Application of software product quality international standards through software development life cycle

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Abstract. *International standardizations efforts as a systematization and enhancement of the best practices have valuable impact on software product quality assurance. Software product quality and its different aspects are goals of all software development life cycle phases.*

The international standards selected and described in this paper comprise 1) those defining software (development) life cycle processes (ISO/IEC 12207) and its information products i.e. related documentation (ISO/IEC 15289), 2) those defining quality models/different quality views (internal quality, external quality and quality in use) and quality (sub)characteristics and metrics (ISO/IEC 9126 parts 1-4), and 3) those defining software products evaluation (ISO/IEC 14598 parts 1-6).

In the paper it is proposed too how the mentioned international standards could be used through software development life cycle phases to plan, check and gain software quality.

Keywords. software product quality, international standard, software development life cycle, ISO/IEC 12207, ISO/IEC 15289, ISO/IEC 9126, ISO/IEC 14598

1 Introduction

From early 1990′s a lot of efforts have been put into standardization of software engineering area and promotion of quality aspects and importance. In Software engineering body of knowledge [3] it is stated that "a software engineer should understand the underlying meanings of quality concepts and characteristics and their value to the software under development or to maintenance". In software engineering and other related (information technology) standards the best practices and software quality models are incorporated. They address at least three levels (aspects) of quality: the quality of (software) organizations, the quality of software (development) processes and finally, the quality of software products. Software product quality was represented by early models by Boehm and McCall [3] in 1970-es while the first software product quality international standard ISO/IEC 9126: Software engineering - Product quality was introduced in 1991.

It is obviously that the issue of software product quality has a quite long history (for ICT).

In the paper it is described how some of the international (software engineering) standards could be used through software development life cycle phases to plan, check and gain software quality.

2 Software development life cycle models and related standards

There is no good product without the well defined and implemented processes of its production.

Software is developed according the chosen software development life cycle model, while all corresponding processes (on system and software level) are defined and described in ISO/IEC 15288 and ISO/IEC 12207 standards.

2.1 Software development life cycle models

In ISO/IEC 12207 [4, 4] life cycle is defined as "evolution of a system, product, service, project or other human-made entity from conception through retirement", while life cycle model is defined as "framework of processes and activities concerned with the life cycle that may be organized into stages, which also acts as a common reference for communication and understanding"

SDLC or Software Development Life Cycle represents conceptual model in project management with defined following activities or steps [22]:

- Planning: requirement gathering or requirement analysis from which a document is created in which the scope of the project is determined and documented.
- Implementation: code writing according to the requirements.

- Testing: finding defects or bugs in the created software.
- Documentation: documenting every step in the project.
- Deployment and Maintenance: deploying the software after it has been approved for release.
- Maintaining: maintaining and improving the software (according new requirements/change requests).

Some definitions offer four stages model i.e. planning, analysis, design, and implementation. ISO/IEC 15288 and ISO/IEC 12207 have defined life cycle processes in their structures.

According to the generic or classic lifecycle model [21], consisting of six stages (requirements, analysis, design, coding, testing and acceptance) numerous lifecycle models have been developed [20], such as water fall, iterative, spiral, prototype, RAD (rapid application development), Cocomo, V-model, fish model, component assembly model, etc.

SDLC helps us to achieve our goals in project management, enables tracking of progress, requires lot of formal documentation for easier maintaining, and keeps project clean, minimizes time, risk and cost.

There is no the best or the worst SDLC model in general. Every model is specific and has strengths and weakness for specific project. Choosing right SDLC model is important and difficult because wrong model selection has several impacts.

According to Pundhir and Mishra [19, 21-22] "The selection of a suitable model is based on the following characteristics: Requirements, Development team, Users, Project type and associated risks."

The authors elaborate various models through previous criteria's and his conclusion is that there are many existing models for software development of different project sizes and requirements, waterfall and spiral models are used commonly, each model has advantages and disadvantages, and nowadays software industry likes to implement "V-model".

In another interesting study the authors compare different SDLC models [2] and conclude that for frequently requirement changes and smaller projects the best choice is "Agile model", for the large projects with clear requirements the best choice is "Waterfall model", while for large projects with requirement changes the best choice is "V-model".

2.2 System and software cycle processes: ISO/IEC 15288 and ISO/IEC 12207

Software development and life cycle processes described in previous chapter can be successfully managed using standards. Usage of standards ensures coverage of communication between acquirers and suppliers, all software life cycles stages definition, quality and uniformity. Two main standards used in this role are ISO/IEC 15288 and ISO/IEC 12207. Process models in both standards are similar, only ISO/IEC 12207 is more software specialized and software oriented.

ISO/IEC 15288 [7]: "establishes a common framework for describing the life cycle of systems created by humans. It defines a set of processes and associated terminology. These processes can be applied at any level in the hierarchy of a system's development. ISO/IEC 15288 concerns those systems that are man--made and may be configured with one or more of the following: hardware, software, humans, or processes."

ISO/IEC 15288 initial planning started in 1994, scheduled to be published in August 2002 [7]. The version from 2002 has been superseded in 2008.

ISO/IEC 15288 specific purpose is coverage of life cycle of kind systems created by humans, ISO/IEC 12207 relates software life cycle, ISO/IEC 9126 covers software quality model, while ISO/IEC 15504 (SPICE) covers software capability through maturity model of processes (Figure 1).

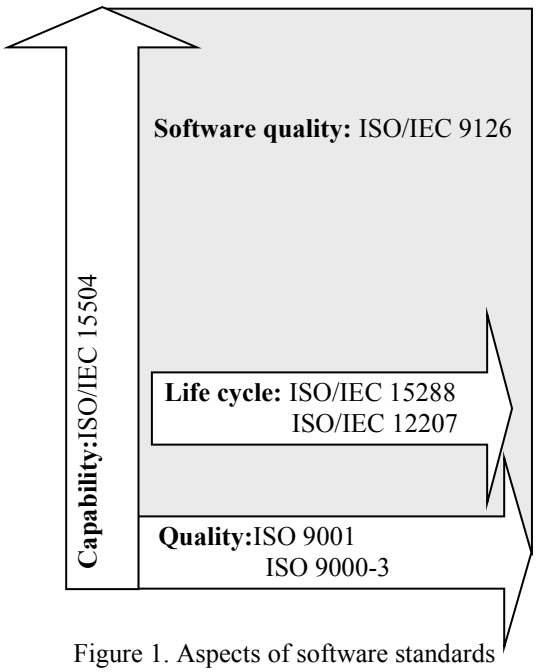

Figure 1. Aspects of software standards

In ISO/IEC 15288 [8] there are four groups of processes. The first group Agreement consists of Acquisition and Supply processes. The second group is Organizational Project-Enabling with Life Cycle Model, Infrastructure, Project Portfolio, Human Resource and quality Management processes. Project processes constitute the third group and they are Project Planning, Project Assessment and Control, Decision, Risk, Configuration and Information Management processes, and Measurement Processes. The last groups are Technical Processes: Stakeholder Requirements Definition, System requirements Analysis, System Architectural Design, Implementation, System integration, System Qualification Testing, Software Installation, Software

Acceptance Support, Software Operation, Software Maintenance and Software Disposal Process.

ISO/IEC 12207standard was initiated in 1989, published in 1995 and revised in 2008.

It describes three groups of all together 18 processes through their names, purposes, outcomes, activities and tasks (Table 1).

Table 1. The structure of ISO/IEC 12207 process

Process:
7.a.b The process name
a. the process group
b. the process
Purpose:
7.a.b.1 The process purpose
Outcomes:
7.a.b.2 The process purpose
Activities and Tasks:
7.a.b.3 The process activities and tasks
7.a.b.3.1 **The first activity** of the process
7.a.b.3.1.1 **The first task** of the first activity of the process
7.a.b.3.1.2 The first task of the first activity of the process
...
7.a.b.3.n The nth task of the first activity of the process
7.a.b.3.n **The nth activity** of the process
7.a.b.3.n.1 The first task of the nth activity of the process
7.a.b.3.n.2 The second task of the nth activity of the process
...
7.a.b.3.n.m **The mth task** of the nth activity of the process

The first group Software Implementation consists of Software Implementation, Requirements Specification, Architectural Design, Detail Design, Construction, Integration and Software Qualification Testing processes. In the second group of Software Support there are the following processes: Software Documentation and Software Configuration management processes, Software Quality Assurance, Software Verification and Validation processes, Software Review and Audit Processes, and Software Problem Resolution Processes. The last Software Reuse processes group consists of Domain Engineering, Reuse Asset Management and Reuse Program Management processes.

2.3 System and software life cycle information products (documentation): ISO/IEC 15289

ISO/IEC 15289 is a system and software engineering standard first published in 1995 while the newest edition (the second one) has been published in 2011. The standard deals with life cycle data and information items, it describes life cycle data, records and documents characteristics, defines generic types of information items and its generic contents, explains how information items are mapped to the life cycle and service management processes, gives generic content of records and specific information items (document) content.

Generic types of information items are [9, 10]: description, plan, policy, procedure, report, request, and specification.

In the standard for each system life cycle process defined in ISO/IEC 15288 and each software life cycle defined in ISO/IEC 12207 typical input and output information items are defined and mapped to.

3 Software quality standards: ISO/IEC 9126, ISO/IEC 14598 and SQUARE

3.1 Software quality: the levels

Quality of every product is affected by the quality of production processes and the quality, i.e. capability of production environment (organization). The same applies to software product. Figure 2 illustrates the levels of software product quality and related (quality) international standards and methodologies.

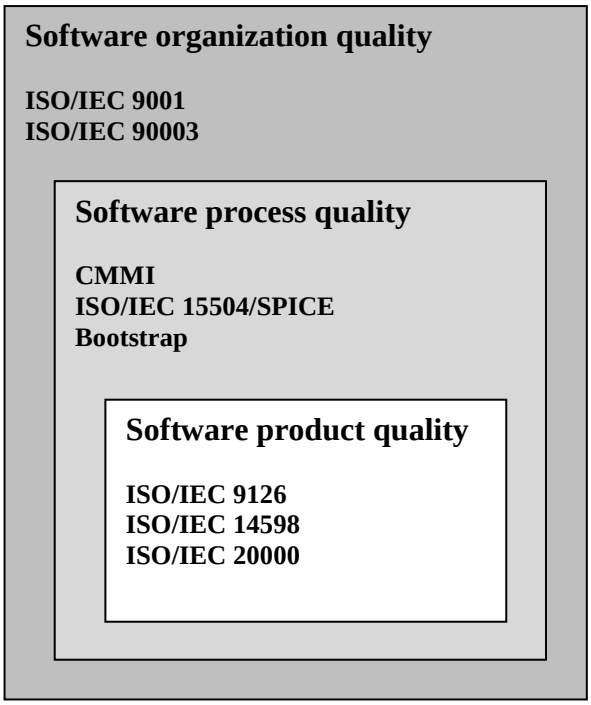

Figure 2. Levels of software product quality

3.2 Software quality models and metrics: ISO/IEC 9126

The international standard which deals with software quality models and metrics is ISO/IEC 9126. From the first version published in 1991 of 13 (in total 18) pages it expanded in four parts of the standards of all together 232 pages.

The first part [11] describes software product quality model based on external, internal and quality in use and related software quality (sub)characteristics.

External quality is based on typically static measures of products that are being developed, internal quality on typical measurement of behavior in the execution of code, while quality in use is based on the fact that a goal or purpose of a product is that it has the required effect in particular, the specific context of use.

External and internal quality related characteristics are Functionality, Reliability, Usability, Efficiency, Maintainability and Portability, while the characteristic of quality of use is described with help of subcharacteristics Effectiveness, Productivity, Safety and Satisfaction.

ISO/IEC 9126-1 standard also introduces the other parts of the standard giving us the example external [16], internal metrics [17] and quality in use metrics [18].

3.3 Software quality evaluation process: ISO/IEC 14598

ISO/IEC 14598 Information technology – Software product evaluation is a set of international standards consisting of 6 parts: 1. General overview, 2. Planning and management, 3. Process for developers, 4. Process for acquirers, 5. Process for evaluators, and 6. Documentation of evaluation modules.

Part 1 of ISO/IEC 14598 [5, 9] introduces the other parts of the standard and defines software evaluation process through following steps and related actions:

- Establish evaluation requirements – establish purpose of evaluation, identify types of product(s), and specify quality model;
- Specify the evaluation design the evaluation – select metrics, establishing rating levels for metrics, establish criteria for assessment;
- Design the evaluation – produce evaluation plan;
- Execute the evaluation – take measures, compare with criteria, and assess results.

Evaluation is planned and managed activity with its description in second part of the standard [12]. In this part of the standard are described requirements, recommendations and guidelines for software evaluation from planning, where is necessary to specify objectives, develop plan and manage experiences, until carrying out evaluation process, collecting results with corresponding technology. This part of standard the importance of the process of collecting evaluation experiences is emphasized too because these experiences are foundation to improve further evaluations. Support for project management, evaluation planning, promotion, evaluation projects and collection of the evaluation results are also described and in Annex A of the standard Quantitative Evaluation Plan Template is given.

ISO/IEC 14598-3 [13] should be used by organizations that are planning to develop a new product or enhance an existing product and intending to perform product evaluation using members of its own technical staff [5, 6] such as developers, project managers, software designers, quality assurance and maintainers, software acquirers etc. Full quality usage of standard assumes that standard should be used from early project stages, and involvement of the organization is needed as it is described earlier. This part ensures internal quality, describes evaluation process requirements from general, organizational and project, through establishment of evaluation, specification of internal and external requirements, design of evaluation, execution of evaluation and feedback of evaluation to organization.

Evaluation process for acquirers is described in Part 4 [14] and it should be used by organizations that are planning to acquire or reuse an existing or pre-developed software product, to decide on the acceptance of the product or for selecting a product from among alternatives [5, 6].

Part 5 of ISO/IEC 14598 [6] describes evaluation process for evaluators (test labs, suppliers, acquirers, certification authorities...) where an independent assessment of existing product or product in development is described. Initial agreement is entry point to establish evaluation process, standard defines parties involved in process, characteristics of the evaluation process (activities, input, output), requirements of the evaluation process through steps of implementing evaluation and gives at the end conclusions for further actions.

ISO/IEC 14598-6 [15] defines documentation of evaluation process, formats, characteristics, interpretation of results, etc., and gives examples of evaluation through annexes where are described informative examples of evaluation.

3.4 Software product quality requirements and evaluation (SQuaRE) process: ISO/IEC 25000

After some time the need to consolidate both ISO/IEC 9126 and 14598 standards has emerged. ISO/IEC started to produce new, extensive set of standards **SQuaRE** (**S**oftware product **Qua**lity **R**equirements and **E**valuation), or ISO/IEC 25000 set of standards. SQuaRE set of standards consists of the following divisions:

- 2500n - Quality Management Division,
- 2501n - Quality Model Division,
- 2502n - Quality Measurement Division,
- 2503n - Quality Requirements Division, and
- 2504n - Quality Evaluation Division.

Numbers from 25050 to 25099 are reserved to be used for SQuaRE extension International Standards, Technical Specifications, Publicity Available Specifications (PAS) and/or Technical Reports (10, iv).

Planed and already published SQuaRE standards are shown in Table 2.

4 Software product quality international standards through software development life cycle

In each part of ISO/IEC 9126 standard there is an Annex B (Informative) showing an example usage of the ISO/IEC 9126 Quality model and related metrics during the software development and implementation to achieve a quality product that meets user's specified requirements.

In given example of the software development life cycle (SDLC) there are 8 steps/phases which can be used but these steps can be mapped into different SDLC models. These steps/phases are Requirement analysis, Architectural design, Software detailed design, Software coding and testing, Software integration and software qualification testing, System integration and system qualification testing, Software installation, and Software acceptance support, and they are mapped to the key life cycle processes from the ISO/IEC 12207 standard (and some ISO/IEC 15288 too).

For every step standard defines actual measures, key deliverables of the step, and metrics that can be used in the particular step. Every step of life cycle produces documentation that can be managed using ISO/IEC 15288 standard. ISO/IEC 15288 also helps evaluators to identify documents that are necessary to define and provide successful evaluation, to define its content, purpose, plans and schedule, and it helps to use other standards in developing of documentation and ensure management of this documentation.

Deliverables of every life cycle step are described in outcomes of every process in ISO/IEC 12207 standard. In section 6 of standard and its subsections are described system specific processes while section 7 and its subsections describes software specific processes and their purpose, outcomes, activities and tasks. These key deliverables may be measured for quality with help of ISO/IEC 9126 related metrics/measures convenient to the particular SDLC phase, while the software evaluation processes and related documentation are defined and described in ISO/IEC 14598 set of standards.

The usage and connection of international standards mentioned above through SLCP is shown in Figure 3.

In ISO/IEC 9126 standard Annex B the Quality Approach Steps related to the steps of evaluation process from ISO/IEC 14598-1 are suggested:

- Goal quality - for each of the 7 quality characteristics and sub-characteristics the goal quality (relative, e.g. high, medium, low) weights should be determined (in a form of quality measurement table);
- Set measure and required level - for each of the 7 characteristics and sub-characteristics the measure to be applied should be identified and their required levels to achieve the previously set goal qualities; it is suggested to do it for each of the phases in the SLCP and for each of the measurement categories that may be performed;
- Identify deliverables for management & applicable metrics - a measurement plan (similar to suggested Table B.4) should be developed containing the deliverables that are measured, and for each deliverable metrics that are to be used and the criteria for determining the actual level in assessment; it is suggested to do it for each of the phases in the SLCP and for each of the measurement categories that may be performed too; it should be mentioned again that in each of the ISO/IEC 9126 parts containing metrics – parts 2, 3 and 4, in the metrics tables for some metrics there is a ISO/IEC 12207 reference which links ISO/IEC 9126 and ISO/IEC 12207;
- Update the quality measurement table – after completing all measurements the results should be mapped onto the quality measurement table and conclusions, together with identified areas where quality improvements are required/possible for the product to meet the goal quality should be put in the form of a report.

In Annex C (informative) of ISO/IEC 14598-5 there is the list of proposed types of (product) information that may be used for an evaluation mapped to particular product of SLCP, and described in more detail in ISO/IEC 15289.

Practical approach from viewpoint of developer, acquirer or evaluator is described in ISO/IEC 14598 (Parts 3, 4 and 5), where standard contains SLCP through evaluation of product divided into three parts. Every participant of SLCP uses part of ISO/IEC 14598 standard for corresponding stage of life cycle in evaluating product quality.

From perspective of SLCP, ISO/IEC 9126 and ISO/IEC 12207 have many relations in implementation of SLCP and strong relationship.

According Al-Qutaish [1] in ISO/IEC 9126 and ISO/IEC 12207 standards many cross-references exist in SLCP and author proposes set of measures to improve mapping of both ISO/IEC standards. In ISO/IEC 12207 some processes doesn't have corresponding metrics in ISO/IEC 9126, some metrics in ISO/IEC 9126 can't be clearly identified according to SLCP described in ISO/IEC 12207, and this is the lack of the ISO 9126 standard.

Author [1] gives numerous suggestions to be built into ISO/IEC 25000 and improvements of ISO/IEC 9126 standard to avoid cross-references and cover all processes and corresponding measures of the SLCP. Some comments are: nonexistent metric for "organizational processes", confusion between "system integration" and "software integration" in ISO/IEC 12207 for ISO/IEC 9126 user, etc.

At the end author [1] proposes investigation and analyzing of data collection points for ISO/IEC 9126 in ISO/IEC 12207 SLCP.

Table 2. SQuaRE planed and published standards (June 2013)

Planed	Published	Revises
2500n – Quality Management		
25000: Guide to SquaRE (NP)	ISO/IEC 25000:2005 Software Engineering – Software product Quality Requirements and Evaluation (SQuaRE) - Guide to SQuaRE	
25001: Planning and management	ISO/IEC 25001:2007 Software engineering - Software product Quality Requirements and Evaluation (SQuaRE) - Planning and management	ISO/IEC 14598-2:2000
2501n - Quality Model		
25010:Quality model and guide (Rev)	ISO/IEC 25010:2011 Systems and software engineering - Systems and software Quality Requirements and Evaluation (SQuaRE) - System and software quality models	ISO/IEC 9126-1:2001
	ISO/IEC 25012:2008 Software engineering - Software product Quality Requirements and Evaluation (SQuaRE) - Data quality model	
2502n - Quality Measurement		
25020:Measurement reference model and guide (NP)	ISO/IEC 25020:2007 Software engineering - Software product Quality Requirements and Evaluation (SQuaRE) - Measurement reference model and guide	
25021:Measurement primitives (NP)	ISO/IEC 25021:2012 Systems and software engineering - Systems and software Quality Requirements and Evaluation (SQuaRE) - Quality measure elements	ISO/IEC TR 25021:2007
25022:Measurement of internal quality		
25023:Measurement of external quality		
25024:Measurement of quality in use		
2503n - Quality Requirements		
25030: Quality requirements and guide (NP)	ISO/IEC 25030:2007 Software engineering - Software product Quality Requirements and Evaluation (SQuaRE) - Quality requirements	
2504n - Quality Evaluation		
25040:Quality evaluation overview and guide	ISO/IEC 25040:2011 Systems and software engineering - Systems and software Quality Requirements and Evaluation (SQuaRE) - Evaluation process	ISO/IEC 14598-1:1999
25041:Evaluation modules	ISO/IEC 25041:2012 Systems and software engineering - Systems and software Quality Requirements and Evaluation (SQuaRE) - Evaluation guide for developers, acquirers and independent evaluators	ISO/IEC 14598-3:2000 ISO/IEC 14598-4:1999 *ISO/IEC 14598-5:1998*
25042:Process for developers		
25043:Process for acquirers		
25044:Process for evaluators		
	ISO/IEC 25045:2010 Systems and software engineering - Systems and software Quality Requirements and Evaluation (SQuaRE) - Evaluation module for recoverability	
ISO/IEC 25050-25099		
	ISO/IEC 25051:2006 Software engineering - Software product Quality Requirements and Evaluation (SQuaRE) - Requirements for quality of Commercial Off-The-Shelf (COTS) software product and instructions for testing	ISO/IEC 12119:1994 Revised by: ISO/IEC DIS 25051 (under development)
	ISO/IEC TR 25060:2010 Systems and software engineering - Systems and software product Quality Requirements and Evaluation (SQuaRE) - Common Industry Format (CIF) for usability: General framework for usability-related information	
	ISO/IEC 25062:2006 Software engineering - Software product Quality Requirements and Evaluation (SQuaRE) - Common Industry Format (CIF) for usability test reports	

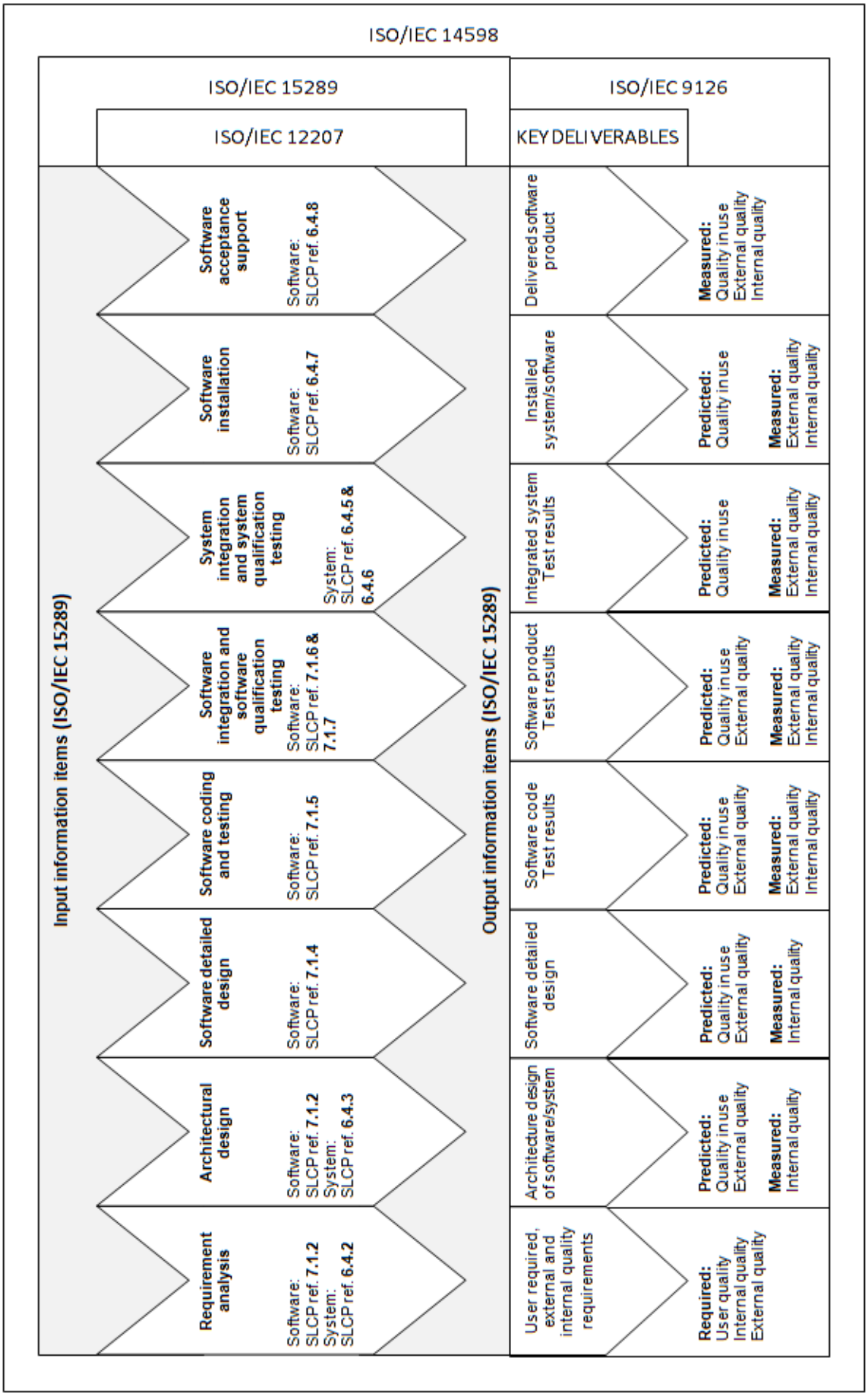

Figure 3.Software product quality and related international standards through software development life cycle

5 Conclusion

Usage of ISO/IEC 9126, ISO/IEC 14598 and other standards related to software quality is not easy because there are too many relationships between this standards, too many cross-references, different types of SLCP-s, etc.

Projects of synchronization of related standards such as SQuaRE are one of possible solutions for this problem. Some investigations proposed from authors mentioned above may lead to new organizational, functional and clear usage of these standards. Purpose of standards is to clear confusion, give the right direction, not to make things complicated.

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