

Enhancing Quality Software Through CMMI-ISO 9001:2008 and ISO 9126

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Abstract—One of the software development standards in use today is the Capability Maturity Model Integration (CMMI) of the Software Engineering Institute (SEI) and ISO 9126. Based on the 2009 survey conducted by Pornchai Mongkolnam, in Asia there has been a 1,901 CMMI appraisal, to the North American continent as 1328, as many as 536 Europe, and South America 289 CMMI assessment. In India alone there has been a 409 CMMI appraisal, including three world ranking, making India the more trusted by the world International for application development. Meanwhile in Indonesia CMMI implementation is not too meaningful. Only a mixture of two companies (foreign and local) that implements it. That was probably due to the application of the mandatory in the meet (mandatory) from its headquarters abroad or indeed the company began to enter into foreign markets that require CMMI certification. This study seeks to help measure the maturity of software development using an integrated approach between CMMI and ISO 9126 in a local development company. Hopefully this can be more give their views so as to facilitate its peers able to take to implement the same thing.

ISO 9001 is a standard for quality management systems while CMMI is a model for process improvement. If an organization that has achieved ISO registration wishes to improve processes continuously, CMMI can be a strong candidate because it provides a more detailed roadmap for process improvement. However, with respect to

adopting CMMI in organizations that are familiar with ISO 9001, there are some issues that need to be resolved. For example, ISO 9001 and CMMI have different targets, intent, and quantity of detail. In this paper, we present an integrated model of ISO 9001:2000 and CMMI and ISO 9126, which would resolve the above problems. We expect that this model will be a useful tool for ISO registered organizations aim to attain higher CMMI levels.

Keywords— Software • Software Quality • ISO 9126 • CMMI

INTRODUCTION

The fundamental of the software quality from the definition of software quality concept and percept that many people supporting the project affect the software quality product. One of standard is ISO 9001 registered organizations are not likely to implement CMMI with ISO 9001:2008 because such implementation would cause extra efforts brought about by the difference between the two. Therefore it would be a priority to identify the similarities and differences between ISO 9001:2008 and CMMI. Generally, a mapping table between standards to transition one to another is used.

Computers are being used in an increasingly wide variety of application areas, and their correct operation is often critical for business success and/or human safety. Developing or selecting high quality software products is therefore of prime importance. Comprehensive specification and evaluation of software product quality is a key factor in ensuring adequate quality. This can be achieved by defining appropriate quality characteristics, taking account of the purpose of usage of the software product. It is important that every relevant software product quality characteristic is specified and evaluated, whenever possible using validated or widely accepted metrics.(3). Among all the Software-related standards in the worlds, there are few that every person who practices software at least something about ISO standard (1), ISO standard established an influential vocabulary and conceptual for quality (4). The

ISO/IEC 9126 standard has been developed in order to address software quality issues (3), (5), (6),(7)(8)It specifies software product quality

characteristics and sub-characteristics and proposes metrics for their evaluation.

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PREVIOUS RESEARCH

Previous research about application for a wizard based software quality measurement standard ISO 9126. (10), To obtain software quality are expected, measures quality a software product is a critical element of the security device can represent basic study of the specification, design and coding. Organizations must monitor and measure the characteristics of the products to prove that the product requirements have been met. Thus, in this regard is required measurement and monitoring of effective evaluation of the software produced in accordance with existing standards.

Of several standards to evaluate the process of developing a software include Capability Maturity Model Integration and ISO 9126. Integration of these two standards would produce an evaluation standard software development process better and details of the software development process. So we need a tool to facilitate the evaluation of the measurement of software development maturity. This will help the developer and end user benefits that the process of software development is in conformity with the standards and produce a software product is good.

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Maturity measurement applications are tools that can help in the process used to measure the maturity of software development by presenting a few questions. Published in web-based form that allows the user to take measurements anywhere and maturity to help facilitate an evaluation process of software development.

PURPOSE OF THE INTEGRATED MODEL

ISO 9001 requires that processes to be continuously improved even after achieving ISO registration. CMMI can be a good to an organization in the software and systems industry to achieve further process improvement, because CMMI is quite detailed and contains more concepts of 'improvement of process' than ISO 9001:2008. Furthermore, considering that many ISO 9001:1994 registered organizations are trying to introduce SW-CMM, it is expected that many ISO 9001:2000 registered organizations will want to adopt CMMI into their systems. As we described in the Introduction, it is simple to implement ISO 9004:2008 to ISO registered organizations because the structure of ISO 9004:2000 is similar to that of ISO 9001:2008. Therefore, it would be ideal for ISO registered organizations to adopt CMMI if the structure of CMMI is similar to that of ISO 9001:2008 [15].

OVERALL VIEW OF ISO/IEC 9126

ISO/IEC 9126 describes a two-part model for software product quality: a) internal quality and external quality, and b) quality in use. The first part of the model specifies six characteristics

for internal and external quality, which are further subdivided into subcharacteristics.

These subcharacteristics are manifested externally when the software is used as a part of a computer system, and are a result of internal software attributes. This part of ISO/IEC 9126 does not elaborate the model for internal and external quality below the level of subcharacteristics(3).

The characteristics defined are applicable to every kind of software, including computer programs and data contained in firmware. The characteristics and subcharacteristics provide consistent terminology for software product quality. They also provide a framework for specifying quality requirements for software, and making trade-offs between software product capabilities.(11)

This generic quality model can then be instantiated as a model for internal quality or for external quality by using different sets of metrics(7). The model itself is based on the six characteristics functionality, reliability, usability, efficiency, maintainability, and portability(12), (11), And A quality model is a very useful tool for quality requirement engineering as well as quality evaluation. ISO/IEC 9126-1 provides a software product quality model. It is intended to be used as a general purpose default standard quality model(11).

Evaluation of software products in order to satisfy software quality needs is one of the processes in the software development lifecycle. Software product quality can be evaluated by measuring internal attributes (typically static measures of intermediate products), or by measuring external attributes (typically by measuring the behaviour of the code when executed), or by measuring quality in use attributes. The objective is for the product to have the required effect in a particular context of use improving product quality, and product quality

contributes to improving quality in use(3).

The full table of Characteristics and Subcharacteristics for the ISO 9126-1 Quality Model is:-

Characteristics	Subcharacteristics	Definitions
Functionality	Suitability	This is the essential Functionality characteristic and refers to the appropriateness (to specification) of the functions of the software.
	Accuratenesses	This refers to the correctness of the functions, an ATM may provide a cash dispensing function but is the amount correct?
	Interoperability	A given software component or system does not

Characteristics	Subcharacteristics	Definitions
		typically function in isolation. This subcharacteristic concerns the ability of a software component to interact with other components or systems.
	Compliance	Where appropriate certain industry (or government) laws and guidelines need to be complied with, i.e. SOX. This subcharacteristic addresses the compliant capability of software.
	Security	This subcharacteristic relates to unauthorized

Characteristics	Subcharacteristics	Definitions
		ed access to the software functions.
Reliability	Maturity	This subcharacteristic concerns frequency of failure of the software.
	Fault tolerance	The ability of software to withstand (and recover) from component, or environmental, failure.
	Recoverability	Ability to bring back a failed system to full operation, including data and network connections.
	Understandability	Determines the ease of which the

Characteristics	Subcharacteristics	Definitions
Usability		systems functions can be understood, relates to user mental models in Human Computer Interaction methods.
	Learnability	Learning effort for different users, i.e. novice, expert, casual etc.
	Operability	Ability of the software to be easily operated by a given user in a given environment.
Efficiency	Time behavior	Characterizes response times for a given throughput, i.e. transaction rate.
	Resource behavior	Characterizes resources

Characteristics	Subcharacteristics	Definitions
		used, i.e. memory, cpu, disk and network usage.
Maintainability	Analyzability	Characterizes the ability to identify the root cause of a failure within the software.
	Changeability	Characterizes the amount of effort to change a system.
	Stability	Characterizes the sensitivity to change of a given system that is the negative impact that may be caused by system changes.
	Testability	Characterizes the effort needed to verify (test)

Characteristics	Subcharacteristics	Definitions
		a system change.
Portability	Adaptability	Characterizes the ability of the system to change to new specifications or operating environments.
	Installability	Characterizes the effort required to install the software.
	Conformance	Similar to compliance for functionality, but this characteristic relates to portability. One example would be Open SQL conformance which relates to portability of database used.
	Replaceability	Characterizes

Characteristics	Subcharacteristics	Definitions
	ty	es the <i>plug and play</i> aspect of software components, that is how easy is it to exchange a given software component within a specified environment.

MODEL SOFTWARE LIFE CYCLE

The concepts can be mapped on to other models of software life cycles if the user so wishes as

- **STEP #1 QUALITY REQUIREMENTS IDENTIFICATION**

For each of the Quality characteristics and sub-characteristics defined in the Quality model determine the Quality in Use, External and Internal Quality Assigning relative weights will allow the evaluators to focus their efforts on the most important sub characteristics.

- **Step #2 Specification of the evaluation**

This step is applied during every development process activity, For each of the Quality sub-characteristics defined in the Quality model identify the metrics to be applied and the required levels to achieve the User Needs set in Step 1

- **Step #3 Design of the evaluation**

This step is applied during every development process activity. Develop a measurement plan (similar to example in Table 2) containing the deliverables that are used as input to the measurement process and the metrics to be applied.

- **Step #4 Execution of the evaluation**

This step is applied during every development process activity. Execute the evaluation plan and complete the column. process for evaluations may be used as a guidance for planning and executing the measurement process.

- **Step #5 Feedback to the organization**

This step is applied during every development process activity. Once all measurements have been completed map the results and document conclusions in the form of a report. Also identify specific areas where quality improvements are required for the product to meet the user needs.

ISO 9126-4 QUALITY IN USE METRICS

Effectiveness metrics assess the tasks performed by users achieve specified goals with accuracy and completeness in a specified context of use.

- **Task effectiveness**, purpose of the metric whether proportion of the goals of the task is achieved correctly, measurement formula :

$$M1 = |1 - \sum A_i|$$

A :proportional value of each missing or incorrect component in the task output

- **Task Completion**, whether proportion of the tasks are completed, measurement formula :
 $X = A / B$

A: Number of tasks completed

B: total number of task attempted

- **Error Frequency**, wheter the frequency of error.measurement formula :

$$X = A / T$$

A: Number of error made by user

T: time or number of tasks

Productivity metrics assess that users consume in relation to the effectiveness achieved in a specified context of the time to complete the task, although other relevant resources could include the user's effort, materials or the financial cost of usage.

- **Task time**, to measure how long does it take to complete a task, Formula :
 $X = T_a$
Ta : Task Time
- **Task Efficiency**, to measure efficiency are the users
 $X = M1/T$

M1 = task effectiveness

T = task time

- **Economic productivity**, to measure costeffective is the user
 $X = M1/C$

M1 = task effectiveness

C = total cost of the task

- **Productivity proportion**, to measure costeffective is the user
 $X = T_a/T_b$

Ta = productivity time=task-help me

Tb = task time

- **Relative user efficiency**, to measure efficient is a user compared to an expert
Relative user efficiency : X = A/B

A: ordinary user's task efficiency

B: expert user's task efficiency

Safety metrics assess the level of risk of harm to people, business, software property or the environment in a specified context of use .it include the health and safety to the both the user and those affected by use, as well as unintended physical .

- **User health and safety**, to measure the incidence of health problems among users of the product.
 $X = 1-A/B$
A: number of user's reporting RSI
B: total number of user's
- **Safety of people affected by use of the system**, to measure

the incidence of hazard to people affected by use of the system .

$$X = 1 - A/B$$

A: number of people put a hazard

B: total number of people potentially affected by the system

- **Economic damage**, to measure the incidence of economic damage.

$$X = 1 - A/B$$

A: number of occurrences of economic damage

B: total number of usage situations

- **Software damage**, to measure the incidence of software corruption.

$$X = 1 - A/B$$

A: number of occurrences of software corruption

B: total number of usage situations

Satisfaction metrics assess user's attitudes towards the use of products in a specified context of use. Satisfaction is influenced by the user's perception of properties of the software product (such as those measured by the external metrics) and by the user's perception of the efficiency, productivity, and the safety in use.

- **Satisfaction scale**, to measure the satisfied of the user's

$$X = A/B$$

A: questionnaire producing psychometric scales

B: population average

- **Satisfaction questionnaire**, to measured the satisfied of the user's with specific software features

$$X = \Sigma(A_i) / n$$

A): response to a question

n: number of responses

- **Discretionary questionnaire**, to measured the proportion of potential user's choose to use the system.

$$X = A/B$$

A: number of times that specific software functions/application/systems are used

B: number of times they are intended to be used

MODEL OF ISO 9001:2008

ISO 9001:2008 is a necessary requirement for quality management system. It is a part of ISO 9000 family that consist of ISO 9000 (fundamentals and vocabulary), ISO 9001 (requirements), ISO 9004 (guidelines for performance improvements) and ISO 19011 (guidelines for quality and environmental management systems auditing). ISO 9001:2008 is an abstract and sparse document that can be applied to any category of business. ISO 9001 could be interpreted by ISO 9000-3[2] or TickIT[3] when applied to organizations in the software industry. For every requirement in ISO 9001, an organization can choose to have two status, 'satisfied' or 'not satisfied'. If every requirement is satisfied, then ISO registrations achieved. Compared with ISO 9001:2008 ISO 9001:2008 and ISO 9004:2000 are both similar in terms of structure and terminology used to allow easy conversion from one to the other.

Table.1 Method for integration classified according to the correspondence types

Types of correspondence	Methods to integrate models
When ISO 9001:2008 shall-statements (requirements) fully satisfy CMMI practices	ISO 9001:2008 shall-statements are kept and the relationships between CMMI and the integrated model are recorded.
When ISO 9001:2008 shall-statements can or can not satisfy CMMI practices by interpretation	ISO shall-statements are modified - ISO requirements' focus are calibrated by using square brackets ([]). Relationships between CMMI and the integrated model are recorded.
When ISO 9001:2008 shall-statements partially satisfy CMMI practices	Relationships between ISO 9001:2008 shall-statements and CMMI are recorded.

Source :Chanwoo Yet.al.

Table Structure of the integrated model

Integrated model's contents		CMMI
4. Quality management system		
4.1 General requirements		GP 2.1, 2.2, 2.3, 2.4, 2.5, 2.6, 2.8, 2.9, 2.10, 3.1, 3.2
4.2 Documentation Requirements		
4.2.1 General		OPD
4.2.2 Quality manual		OPD
4.2.2.1 Organization's set of standard process		OPD, GP 3.1

Integrated model's contents		CMMI
4.2.2.2 Organization's set of standard process tailoring criteria and guidelines		OPD, GP 3.1
4.2.3 Control of documents		IPM, GP 3.2
4.2.4 Control of records		
4.2.5 Process assets management		OPD, IPM, GP 3.2
4.2.6 Measurement management		OPD
14.3 Decision analysis and resolution		DAR
5. Management responsibility		
5.1 Management commitment		GP 2.10, OEI
5.2 Customer focus		
5.3 Quality policy		GP 2.1
5.4 Planning		
□ 5.4.1 Quality objectives		OPF
5.4.2 Quality management system planning		
5.5 Responsibility, authority and communication		
5.5.1 Responsibility and authority		GP 2.4
5.5.2 Management representative		
5.5.3 Internal communication		
5.6 Management review		
5.6.1 General		GP 2.10
5.6.2 Review input		GP 2.10
5.6.3 Review output		GP 2.10
6. Resource management		
6.1 Provision of resources		GP 2.3
6.2 Human resources		

Integrated model's contents		CMMI
6.2.1 General		GP 2.5
6.2.2 Competence, awareness and training		OT, OEI, GP 2.5
6.3 Infrastructure		GP 2.3
6.4 Work environment		OEI
7. Product realization		
7.1 Planning of product realization		GP 2.2
7.2 Customer-related processes		
7.2.1 Determination of requirements related to the product		RD
7.2.2 Review of requirements to the product		RD, REQM
7.2.3 Customer communication		GP 2.7
7.3 Design and development		
7.3.1 Design and development planning		GG 2, PP, VAL, VER, PMC, GP 2.4, OEI
7.3.1.1 Establishing design and development plan		GP 3.1, PP, IPM
7.3.1.2 Team composition and operation		IPM, IT, OEI
7.3.1.3 Risk management		RSKM
7.3.2 Design and development inputs		
7.3.A Design and development process		
7.3.A.1 Design and development process management		IPM, REQM
7.3.A2 Technical solution		TS
7.3.A3 Product integration		PI
7.3.4 Design and development review		PMC, IPM, RSKM
7.3.5 Design and development verification		VER
7.3.6 Design and development validation		VAL

Integrated model's contents		CMMI
7.3.7 Control of design and changes		CM
7.4 Purchasing		
7.4.1 Purchasing process		SAM, ISM
7.4.2 Purchasing information		
7.4.3 Verification of purchased product		SAM, ISM
7.5 Production and service provision		
7.5.1 Control of production and service provision		
7.5.2 Validation of processes for production the service provision		
7.5.3 Identification and traceability		CM, GP 2.6
7.5.4 Customer property		
7.5.5 Preservation and delivery of product		PI
7.6 Control of monitoring and measuring devices		
8. Measurement, analysis and Improvement		
8.1 General		
8.2 Monitoring and measurement		MA
8.2.1 Customer satisfaction		
8.2.2 Internal audit		OPF, GP 2.9, PPQA
8.2.3 Quantitative project management		QPM
8.2.3.1 Monitoring and measurement of processes		MA, GP 2.8, QPM

Integrated model's contents			CMMI
	8.2.3.2 Monitoring and measurement of product		MA, QPM
	8.2.4 Monitoring and measurement of product		MA
	8.3 Control of nonconforming product		
	8.4 Analysis of data		MA, OPP
	8.4A Measurement management		OPF, MA
	8.5 Improvement		
	8.5.1 Continual improvement		OPF
	8.5.1.1 Selecting improvements		OID
	8.5.1.2 Deploying improvements		OID
	8.5.2 Casual Analysis and Resolution		CAR
	8.5.2.1 Corrective action		OPF, CAR
	8.5.2.2 Preventive action		CAR

Source :Chanwoo Yet.al.

CMMI PROCESS MODEL

CMMI (Capability Maturity Model Integration) is an integrated model of many CMMs intended to achieve process improvement. CMM is a model that contains the essential elements of effective processes for one or more disciplines and describes an evolutionary improvement path from ad hoc, immature processes to disciplined, mature processes with improved quality and effectiveness.

CMMI has two representations. One is the staged representation. The other is the continuous representation. In the staged representation maturity level of an organization ranges from level 1 to 5. In the continuous representation each process capability level ranges from 0 to 5. The staged representation is most suitable for an organization that does not know which processes need to be improved first because the staged

representation offers process areas applicable to

each maturity level. The continuous representation provides flexibility for selecting processes fit for achieving business goal of the organization. CMMI provides 25 process areas (Process areameans a cluster of related practices in an area that,when implemented collectively, satisfies a set of goals considered important for making significant improvement in that area. Goals are classified as generic goals and specificgoals. A generic goal describes the characteristics thatmust be present to institutionalize the processes thatimplement a process area. A specific goal describesthe unique characteristics that must be present to

satisfy the process area. Practices are expected components for satisfying goals. Practices are classified as generic practices andspecific practices. A generic practice is the descriptionof an activity that is considered important in achievingthe associated generic goal. A specific practice is thedescription of an activity that is considered important

in achieving the associated specific goal.

CMMI Process model

The Capability Maturity Model Integration [5] describes the characteristics of effectiveprocesses. It is a process improvement approach that provides organizations with the essentialelements of effective process. CMMI best practices enable organizations to do thefollowing:

- link management and engineering activities to their business objectives,
- expand the scope of and visibility into the product lifecycle and engineering activities to ensure that the product or service meets customer expectations,
- implement more robust high-maturity practices,
- incorporate lessons learned from additional areas of best practices,

- more fully comply with relevant ISO standards,
- address additional organizational functions critical to their products and services.

This model can be used in such a way as to define the Maturity Level (ML) of the

organization, taking into account its software process, as to guide an improvement

process work.

There are five MLs and each of this level acts as a foundation for the following

level and indicates the capability of the organization software process.

In ML 1 – Initial, the success of the organization depends on the efforts of the people.

In ML 2 – Repeatable, organization already possesses a plan for new projects based

on its specifications and experiences of similar projects.

For ML 3 – Defined, there is existence of a standard software process for all the organization.

In ML 4 – Managed, the organization keeps a quantitative control of the software

process quality and of the software products quality.

At ML 5 – Optimizing, organization provides a continuous improvement of its software processes in an organizational way.

The latest version of CMMI ver 1.2 was released in August 2006. There are 3 constellations of CMMI in the new version: CMMI Development, CMMI Services and

CMMI Acquisition.

CMMI for Development Ver 1.2 consists of 22 process areas with capability or

maturity levels.

CMMI should be adapted to each individual company, therefore companies are not

“certified.” A company is appraised (e.g. with an appraisal method like SCAMPI) at a

certain level of CMMI.

The CMMI provides a framework for process improvement that consists of Process

Areas (PAs), to be influential in various aspects of the development process and

resultant software quality.

The processes are divided into four categories namely:

- a) Process Management,
- b) Project Management,
- c) Support and
- d) Engineering.

Each ML focuses on different processes with these four categories.

The PAs contain goals and best practices, specific and generic, and subpractices

that the employees must control to reach the goals [9].

METHOD OF INTEGRATION OF ISO 9126 AND CMMI

The integration of a process model and a standard for software product quality propose

practical alternative for software producing organizations. A method is to analyze

examples of a software process model that has potential for the use of ISO 9126

standard.

The activities that encompasses PAs describe how to establish the software process

capability. Implementing the norm ISO 9126 in the PAs of the activities define what

must be done to establish the software process capability.

In other words, the CMMI based process improvement can result in better project

performance and higher quality products if the measures of performance and some

related practices are used in conjunction with the ISO 9126 norm.

There are a lot of chances of CMMI application points of ISO 9126 concepts use.

Using the ISO 9126 norm in examples of the CMMI must be simple and easy to

implement, some examples are described:

Requirements Management (RM) – a Process Area for ML 2: Repeatable

The purpose of RM is to manage the requirements of the project's products

and product components and to identify inconsistencies between those

requirements and the project's plans and work products.

In order to add value to this purpose the incorporation of ISO 9126 into software process is to establish mutual agreement between the requirements provider and requirements receiver so that commitment to the requirements is obtained from the

project participants.

Organizational Process Focus (OPF) – PA for ML 3: Defined

The purpose of OPF is to plan and implement organizational process

improvement based on a thorough understanding of the current strengths and

weaknesses of the organization's processes and process assets.

The improvements of the organizational processes with the incorporation of ISO

9126 may be obtained from various resources including product evaluation activities

that will improve organization's overall software process and product capability.

Causal Analysis and Resolution (CAR) – PA for ML 5: Optimizing

The purpose of CAR is to identify causes of defects and other problems and take

action to prevent them from occurring in the future.

The incorporation of ISO 9126 into process is the identification of problems in

reaching goals related to the product characteristics [9].

Method to make the integrated model CMMI and ISO 9001:2008

With applied the concise N-N mapping for the

integrated model while the concise N-N mapping was

derived by using a N-N mapping some changes

need to be made to the mapping table. First, many

practices have dependencies among one another, and

the N-N mapping table does not preserve these

dependencies. Therefore, we need to place dependent

practices in an adequate place together. Second, the

concise N-N mapping may possibly make the

relationship between CMMI practices and ISO

9001:2008 requirements too simple. Thus, in order to

resolve this, some additional explanations on the

relationships between CMMI practices and ISO

9001:2008 requirements should be added to the

integrated model. Third, granularity of the integrated

model is another issue. CMMI assesses that a process

area is satisfied only when all the goals in the process

area are satisfied. In other words, each goal in the

process area is a primitive unit to be assessed.

However, if the goals in CMMI are selected for the

target of the integrated model, then the relationship

between ISO 9001:2008 and CMMI can become "All

Match". Therefore, practices in each process area are

selected as the CMMI-side target of the integrated

model.

After developing a concise N-N mapping, CMMI

practices were merged with ISO 9001:2008

requirements using the method [15].

CONCLUSIONS

we proposed an integrated model by inserting CMMI practices into ISO 9001:2008 requirements. And ISO 9126 We expect that this model will be helpful to implementation of Quality Managorganizations ament Sysytem based in ISO, it will allow existing ISO assets to be re-used without redundant efforts. In addition, the model will help organizations to perform gap analysis and maintain their quality manual without any difficulty when adopting CMMI. And, even if an organization does not have ISO registration but plans to adopt CMMI only, the organization will be able to implement ISO 9001:2008 and CMMI simultaneously by this integrated model for the software's product. In future research, we plan to conduct experiments to confirm how effective this model will be real application..

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