Software Quality Assessment Standards and Metrics: A Systematic Literature Review

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Abstract. *The paper presents results of performing a systematic literature review process aiming to answer which ISO standards and metrics are used for software quality assessment and which are their area of application. The review was performed on 696 original scientific studies. After applying inclusion criteria, 32 papers were filtered that dealt with this topic. Results of performed review were 8 identified software quality standards with different areas of application. Also, 62 metrics were identified for software quality assessment with corresponding software quality attributes. These metrics are divided into two groups for product quality assessment and for quality in use assessment. In the context of product quality 42 metrics were identified and 20 metrics for quality in use assessment.*

Keywords. Software Quality, Standards, Metrics, Systematic literature review, SLR, Software development

1 Introduction

According to ISO/IEC 25000, software quality is the capability of software product to satisfy stated and implied needs when used under specified condition (Hakim et al., 2016).

Software quality is an important aspect of the development process but in today's dynamic environment many development teams do not have time to focus on software quality. Because of that, at the end of project teams need to devote time to redo some parts of applications due to quality issues (Kasims, 2018).

Thus, to identify software quality assessment standards and metrics that could help development teams to achieve better quality, systematic literature review will be performed. The aim of this research is to find scientific studies that present software quality standards and the area of their application. Also, goal of this research is to find software quality evaluation process and metrics.

There are existing systematic literature reviews that focus on software quality standards and metrics. For example, Rehman & Khan's (2012) research identify different quality attributes that affect software quality and corresponding quality metrics. They identify different quality attributes and metrics. Research performed by Wedyan & Abufakher (Wedyan & Abufakher, 2019) studies the impact of design patterns on quality attributes and the evaluation of quality attributes. They identified 50 different papers with belonging quality attributes and metrics. Another study (Kaur, 2020) focuses on the relationship between code smells and software quality attributes. Their conclusion is that different code smells have the opposite effect on different software quality attributes.

However, to our knowledge, there are no reviews that show a complete overview of software quality ISO standards, metrics, and software quality assessment processes that could help a development team to evaluate and improve their product.

This paper presents the results of systematic literature review on the topic of software quality assessment process and quality standards and metrics. Focus is on ISO standards, which describe the best practices, and they are internationally agreed by experts. Paper is organized as follows: research methodology stating research questions is presented in the second section, third section provides research results in which are identified software quality assessment standards and metrics for an evaluation of different quality attributes which are then analysed and discussed in section four, and finally, section five represents the conclusion of the study.

2 Research methodology

Research methodology that was used in this research is Systematic literature review (SLR). SLR allows to identify, evaluate, and interpret available research relevant to the stated research question. It follows a strict research protocol which makes it replicable and repeatable by other researchers. According to

Kitchenham and Chartes (2007) Systematic literature review has three phases: planning the review, conducting the review, and reporting the review which are designed in a such a way to make it objectivistic and bias free.

2.1. Planning the review

Planning is the first phase of the literature review. In this phase, research questions are stated and a review protocol is created and validated (Brereton et al., 2007).

To find all relevant studies, two research questions are stated. **RQ1 -** What standards are used for software quality assessment and what are their areas of application? **RQ2 -** What metrics are used for measuring software quality attributes?

Digital databases used in this search have been recommended by study (Brereton et al., 2007) as the most relevant databases in software engineering. *Table 1.* shows used digital databases and search string.

Table 1. Digital databases and search string

Digital databases	Search string
IEEExplore	("software quality") AND ("ISO") AND ("standard" OR "model")
ACM Digital library	
Scopus	
Web of Science	

The review process had *four phases*, namely: (1) searching digital databases by a search string; (2) filtering studies by inclusion criteria applied to abstracts; (3) filtering studies by inclusion criteria applied to introduction and conclusion and (4) full-text review and removing duplicates.

Defined *inclusion criteria* were as follows: (1) study focuses on ISO software quality standards and quality attributes metrics; (2) study is an original scientific work; (3) study is published after 2017; (4) study is written in English and (5) study is published in scientific conference or journal.

Furthermore, for study to pass to the data extraction phase it needs to meet all defined criteria.

2.2. Conducting the review

The four-phase process of filtering the studies is presented in *Table 2.* In the first phase, 696 studies were found. In the next phase, 158 papers are filtered. After filtering studies by applying inclusion criteria on introduction and conclusion, 77 studies were filtered. In the end, 32 papers met the defined criteria and were used in the data extraction phase. Studies were analysed to answer research questions. Title, authors, type of the study, and major results and conclusions were extracted from the studies. Furthermore, from examples of software quality assessment process defined in filtered studies ISO standards with the corresponding area of application, quality attributes and metrics will be extracted.

Table 2. Review phases

Source	Phase 1	Phase 2	Phase 3	Phase 4
IEE Explore	128	35	23	15
ACM Digital library	210	28	7	1
Scopus	193	60	27	7
Web of Science	165	35	20	9
TOTAL	**696**	**158**	**77**	**32**

3 Results

Results of the conducted research are shown by stated research questions.

Quality standards are used for software quality assessment. However, in different areas of software engineering, different standards are used. In this study, we identified eight quality standards and their area of application (**RQ1**). Results are presented in *Table 3.* Identified areas of application represent different areas of software engineering. Some areas are being repeated in the table because one standard can be used in many areas of software engineering.

Table 3. Software quality standards and their area of application

Standard	Area of application	References
ISO/IEC 25000	• Web applications	Wiese et al. (2021)
ISO/IEC 25010	• Mobile games • Mobile applications • Information system • Web application security • E-books • Ecommerce • Internet of things	Alves, Albino, et al. (2016) Alves, Savaris, et al. (2016) Anggraini et al. (2019, p. 25010) Hakim et al. (2016) Hasanah et al. (2020) Haslinda et al. (2015) Hovorushchenko & Pomorova (2016, p. 2011) Idri, Bachiri, & Fernández-Alemán (2016) Idri, Bachiri, Luis Fernandez-Aleman, et al. (2016) Idri et al. (2017)

		Manglapuz & Lacatan (2019) Peters & Aggrey (2020) Rahmi Dewi et al. (2020) Sekarini et al. (2020) Tambotoh et al. (2017) Trichkova-Kashamova (2021) Trisnadoli et al (2015) Zulfa et al. (2020)
ISO/IEC 25012	• Data security	Verdugo & Rodriguez (2020)
ISO/IEC 25022	• Mobile games • Mobile applications	Sulla-Torres et al. (2020) Trisnadoli et al. (2015)
ISO/IEC 25023	• Web application security	Aziz et al. (2018)
ISO 25062	• Mobile applications	Moumane, Idri, & Nafil (2016) Moumane, Idri, & Abran (2016)
ISO/IEC 9126	• Mobile games • Information systems • E-learning • Web applications	Barros et al. (2015) Rochimah et al. (2015) Trisnadoli et al. (2015) Dzulfiqar et al. (2018) Beckhauser et al. (2018) Molnar et al. (2019)
ISO 9241	• Mobile applications	Moumane, Idri, & Nafil (2016) Moumane, Idri, & Abran (2016)

Related to second research question (**RQ2**), the review showed metrics for the assessment of quality attributes. We identified 20 different quality attributes and belonging metrics. In total, 62 different metrics are reported. Metrics are divided into two tables depending on the type of quality. *Table 4.* shows the quality attributes and their metrics for *products quality measurement*, while *Table 5.* shows the quality attributes and their metrics for *quality in use assessment*. For product quality evaluation, eight software quality attributes are identified with 42 belonging metrics.

Table 4. Product quality assessment

Quality attributes	Metrics	References
Functional Suitability	• Questionary • Expert evaluation • System compatibility with the required level of precision • The suitability of the function with its purpose • Conformity of usage function with usage procedure	Haslinda et al. (2015) Hasanah et al. (2020) Idri et al. (2017) Trichkova-Kashamova (2021)
Reliability	• Questionary • Expert evaluation	Haslinda et al. (2015) Idri et al. (2017) Trichkova-Kashamova (2021)
Security	• Questionary • Access controllability • Data Encryption • Strength of cryptographic algorithm • Data Integrity Conformance • Internal Data Corruption Prevention • Validity of Array Accesses • Utilization of Digital • Signature Access • System Log Retention Conformance • Authentication Protocol Conformance • Authentication protocol measures • Establishment of authentication rules measures • User Health and Safety • Expert evaluation	Haslinda et al. (2015) Soad et al. (2016) Aziz et al. (2018) Sekarini et al. (2020) Hakim et al. (2016) Trisnadoli et al. (2015) Trichkova-Kashamova (2021)
Performance	• Questionary • Expert evaluation	Haslinda et al. (2015) Idri et al. (2017)

		Trichkova-Kashamova (2021)
Maintainability	• Questionary • Code analysis without running • Expert evaluation • Size • Complexity • Coupling • Cohesion • Encapsulation	Haslinda et al. (2015) Rahmi Dewi et al. (2020) Trichkova-Kashamova (2021) Wiese et al. (2021)
Compatibility	• Questionary • Expert evaluation	Haslinda et al. (2015) Trichkova-Kashamova (2021)
Portability	• Questionary • Adaptability of data structures • Organizational environment adaptability • Porting user friendliness • System software environmental adaptability • Ease of setup re-try Installation effort Installation flexibility • Continued use of data • Function inclusiveness • Expert Evaluation	Kaur (2020) Idri, Bachiri, Luis Fernandez-Aleman, et al. (2016) Trichkova-Kashamova (2021)
Operability	• Questionary • Input validity Checking • User operation • Cancellability • User operation Undoability • Customizability • Physical • Accessibility • Operation status monitoring capability • Operational Consistency • Message Clarity • Interface element clarity • Operational error recoverability	Idri et al. (2017) Rochimah et al. (2015)

Quality attributes and their metrics for *quality in use assessment* are presented in the following table. For this type of quality, 12 different attributes and 20 metrics are reported.

Table 5. Quality in use assessment

Quality attributes	Metrics	References
Usability	• Goal completeness • Error Frequency • Goal Time Efficiency • Satisfaction Scale • Questionary • System Usability Scale • Expert evaluation	Trisnadoli et al. (2015) Haslinda et al. (2015, p. 25010) Soad et al. (2016) Alves, Albino, et al. (2016) Trichkova-Kashamova (2021)
Efficiency	• Questionary • Expert evaluation	(Haslinda et al., 2015) (Idri et al., 2017) Trichkova-Kashamova (2021)
Flexibility	• Flexible Context of Use	Trisnadoli et al. (2015)
Performance	• Questionary • Expert evaluation	Haslinda et al. (2015) Idri et al. (2017) Trichkova-Kashamova (2021)
Operability	• Questionary • Input validity Checking • User operation Cancellability • User operation Undoability • Customizability • Physical Accessibility • Operation status monitoring capability Operational • Consistency Message Clarity • Interface element clarity	Idri et al. (2017) Rochimah et al. (2015)

	• Operational error recoverability	
Functionality	• Questionary	Soad et al. (2016)
Educational (Pedagogical)	• Questionary	Soad et al. (2016)
Support	• Questionary	Soad et al. (2016)
Learnability	• Completeness of user documentation and/or help facility • Questionary	Rochimah et al. (2015) Dzulfiqar et al. (2018)
Understandability	• Completeness of description • Demonstration capability • Evident Functions • Function understandability • Questionary	Rochimah et al. (2015) Dzulfiqar et al. (2018)
Attractiveness	• Questionary	Dzulfiqar et al. (2018)
Sociocultural (Communication)	• Questionary	Soad et al. (2016)

4 Discussion

Software quality standards define quality model which contains quality characteristics and sub-characteristics and enable to evaluate software quality. A lot of scientific studies put focus on a software quality standard. Some of them use different standards to measure software quality (Rahmi Dewi et al., 2020, p. 25010). The most popular and most widely used framework for software quality is ISO/IEC 25000. It is a series of standards, also known as SQuaRE series of standards (System and Software Quality Requirements and Evaluation). This series contains the following divisions: ISO/IEC 2502n - Quality Measurement Division; ISO/IEC 2503n - Quality Requirements Division; ISO/IEC 2504n - Quality Evaluation Division (Hakim et al., 2016). According to this framework software quality is the capability of a software product to enable the behaviour of a system to satisfy stated and implied needs when used under specified conditions (Hakim et al., 2016).

One of the most popular quality standards, ISO/IEC 25010, defines two aspects of quality: product quality and quality in use. Product quality describes properties of a software product, and they are usually available during the development process. On the other hand, quality in use describes the impact that the product has on users (Idri et al., 2017). A quality in use refers not only to the technological view, but also to pedagogical, socio-cultural, and socio-economic aspects. For example, pedagogical characteristics refer to intends to address the issues related to teaching and learning, and communication refers to the ability to provide communication and interaction among users. (Soad et al., 2016). A product quality contains eight attributes: Functional suitability, Reliability, Performance efficiency, Operability, Security, Compatibility, Maintainability and Transferability. These attributes are divided into sub-attributes that can be measured. On the other hand, quality in use contains five attributes also divided into sub-attributes.

However, in this paper we combined attributes and sub-attributes identified in reviewed papers for systematic presentation of software quality metrics. These papers used attributes and sub-attributes defined by ISO standards.

With ISO/IEC 25010 one of the most used standards is ISO/IEC 9126. This is a generic quality model which contains six attributes and 27 sub-attributes. This standard also defines metrics for sub-attributes measurements. Studies show that is most used in the following areas: mobile games development, information systems, and e-learning (Trisnadoli et al., 2015).

Furthermore, above-mentioned software quality standards define metrics for software quality assessment. Metrics are defined by software quality attributes and sub-attributes. Different types of quality require use of different metrics. Product quality contains the following quality attributes: functional suitability, reliability, security, performance, maintainability, portability, and operability (Trichkova-Kashamova, 2021). For these quality attributes in most cases parameters are clearly defined and results of measurements can be easily compared. For example, in the context of security, authentication protocol measures are calculated by the function F, mathematical formula is F = A/B where A is number of provided authentication protocols (e.g., user id/password or IC card) and B is number of required authentication protocols in the specification (Hakim et al., 2016). On the other hand, quality in use contains the following quality attributes: usability, efficiency, flexibility, operability, functionality, pedagogical, support, learnability, understandability, attractiveness, and communication (Trichkova-Kashamova, 2021). In this case, for quality measuring is necessary to collect data from users. For this purpose, usually a questionary is used to collect data and additional analysis needs to be provided to rate quality in the context of use (Soad et al., 2016).

Nevertheless, one of the most used ways to evaluate software quality is expert evaluation. The implementation of this approach starts with the evaluation of the system by experts in the field of

information technology and users of the system. A set of indicators is described, and they are presented in the survey. Collected data is analysed. Decisions are taken about the functional development of the system after an inspection of the obtained values (Trichkova-Kashamova, 2021).

5 Conclusion

The paper provides the presentation of most used software quality standards and their area of application. Also, the paper presents metrics for software quality assessment grouped by type of software quality.

Systematic literature review was performed on 696 original studies. After applying inclusion criteria, 32 papers were filtered that dealt with this topic. The result of the performed review was 8 identified software quality standards with different areas of application. Also, we identified 62 metrics for software quality assessment for measuring different software quality attributes. These metrics are divided into two groups for product quality assessment and for quality in use assessment. Furthermore, 42 metrics were identified in the context of product quality and 20 for quality in use assessment.

This study showed different standards and metrics that could help development teams to improve software quality during the development process. However, usage of these standards and metrics in practice could be expensive and complicated. For that reason, additional research is necessary to identify appropriate tools for faster software quality assessment. Identifying tools for software quality assessment will enable development team to easily use them in development process and improve quality in iteration base.

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