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# D2.5: Assessment and comparison of metrics

# MEASURE

## Table of Contents

# 1. Introduction

## 1.1. Role of this deliverable

As its title suggests, this deliverable D2.5 describes the assessment and comparison of the 150+ software metrics implemented in the MEASURE platform. There are several ways in which an assessment could be made, but we chose one that would prepare us for the future (since we are at the end of the project), namely an assessment with regard to a sustainability dimension. Moreover, we tried to have independent opinions on that, i.e., to have also people outside of the project that assessed the metrics, in this way testing the potential of our metrics.

This was organised using a "focus group study" during the MEGSUS'18 Workshop[1]. The results of this study that assessed the MEASURE metrics are reported in this Deliverable 2.5 and were also published in the following paper (in the post-proceedings of the workshop):

> "***A focus group for operationalizing software sustainability with the MEASURE platform*". Nelly Condori-Fernandez (Vrije Universiteit Amsterdam), Alessandra Bagnato (Softeam), Eva Kern (Leuphana University Lueneburg). Proc. of MEGSUS'18 Workshop, CEUR Workshop Proceedings 2286, 2018, pp. 7-19. Online: http://ceur-ws.org/Vol-2286/invited_paper_4.pdf**

Regarding metrics and sustainability, the field of measuring the sustainability of software products is still in the early stages of development. However, there are different approaches how to assess sustainability issues of software and its engineering - including metrics with a practical orientation as well as more theoretical models covering software sustainability.

As a step in moving forward bringing existing approaches together, this deliverable presents a focus group study conducted to find out in which extent the quality attributes related to the technical sustainability can be measured by using existing metrics available in the MEASURE platform.

Our results show that the extent of measurability varies across the software development phases. Functional correctness, robustness, maturity, and testability are the most measurable quality attributes, which our MEASURE platform supports.

## 1.2. Relationship with others MEASURE deliverables

This deliverable is linked to previous deliverables "D2.4: Reuse and combinatory of metrics" where we analyse and combine measures and "D2.3: Methods for methodological and technical integration of MEASURE metrics", in which metrics integration within the MEASURE platform are presented. Also, there is a complementary relation of this deliverable to Deliverable 5.5, where an evaluation of the metrics and MEASURE tools was performed on concrete scenarios.

## 1.3. Contributors

This deliverable was edited by Alin Stefanescu from University of Bucharest, based on the report by Alessandra Bagnato, Softeam, Nelly Condori-Fernandez, Vrije Universiteit Amsterdam, Eva Kern, Leuphana University of Luneburg. Also, we mention below all the participants who took part in our

[1] *http://eseiw2018.wixsite.com/megsus18 "4th International Workshop on Measurement and Metrics for Green and Sustainable Software Systems (MeGSuS'18) October 9, 2018 - Oulu, Finland"*

focus group study: Jerome Rocheteau from the Institut Catholique d’arts et metiers (ICAM), Birgit Penzenstadler from California State University Long Beach, Shola Oyedeji from Lappeenranta University of Technology, Denisse Munante from University of Bordeaux, Diogo Silveira Mendoa from Pontifical Catholic University of Rio de Janeiro, and Thibault Beziers la Fosse from Laboratoire des Sciences du Numerique de Nantes, Software Modeling Group (LS2NNAOMOD).

## 1.4. Structure of the deliverable

The deliverable is structured as follows: Section 2 presents the MEASURE platform and the Software Sustainability Model. The design of a focus group, including a description of the participants, research questions, methods, and validity is introduced in Section 3, whereas Section 4 summarizes and discusses the results of our study. We provide a list of referenced metrics in the Appendix.

# 2. Context

## 2.1. Introduction

Assessment based on the notion of sustainability, as a software quality property, is still emerging and poorly understood [1]. Consequently, how software should be assessed against sustainability concerns is still immature even though it is attracting increasing attention from both research and practice.

This is especially the case when it comes to technical sustainability of software. According to [2], [3] technical sustainability has the central objective of long-time usage of systems and their adequate evolution with changing surrounding conditions and respective requirements. However, so far, there is a knowledge gap how to transfer theoretical knowledge into practical routines [4]–[7]. Here, software measurement can help in creating transparency into software properties and in providing information on sustainability issues of software to developers. Sustainability issues of software are discussed in more details in [8]–[10]. Thus, in this deliverable, we will concentrate on the presentation of bringing the metrics of the MEASURE platform - and aspects of a Software Sustainability Model [11] together. Doing so, we bring practical and scientific approaches in assessing the technical sustainability of software products together.

## 2.2. Metrics inside MEASURE

Our MEASURE platform offers a comprehensive set of tools for automated and continuous measurement over all stages of the software development life cycle (specification, design, development, implementation, testing, and production). Thus, the MEASURE project can develop a body of knowledge that shows software engineers why, how and when to measure quality of process, products and projects. Nowadays, an emergent quality property of the software systems is **sustainability**.

Although there is an urgent demand for innovative solutions and smart applications for a sustainable society worldwide, sustainability measurement and assessment are big challenges. The MEASURE project developed a set of 150+ metrics related to different aspects of software engineering. Within this last deliverable in WP2, and with the help of an external focus group we contribute to address sustainability under a multi-dimensional perspective on the entire software development life cycle.

## 2.3. The software sustainability-quality model

Lago et al. [3] and Venters et al. [16] agree on defining software sustainability in terms of multiple and interdependent dimensions (e.g. economic, technical, social, environmental, individual). Several efforts have been put to define software sustainability in terms of quality requirements (e.g. [10], [16]–[19]). For instance, Condori-Fernandez and Lago [19] provided (i) a detailed characterization of each software sustainability dimension, which is a first step towards its respective operationalization, and (ii) a list of direct dependencies among the four sustainability dimensions: economic, technical, social, and environmental.

The economic dimension aims to ensure that software-intensive systems can create economic value. It is taken care of in terms of budget constraints and costs as well as market requirements and long-term business objectives that get translated or broken down into requirements for the system under consideration. The social dimension aims to allow current and future generations to have equal and equitable access to the resources in a way that preserves their socio-cultural characteristics and achieve healthy and modern society. The environmental dimension seeks to avoid that software-intensive systems harm the environment they operate in. And, the technical dimension is concerned with supporting long-term use and appropriate evolution/adaptation of software-intensive systems in constantly changing execution environment. Based on these definitions, quality attributes (QA) that contribute to the corresponding sustainability dimensions of software-intensive systems were identified [19]. As a result of this characterization per sustainability dimension in terms of quality attributes and identification of direct dependencies, a software sustainability-quality model was proposed, which can be found in [11].

# 3. Focus Group Study Design

## 3.1. Goal and research questions

The goal of our focus group study, according to the Goal/Question/Metric template, is as follows:

**Analyze metrics** from the MEASURE platform and Software Sustainability-Quality Model [11] **for the purpose** of operationalizing quality attributes that contribute to technical sustainability **from the viewpoint** of software engineer (researcher or practitioner) in the context of the MeGSuS workshop[2].

Our focus group study represents our assessment exercise of the MEASURE platform. We define the following research question:

**RQ1**: *In which extent can the MEASURE platform be useful for measuring technical sustainability?*

For determining the potential usefulness of MEASURE for operationalizing the sustainability-quality attributes, from our research question, we set out three specific questions to our participants:

**RQ1:1**: *Do you agree with the contribution of the selected quality attributes as contributors to technical sustainability?*

**RQ1:2**: *In which phase of the software development life cycle, do you think it would be feasible to measure the list of quality attributes*?

**RQ1:3**: *Which metrics from the MEASURE platform can be useful for measuring technical sustainability?*

## 3.2. Metrics inside MEASURE

For answering our research question, we considered it advisable that our participants should have a very good knowledge competence on software measurement, as well as interest in any research topic related to software sustainability. Both criteria were successfully satisfied by our eight participants, attendees of the MeGSuS workshop. Two of them were practitioners. All of them contributed to the workshop focusing on software measurement and showed their interest in the topic by that.

## 3.3. Instrumentation and data collection

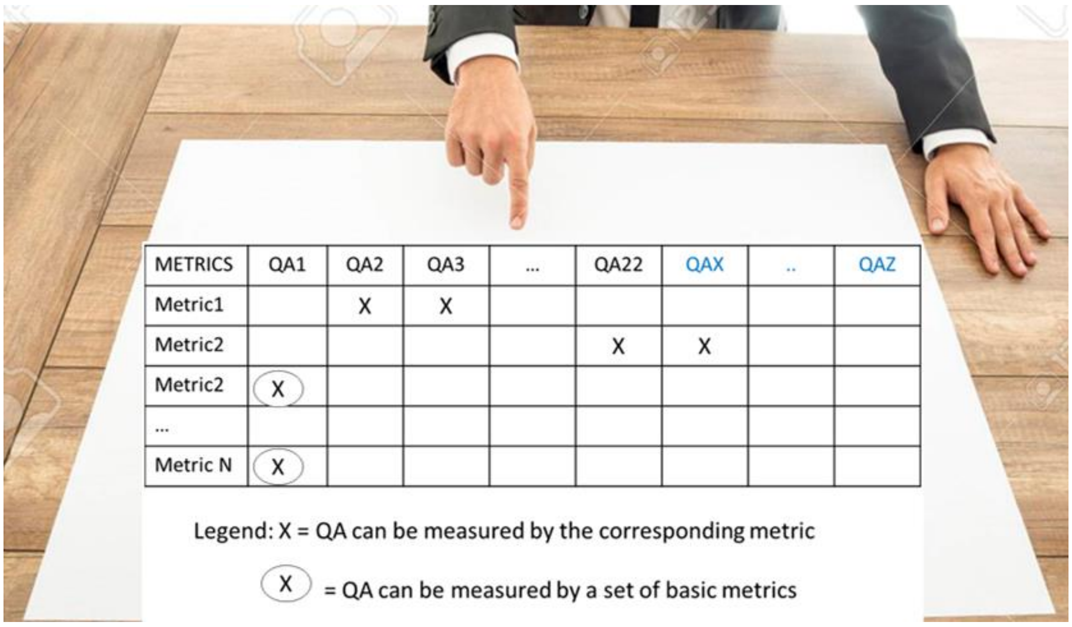
The focus group study was organized in four small groups, to run the study, the following instrumentation was distributed among the groups:

- Technical sustainability definition
- List of quality attributes and corresponding definitions of the attributes
- Metrics from the MEASURE platform, whose definitions were accessible via a wiki website[3].

After reading and clarifying the definitions, the participants selected the phase of the software development, they felt most familiar with. Regarding our two first specifics questions, verbal data

[2] *http://eseiw2018.wixsite.com/megsus18*

[3] *https://github.com/ITEA3-Measure/Measures/wiki*



| METRICS | QA1 | QA2 | QA3 | ... | QA22 | QAX | .. | QAZ |
|---|---|---|---|---|---|---|---|---|
| Metric1 | | X | X | | | | | |
| Metric2 | | | | | X | X | | |
| Metric2 | ⓧ | | | | | | | |
| ... | | | | | | | | |
| Metric N | ⓧ | | | | | | | |

Legend: X = QA can be measured by the corresponding metric

ⓧ = QA can be measured by a set of basic metrics

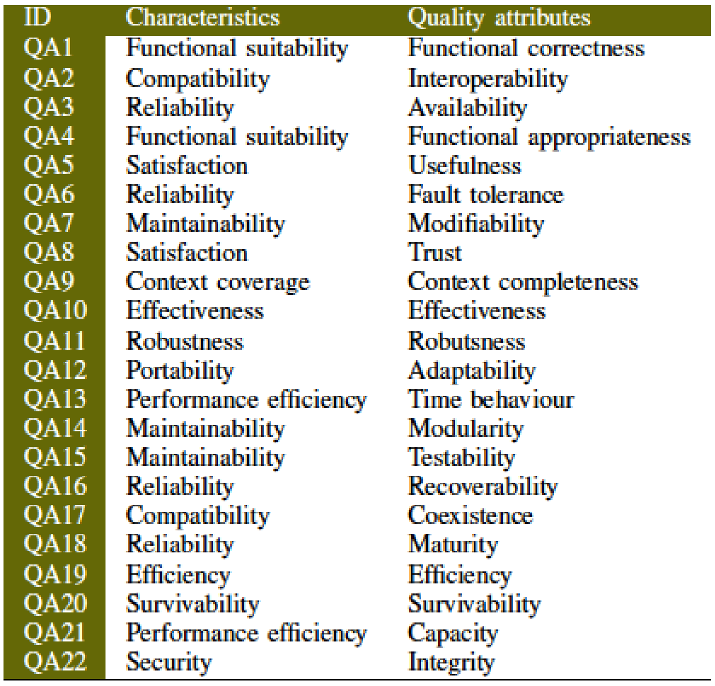
*Figure 1. Matrix used for mapping selected metrics with the quality attributes (QA)*

was collected, whereas for our third question, a large sheet of paper containing a grid was used by each focus group.

As shown in Figure 1, participants used an ”X” for representing the relation: ”M can measure QA” or ”QA can be measured by M”.

Those ”X” enclosed by a circle were used to identify a set of basic metrics that can measure a QA.

Figure 2 shows the twenty-two quality attributes of technical sustainability that were analyzed by our focus group participants.



| ID | Characteristics | Quality attributes |
|---|---|---|
| QA1 | Functional suitability | Functional correctness |
| QA2 | Compatibility | Interoperability |
| QA3 | Reliability | Availability |
| QA4 | Functional suitability | Functional appropriateness |
| QA5 | Satisfaction | Usefulness |
| QA6 | Reliability | Fault tolerance |
| QA7 | Maintainability | Modifiability |
| QA8 | Satisfaction | Trust |
| QA9 | Context coverage | Context completeness |
| QA10 | Effectiveness | Effectiveness |
| QA11 | Robustness | Robutsness |
| QA12 | Portability | Adaptability |
| QA13 | Performance efficiency | Time behaviour |
| QA14 | Maintainability | Modularity |
| QA15 | Maintainability | Testability |
| QA16 | Reliability | Recoverability |
| QA17 | Compatibility | Coexistence |
| QA18 | Reliability | Maturity |
| QA19 | Efficiency | Efficiency |
| QA20 | Survivability | Survivability |
| QA21 | Performance efficiency | Capacity |
| QA22 | Security | Integrity |

*Figure 2. Technical sustainability-quality attributes identified*

## 3.4. Procedure

As shown in Figure 3, the procedure of our focus group study involves the following four phases:

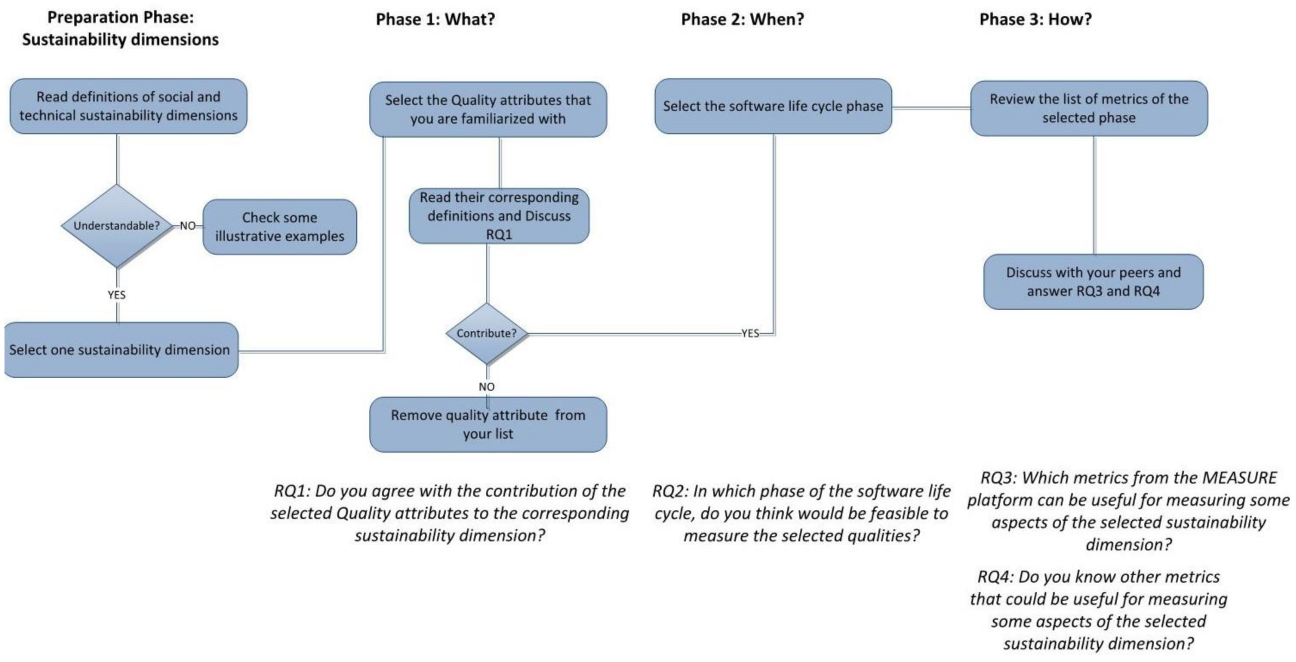

Preparation Phase: Sustainability dimensions
Phase 1: What?
Phase 2: When?
Phase 3: How?
Read definitions of social and technical sustainability dimensions
Understandable?
NO
Check some illustrative examples
YES
Select one sustainability dimension
Select the Quality attributes that you are familiarized with
Read their corresponding definitions and Discuss RQ1
Contribute?
YES
NO
Remove quality attribute from your list
Select the software life cycle phase
Review the list of metrics of the selected phase
Discuss with your peers and answer RQ3 and RQ4
RQ1: Do you agree with the contribution of the selected Quality attributes to the corresponding sustainability dimension?
RQ2: In which phase of the software life cycle, do you think would be feasible to measure the selected qualities?
RQ3: Which metrics from the MEASURE platform can be useful for measuring some aspects of the selected sustainability dimension?
RQ4: Do you know other metrics that could be useful for measuring some aspects of the selected sustainability dimension?

*Figure 3. Focus group procedure*

**1) Preparation phase**:

This phase has two objectives:

i. to get a common understanding on what software sustainability means regarding technical sustainability dimensions,
ii. to decide which sustainability dimensions are going to be used in the next phase. This phase has been carried out by the organizers of the focus group, consisting of one moderator and two assistants. After having a discussion (before realizing the focus group), and considering also the time allocated for this study as part of the MeGSuS workshop, the researchers decided to work with the technical sustainability dimension.

The activities of the next phases were carried out during the focus group.

2) **Phase 1: What?**

The objective of this phase is to validate the contribution of the corresponding QAs to the technical sustainability dimension. Thus, in this phase, participants answered RQ1:1. The moderator introduced briefly the motivation of the focus group, presented an overview of the sustainability-quality model as well as a plan of activities to be carried out. The outcome of this phase is a list of selected QAs that will be analyzed in the following phases.

The average time taken for this phase was about 10 minutes.

**3) Phase 2: When?**

The objective of this second phase is to discuss on which phases of the software life cycle the selected qualities could be measured. Thus in this phase, based on their participants experience, RQ1:2 was answered.

The average time taken was about 5 minutes.

**4) Phase 3: How?**

The objective of this third phase is to assess the usefulness of the metrics from the MEASURE platform. Thus, in this phase, participants answered RQ1:3.

It took approximately 25 minutes.

All participants of the four focus groups shared their mapping results, by emphasizing the reasoning behind the mappings, difficulties of understanding the purpose of some metrics and discussing open questions on the connection of the issues. In this phase, we were open to new metrics that could be suggested by the participants. However, due to time restrictions, this data was not collected.

## 3.5. **Threats to validity**

We identified the following threats to validity [20] of our study.

- *External validity*. It is the ability to generalize the results from a sample to a population. As focus groups tend to use rather small, homogeneous samples, generalization is the main limitation of our study. Our study involved four mini-groups, with people from different countries, but most of them were researchers. To mitigate this threat, we are going to replicate this first focus group, involving more groups representing a diverse sample of people.
- *Internal validity*. It is strengthened by a moderator providing an appropriate amount of guidance without introducing any of his/her own opinion or stifling free expression. In order to reduce this threat, the moderator used an introductory material (Powerpoint-slides) for contextualizing the focus group study.
- *Construct validity*. It is concerned with whether the focus group is actually measuring what they are trying to measure. In our focus group, we focus on investigate the coverage and measurability aspects. By using two different existing approaches - one with a more practical orientation and one theoretical model - having a common focus, the direction of the focus group was specifically predefined. This ensured that the focus of discussion was also set on the technical sustainability dimension.

## 4. Results and discussion

In order to answer our main research question related to the usefulness of the MEASURE platform for measuring the technical sustainability dimension, we analyzed the collected data from each focus group (see matrix, Figure 6). Usefulness of the platform is analyzed regarding coverage and measurability aspects, which are discussed as follows.

### 4.1. Analyzing the coverage of the MEASURE platform

Considering the total of metrics available at the MEASURE platform [21], [22], [13], which are organized by software development phase, Table II shows the percentage of software metrics selected by the participants of each mini-focus group as useful for measuring any QA of the technical sustainability dimension. According to these results, we observe that all metrics available for the specification phase (100%) could be related with the corresponding QAs, whereas only 25% of 51 metrics for the implementation phase were related.

*Table II Percentage of metrics selected by the focus group participants per development phase*

| Phase | Number of selected metrics | Total of metrics[3] | Percentage |
|---|---|---|---|
| Specification | 10 | 10 | 100% |
| Design | 16 | 35 | 46% |
| Implementation | 13 | 51 | 25% |
| Testing | 15 | 22 | 68% |

Next we present the selected metrics by each mini-focus group.

1) Metrics for the specification phase: Table III (see Appendix):”Selected metrics of the specification phase” shows the 10 selected specification phase metrics that were mapped with the QAs of the technical sustainability dimension.
2) Metrics for the design phase: Table IV (see Appendix): ”Selected metrics of the design phase” shows the 18 selected design phase metrics that were mapped with the QAs of the technical sustainability dimension.
3) Metrics for the implementation phase: Table V (see Appendix): ”Selected metrics of the implementation phase” shows the 13 selected implementation phase metrics that were mapped with the QAs of the technical sustainability dimension.
4) Metrics for the testing phase: Table VI (see Appendix): ”Selected metrics of the testing phase” shows the 21 selected testing phase metrics that were mapped with the QAs of the technical sustainability dimension.

As shown in the matrix of Figure 6 in Appendix, the specification, design, implementation, and testing metrics were associated to the quality attributes presented in Figure 2.

### 4.2. Analyzing the measurability of the quality attributes

Considering the twenty-two QAs of the technical sustainability dimension (see Figure 2), Figure 4 shows the percentages of QAs that can be measured by at least one of the selected metrics. Most of the QAs can be measured at the specification phase (82%, 18 of 22 QAs), followed by design (59%, 13 of 22 QAs), testing (32%, 7 of 22 QAs) and implementation (23%, 5 of 22 QAs).

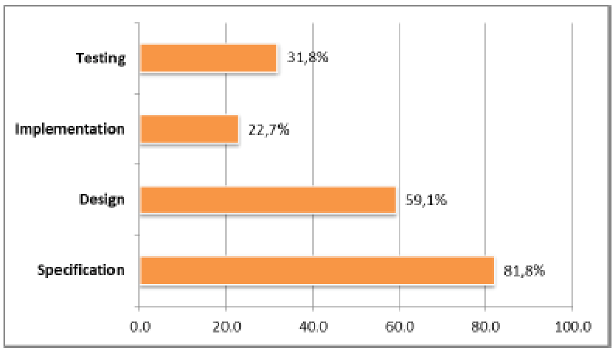
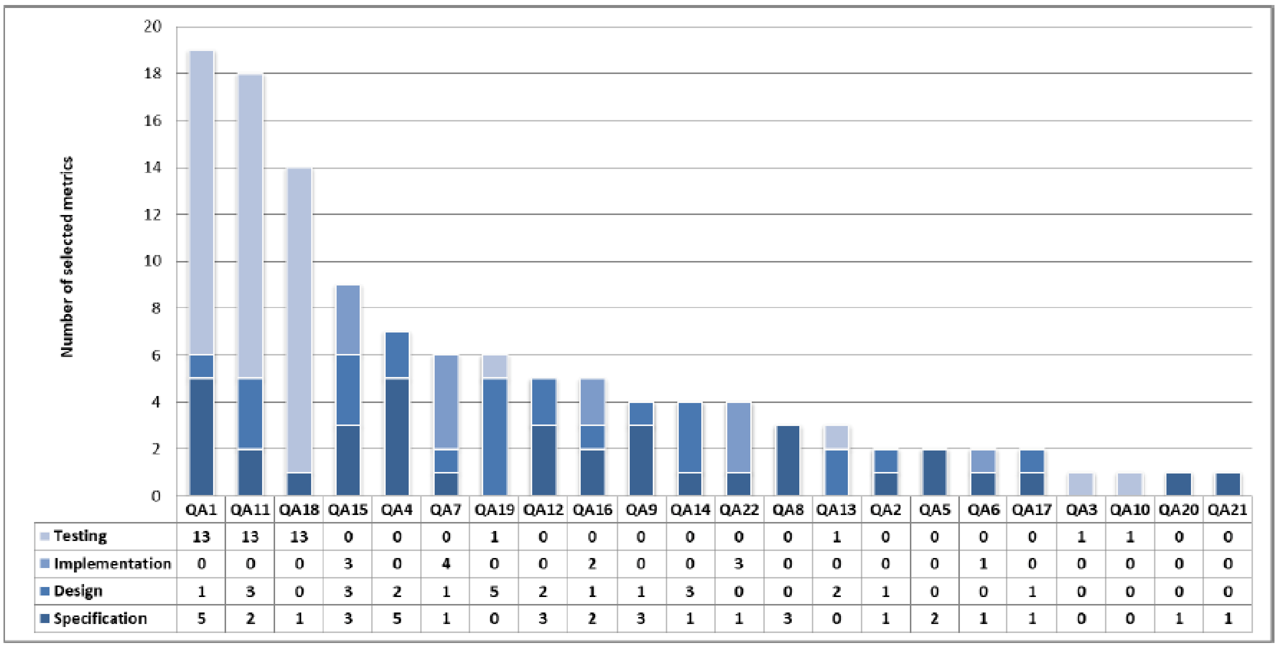


*Figure 4. Percentage of measurable quality attributes per phase*

This indicates that most of the QAs related to the technical sustainability can be qualified as measurable. In order to represent the extent of measurability for each development phase, we calculated the number of available metrics selected from the platform for measuring each QA (see Figure 5).



| | QA1 | QA11 | QA18 | QA15 | QA4 | QA7 | QA19 | QA12 | QA16 | QA9 | QA14 | QA22 | QA8 | QA13 | QA2 | QA5 | QA6 | QA17 | QA3 | QA10 | QA20 | QA21 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Testing | 13 | 13 | 13 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 |
| Implementation | 0 | 0 | 0 | 3 | 0 | 4 | 0 | 0 | 2 | 0 | 0 | 3 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 |
| Design | 1 | 3 | 0 | 3 | 2 | 1 | 5 | 2 | 1 | 1 | 3 | 0 | 0 | 2 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 |
| Specification | 5 | 2 | 1 | 3 | 5 | 1 | 0 | 3 | 2 | 3 | 1 | 1 | 3 | 0 | 1 | 2 | 1 | 1 | 0 | 0 | 1 | 1 |

*Figure 5 Measurability: Number of metrics per quality attribute related to technical sustainability*

According to these results, we observe that our participants found that functional correctness, robustness and maturity can be measured by using a good number of metrics at the testing phase (13 metrics). In case of the specification phase, especially functional correctness and functional appropriateness are of high importance, meaning covered by many metrics (5 of 10 metrics). Efficiency is connected with most of the metrics of the design phase while the quality attribute is not covered in the other phases analyzed. Overall, functional suitability is connected to many of the proposed metrics for the analysed software development phases.

## 5. Conclusions

In this deliverable, we describe the result of the focus group designed to discuss the assessment and comparison on metrics with respect to ”What, when and how to measure software sustainability”. We organized the study within the MeGSuS 2018: 4th International Workshop on Measurement and Metrics for Green and Sustainable Software Systems [23].

Through the focus group, we found a good number of metrics that were selected from the MEASURE platform as “potentially” useful for measuring quality attributes of the technical sustainability dimension along certain phases of the software development life cycle (i.e. design, specification, testing, implementation). This result provides evidence on the coverability of the MEASURE platform for the specification, design, implementation and testing phases.

Moreover, the study has also shown that most of the technical sustainability-quality attributes are measurable. The results can be appreciated and are summarized in Figure 5, where we can highlight the following results:

- Metrics for the specification phase were distributed among the various QAs with higher metrics related to QA1 and QA4.
- Metrics for the design phase were distributed among the various QAs with higher metrics related to QA19, QA15 and QA14.
- Metrics for the implementation phase focus, according to the results of the focus group, on a limited number of QAs (QA15, QA7, QA22) related to technical sustainability dimension. The subgroup considered that maintenability / testability, maintenability / modifiability, and security were the QAs associated to the higher number of implementation metrics (see Table V).
- Metrics for the testing phase focus on a limited number of QAs (QA1, QA11, QA18) related to technical sustainability dimension. The sub-group considered that functional suitability, robustness, and reliability were the QAs associated to the higher number of testing metrics (see Table VI).

Functional correctness, robustness, maturity and testability are the most measurable quality attributes considering the four phases. The focus group acknowledged that the technical sustainability dimension [19] could be operationalized by the MEASURE platform implemented metrics. For validating these results, we are going to replicate the study to find both similarities and differences.

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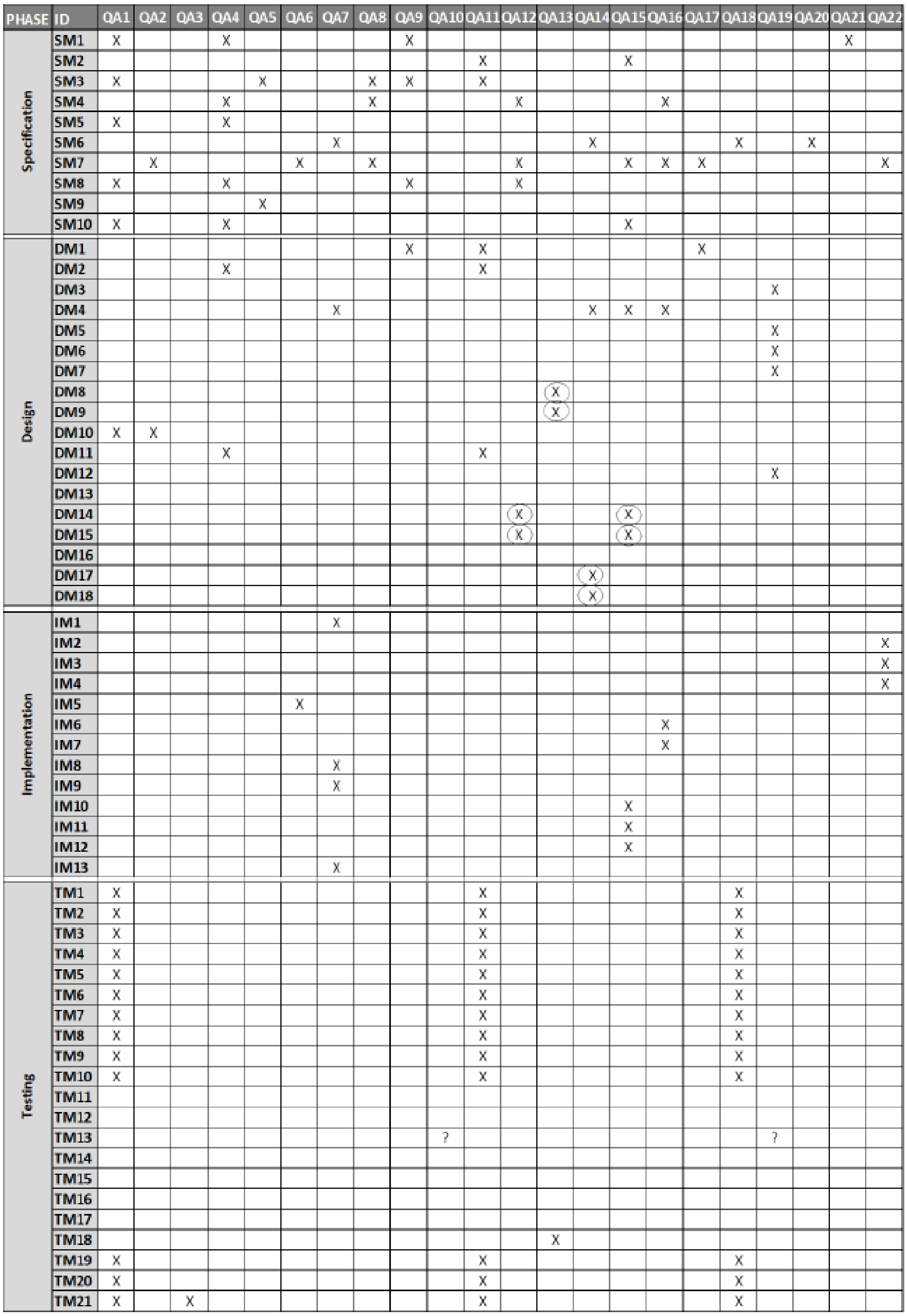
## Appendix



| PHASE | ID | QA1 | QA2 | QA3 | QA4 | QA5 | QA6 | QA7 | QA8 | QA9 | QA10 | QA11 | QA12 | QA13 | QA14 | QA15 | QA16 | QA17 | QA18 | QA19 | QA20 | QA21 | QA22 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Specification | SM1 | X |  |  | X |  |  |  |  | X |  |  |  |  |  |  |  |  |  |  |  | X |  |
|  | SM2 |  |  |  |  |  |  |  |  |  |  | X |  |  |  | X |  |  |  |  |  |  |  |
|  | SM3 | X |  |  |  | X |  |  | X | X |  | X |  |  |  |  |  |  |  |  |  |  |  |
|  | SM4 |  |  |  | X |  |  |  | X |  |  |  | X |  |  |  | X |  |  |  |  |  |  |
|  | SM5 | X |  |  | X |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|  | SM6 |  |  |  |  |  |  | X |  |  |  |  |  |  | X |  |  |  | X |  | X |  |  |
|  | SM7 |  | X |  |  |  | X |  | X |  |  |  | X |  |  | X | X | X |  |  |  |  | X |
|  | SM8 | X |  |  | X |  |  |  |  | X |  |  | X |  |  |  |  |  |  |  |  |  |  |
|  | SM9 |  |  |  |  | X |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|  | SM10 | X |  |  | X |  |  |  |  |  |  |  |  |  |  | X |  |  |  |  |  |  |  |
| Design | DM1 |  |  |  |  |  |  |  |  | X |  | X |  |  |  |  |  | X |  |  |  |  |  |
|  | DM2 |  |  |  | X |  |  |  |  |  |  | X |  |  |  |  |  |  |  |  |  |  |  |
|  | DM3 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | X |  |  |  |
|  | DM4 |  |  |  |  |  |  | X |  |  |  |  |  |  | X | X | X |  |  |  |  |  |  |
|  | DM5 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | X |  |  |  |
|  | DM6 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | X |  |  |  |
|  | DM7 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | X |  |  |  |
|  | DM8 |  |  |  |  |  |  |  |  |  |  |  |  | ⓧ |  |  |  |  |  |  |  |  |  |
|  | DM9 |  |  |  |  |  |  |  |  |  |  |  |  | ⓧ |  |  |  |  |  |  |  |  |  |
|  | DM10 | X | X |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|  | DM11 |  |  |  | X |  |  |  |  |  |  | X |  |  |  |  |  |  |  |  |  |  |  |
|  | DM12 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | X |  |  |  |
|  | DM13 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|  | DM14 |  |  |  |  |  |  |  |  |  |  |  | ⓧ |  |  | ⓧ |  |  |  |  |  |  |  |
|  | DM15 |  |  |  |  |  |  |  |  |  |  |  | ⓧ |  |  | ⓧ |  |  |  |  |  |  |  |
|  | DM16 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|  | DM17 |  |  |  |  |  |  |  |  |  |  |  |  |  | ⓧ |  |  |  |  |  |  |  |  |
|  | DM18 |  |  |  |  |  |  |  |  |  |  |  |  |  | ⓧ |  |  |  |  |  |  |  |  |
| Implementation | IM1 |  |  |  |  |  |  | X |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|  | IM2 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | X |
|  | IM3 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | X |
|  | IM4 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | X |
|  | IM5 |  |  |  |  |  | X |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|  | IM6 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | X |  |  |  |  |  |  |
|  | IM7 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | X |  |  |  |  |  |  |
|  | IM8 |  |  |  |  |  |  | X |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|  | IM9 |  |  |  |  |  |  | X |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|  | IM10 |  |  |  |  |  |  |  |  |  |  |  |  |  |  | X |  |  |  |  |  |  |  |
|  | IM11 |  |  |  |  |  |  |  |  |  |  |  |  |  |  | X |  |  |  |  |  |  |  |
|  | IM12 |  |  |  |  |  |  |  |  |  |  |  |  |  |  | X |  |  |  |  |  |  |  |
|  | IM13 |  |  |  |  |  |  | X |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Testing | TM1 | X |  |  |  |  |  |  |  |  |  | X |  |  |  |  |  |  | X |  |  |  |  |
|  | TM2 | X |  |  |  |  |  |  |  |  |  | X |  |  |  |  |  |  | X |  |  |  |  |
|  | TM3 | X |  |  |  |  |  |  |  |  |  | X |  |  |  |  |  |  | X |  |  |  |  |
|  | TM4 | X |  |  |  |  |  |  |  |  |  | X |  |  |  |  |  |  | X |  |  |  |  |
|  | TM5 | X |  |  |  |  |  |  |  |  |  | X |  |  |  |  |  |  | X |  |  |  |  |
|  | TM6 | X |  |  |  |  |  |  |  |  |  | X |  |  |  |  |  |  | X |  |  |  |  |
|  | TM7 | X |  |  |  |  |  |  |  |  |  | X |  |  |  |  |  |  | X |  |  |  |  |
|  | TM8 | X |  |  |  |  |  |  |  |  |  | X |  |  |  |  |  |  | X |  |  |  |  |
|  | TM9 | X |  |  |  |  |  |  |  |  |  | X |  |  |  |  |  |  | X |  |  |  |  |
|  | TM10 | X |  |  |  |  |  |  |  |  |  | X |  |  |  |  |  |  | X |  |  |  |  |
|  | TM11 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|  | TM12 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|  | TM13 |  |  |  |  |  |  |  |  |  | ? |  |  |  |  |  |  |  |  | ? |  |  |  |
|  | TM14 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|  | TM15 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|  | TM16 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|  | TM17 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|  | TM18 |  |  |  |  |  |  |  |  |  |  |  |  | X |  |  |  |  |  |  |  |  |  |
|  | TM19 | X |  |  |  |  |  |  |  |  |  | X |  |  |  |  |  |  | X |  |  |  |  |
|  | TM20 | X |  |  |  |  |  |  |  |  |  | X |  |  |  |  |  |  | X |  |  |  |  |
|  | TM21 | X |  | X |  |  |  |  |  |  |  | X |  |  |  |  |  |  | X |  |  |  |  |

Figure 6 Mapping between quality attributes related to technical sustainability dimension and metrics from the MEASURE platform. (X = ”Metric can measure quality attribute” or rather ”Quality attribute can be measured by metric”, ? = ”connection needs to be discussed”)

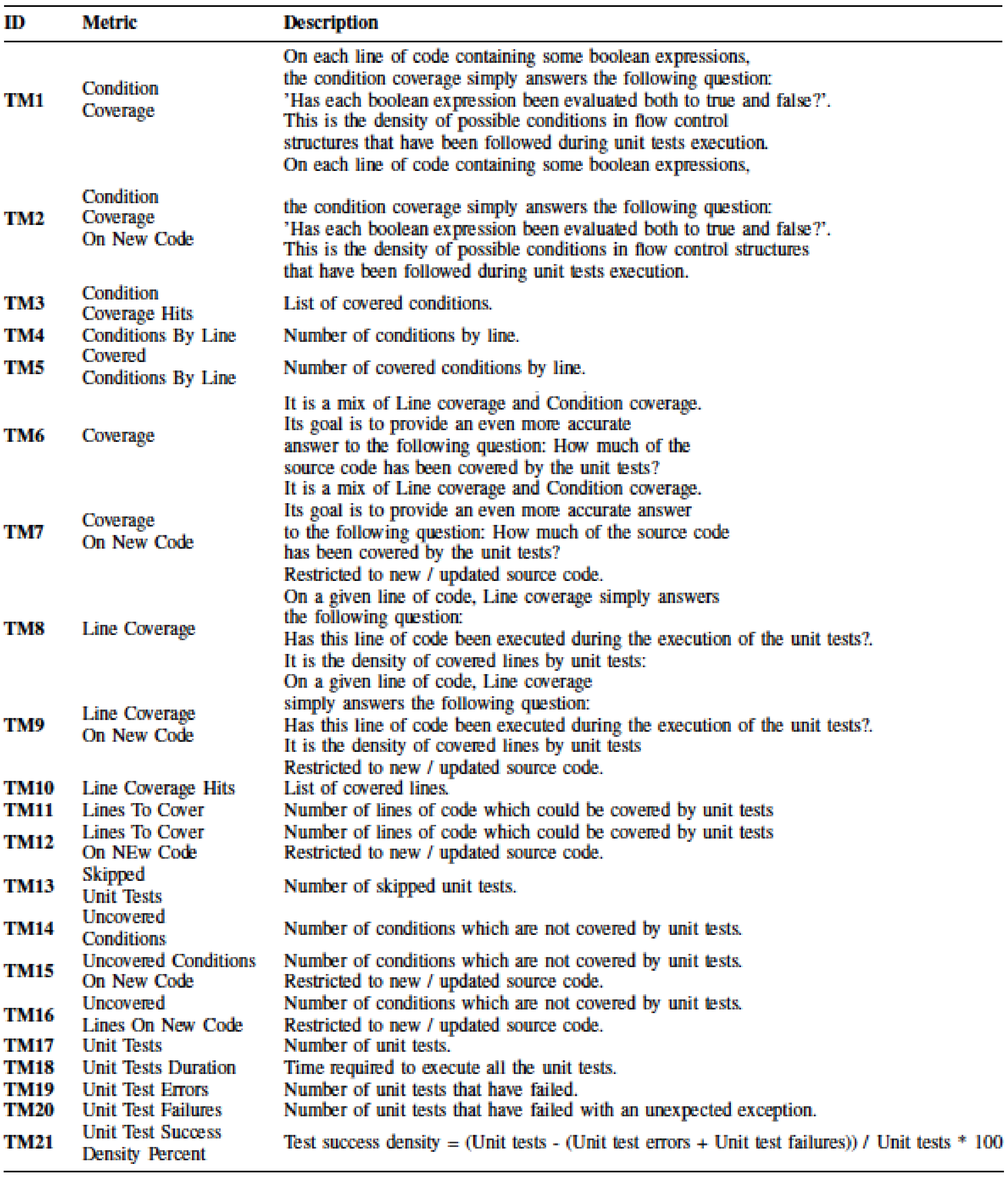
TABLE III: Selected metrics of the specification phase

| ID | Short name | Description |
|---|---|---|
| SM1 | Number of Requirement | Total number of requirement defined in the selected scope. |
| SM2 | Number of Tests | Total number of tests defined in the selected scope. |
| SM3 | Requirements Satisfaction Quality Indice | Percentage of requirements that have been satisfied. |
| SM4 | Requirement Traceability To Implementation Indice | Percentage of requirements that have been satisfied. |
| SM5 | Requirement Coverage Indice | The average number of requirements tracing an architecture model. |
| SM6 | Requirement Complexity Indice | The average number of sub requirements defined to rafine an existing requirement. |
| SM7 | Number Of Risks | Total number of risks defined in the selected scope. . |
| SM8 | Number Of Business Rules | Total number of requirement defined in the selected scope. |
| SM9 | Number Of Goals | Total number of goals defined in the selected scope. |
| SM10 | Requirement Traceability To Test Indice | The % of requirement of tracing a test model. |

TABLE IV: Selected metrics of the design phase

| ID | Short name | Description |
|---|---|---|
| DM1 | Class Complexity Index | The number of direct subclasses of a class. A class implementing an interface counts as a direct child of that interface. |
| DM2 | Package Dependecies Ratio | The average number of dependencies from a package. |
| DM3 | Number of Methods | Total number of methods defined in the selected scope. |
| DM4 | Software Component decomposition | The number of software components identified in an application architecture. |
| DM5 | Number of Classes | Total number of classes in the selected scope |
| DM6 | Number of Interfaces | Total number of interfaces in the selected scope. |
| DM7 | Number of Methods | Total number of methods defined in the selected scope. |
| DM8 | Number of Components | Total number of Components defined in the selected scope. |
| DM9 | Number of Packages | Total number of Packages defined in the selected scope. |
| DM10 | Class Dependency Ratio | The average number of dependencies from a class. |
| DM11 | Package Dependency Ratio | The average number of dependencies from a package. |
| DM12 | Model Abstractness Index | The% of abstract classes (and interfaces) divided by the total number of types in a package. |
| DM13 | Number of Fields | Total number of fields defined in the selected scope. |
| DM14 | Number of Use Cases | Total number of use cases defined in the selected scope. |
| DM15 | Number of Actors | Total number of actors defined in the selected scope. |
| DM16 | Number of Component Types | Total number of interfaces component types in the java Modelio model. Along with the total number of data, this metric provides an idea of the functional richness of the modelled application. |
| DM17 | Number of Aggregated Components | Total number of aggregated components in the java Modelio model. Along with the number of composed components, this metric reflects the usage of the software decomposition in the modelled application. |
| DM18 | Number of Composed Components | Count the number of Interface annotated @ComposedComponent in Java Model. |

TABLE VI: Selected metrics of the testing phase



| ID | Metric | Description |
|---|---|---|
| **TM1** | Condition Coverage | On each line of code containing some boolean expressions, the condition coverage simply answers the following question: 'Has each boolean expression been evaluated both to true and false?'. This is the density of possible conditions in flow control structures that have been followed during unit tests execution. |
| **TM2** | Condition Coverage On New Code | On each line of code containing some boolean expressions, the condition coverage simply answers the following question: 'Has each boolean expression been evaluated both to true and false?'. This is the density of possible conditions in flow control structures that have been followed during unit tests execution. |
| **TM3** | Condition Coverage Hits | List of covered conditions. |
| **TM4** | Conditions By Line | Number of conditions by line. |
| **TM5** | Covered Conditions By Line | Number of covered conditions by line. |
| **TM6** | Coverage | It is a mix of Line coverage and Condition coverage. Its goal is to provide an even more accurate answer to the following question: How much of the source code has been covered by the unit tests? |
| **TM7** | Coverage On New Code | It is a mix of Line coverage and Condition coverage. Its goal is to provide an even more accurate answer to the following question: How much of the source code has been covered by the unit tests? Restricted to new / updated source code. |
| **TM8** | Line Coverage | On a given line of code, Line coverage simply answers the following question: Has this line of code been executed during the execution of the unit tests?. It is the density of covered lines by unit tests: |
| **TM9** | Line Coverage On New Code | On a given line of code, Line coverage simply answers the following question: Has this line of code been executed during the execution of the unit tests?. It is the density of covered lines by unit tests Restricted to new / updated source code. |
| **TM10** | Line Coverage Hits | List of covered lines. |
| **TM11** | Lines To Cover | Number of lines of code which could be covered by unit tests |
| **TM12** | Lines To Cover On NEw Code | Number of lines of code which could be covered by unit tests Restricted to new / updated source code. |
| **TM13** | Skipped Unit Tests | Number of skipped unit tests. |
| **TM14** | Uncovered Conditions | Number of conditions which are not covered by unit tests. |
| **TM15** | Uncovered Conditions On New Code | Number of conditions which are not covered by unit tests. Restricted to new / updated source code. |
| **TM16** | Uncovered Lines On New Code | Number of conditions which are not covered by unit tests. Restricted to new / updated source code. |
| **TM17** | Unit Tests | Number of unit tests. |
| **TM18** | Unit Tests Duration | Time required to execute all the unit tests. |
| **TM19** | Unit Test Errors | Number of unit tests that have failed. |
| **TM20** | Unit Test Failures | Number of unit tests that have failed with an unexpected exception. |
| **TM21** | Unit Test Success Density Percent | Test success density = (Unit tests - (Unit test errors + Unit test failures)) / Unit tests * 100 |