

Harmonization of usability measurements in ISO9126 software engineering standards

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Abstract - The measurement of software usability is recommended in ISO 9126-2 to assess the external quality of software by allowing the user to test its usefulness before it is delivered to the client. Later, during the operation and maintenance phases, usability should be maintained, otherwise the software will have to be retired. This then raises harmonization issues about the proper positioning of the usability characteristic: does usability really belong to the external quality view of ISO 9126-2 and should the external quality characteristic of usability be harmonized with that of the quality in use model defined in ISO 9126-1 and ISO 9126-4? This paper analyzes these two questions: first, we identify and analyze the subset of ISO 9126-2 quality subcharacteristics and measures of usability that can be useful for quality in use, and then we recommend improvements to the harmonization of these ISO 9126 models.

Key words – external quality, quality model, quality in use, usability subcharacteristics and measures

I. INTRODUCTION

Usability is a key criterion in a number of disciplines for the acceptance of a product by a customer, since a nonusable product is considered a failure. In software engineering, software product usability is a necessary, if not a fundamental, quality characteristic to be considered by all project team members. For software users, usability is a performance criterion; for the developers, it is a demonstration of the fulfillment of the functional quality requirement; and for the manager, is a criterion for the selection of the product. To meet all these demands, usability goals must be clearly defined as quality requirements at the beginning of a development project, and they must be assessed throughout the product life cycle.

Researchers have investigated this concept of usability and proposed their own models with different taxonomies and different subcharacteristics, such as Nielsen [1] and Dix et al. [2]. Their usability models include the same subcharacteristics (Table I), but differ in the proposed measures.

The International Organization for Standardization (ISO) provides two aspects of usability through two of its standards (ISO 9241 and ISO 9126). The first is process-oriented, and is widely recognized in the domain of Human-Computer Interaction (HCI), where usability corresponds to the “extent to which a product can be used by specified users to achieve

specified goals with effectiveness, efficiency and satisfaction in a specified context of use” [3]. The second, ISO 9126, is product-oriented, and defines usability as the “capability of the software product to be understood, learned, used and attractive to the user, when used under specified conditions” [4]. Understandability, learnability, operability, attractiveness and usability compliance are the subcharacteristics of the usability characteristic in ISO 9126-1, for which a set of 28 measures is provided in the ISO 9126-2 technical report [5] to assess the external quality of the software product.

As can be noted, even though these definitions from two distinct standards are different and come from different perspectives of usability, they converge towards one goal, that of facilitating the use of the software product by the user. Abran et al. [6] have jointly investigated the ‘usability’ models of these two ISO standards and proposed an integrated usability model; however, this analysis was limited to the ISO 9126 characteristic of usability, and did not include the distinct concept of ‘quality in use’ included in ISO TR 9126-4. Table I presents a summary of usability characteristics for each of the usability models.

TABLE I
 TAXONOMIES OF USABILITY CHARACTERISTICS

Dix et al. (1993)	Nielsen (1994)	ISO 9241 (1998)	ISO 9126 (2001)	Abran et al. (2003)
Effectiveness Efficiency Satisfaction Learnability	Effectiveness Efficiency Satisfaction Learnability	Effectiveness Efficiency Satisfaction	Understandability Learnability Operability Attractiveness Usability compliance	Effectiveness Efficiency Satisfaction Learnability Security

The objective of this paper is to analyze the extent to which the usability characteristic in technical report ISO 9126-2 can be harmonized with the ‘quality in use’ model of ISO 9126-1 and ISO TR 9126-4. This issue has been identified in [7] but not investigated in details.

Our interest, in particular, is to look into how can the apparent lack of connection between the quality in use characteristics and the corresponding proposed measures, be harmonized with previous measures of usability within the external quality model.¹

¹ Usability is also a characteristic of the ISO 9126 model of internal quality. The analysis of usability in this later model is outside the scope of this paper.

Section II presents a survey of ISO 9126 standard. Section III comprises an analysis of the concepts and definitions in these ISO 9126 documents, and section IV an analysis of the corresponding proposed measures. Our recommended modifications to the ISO 9126 model of quality in use are presented in section V, and our conclusion in section VI.

II. ISO 9126

The ISO 9126 series of documents consists of four parts under the general title, “Information Technology – Software Product Quality”. The first part (ISO 9126-1) specifies the ISO software product quality model. The other three parts provide an inventory of candidate “metrics” that can be used to evaluate the characteristics and the subcharacteristics of the quality model. The software product is defined in ISO 9126 as “the set of computer programs, procedures, and possibly associated documentation and data. Products include intermediate products, and products intended for users such as developers and maintainers” [4].

The ISO 9126-1 quality model is defined as “a framework which explains the relationship between different approaches to quality” [4] and distinguishes three views of software quality: internal quality, external quality and quality in use (Figure 1):

- Internal quality corresponds to the “totality of the characteristics of the software product from an internal view,” which can be achieved by measuring the internal properties of the software product without executing it.
- External quality corresponds to the “totality of characteristics of the software product from an external view,” which means that the quality of the software product can be evaluated during its execution by measuring its external properties.
- Quality in use represents 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 corresponds to the use of the software during the operation and maintenance phases, and is not related to its intrinsic properties.

In the set of ISO 9126 quality views in Figure 1, internal quality has an impact on external quality, which in turn has an impact on quality in use.

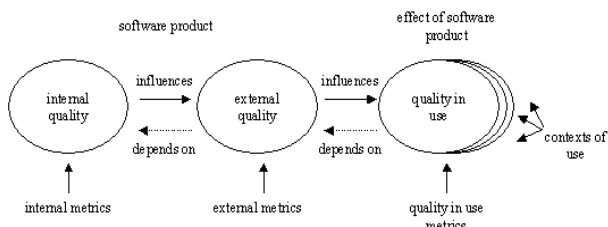


Fig. 1. Quality along the Software Life Cycle [4]

Therefore, the achievement of quality in use depends on the achievement of external quality, which itself depends on the achievement of the internal quality of the software product itself.

The internal and external quality models share the same, two-level hierarchical structure. The first level, with six characteristics, is broken down into 27 subcharacteristics (Figure 2) in the second level. A set of internal and external measures approved by the ISO to specify and quantitatively assess these quality characteristics is provided in technical reports ISO 9126 Part 2 [5] and Part 3 [8]. The quality in use model has only one level, and that includes four characteristics (Figure 3) with a set of measures provided in technical report ISO 9126, Part 4 [9]. These technical reports are not intended to give an exhaustive set of measures for all the characteristics, but only those measures for which there is a consensus within the ISO.

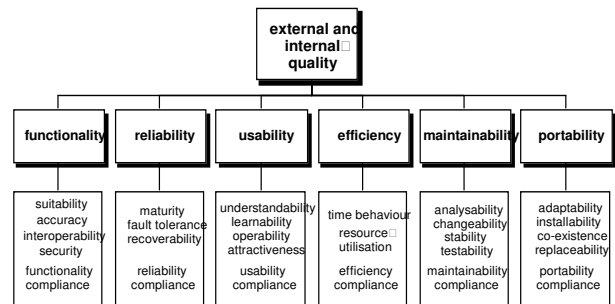


Fig. 2. Quality Model for Internal and External Quality [4]



Fig. 3. Quality Model for Quality in Use [4]

In software engineering, it is expected that a proper and exhaustive identification of project specifications and goals early in the development phases will decrease the risk of rework, delay and being over budget. Similarly, it is expected that evaluating the internal and external quality of the software product before delivery will provide an opportunity to correct errors, to implement required changes and to decrease the risk of expensive rework and unforeseeable costs.

The usability quality characteristic, as described in the ISO 9126 external and internal quality models, should allow software designers and developers to assess the “capability of the software product to be understood, learned, used and attractive” in the early phases of the software product life cycle. In these early phases, usability is limited by a number of

development constraints, such as a short test period, a limited number of users and a temporary environment. In the later, much longer phases of operation and maintenance, usability is not so constrained: a long period of time for testing, real end-users and a real environment.

How can usability in the early phases be distinguished from usability in the operation and maintenance phases, and how can it be assessed? Then, how does the assessment of the usability of the software product, as defined in ISO TR 9126-2 and -3, contribute to the assessment of quality in use as defined in ISO TR 9126-4? The link with the current four characteristics of quality in use in Figure 3 is not obvious, and has not yet been investigated.

The ISO has recognized the need for further enhancements to ISO 9126, primarily as a result of advances in the information technologies and changes in environment [10]. Therefore, the ISO is now working on the next generation of software product quality standards, which will be referred to as Software Product **Quality Requirements and Evaluation** (SQuARE – ISO 25000) [11]. Our analysis of the usability presented in this paper could contribute to the enhancement of these ISO documents, and will be carried out in two steps: first, the analysis of the usability characteristic: concepts and related definitions, and then the analysis of the measures proposed for usability by the ISO TR 9126-2.

III. ANALYSIS OF THE CONCEPTS AND RELATED DEFINITIONS

A. Overview

The usability suggested by researchers corresponds not only to the usability of the software in its early phases, but also to its postdelivery. These concepts converge to the “quality in use” definition (Figure 3): “the capability of the software product to enable specified users to achieve specified goals with effectiveness, productivity, safety and satisfaction in specified contexts of use” [4]. In this view, usability is to be evaluated on the basis of tests of the software in its real environment for a specific task.

To investigate the ambiguity noted between usability as an “external quality” characteristic and “quality in use”, a set of criteria and related harmonization issues were identified as the basis of this analysis.

B. Set of Criteria

Two categories of criteria were identified from the analysis of the textual statements about usability in both ISO 9126-1 and ISO TR 9126-2:

- Category A: criteria related to the definitions of the usability characteristic and its subcharacteristics in ISO 9126-1,
- Category B: criteria related to the external measures of usability subcharacteristics in ISO TR 9126-2.

In the lists presented next, each criterion is identified by a sequential number, together with the text, taken as is from the ISO documents, and the corresponding page number (bold type emphasis added).

Category A: Criteria from ISO 9126-1 [4]

- Criterion 1: Understandability: The capability of the software product to enable the user **to understand** whether the software is suitable, and how it can be **used for particular tasks** and conditions of use (page 9).
- Criterion 2: Learnability: The capability of the software product to enable the user **to learn** its application (page 9).
- Criterion 3: Operability: The capability of the software product to enable the user **to operate** and **control it** (page 9).
- Criterion 4: Attractiveness: The capability of the software product to be **attractive** to the user (page 10).
- Criterion 5: Usability compliance: The capability of the software product **to adhere** to standards, conventions, style guides or regulations relating to usability (page 10).
- Criterion 6: Operability corresponds to **controllability**, error tolerance and conformity with user expectations, as defined in ISO 9241-10 (Note 2, page 9).
- Criterion 7: Usability is defined in ISO 9241-11 in similar way to the definition of quality in use in this part of ISO 9126. Quality in use may be influenced by any of the quality characteristics, **and is thus broader than usability**, which is defined in this part of ISO/IEC 9126 in terms of understandability, learnability, operability, attractiveness and compliance (Note 3, page 12).

Category B: Criteria from ISO TR 9126-2 [5]

- Criterion 8: Measures² for understandability, learnability and operability have **two types of method of application**: user test or test of the product in use (page 29).
- Criterion 9: **User test**: Users attempting to use a function test many external measures. These measures can vary widely among different individuals (Note 1, page 29).
- Criterion 10: **Test of the product in use**: Rather than test specific functions, some external measures observe the use of a function during more general use of the product to achieve a typical task as part of a test of the quality in use (Note 2, page 29).

² While the term ‘metrics’ is used in ISO 9126, it has been agreed that, in the upcoming revision of ISO 9126, this term will be replaced by ‘measures’ to harmonize it with other software engineering measurement standards.

Criterion 11: Users should be able to select a software product, which is suitable for their intended use. An external understandability measure should be able to assess whether new users can understand: whether the software is suitable, **how it can be used for particular tasks** (page 29).

Criterion 12: An external operability measure should be able to assess whether users can operate and control the software. Operability measures can be categorised by the “*dialogue principles*” in ISO 9241-10: **suitability of the software for the task, controllability of the software** (page 29).

C. Harmonization Issues

The external quality and quality in use of the software product, as defined in ISO 9126-1, should be assessed at the time of execution of the software product and during its operation and maintenance. As already illustrated in Figures 2 and 3, the ISO quality in use model assesses the use of the software by means of characteristics other than those of the external quality model. This then raises questions about the proper positioning of the usability characteristic and subcharacteristics, as well as of their corresponding measures, such as:

- Harmonization issue 1: Does usability really belong to the external quality view of ISO TR 9126-2?
- Harmonization issue 2: Should the external quality characteristic of usability be harmonized with that of the quality in use model defined in ISO 9126-1 and ISO TR 9126-4?

To tackle these questions, the link between the name of each subcharacteristic and its corresponding definition provided in ISO 9126-1 is analyzed first, in particular with respect to the objective of the subcharacteristic (criteria 1 to 5).

It is easy to see that the definitions related to the subcharacteristics of usability allow the user to understand, to learn, to operate and to be attracted by the software product. This is illustrated by words which are exactly mapped to the characteristics they describe, such as “to understand” for “understandability”, “to learn” for “learnability”, etc. However, according to criteria 1, 3 and 6, the understandability and operability subcharacteristics constitute an exception: their objectives are more than to understand and operate the software product – they are also to control and accomplish a particular task. Such objectives require a broader level of software testing at the time of its use in its real environment. Furthermore, usability as defined in ISO 9241 forms a part of quality in use of the software product (criterion 7 is thus broader than usability as defined in ISO 9126-1 and -2).

In our examination of criteria 8 to 10 below, two types of methods of application of external measures are identified, mainly for the understandability, learnability and operability subcharacteristics. One method of application is based on the

tests conducted by the user (user tests) and the other is based on the tests of the product when it is used to complete a particular task (tests of the product in use). Moreover, an external measure of understandability must make it possible to evaluate, among other things, how the software product can be used for a particular task (criterion 11), and an external measure of operability must make it possible to evaluate, among other things, whether or not the software product is suitable for the task (criterion 12).

Thus, from this analysis, the answers to the both harmonization questions can only be affirmative.

- 1: The usability characteristic constitutes an essential part of the external quality model in ISO TR 9126-2, since it enables determination of the extent to which the software product can be understood, learned, operated by, and attractive to, the user at the time of test and operation.
- 2: The usability characteristic can also constitute a part of the ISO 9126-1 and ISO TR 9126-4 model of quality in use through its subcharacteristics understandability and operability, to which learnability is added.

IV. ANALYSIS OF THE PROPOSED MEASURES

The goal of this analysis is to verify to what extent the current measures proposed in ISO TR 9126-2, for all the subcharacteristics of the usability characteristic, can be useful to evaluate:

- (1) external usability during the execution of the software before its delivery, and
- (2) usability as a part of quality in use during the operation and maintenance of the software after it has been delivered.

This analysis of the measures proposed in ISO TR 9126-2 is carried out using the following criteria:

- Name of the measure: this criterion checks whether or not the name of the measure ends with the expression “*In use*” or not.
- Method of application: this criterion checks whether the method of application of the measure proposed by the ISO corresponds to a “*User test*” or to a “*Test of the product in use*”.

Analysis of the 28 proposed usability measures makes it possible to distinguish three categories of measures:

- Category I: The name of the measure does not end with “*In use*” and its method of application corresponds to a “*User test*”.
- Category II: The name of the measure ends with “*In use*” and its method of application corresponds to a “*Test of the product in use*”.
- Category III: The name of the measure does not end with “*In use*” and its type of application method is not clearly identifiable.

The detailed results of this analysis are presented in Tables II, III and IV, which list the sets of measures identified for each category.

TABLE II
LIST OF "CATEGORY I" MEASURES IN ISO TR 9126-2

Subcharacteristics	Name of the Measure	Method of Application
Understandability	Completeness of description	User test
	Demonstration accessibility	User test
	Evident functions	User test
	Function understandability	User test
	Understandable input and output	User test
Learnability	Ease of function learning	User test
	Effectiveness of the user documentation and/or help system	User test
	Help accessibility	User test
	Help frequency	User test
Operability	b) Controllable	Error correction
	d) Self-descriptive	Self-explanatory error messages
	e) Operational-error tolerant	Undoability user error correction
	f) Suitable for individualisation	Customisability
Physical accessibility		User test
Attractiveness	Interface appearance customisability	User test
	Attractive interaction	User test
Usability compliance	Usability compliance	User test

TABLE III
LIST OF "CATEGORY II" MEASURES IN ISO TR 9126-2

Subcharacteristics	Name of the Measure	Method of Application	
Understandability	Demonstration accessibility in use	Test product in use	
Learnability	Ease of learning to perform a task in use	Test product in use	
	Effectiveness of user documentation and help systems in use	Test product in use	
Operability	a) Conforms to operational user expectations	Operational consistency in use	
	b) Controllable	Error correction in use	
	c) Suitable for task operation	Default value availability in use	
	d) Self-descriptive	Message understandability in use	Test product in use
		e) Operational-error tolerant	Operational error recovery in use
	Time between human error operations in use	Test product in use	

TABLE IV
LIST OF "CATEGORY III" MEASURES IN ISO TR 9126-2

Subcharacteristics	Name of the Measure	Method of Application
Understandability	Demonstration effectiveness	Test product in use/User test
Operability f) Suitable for individualisation	Operation procedure reduction	Test product in use/User test

The distribution of the number of external usability measures for each category is presented in Table V:

- 17 measures out of 28 (Category I) test-specific functions of the software are based on the tests conducted by the user. Indeed, all subcharacteristics have useful measures for evaluating the usability as an external quality characteristic of ISO TR 9126-2 quality model - that is, the quality of the software product from an external view; before its delivery. Therefore, the first issue is confirmed.
 - 9 measures out of 28 (Category II) test the ability of the software product in use to accomplish a particular task. They concern primarily the subcharacteristics understandability, learnability and operability which can be used to evaluate the usability of the software product once it has been delivered. Therefore, the usability can constitute a new characteristic of ISO 9126-1 and ISO TR 9126-4 quality in use model through these three subcharacteristics. The second issue is then confirmed too.
- For the attractiveness and usability compliance subcharacteristics, there are no other measures available left for analysis. The only measures proposed by ISO TR 9126-2, for these subcharacteristics, concern the Category I.

TABLE V
DISTRIBUTION OF EXTERNAL MEASURES IN THE USABILITY CATEGORIES

Usability Subcharacteristics	Number of all external quality measures	Number of measures for Category I	Number of measures for Category II	Number of measures for Category III
Understandability	7	5	1	1
Learnability	6	4	2	
Operability	12	5	6	1
Attractiveness	2	2		
Usability compliance	1	1		
Total	28	17	9	2

- For the 2 measures out of 28 (Category III) about the understandability and operability subcharacteristics, it is not clearly identifiable whether or not they can be used to evaluate the quality of the software product before its delivery or after it has been delivered, or in both cases.

For the learnability, attractiveness and usability compliance subcharacteristics, there are no other measures left for analysis.

V. RECOMMENDATIONS

The results of the analyses of both the concepts and the definitions contained in ISO 9126 Parts 1 and 2, as well as of the measures proposed in ISO TR 9126-2, converge to confirm that the usability characteristic, its subcharacteristics and associated measures, are well positioned within the external quality model of ISO 9126-1 and thereafter that of ISO TR 9126-2. In addition, these analyses reveal that many of these measures are also useful in evaluating the quality in use of the software product, through the understandability, learnability and operability subcharacteristics but are not currently included in ISO TR 9126-4.

This leads to the following recommendation: the usability characteristic and some of its subcharacteristics, that is, understandability, operability and learnability, should be integrated within the model of quality in use of ISO 9126. To differentiate them from those of the external quality model, the expression “*In use*” is added, for example ‘learnability (in use)’. The proposed enhanced model for quality in use is represented by Figure 4. The corresponding set of measures for this added quality in use characteristic could then be adopted from the Category II measures listed in Table III.

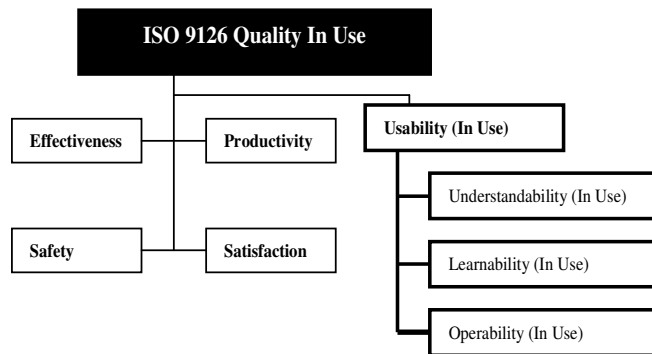


Fig. 4. Enhanced model proposed for quality in use in ISO 9126

VI. CONCLUSION

The objective of this paper was to analyze the usability characteristic, its subcharacteristics and associated measures in technical report ISO/IEC 9126-2 in order to identify, and resolve harmonization issues arising in the usability characteristic in the ISO 9126 model of external quality and in the ISO 9126 model of quality in use. This analysis was carried out using criteria derived from ISO 9126-1 and ISO TR 9126-2, and a review of the set of corresponding ISO TR 9126-2 measures for the usability characteristic.

In summary, while the usability characteristic is considered to be well positioned within ISO TR 9126-2 because it makes it possible for the user to evaluate a priori the external quality of the software product on the one hand, this characteristic should also be harmonized with the ISO model for the quality in use on the other. An improved model for quality in use was therefore proposed, including an additional characteristic of *usability (in use)* and three corresponding subcharacteristics *understandability (in use)*, *operability (in use)* and *learnability (in use)*. Some corresponding measures were also selected as a subset of the measures already included in ISO TR 9126-2.

A number of additional harmonization issues still need to be tackled by the ISO group working on the next update of the ISO 9126 series, including harmonization with the ISO 9126 model of internal quality and measures of quality in use, as documented in [12-13], and the ISO 9241 standard on process usability, as documented in [6].

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