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Measuring the Software Product Quality during the Software Development Life-Cycle: An International Organization for Standardization Standards Perspective

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Abstract: Problem statement: The International Organization for Standardization (ISO) published a set of international standards related to the software engineering, such as ISO 12207 and ISO 9126. However, there is a set of cross-references between these two standards. **Approach:** The ISO 9126 on software product quality and ISO 12207 on software life cycle processes had been analysed to investigate the relationships between them and to make a mapping from the ISO 9126 quality characteristics to the ISO 12207 activities and vers versa. **Results:** This study presented a set of comments and suggestions to improve the ISO 9126. **Conclusion:** The weaknesses of the cross-references between the two ISO standards had been highlighted. In addition, this study provided a number of comments and suggestions to be taken into account on the next version of the ISO 9126 international standard.

Key words: ISO 9126, ISO 12207, ISO software engineering standards, software life cycle processes, software product quality evaluation, software product measurement

INTRODUCTION

The last decade of 20th century has seen a rapid increase in the use of the software products in a variety of application areas and their correct operation is often critical for business success and human safety. This trend is expected to continue in light of the progress and utilization of the measurement evaluation of software product quality, particularly from the international standardization perspective.

In the area of software engineering, the concept of software measurement (or what is commonly called software 'metrics') is not new. Since 1972, a number of so-called software 'metrics', or 'measures', have been developed.

In order to standardize the software product quality measurement process, in 1991, the ISO published its first international consensus on the terminology for the quality characteristics for software product evaluation: This standard was called "software product evaluation-quality characteristics and guidelines for their use" (ISO 9126: 1991)[5]. From 2001-2004, the ISO published an expanded version, containing both the ISO quality models and inventories of proposed measures for these models (ISO 9126 parts 1, 2, 3 and 4)[9,11,12].

Since 1991, ISO produced a number of International Standards (IS) and Technical Reports (TR) related to the software engineering. However, in this study we have highlighted the ISO 9126 metrics and their relationships to the ISO 12207 software life cycle processes and activities. In other words, this study explains which software metrics you can compute during the software life cycle.

In 2002, ISO produced the ISO 15939 international standard[8] which contains the definitions of the terms to be used in the software measurement process, including the term 'measure' instead of the term 'metrics'. However, in this study we will use the term 'metrics' in order to be aligned with the four parts of the ISO 9126 international standard.

The current version of the ISO 9126 international standard consists of inventories of proposed metrics to measure the quality of the internal, external and in-use software product. However, for each of these metrics there is a cross-reference on where they could be measured during the ISO 12207 Software Life Cycle Processes and activities (SLCP). This study provides a mapping between these two standards to highlights the weaknesses of these cross-references and proposes a way to address them and it provides an approach to use the ISO 9126 metrics to measure the software quality during the software life cycle.

The International Organization for Standardization (ISO) published a set of international standards related to the software engineering. However, some of these international standards have many relationships between them. This study investigates the relationships between ISO 9126 on software product quality and ISO 12207 on software life cycle processes.

However, the relationships between them are many-to-many relationships since each of ISO 9126 characteristic/subcharacteristic could be measured in different ISO 12207 software life cycle processes and activities and in each ISO 12207 software life cycle process or activity we can measure different ISO 9126 characteristics/subcharacteristics. Furthermore, this study highlights the weaknesses and the cross-references between the two ISO standards. Finally, a number of suggestions and comments have been addressed.

Recently, the ISO has recognized a need for further enhancement of ISO 9126 International Standard, primarily as a result of advances in the fields of information technologies and changes in environment[3]. Therefore, the ISO is now working on the next generation of software product quality standards[12], which will be referred to as Software Product Quality Requirements and Evaluation (SQuaRE-ISO 25000 series). This series of standards will replace the current ISO 9126 International Standard. However, many researches have focused on some weaknesses on the current ISO 9126 and even on the draft versions of the upcoming new ISO 25000 series of standards (SQuaRE)[1,2].

MATERIALS AND METHODS

ISO 9126 on software quality measurement: The ISO 9126 series of standards now consists of one international standard[7] and three technical reports[11,12]:

- ISO 9126-1: Quality model[7]
- ISO TR 9126-2: External metrics[9]
- ISO TR 9126-3: Internal metrics[10]
- ISO TR 9126-4: Quality in-use metrics[11]

The first document of the ISO 9126 series-Quality model-contains two-part quality model for software product quality[7]:

- Internal and external quality model
- Quality in-use model

The first part of the two-part quality model determines six characteristics in which they are subdivided into twenty-seven subcharacteristics for internal and external quality, as in Fig. 1[7]. These subcharacteristics are a result of internal software attributes and are noticeable externally when the software is used as a part of a computer system. The second part of the two-part model indicates four quality in-use characteristics. All the quality characteristics and their corresponding sub-characteristics are defined in ISO 9126-1[7].

The 2nd, 3rd and 4th documents of the ISO 9126 series provide the following information[11,12]:

- Sets of metrics for each external quality sub-characteristic, internal quality sub-characteristic and quality in-use characteristic
- Explanations of how to apply and use these sets of metrics
- Examples of how to apply these metrics during the software product lifecycle

ISO 12207 on software life cycle processes: It consists of processes, activities for each process and tasks for each activity[5,7]. Figure 2 shows the software life cycle processes, the number of activities in each process and the number of tasks in each process. The full list of the process, activities and tasks can be seen in ISO 12207[6] and IEEE/EIA 12207[4] (the IEEE/EIA 12207 is the IEEE version of the ISO 12207).

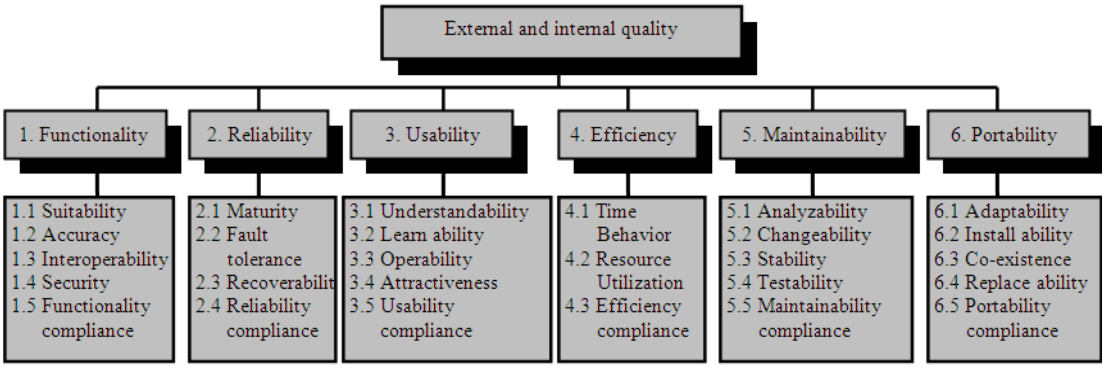

Fig. 1: ISO 9126 quality model for external and internal quality (characteristics and sub-characteristics)[7]

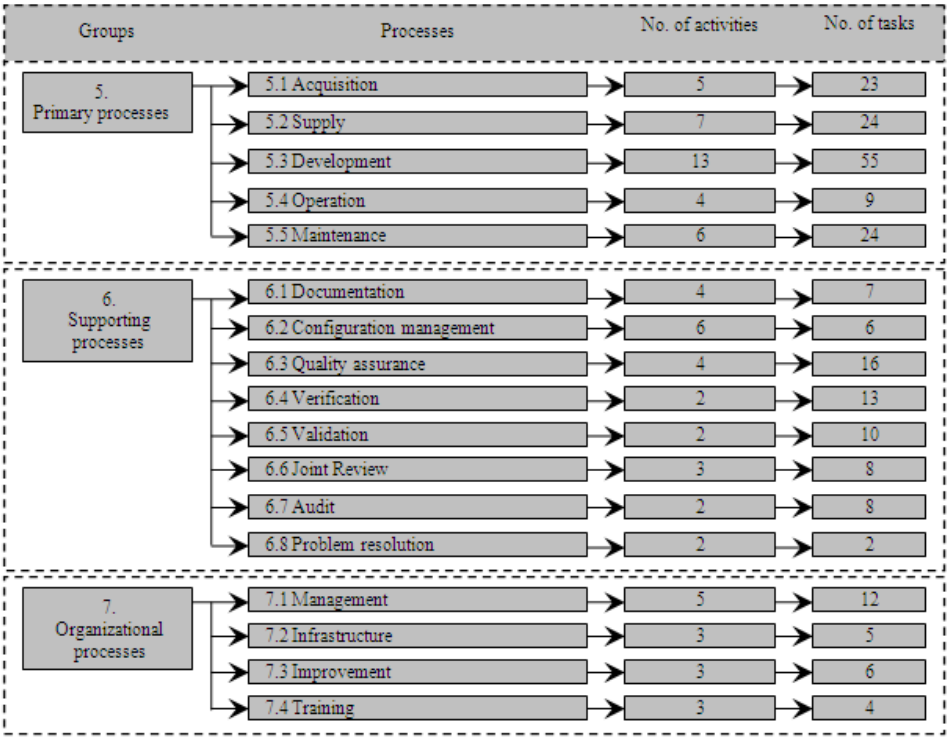

Fig. 2: ISO 12207 software life cycle processes, activities and tasks

The ISO 12207 software life cycle processes are grouped into three broad classes: Primary; supporting and organizational. Primary processes are the prime movers in the life cycle; they are acquisition, supply, development, operation and maintenance. Supporting processes are documentation, configuration management, quality assurance, joint review, audit, verification, validation and problem resolution. A supporting process supports another process in performing a specialized function. Organizational processes are management, infrastructure, improvement and training. An organization may employ an organizational process to establish, control and improve a life cycle process.

RESULTS

For each metric of the internal, external and in-use metrics, the ISO 9126 parts 2-4 provides the following information: metric name, purpose of the metric, method of application, measurement formula, interpretation of measured value, metric scale type, measure type, input to measurement, ISO 12207 SLCP Reference and target audience[11,12].

Hereinafter we will discuss the detailed mappings between the ISO 9126 quality metrics of the Internal, external and in-use software product and the ISO 12207 software life cycle processes and activities will be provided. Furthermore, this mapping will focus on an investigation of the "ISO 12207 Software Life Cycle Processes (SLCP) References" provided by ISO 9126 for each of its metrics.

Internal quality metrics: Within the ISO 9126-3 on software product internal quality metrics, there are 70 metrics. These metrics can be measured during the software life cycle. Internal quality defined in ISO 9126-1 as the totality of characteristics of the software product from an internal view. Internal quality is measured and evaluated against the internal quality requirements. Details of software product quality can be improved during code implementation, reviewing and testing, but the fundamental nature of the software product quality represented by internal quality remains unchanged unless redesigned[10].

Table 1 shows the number of internal quality metrics which can be measured during each of the ISO 12207 software life cycle processes. For example, within the "verification process" (of the "supporting processes") 59 metrics can be measured.

Table 1: Mapping between the ISO 9126 internal quality metrics and the ISO 12207 processes

ISO 12207 processes	No. of related ISO 9126 metrics
5.0 Primary life cycle processes:	
5.1 Acquisition	0
5.2 Supply	0
5.3 Development	1
5.4 Operation	0
5.5 Maintenance	0
6.0 Supporting life cycle processes:	
6.1 Documentation	0
6.2 Configuration management	0
6.3 Quality assurance	2
6.4 Verification:	59
6.5 Validation	13
6.6 Joint review	59
6.7 Audit	0
6.8 Problem resolution	4

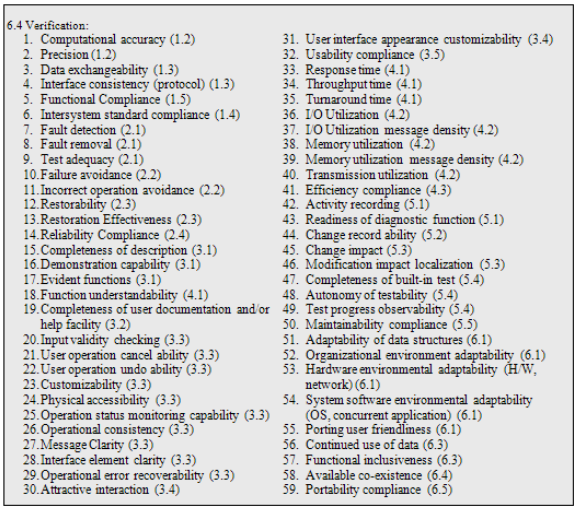

Fig. 3: Example on the ISO 9126-3 internal quality metrics and where they could be measured during the ISO 12207 software life-cycle processes and activities

As an example, Fig. 3 shows a detailed structure of the software product internal quality metrics' names and where they can be measured during the verification process (which is a part of the ISO 12207 supporting process) along with the corresponding characteristic and subcharacteristic reference number for each of those metrics (for example 1.2 means the accuracy subcharacteristic of the functionality characteristic). In Fig. 3 only the software life processes/activities which have internal quality metrics are mentioned.

However, from Table 1 we can note that there is no any metric which could be measured during 4 out of 5 primary life cycle processes. This means that there is no any metric from ISO 9126 external quality metrics could be useful during the acquisition, supply, operation and maintenance primary life cycle processes.

Table 2: Mapping between the ISO 9126 external quality metrics and the ISO 12207 processes

ISO 12207 Processes	No. of related ISO 9126 Metrics
5.0 Primary life cycle processes:	
5.1 Acquisition	0
5.2 Supply	0
5.3 Development	14
5.4 Operation	93
5.5 Maintenance	84
6.0 Supporting life cycle processes:	
6.1 Documentation	0
6.2 Configuration management	0
6.3 Quality assurance	14
6.4 Verification	0
6.5 Validation	47
6.6 Joint review	0
6.7 Audit	0
6.8 Problem Resolution	1

Moreover, there is no any metric which could be measured during 3 out of 8 of the supporting life cycle processes; that is, documentation, configuration management and audit processes.

External quality metrics: Within the ISO 9126-2 on software product external quality metrics, there are 110 metrics. These metrics can be measured during the software life cycle. External quality defined in ISO 9126-1 as the totality of characteristics of the software product from an external view. It is the quality when the software is executed, which is typically measured and evaluated while testing in a simulated environment with simulated data using external metrics. During testing, most faults should be discovered and eliminated. However, some faults may still remain after testing. As it is difficult to correct the software architecture or other fundamental design aspects of the software, the fundamental design usually remains unchanged throughout testing[9].

Table 2 shows the number of external quality metrics which can be measured during each of the ISO 12207 software life cycle processes. For example, within the "operation process" of the "primary processes", 93 metrics can be measured.

Quality in-use metrics: Within the ISO 9126-2 on software product quality in-use metrics, there are 15 metrics. These the 15 metrics can be measured during the software life cycle. Quality in-use defined in ISO 9126-1 as the user's view of the quality of the software product when it is used in a specific environment and a specific context of use. It measures the extent to which users can achieve their goals in a particular environment, rather than measuring the properties of the software itself. The term 'user' refers to any type of intended users, including both operators and maintainers and their requirements can be different[11].

Table 3: Mapping between the ISO 9126 quality in-use metrics and the ISO 12207 processes

ISO 12207 Processes	No. of related ISO 9126 metrics
5.0 Primary life cycle processes:	
5.1 Acquisition	0
5.2 Supply	0
5.3 Development	12
5.4 Operation	15
5.5 Maintenance	0
6.0 Supporting life cycle processes:	
6.1 Documentation	0
6.2 Configuration management	0
6.3 Quality assurance	0
6.4 Verification	0
6.5 Validation	11
6.6 Joint review	0
6.7 Audit	0
6.8 Problem resolution	0

Table 4: External on quality metrics which is not clear where to be measured

1	Estimated latent fault density	9	Fault removal
2	Incorrect operation avoidance	10	Restartability
3	Failure density against test cases	11	Mean time between failures (MTBF)
4	Availability	12	User support functional consistency
5	Failure resolution	13	Breakdown
6	Mean down time	14	Restore effectiveness
7	Fault density	15	Failure avoidance
8	Mean recovery time	16	Restorability

Table 3 shows the number of quality in-use metrics which can be measured during each of the ISO 12207 software life cycle processes. For example, during the "software qualification testing" activity of the "development process" of the "primary processes", 12 metrics can be measured.

DISCUSSION

In ISO 9126-3, there are some external quality metrics-as in Table 4 which have been referred to be measured during the 'integration' activity of the 'development process' of the 'primary processes'. But, within the 'development' process, there are two activities related to the 'integration', that is, 'system integration' and 'software integration'. However, this document (ISO 9126-3) did not specify during which 'integration' activity those metrics can be measured.

It is clearly noted that through the ISO 12207 'organizational processes' none of the 195 quality metrics-from the ISO 9126 series of international standards-can be measured. Therefore, the ISO 9126 is not usable for the ISO 12207 organizational processes.

As mentioned in ISO 9126-1, the quality in-use metrics should be measured during the execution of the software product in an actual working environment. However, from Table 4 we can see that there are 12 metrics which could be measured through the 'software qualification testing' activity. But since ISO 12207 mentioned that the "software qualification testing" activity is a part of the 'development process' Thus, it's strange and make no sense to measure that 12 metrics.

The 'joint review process' of the 'supporting processes' consists of three activities: One of these activities is the 'technical reviews' activity. This activity contains one task, that is, "Technical reviews shall be held to evaluate the software products or services under consideration and provide evidence that they are complete[6]. Now, if we go back to Table 1, we will find that there are 59 internal quality metrics that could be measured during the 'joint review' process. Whereas, from Table 2 and 3, it is seen that there is no any external quality or quality in-use metrics that can be measured during 'joint review' process.

CONCLUSION

The current edition of the ISO 9126 consists of inventories of proposed metrics to measure the quality of the internal, external and in-use software product. However, for each of these metrics there is a cross-reference on where it could be measured during the ISO 12207 software life cycle processes and activities. This study provided a mapping between those two standards to investigate the cross-references between them. Based on this mapping, the following comments and suggestions for the upcoming new ISO 25000 series of standards (SQuaRE) can be concluded:

- There is no any metric can be measured during the 'organizational processes'
- A number of external quality metrics where mentioned in ISO 9126-2 to be measured during the 'integration' activity. However, within the ISO 12207 there are two activities labeled 'system integration' and 'software integration', Table 4 for the names of these metrics. However, this will make the user of the ISO 9126 confused
- Many of the ISO 9126 quality metrics referred to processes. However, as known, each process in ISO 12207 contains a number of different activities. Thus, it is more usable for the ISO 9126 users to refer to the activities of the ISO 12207. This can be done using cross-reference numbers from ISO 12207. For example, the cross-reference number 5.3.9 is referring to "primary processes", 'development process' and 'software qualification testing' activity, respectively, Fig. 3 for an example on where the ISO 9126 internal quality metrics could be measured within the ISO 12207 verification activities

In addition to the mapping in this study, as a future work, it is a good idea to investigate where to collect the data for each of the ISO 9126 quality metrics in the ISO 12207 software life cycle processes and activities. This will save time and assure that the data have been completely collected before the measurement of the metrics is performed.

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