2013
2nd International Workshop on Green and Sustainable Software (GREENS)

Proceedings

May 20, 2013
San Francisco, CA, USA

2013
2nd International Workshop on
Green and Sustainable Software
(GREENS)

IEEE Catalog Number: CFP1302T-ART
ISBN: 978-1-4673-6267-2

Production: Conference Publishing Consulting, D-94034 Passau, Germany
info@conference-publishing.com

A Systematic Literature Review for Software Sustainability Measures

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***Abstract*—Nowadays, sustainability is a key factor that should be considered in the software quality models. It is increasingly important how environmentally friendly is a software product, both in its execution and during its development process. Therefore, we have proposed, in a previous work, a quality model (25010+S) an extension of the ISO/IEC 25010 standard by considering aspects of sustainability on its characteristics and sub-characteristics. However, in order to make the model useful, it is necessary to identify measures for each sub-characteristic and characteristic. For that reason, the objective of this paper is to carry out a Systematic Literature Review to discover the state-of-the art in software sustainability measures.**

***Index Terms*—Sustainability Measures, Sustainability Indicators, Systematic Literature Review, Quality Model, Sustainability Models**

I. INTRODUCTION

Sustainable Software is software, whose direct and indirect negative impacts on economy, society, human beings, and environment that result from development, deployment, and usage of the software are minimal and/or which have a positive effect on sustainable development [1].

This idea can be extended and cover the whole software development process. Thus, we can refer to a Sustainable Software Engineering as "the art of defining and developing software products in a way so that the negative and positive impacts on sustainability that result and/or are expected to result from the software product over its whole lifecycle are continuously assessed, documented, and optimized" [2].

While sustainability is a standardized practice in a number of engineering disciplines there is currently no such awareness within the software engineering community, as remarked in [3].

One way to achieve sustainability as part of any software development is to make it to be a part of the product quality and of the quality in use of the software product. This way, the sustainability assessment would be considered as another quality aspect to be taken into account by developers, in accordance with the priorities and requirements imposed for the product being developed. In [4] a quality model (25010+S) based on ISO/IEC 25010 [5] that considers sustainability as a new factor that affects quality was presented. The main idea behind the adaptation of the standard in order to obtain the 25010+S model is that there are three types of characteristics (subcharacteristics) in [5] quality models:

1. Characteristics that can be considered as sustainability-related by themselves (e.g. freedom from risk). In this case the characteristic remains as is, on the standard quality model.

2. Characteristics that do not consider the sustainability by themselves but could have a direct impact on it (e.g. Effectiveness). The quality model is extended to include also a green "sustainable" version of the characteristic. Furthermore, to make clear the relationships between the two definitions we will keep the same name but adding sustainability on its name (e.g. Sustainability Effectiveness).

3. Characteristics for that a sustainable version does not seem to make sense (e.g. Security). In this case, the characteristic is maintained on the model as it appears in the standard

From the above classification, the authors derive that characteristics in the first group represent an initial effort from the standard to consider sustainability aspects. The second group consists of those characteristics that are related to the requirements of the product, its features or its functionalities and, so, it is perfectly possible and logical to include an adapted sustainable version. Lastly, the third group consists of those characteristics that have to do with the capabilities of the product rather than its requirements, therefore a sustainable version it is not suitable.

A summary of the 25010+S product quality model proposed in [4] is shown in TABLE I. In the "Sustainable subcharacteristic" column appears the type 1 subcharacteristics whereas in the "Adaptable subcharacteristic" column the type 2 subcharacteristics are presented. Due to the type 3 subcharacteristics are unrelated to sustainability, they are not detailed. Therefore, the Compatibility, Reliability and Portability characteristics do not appear in this table because all its subcharacteristics have been classified as unrelated to sustainability. TABLE II. shows a summarized 25010+S quality in use model; in this case all the characteristics have almost type 1 or type 2 subcharacteristic. More details on these models can be found in [4]. Once the model has been defined, numerous possibilities of use are open. Among them, one of the

main ways of using quality models is through the usage of measures and indicators.

TABLE I. PRODUCT QUALITY MODEL OF 25010+S PROPOSED IN [4]

Charcteristic	Sustainble Subcharacteristic	Adaptable Subcharacteristic
Functional Suitability		Sustainability Functional appropriateness
Performance Efficiency	Time behavior	
	Resource utilization	
		Sustainability Capacity
Usability		Sustainability Appropriateness recognizability
	Learnability	
		Sustainability Operability
	Accessibility	
Maintainability	Reusability	
	Modifiability	
Portability	Adaptability	

TABLE II. QUALITY IN USE MODEL OF 25010+S PROPOSED IN [4]

Charcteristic	Sustainble Subcharacteristic	Adaptable Subcharacteristic
Effectiveness		Sustainability Effectiveness
Efficiency		Sustainability Efficiency
Satisfaction	Usefulness	
Freedom from risk	Freedom from risk	
	Environmental risk mitigation	
Context coverage	Context coverage	
	Context completeness	
	Flexibility	

So, our objective with this work is to develop a systematic literature review in order to know the state-of-the-art related to software sustainability measures that assess some quality characteristics related on sustainability.

To do that, we have followed the guidelines given in [6], comprising three main phases:

- Planning the review: This phase includes pre-review activities, such as: 1) Identifying the need for an SLR, 2) Defining the research questions(s) that the systematic review will address and 3) Producing a review protocol (i.e. plan) defining the basic review procedures.
- Conducting the review: In this phase the review itself is carried out, the primary studies (i.e. the selected papers) are selected and data extraction and synthesis are performed.
- Reporting the review: The final phase involves writing up the results of the review.

This paper corresponds to the third phase (reporting the review) and is organized as follows. Section 2, 3 and 4 present the planning, the conduction and the results of the SLR, respectively. In Section 5 the main threats to validity are shown. Finally, our conclusions and future works are outlined in Section 6.

II. PLANNING THE SYSTEMATIC LITERATURE REVIEW

As previously stated, the need of this review is to find out the current state of the art in the measures of software sustainability.

The following research questions guided the design of the review process:

RQ1. How much activity was there in the last 20 years?

RQ2. Are there software sustainability measures and indicators proposed in the literature?

RQ3. What sustainability aspects have been paid more attention?

RQ4. What are the limitations of current research?

RQ5. Are there measures proposals that fit on the 25010+S model?

The development of the review protocol is the most relevant activity of the review process, since it establishes the basis of the search.

A. Source Selection

The search process for this study is based on an semi-automated search of the following digital libraries:

- IEEE Digital Library (http://ieeexplore.ieee.org)
- ACM Digital Library (http://dl.acm.org)
- Specific forums on Software Sustainability: Conference
- Proceedings of GREENS 2012 and re4susy 2012.

B. Search String

The aim for our search string is to capture all results that relate sustainability or environmental issues with software measurement. The general search string used on all databases is:

```
General Query:
(sustainab* OR environment* OR ecolog* OR green)
AND
(software measure* OR software metric* OR software
indicators)
```

However, due to the great amount of results obtained, we have debugged the results using the tools given by the different digital libraries search engines. Following we show deeply the searches done on each source.

1) Searching on ACM Digital Library

After some initials tests (done with the general quey by using ACM forms for searching) and have some problems when using the wildcard * (where we got over 35,000 results) we decided to use, on the query, all the words literally even though they shared a common root. Another decision was to remove the term "environment" that got a lot of results related to very different fields and it is a widely used word with several meanings.

With these assumptions, we carried out the first search (query 1, shown below) using the following terms: sustainability (or ecological, environmental, green), measurement (or metric, measures) and software. This Query 1 returned 10,273 results. From them, we reviewed the 400 most relevant results, selecting 31 in an earliest analysis.

ACM query 1

```
(sustainable OR sustainability OR ecologic OR
ecological OR ecologically OR ecologist OR ecology OR
green)
AND (measure OR measures OR measurements OR
measurement OR metric OR metrics OR indicator OR
indicators)
AND (software)
```

We performed a second query (Query 2) to discover some works that did not appear in the 400 most relevant works from the first query. This second search, rather than examining the paper's full text, is limited to search the proposed terms in the title or in the abstract. Query2 got 41 results, and after a preliminary abstract revision we included 11 papers.

ACM query 2

```
(Title:(sustainable OR sustainability OR
environmental OR environmentally OR ecologic OR
ecological OR ecologically OR ecologist OR ecology OR
green)
OR Abstract:(sustainable OR sustainability OR
environmental OR environmentally OR ecologic OR
ecological OR ecologically OR ecologist OR ecology OR
green))
AND
(Title:(measure OR measures OR measuring OR
measurements OR measurement OR metric OR metrics OR
indicator OR indicators)
OR Abstract:(measure OR measures OR measuring OR
measurements OR measurement OR metric OR metrics OR
indicator OR indicators))
AND
(Title:(software) OR Abstract:(software))
```

Finally, we add a new search focused solely on keywords (Query3), but removing the term software. We obtained 36 results, including just 7 results after the abstract reviews.

ACM query 3

```
(Keywords:measure OR Keywords:measures OR
Keywords:measurements OR Keywords:measurement OR
Keywords:metric OR Keywords:metrics)
AND
(Keywords:sustainable OR Keywords:sustainability OR
Keywords:environmental OR Keywords:environmentally OR
Keywords:ecologic OR Keywords:ecological OR
Keywords:ecologically OR Keywords:ecologist OR
Keywords:ecology OR Keywords:green)
```

The three used queries offer a total set of 49 papers, 2 of them repeated. After reviewing the full text of these 47 selected papers, we included definitely 9 papers. Three papers appear in the Query1, another three in Query2, and four are in Query3 (one of them was also in Query1).

2) Searching on IEEE Digital Library

After applying the general search string (general query) we obtained a total of 6.133 results returned. As it was a really big set of results we selected the 100 first results ordered by relevance.

And we refined the search as follows.

We looked for papers that accomplish the previous search string but, among them, we select those that contain the words, Sustainable-software on the full text of the paper. Then the search string (query 1) was

IEEE query 1

```
(((sustainab* OR environment* OR ecolog* OR green))
AND ("software metric" OR "software metrics" OR"
software measure" OR "software measures" OR "software
indicator" OR "software indicators")),  Sustainable-
software
```

With this new restriction we obtained 4 results.

As this the set was too small, we refined again the search string (query 2) by looking for papers containing the word sustainability into the full text:

IEEE query 2

```
(((sustainab* OR environment* OR ecolog* OR green))
AND ("software metric" OR "software metrics" OR"
software measure" OR "software measures" OR "software
indicator" OR "software
indicators")) , sustainability
```

Obtaining then 41 Results

Finally, we thought that it would be interesting to search those papers with the words green software on the text (query 3):

IEEE query 3

```
((sustainab* OR environment* OR ecolog* OR green) AND
("software metric" OR "software metrics" OR" software
measure" OR "software measures" OR "software
indicator" OR "software indicators")) , Green
Software
```

In this case, we obtained 402 results, selecting from them the first 100 ordered by relevance.

Then, we have reviewed the abstract of 245 results.

After reading the abstracts, we have selected as possibly relevant a total of 17 papers distributed by query as follows:

We start by reading the results from query 1. From 4 results 3 were included

Next we review query 2 and from 41 results only 6 were included. We then review the results from query 3 and from 100 results, 3 were included. We finally review the results from the general query selecting a total of 5 from the 100 returned results.

This made a total of 17 papers but, once the duplicated works were eliminated, the final set selected from the abstract was composed by a total of 12 papers.

The next step was to read the complete text from these 12 papers and finally a final set of 5 papers that include sustainability measures were selected.

3) Searching on Specific Forums of Software Sustainability

In this case, the search is performed manually because we had the proceedings or the program of the conference. Therefore, a search engine was not available. The forums where we searched were: GREENS 2012, and RE4SUSY2012.

C. Inclusion and Exclusion Criteria

The following inclusion criteria were chosen in order to select the right publications to answer our research questions:

- Publication between 1/1/1992 - 31/12/2012
- All the phases of the software development process
- References to software engineering
- Scientific soundness
- Relevance with respect to research questions
- Definition of measures or indicators related to software sustainability

The following were defined as exclusion criteria:

- "Environment" meant in the sense of system environment, not nature.
- "Ecosystem" meant as population of interacting systems, for example, agents.
- Measures related to software process, to enterprise, to quality of service or to hardware
- The paper does not propose measures, or are not relevant
- Studies are only available in the form of abstracts or Powerpoint presentations
- Duplicate studies

III. Conducting the Review

The process was conducted as follows:

(1) Each one of the three authors of this paper executes the search on one of the databases and saves the references in bibliographic files being the principal researcher for this database.

(2) The principal researcher reads all titles and abstracts and checks the inclusion and exclusion criteria for each entry. The main criterion is the topic of the content.

(3) The principal researcher classifies the measures of the papers according to the type of measure and the quality characteristic/sub-characteristic.

(4) The other two authors reassess the classification and inclusion/exclusion of search results made by the others. This step has meant the inclusion or exclusion of more paper into the first selection done by the principal researcher of each database.

(5) The three authors extract statistics and analyze the results in further detail, discussing about them and trying to arrive to conclusions on the topic.

A. Selection of Primary Studies

The search process was completed on 31/01/2013 in the digital libraries and specific forum of software sustainability previously mentioned, and 740 papers were found (see TABLE III.). These papers were then analyzed. This was done by first analysing the title and the abstract reducing the set of selected papers to 70.

After reading the paper's full text a total of 17 papers were included, one of them was duplicated so, the final set of papers we have worked with for doing the SLR were 16 papers (see TABLE IV.). The references of the 16 papers are shown at the end of this paper (Appendix I).

TABLE III. Distribution of studies by source

		Returned by the search engine	Selected by abstract
ACM	Query 1	400	31
	Query 2	41	11
	Query 3	36	7
IEEE	General Query	100	5
	Query 1	4	3
	Query 2	41	6
	Query 3	100	3
Specific Forums		18	4
Total		740	70

TABLE IV. Final Selected papers

Digital Library	Selected by abstract (without repeated)	Selected by Full text
ACM	47	9
IEEE	17	5
Specific forums	4	3
Total (without repeated)		**16**

B. Data Extraction and Monitoring

Once the primary studies had been selected, the authors read the full articles to extract relevant information for this SLR. This information was stored in an MS Excel file (available at: http://alarcos.esi.uclm.es/download/). For each measure found in a paper, the information stored in the Excel file is:

- Name.
- Definition.
- Type: base measure, derived measure or indicator [7]
- Quality perspective: product quality, quality in use, process quality, quality of Service or at company level
- Sustainability characteristic related to the measure, based on ISO25010+S model [4].

All these data were used to extract the results presented in the next section.

IV. Results

This section provides the results of our systematic literature review. For the purpose of our analysis, the papers were analyzed in order to answer the research questions listed in section 2. Next, the answers to each research question are presented.

RQ1. How Much Activity Was There in the Last 20 Years?

We have selected a total of 16 papers (see Fig. 1) that contain measures related to software sustainability, following the next distribution per year (see TABLE V.):

TABLE V. PAPERS PER YEAR

2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
1	1	0	0	0	2	2	2	1	7

Should be noted that 44% of the articles were published during 2012, the remainder (56%) occurred in the previous nine years (see Fig. 2). This seems to mean that there is an emerging trend related to the research on software sustainability.

An important fact to take into account is that specific conferences on software sustainability have not begun to be made until year 2012. This factor strongly influences the number and the period in which the selected elements appear: very few contributions were found before those years and a strong increase appears in the last year.

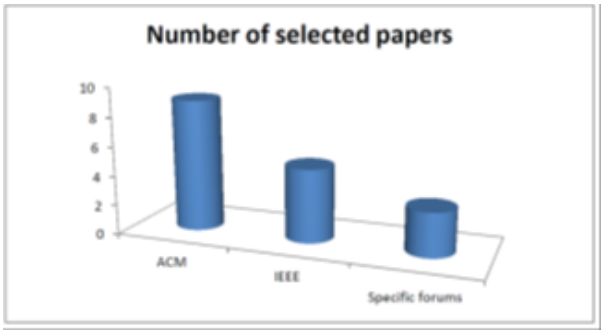

Fig. 1. Number of selected papers by database source

It is also important to remark that we have not found, in the first ten years, papers with any sustainability measure definition. This does not mean that do not exist papers related to software sustainability, this only means that they do not included measure proposals (although some of them pointed out about the importance of defining them).

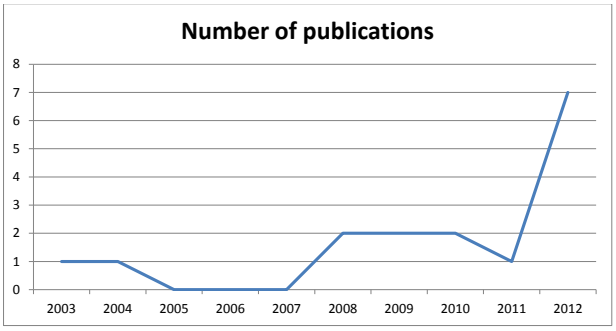

Fig. 2. Number of publications per year

Also as a remarkable result, we want to emphasize that the first time that the concept software sustainability appears is in 2003. This is also the year where the first measures were defined.

Another significant result we want to highlight is the fact that the first time the concept of software sustainability arises in the literature is in year 2003. This is also the year in which the first measures were defined.

Finally, another significant fact is that all selected articles have been published in conferences. We have not found any articles published in journals, either because the topic is very recent and is not mature enough to appear in journals or because we have not been able to find them in our searches. However, under our point of view, this fact is due to the first reason and is aligned with the fact that the first conferences on the topic have started in 2012.

RQ2. Are there Software Sustainability Measures and Indicators Proposed in the Literature?

We have found a total of 82 measures defined in the literature. We are going to discuss them according to several measures classification: how they are calculated, the type of measure, the quality characteristics that could be related, etc.

Following the general trend, most measures are derived (indirect) measures, 45 in this work (which represent 55%), these measures are calculated using base measures (or direct) having found 29 of them (35%). The rest are 8 indicators, in ISO terminology complex measures that need an analysis model based on derived and base measures among other things (see Fig. 3).

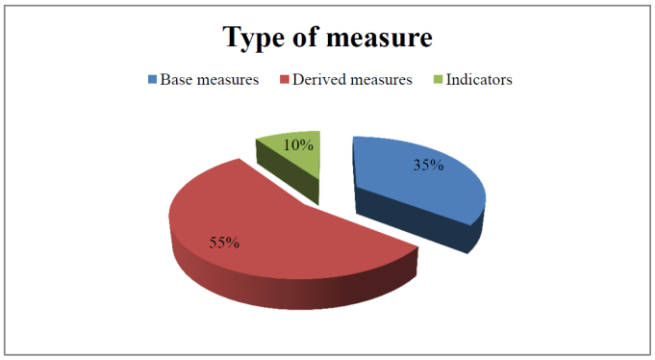

Fig. 3. Type of measure

We found 59 measures for product quality (see Fig. 4) and 2 for quality in use. The rest of the measures found were 4 for software process, 16 for Quality of Service (QoS) and 1 at company level.

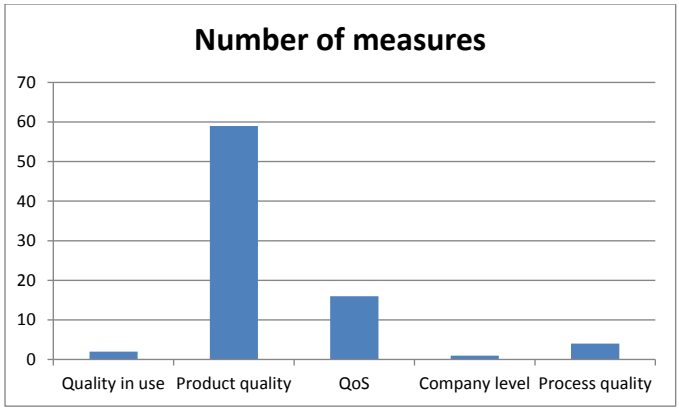

Fig. 4. Number of measures per quality characteristic

RQ3. What Sustainability Aspects Have Been Paid More Attention?

According to the characteristics from the 25010+S Product Quality model (TABLE I.), we have found measures to five characteristics (Fig. 5): Performance efficiency, Maintainability, Portability, Usability, Reliability. However, the distribution is very uneven among them; two thirds of the measures are related to performance efficiency, which is not

surprising if we think the power consumption is directly linked to environmental sustainability.

All the measures (39) assessing the Performance Efficiency characteristic can be classified as measures for the resource utilization subcharacteristic. The three maintainability measures are associated to modifiability subcharacteristic and the three measures of portability are related to adaptability.

We found five measures for reliability, four of them connected with the fault tolerance subcharacteristic and the other one with recoverability. Lastly, usability has eight founded measures, two for learnability and six for accessibility.

Two measures can be classified as quality measures in use. One of them is related to the satisfaction characteristic and the other with the utility.

RQ4. What Are the Limitations of Current Research?

Obviously, and as we suspected from the beginning, there are a limited number of sustainability measures and, the existing ones are related to a limited number of sustainability characteristics. In fact, most of the measures were defined to measure time or resource consumption, which is furthest of software.

Another weak aspect is that there are very few measures related to sustainability in use. This aspect is normal in any software product quality assessment, where the tendency is to maximize the product quality as a mean to achieve the best quality in use. We think this is not the best way to work with quality and we advocate another way to plan the measurement: first, fix the quality in use preferences, later, go to ensure the product quality characteristics necessary to achieve it.

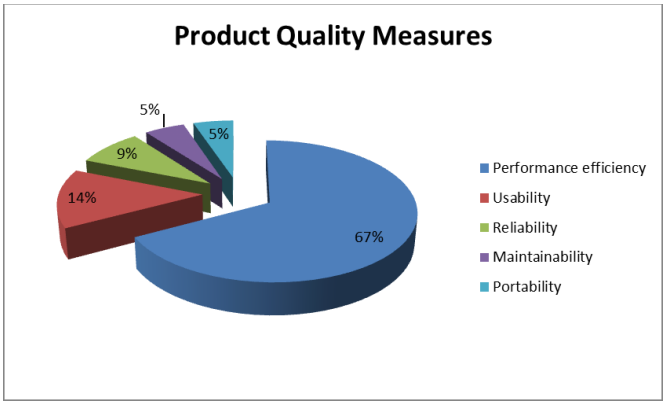

Fig. 5. Product Quality Characteristic Measures

RQ5. Are There Measures Proposals that Fit on the 25010+S Model?

As described in the introduction, the 25010+S model has three kind of characteristics: (type 1) those of the standard that were sustainability-related, (type 2) those of the standard that need a sustainable version and (type 3) those on the standard for which has no sense to have a sustainable version.

When we started with this SLR, we thought we would find many measures for type 1 characteristics and some for type 2. However, upon completion the classification of the measures, we found that some characteristics that were not considered as sustainable (type 3) in the proposed quality model (25010+S) have measures defined in the literature. As opposed, there are no proposed measures for any of the new sustainable characteristics of type2.

In fact, when a measure for sustainability appears in the reviewed literature, that measure is associated with a feature that we considered as being sustainable (type 1) and never of type 2. This can be justified because the measures proposal usually is made taken a quality model as basis for the definition. As the 25010+S model did not exist, it is logical not to find measures for its new specific characteristics.

However, the fact of having sustainability measures for characteristics not considered as sustainable on our model, make us to think on the necessity of review the model. Therefore, we have to carry out a more detailed analysis of the characteristics of type 3.

The performance efficiency characteristic has two sub-characteristics: resource utilization and time behavior. We have identified 39 measures for the resource utilization but no measure for the time behavior, which directly affect sustainability. Maintainability has also two sub-characteristics: reusability and modifiability. All measures have been found to reusability, although modifiability is an interesting aspect of the software sustainability. The sub-characteristics accessibility and learnability (belong to usability), and adaptability (belong to portability) has some few measures.

Finally, we have made a Keyword cloud (see Fig. 6) with the more used keywords (in our case characteristics or sub-characteristics, type of measure and quality perspective) in order to have a visual image on where the importance is centered.

Fig. 6. Keyword cloud created with http://www.wordle.net/

V. Threats to Validity

There are various threats to validity that we have tried to minimize by different mitigation actions:

A. Researcher's bias: The semi-automatic part of the search was performed by three researchers (one researcher for each source) There could be a researcher's bias however we minimized the effects of such a bias by two ways:
   - We explicitly stated the research questions, inclusion and exclusion criteria, and the rationale for performing the search.
   - The selection was reviewed by the other two researchers. Differences were subsequently discussed, resolved and commonly agreed upon.

B. Search string validity: at the beginning the search string included too many irrelevant papers. For that reason, the

search string was refined for each source as presented in section 2.

C. Due to the specific characteristics for each digital library search engine, the queries used have not been identical. Each author took the decisions considered the most *appropriated in* order to obtain the largest number of works related to the measurement of software sustainability. Therefore, although the searches done were not exactly the same, they were very similar, assuring the completion of the search.

VI. Conclusions and Future Works

In this paper, a SLR to discover the state-of-the art in software sustainability measures has been carried out. The main goal is to obtain software sustainability measures for the quality characteristics and subcharacteristics identified in the 25010+S quality model, especially those that we have considered related to sustainability or that can be adapted to take into account aspects of it. In order to do that the digital libraries of ACM and IEEE as well as specific forums on Software Sustainability have been studied.

As a result 16 papers were chosen. A total of 82 measures were extracted from these papers, although only 61 are useful for our quality model. The rest of the measures are for software process, for quality of Service-QoS or at company level. Regarding the product quality characteristic in which the measures can be applied, there are only measures for the following five characteristics: Performance efficiency, Maintainability, Portability, Usability, Reliability. Furthermore, many of the measures are focused on power consumption. Only two measures were found for sustainability in use.

In addition we would like to remark the following results. Reusability and Time behavior are two subcharacteristics that we have consider closely related to sustainability however no measures have been founded in this SLR to assess them. In contrast, we have found a few measures for Fault tolerance (5) and for Recoverability (1) when we classified these subcharacteristics as type 3 or unrelated to sustainability. Regarding the type 2 subcharacteristics, have not been found any measure for them. This is an awaited result because the extended quality model has not yet been published and the definitions of these quality characteristics in ISO/IEC 25010 do not collect any sustainability aspects either explicitly or implicitly.

Other highlight is the almost total absence of quality in use measures. Only two measures can be cataloged as quality in use measures, even though it has subcharacteristics so clearly related to sustainability as Environmental Risk Mitigation. Some causes of this could be: (1) the ISO/IEC 25010 standard has recently introduced significant changes related to quality in use (2011) and this modifications have not been established in software engineering community yet; (2) usually, more attention is paid to the final product quality, in this way it is considered that if the final product has a good quality level then its quality in use is also good, (3) the authors could have had a bias that have not allowed them to recognize or find this type of measures.

Bearing all this in mind, as a future work, new measures for all the characteristics and sub-characteristics of the product quality and the quality in use models of 25010+S need to be defined. Moreover, and taking into account the results obtained on this SLR, we must review the 25010 + S model in order to be sure about the sustainability aspects of the contained characteristics

Acknowledgment

This work is part of the GEODAS-BC (TIN2012-37493-C03-01), the PEGASO (TIN2009-13718-C02-01) and Sistemas Inalambricos de Gestion de Informacion Critica (TIN2011-23795) projects funded by the Spanish Ministerio de Economía y Competitividad and by FEDER (Fondo Europeo de Desarrollo Regional).

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APPENDIX I. SELECTED REFERENCES FOR THE SLR

Author	Title	Year	Journal/Proceedings
Albertao, F., Xiao, J., Tian, C., Lu, Y., Zhang, K.Q. and Liu, C.	Measuring the Sustainability Performance of Software Projects	2010	e-Business Engineering (ICEBE), 2010 IEEE 7th International Conference on, pp. 369 -373
Ameta, G.	Towards a new geometric metric for sustainability assessment	2009	Proceedings of the 9th Workshop on Performance Metrics for Intelligent Systems, pp. 43-48
Amsel, N., Ibrahim, Z., Malik, A. and Tomlinson, B.	Toward sustainable software engineering (NIER track)	2011	Proceedings of the 33rd International Conference on Software Engineering, pp. 976-979
Das, R., Kephart, J.O., Lefurgy, C., Tesauro, G., Levine, D.W. and Chan, H.	Autonomic multi-agent management of power and performance in data centers	2008	Proceedings of the 7th international joint conference on Autonomous agents and multiagent systems: industrial track, pp. 107-114
Gruter, C., Gysel, P., Krebs, M. and Meier, C.	EoD designer: A computation tool for energy optimization of data centers	2012	Green and Sustainable Software (GREENS), 2012 First International Workshop on, pp. 28 -34
Heisig, S. and Moyle, S.	Using model trees to characterize computer resource usage	2004	Proceedings of the 1st ACM SIGSOFT workshop on Self-managed systems, pp. 80-84
Hindle, A.	Green mining: A methodology of relating software change to power consumption	2012	Mining Software Repositories (MSR), 2012 9th IEEE Working Conference on, pp. 78 -87
Hindle, A.	Green mining: investigating power consumption across versions	2012	Proceedings of the 2012 International Conference on Software Engineering, pp. 1301-1304
Jiang, X., Dawson-Haggerty, S., Taneja,J., Dutta, P. and Culler, D.	Creating greener homes with IP-based wireless AC energy monitors	2008	Proceedings of the 6th ACM conference on Embedded network sensor systems, pp. 355-356
Johann, T., Dick, M., Naumann, S. and Kern, E.	How to measure energy-efficiency of software: Metrics and measurement results	2012	Green and Sustainable Software (GREENS), 2012 First International Workshop on, pp. 51 -54
Kim, T., Lee, Y. and Lee, Y.	Energy measurement of web service	2012	Proceedings of the 3rd International Conference on Future Energy Systems: Where Energy, Computing and Communication Meet, pp. 27:1-27:8
Marzolla, M.	Optimizing the energy consumption of large-scale applications	2012	Proceedings of the 8th international ACM SIGSOFT conference on Quality of Software Architectures, pp. 123-132
Medland, R.	Curbing paper wastage using flavoured feedback	2010	Proceedings of the 22nd Conference of the Computer-Human Interaction Special Interest Group of Australia on Computer-Human Interaction, pp. 224-227
Noureddine, A., Bourdon, A., Rouvoy, R. and Seinturier, L.	A preliminary study of the impact of software engineering on GreenIT	2012	Green and Sustainable Software (GREENS), 2012 First International Workshop on, pp. 21 -27
Seacord, R., Elm, J., Goethert, W., et al.	Measuring software sustainability	2003	Software Maintenance, 2003. ICSM 2003. Proceedings. International Conference on, pp. 450 - 459
Soto, M. and Ciolkowski, M.	The QualOSS open source assessment model measuring the performance of open source communities	2009	Empirical Software Engineering and Measurement, 2009. ESEM 2009. 3rd International Symposium on, pp. 498 -501