQM TO THE CMMI-SW

Configuration Management process in CMMI/SW has three specific goals and seven related specific practices. In our work we view the specific practices as goals. These goals will be

Measures for specific practice 1.

Identify configuration items: identify configuration items, components, and relevant products to be grouped within configuration management.

The following table describes questions and measures which are related to first specific practice in CM.

Table 1: Questions and measures related to the first specific practice in CM.

	Questions	Measures
Q1	Do you identify configuration items, components, and related work products?	<ul style="list-style-type: none"> • Identifying configuration items, components, and related work products. • # Configuration items. • # Components. • # Related work products. (# means number of)
Q2	Do you select and specify the products delivered to the customer?	<ul style="list-style-type: none"> • Selecting and specifying the products delivered to the customer. • # Selected and specified products.
Q3	Do you designate internal work products? Examples of work products include the following: design, test plans, test results, drawing, source code, user stories, tools, process description, and requirements.	<ul style="list-style-type: none"> • Designating internal work products. • # work products.
Q4	Do you select and specify tools and other capital assets of the project's work environment?	<ul style="list-style-type: none"> • Selecting and specifying tools and other capital assets of the project's work environment. • # Selected and specified tools. • # Selected and specified capital assets.
Q5	Do you select and specify other items used in creating and describing the work products?	<ul style="list-style-type: none"> • Selecting and specifying other items used in creating and describing the work products. • # Selected and specified items used in creating and describing the work products.
Q6	Do you assign unique identifiers to configuration items?	<ul style="list-style-type: none"> • Assigning unique identifiers to configuration items. • # Unique identifiers.
Q7	Do you identify important characteristics of each configuration items such as author and programming language for software code?	<ul style="list-style-type: none"> • Identifying important characteristics of each configuration items. • # Characteristics.
Q8	Do you specify when each configuration item is placed under configuration management?	<ul style="list-style-type: none"> • Specifying when each configuration item is placed under configuration management.
Q9	Do you specify the owner responsible for each configuration items?	<ul style="list-style-type: none"> • Specifying the owner responsible for each configuration items.
Q10	Do you specify relationships among configuration items?	<ul style="list-style-type: none"> • Specifying relationships among configuration items. • # Relationships among configuration items.

Measures for specific practice 2.

Establish a configuration management: build and manage a configuration management and change management system for guiding the products.

The following table describes questions and measures which are related to second specific practice in CM.

Table 2: Questions and measures related to the second specific practice in CM.

	Questions	Measures
Q1	Do you establish and maintain a configuration management system for controlling work products?	<ul style="list-style-type: none"> • Establishing and maintaining a configuration management system. • # work products.
Q2	Do you establish a mechanism to manage multiple levels of control? Examples of levels of control include the following: uncontrolled, work-in-progress, and released? (uncontrolled: anyone can make change, work-in-progress: author control changes, released: a designated authority control changes)	<ul style="list-style-type: none"> • Establishing a mechanism to manage multiple levels of control.
Q3	Do you store and retrieve configuration items in configuration management system?	<ul style="list-style-type: none"> • Storing and retrieving configuration items in configuration management system. • # Configuration items.
Q4	Do you store and recover versions of configuration items?	<ul style="list-style-type: none"> • Storing and recovering versions of configuration items. • # Versions.
Q5	Do you create configuration management reports from the configuration management system?	<ul style="list-style-type: none"> • Creating configuration management reports. • # Configuration management reports.
Q6	Do you revise the configuration management structure as necessary?	<ul style="list-style-type: none"> • Revising the configuration management structure as necessary. • # Revising the configuration management structure.

Measures for specific practice 3.

Create or release baselines: create or release baselines for internal use and for commitment to the customer.

The following table describes questions and measures which are related to third specific practice in CM.

Table 3: Questions and measures related to the third specific practice in CM.

	Questions	Measures
Q1	Do you include hardware, software, and documentation in the baseline for infrastructure related configurations?	<ul style="list-style-type: none"> • Including hardware, software, and documentation in the baseline. • # Items in the baseline.
Q2	Do you create or release baselines only from configuration items in the configuration management system?	<ul style="list-style-type: none"> • Creating or releasing baselines only from configuration items. • # Baselines.
Q3	Do you document the set of configuration items that are contained in a baseline?	<ul style="list-style-type: none"> • Documenting the set of configuration items that are contained in a baseline. • # Configuration items. • # Baselines.

Measures for specific practice 4.

Track change requests: track change requests for configuration parts.

The following table describes questions and measures which are related to the forth specific practice in CM.

Table 4: Questions and measures related to the forth specific practice in CM.

	Questions	Measures
Q1	Do you track the change requests for configuration items?	<ul style="list-style-type: none"> • Tracking the change requests for configuration items. • # Change requests.
Q2	Do you track the new and changed requirements?	<ul style="list-style-type: none"> • Tracking the new and changed requirements. • # Changed requirements.
Q3	Do you track the failure and defects in work products?	<ul style="list-style-type: none"> • Tracking the failure and defects in work products. • # failure and defects in work products.
Q4	Do you determine the impact that the change will have on work products, related work products, the budget, and the schedule?	<ul style="list-style-type: none"> • Determining the impact that the change will have on work products, related work products, the budget, and the schedule. • # impacted work products.
Q5	Do you initiate and record change requests in the change request database?	<ul style="list-style-type: none"> • Initiating and recording change requests. • # recorded change requests.
Q6	Do you analyze the impact of changes?	<ul style="list-style-type: none"> • Analyzing the impact of changes. • # impacted work products.
Q7	Do you categorize and prioritize change requests?	<ul style="list-style-type: none"> • Categorizing and prioritizing change requests. • # change requests.
Q8	Do you review the change requests to be addressed in the next baseline?	<ul style="list-style-type: none"> • Reviewing the change requests. • # reviewed change requests.
Q9	Do you track the status of change requests to closure?	<ul style="list-style-type: none"> • Tracking the status of change requests to closure. • # Tracked change requests.

Measures for specific practice 5.

Control configuration items: control changes to configuration items.

The following table describes questions and measures which are related to the fifth specific practice in CM.

Table 5: Questions and measures related to the fifth specific practice in CM.

	Questions	Measures
Q1	Do you track the configuration of each configuration item, approving a new configuration and updating the baseline?	<ul style="list-style-type: none"> Tracking the configuration of each configuration item. # Tracked the configuration items.
Q2	Do you control changes to configuration items throughout the life of the product or service?	<ul style="list-style-type: none"> Controlling changes to configuration items. # Changes to configuration items.
Q3	Do you obtain authorization before you change configuration items in the configuration management system?	<ul style="list-style-type: none"> Obtaining authorization before you change configuration items. # Changed configuration items.
Q4	Do you archiving the replaced baseline and retrieving the new baseline?	<ul style="list-style-type: none"> Archiving the replaced baseline and retrieving the new baseline. # Replaced baselines. # New baselines.
Q5	Do you perform reviews to ensure that changes have not caused unintended effects on the baseline?	<ul style="list-style-type: none"> Performing reviews to ensure that changes have not caused unintended effects on the baseline. # Changed configuration items.
Q6	Do you record changes to configuration items and reasons for changes?	<ul style="list-style-type: none"> Recording changes to configuration items. # changes to configuration items.

Measures for specific practice 6.

Establish configuration management records: establish and maintain records representing configuration items.

The following table describes questions and measures which are related to the sixth specific practice in CM.

Table 6: Questions and measures related to the sixth specific practice in CM.

	Questions	Measures
Q1	Do you establish and maintain records describing configuration items?	<ul style="list-style-type: none"> Establish and maintaining records describing configuration items. # Configuration items.
Q2	Do you record configuration management actions in sufficient detail, so the status of each configuration item is known and previous versions can be recovered?	<ul style="list-style-type: none"> Record configuration management actions in sufficient detail. # Changes to configuration items.
Q3	Do you ensure that relevant stakeholders have access to configuration status of configuration items?	<ul style="list-style-type: none"> Ensuring that relevant stakeholders have access to configuration status of configuration items.
Q4	Do specify the latest version of the baseline?	<ul style="list-style-type: none"> Specifying the latest version of baseline. # Baselines.
Q5	Do you describe differences between successive baselines?	<ul style="list-style-type: none"> Describing differences between successive baselines. # Baselines.
Q6	Do you identify the version of configuration items that constitute a particular baseline?	<ul style="list-style-type: none"> Identifying the version of configuration items that constitute a particular baseline. # Versions of configuration items.

Measures for specific practice 7.

Perform configuration audits: perform configuration audits to support the integrity of configuration baselines.

The following table describes questions and measures which are related to the seventh specific practice in CM.

Table 7: Questions and measures related to the seventh practice in CM.

	Questions	Measures
Q1	Do you perform configuration audits to maintain the integrity of configuration baseline?	<ul style="list-style-type: none"> • Performing configuration audits to maintain the integrity of configuration baseline. • # baselines.
Q2	Do you confirm that the resulting baseline and documentations conform to a specific standard?	<ul style="list-style-type: none"> • Confirming that the resulting baseline and documentations conform to a specific standard.
Q3	Do you assess the integrity baselines?	<ul style="list-style-type: none"> • Assessing the integrity baselines. • # Baselines.
Q4	Do you review the structure and integrity of items in the configuration management system?	<ul style="list-style-type: none"> • Reviewing the structure and integrity of items in the configuration management system. • # Changes to configuration items.
Q5	Do you confirm completeness, correctness, and consistency of items in the configuration management system?	<ul style="list-style-type: none"> • Confirming completeness, correctness, and consistency of items. • # Changes to configuration items.
Q6	Do you confirm compliance with appliance configuration management standards and procedures?	<ul style="list-style-type: none"> • Confirming compliance with appliance configuration management standards and procedures.
Q7	Do you track items from the audit to closure.	<ul style="list-style-type: none"> • Tracking items from the audit to closure. • # Configuration items. • # Changes to configuration items.

VALIDITY AND RELIABILITY OF THE DEFINED MEASURES

A questionnaire have been made to examine the validity and reliability of the collection of the defined measures for Configuration Management process (CM). The questionnaire will be used to confirm that the defined measures are really measure the seven goals (specific practices). We will use Cronbach alpha reliability in SPSS to examine the data we have collected.

Cronbach alpha is an instrument that can be used to examine the internal consistency. Which means, do all defined measures for each specific practice examine the same goal? The range values of Cronbach alpha are varying between 0 and 1. If alpha is closer to 1 then there is a high internal consistency between the items being evaluated [15]. If the value of cronbach alpha is less than 0.5 then there is a low internal consistency between the items being evaluated, so the items are rejected [15].

We reviewed and confirmed The questionnaire by academics in software engineering department in Zarqa University and

practitioners (designers and programmers) in Zarqa University. We distributed the questionnaire on six software development institutions in Jordan. We have collected one hundred questionnaires. The questionnaires are filled by analysts, designers, and programmers. Each questionnaire consists of seven parts, one part for each goal (specific practice) of the configuration management process (CM). As shown in appendix A, every part includes a group of statements (measures) linked to a specific practice. Every statement has five options: strongly agree, agree, neither agree nor disagree, disagree, strongly disagree. The questioner will record his viewpoint of the statement related to the specific practice by choosing one of the possible five choices.

After implementing the collected data on Cronbach Alpha we found that alpha values between over 0.5 and less than 1 for the seven parts as follows: 0.769, 0.698, 0.780, 0.769, 0.728, 0.698, and 0.793. Which means that the statements (measures) are consistent and have a good reliability and validity to measure the seven specific practices: Identify configuration items, establish a configuration management system, create or release baselines, track change request, control configuration

items, establish configuration management records, perform configuration audits.

CONCLUSION

In our paper we defined common measures for one important process in Capability Maturity Model Integration (CMMI-SW), which is configuration management. We applied the Goal Question Metrics (GQM) model to the seven relevant specific practices of configuration management to define the measures.

By using the set of the defined measures in this paper the organization can have valid insight into the tasks related to configuration management process. We will have a mature configuration management process if we implement the defined measures in this paper. The group of the defined measures can be used to manage and assess software processes and products.

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APPENDIX A

Questionnaire and Analysis

Questionnaire:

The following is a sample of the questionnaire which is constructed for the configuration management process. Configuration management process provides better conclusion about the performance in the project. We can take suitable actions when the project differs obviously from the estimated plan.

The following are the goals of configuration management process:

1. Identify configuration Items.
2. Establish a configuration management system.
3. Create or release baselines.
4. Track change requests.
5. Control configuration items.
6. Establish configuration management records.
7. Perform configuration audits.

To estimate the fulfillment of the defined specific practices (goals), we will determine few sentences linked to each specific practice. The information in these sentences will help us in the realisation of the above seven goals.

Please, fill the form by writing down (√) in the suitable position. Responding to the question: do you think that the following statements have an impact on the realisation of the related specific practice (goal)?

1. Goal1: Identify Configuration Items.

(Do you think that these sentences have an impact on the achievement of goal1: Identify Configuration Items.)

statement serial	statements	Strongly agree	Agree	Neither agree nor disagree	disagree	Strongly disagree
1	Identify configuration items, components, and related work products.					
2	Selecting and specify the products delivered to the customer.					
3	Designate internal work products.					
4	Selecting and specify tools and other capital assets of the project's work environment.					
5	Selecting and specify other items used in creating and describing the work products.					