Sustainability as a Software Quality Factor

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* Areas of research

**IS QUALITY**
Research areas

- **Software maintenance and reengineering**: Macario Polo, Ignacio García, Francisco Ruiz
- **Software measurement**: Marcela Genero, Manuel Angel Serrano, José Antonio Cruz-Lemus
- **Quality in MDD**: Marcela Genero
- **Data quality/Web quality**: Ismael Caballero, Coral Calero, M. Ángeles Moraga
- **IS security**: Eduardo Fernández-Medina
- **Software and business processes**: Francisco Ruiz, Félix García
- **Software testing**: Macario Polo
- **Knowledge management & GSD**: Aurora Vizcaíno

*ALARCOS RESEARCH GROUP*
The information presented here is a compendium of the works accepted on GIBSE 2013 and GREENS 2013 workshops
* Introduction
* ISO 25010
* ISO 25010+S
* Software Sustainability Measures
* Conclusions and Future Work
* Introduction
* ISO 25010
* ISO 25010+S
* Software Sustainability Measures
* Conclusions and Future Work
* **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. (Dick et al., 2010)

* **Sustainable Software Engineering** is oriented to produce software in the most environmental-friendly and sustainable way.

* While sustainability is a standardized practice in a number of engineering disciplines there is currently no such awareness within the software engineering community.

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Software quality is the capability of software product to satisfy stated and implied needs when used under specified conditions (ISO/IEC 25010:2011)

Usually, software quality is assessed by means of quality models

A software quality model is a defined set of characteristics, and of relationships between them, which provides a framework for specifying quality requirements and evaluating quality (ISO/IEC 25010:2011)

Typically characteristics such as usability or maintainability, but not sustainability or ecological aspects
**INTRODUCTION**

* However increasingly are necessary quality factors to define how *environmentally friendly software is* and how to achieve a sustainable software development process.

* These factors are called *sustainable software quality factors* or simply green factors, among which one must consider the so-called ecological quality factors to define sustainability software on its help in the fight against climate change (Taina, 2011).
Our proposal takes the standard ISO/IEC 25010 (ISO/IEC 25010:2011) as a starting point and analyses the characteristics and subcharacteristics that contain sustainability issues or are directly related to them.

This evolved quality model (Calero and Bertoa, 2013) allows evaluating the sustainability of existing software or ensures a suitable sustainability level when developing new software (or modifying an existing one).
* From this model, we have looked for measures that could be used for assessing sustainable aspects of a software product

* For doing this we have developed a systematic literature review (Calero et al., 2013)

* From both works we have identified several lines of research that must be developed on the future
* Introduction
* **ISO 25010**
* ISO 25010+S
* Software Sustainability Measures
* Conclusions and Future Work
* This standard defines a **product quality model** composed of **eight characteristics** (which are further subdivided into subcharacteristics) that relate to static properties of software.

![Diagram of ISO 25010 product quality model]

**ISO 25010**
Also, it defines a **quality in use model** composed of **five characteristics** (some of which are further subdivided into subcharacteristics) that relate to the outcome of interaction when a product is used in a particular context of use.
AGENDA

* Introduction
* ISO 25010
* ISO 25010+S
* Software Sustainability Measures
* Conclusions and Future Work
To include sustainability aspects into the standard models, we have made a detailed review of the definitions of each characteristic and subcharacteristic that compose the quality models.

From this we have identified three types of characteristics (subcharacteristics) in ISO/IEC 25010 quality models.
* Characteristics that carry themselves sustainability issues (e.g. freedom from risk) → remains as is, as part of the quality model.

* 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 a green "sustainable" version (e.g. Sustainability Effectiveness).

* Characteristics for that do not seem to make sense a sustainable version (e.g. Security). In this case, we maintain the characteristic as it appears in the standard.
Product quality +S model

Performance relative to the amount of resources used under stated conditions

ISO 25010+S

Product Quality:
- Compatibility
- Performance
- Efficiency
- Maintainability
- Functional
- Suitability
- Reliability
- Sustainability
- Usability
- Security
- Portability
- Functional
- Sustainability
- Suitability
- Functional
- Completeness
- Functional
- Correctness
- Functional
- Appropriateness
- Interoperability
- Co-existence
- Time behaviour
- Resource utilization
- Resource
- Capacity
- Sustainability
- Capacity
- Reusability
- Modularity
- Analytical
- Analysability
- Testability
- Modifiability
- Usability
- Portability
- Installability
- Availability
- Fault tolerance
- Maturity
- Adaptability
- Sustainability
- Recognizability
- User interface aesthetics
- Appropriateness recognizability
- User error protection
- Operability
- Recoverability
- Findability
**Product quality +S model**

Degree to which the functions facilitate the accomplishment of specified tasks and objectives.

- **Functional Appropriateness**
- **Functional Correctness**
- **Performance efficiency**
- **Maintainability**
- **Reliability**
- **Sustainability**
- **Usability**
- **Security**
- **Portability**
- **Testability**
- **Modifiability**
- **Reusability**
- **Analysability**
- **Modularity**
- **Capacity**
- **Resource utilization**
- **Sustainability Capacity**
- **Time behaviour**
- **Co-existence**
- **Interoperability**
- **Usability**
- **Accessibility**
- **Appropriateness**
- **Recognizability**
- **User interface aesthetics**
- **User error protection**
- **Operability**
- **Installability**
- **Replaceability**
- **Recoverability**
- **Availability**
- **Fault tolerance**
- **Maturity**
- **Portability**
- **Modularity**
- **Usability**
- **Sustainability**
- **Operability**
- **Appropriateness**
- **Recognizability**

**ISO 25010+S**
**Product quality +S model**

Degree to which a product, system or component can exchange information with other products, systems or components, and/or perform its required functions, while sharing the same hardware or software environment.

Degree to which a product or system protects information and data so that persons or other products or systems have the degree of data access appropriate to their types and levels of authorization.

ISO 25010+S
Quality in use +S model

- Efficiency
- Sustainability
- Efficiency
- Satisfaction
- Usefulness
- Trust
- Freedom from risk
- Comfort
- Pleasure
- Economic risk mitigation
- Health and safety risk mitigation
- Context coverage
- Flexibility
- Environmental risk mitigation
- Context completeness

ISO 25010+S
Quality in use +S model

Resources expended in relation to the accuracy and completeness with which users achieve goals.

- Efficiency
- Sustainability
- Effectiveness

Resources expended in relation to the accuracy and completeness with which users achieve sustainable goals.

- Satisfaction
- Freedom from risk
- Context coverage
- Flexibility
- Health and safety risk mitigation
- Environmental risk mitigation

ISO 25010+S
Quality in use +S model

Degree to which a user is satisfied with their perceived achievement of pragmatic goals, including the results of use and the consequences of use.
Quality in use +S model

Degree to which a user obtains pleasure from fulfilling their personal needs

Degree to which the user is satisfied with physical comfort

ISO 25010+S
* Introduction
* ISO 25010
* ISO 25010+S
* **Software Sustainability Measures**
* Conclusions and Future Work
As a next step, we have developed 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.

We have followed the guidelines given in Kitchenham and Charters (2007) composed of 3 main steps.
1. **Planning the review**: This phase includes pre-review activities, such as: 1) Identifying the need for an SLR, 2) Defining the research question(s) that the systematic review will address and 3) Producing a review protocol (i.e. plan) defining the basic review procedures.

2. **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.

3. **Reporting the review**: The final phase involves writing up the results of the review.
Planning the SLR

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?

SOFTWARE SUSTAINABILITY MEASURES
* **Source selection.** The search was done on 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
**Search string.** The general search string used on all databases is:

(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.
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<td><strong>740</strong></td>
<td><strong>70</strong></td>
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Inclusion 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
**Exclusion criteria.** 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 only available in the form of abstracts or Powerpoint presentations and Duplicate studies.
Final selection papers.

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<tr>
<td><strong>Total (without repeated)</strong></td>
<td><strong>16</strong></td>
<td></td>
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For each measure found in a paper, the **information stored** is:

- Name.
- Definition.
- Type: base measure, derived measure or indicator
- 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.
RQ1) How much activity was there in the last 20 years?

We have selected a total of 16 papers that contain measures related to software sustainability, following the next distribution per year:

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<td>2012</td>
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44%
RQ2) Are there software sustainability measures and indicators proposed in the literature? We have found a total of 82 measures.

![Type of measure](graph1.png)

![Number of measures](graph2.png)
RQ3) What sustainability aspects have been paid more attention?

Quality measures in use (2) → satisfaction (1) and utility (1)

- Performance
  - Efficiency → resource utilization
  - Efficiency → resource utilization
- Maintainability → modifiability
- Portability → adaptability
- Reliability → fault tolerance (80%) and recoverability (20%)
- Usability → learnability (25%) and accessibility (75%)

Software Sustainability Measures
RQ4) What are the limitations of current research?

There are a limited number of sustainability measures and, the existing ones are related to a limited number of sustainability characteristics. There are very few measures related to sustainability in use.
RQ5) Are there measures proposals that fit on the 25010+S model?

There are no proposed measures for any of the new sustainable characteristics that are sustainable versions. All of them are associated with a feature that we considered as being sustainable.

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.
- Introduction
- ISO 25010
- ISO 25010+S
- Software Sustainability Measures
- Conclusions and Future Work
We have proposed ISO 25010+S quality model to formalize sustainability as an aspect of quality in software products.

We have developed a SLR to discover the state-of-the-art in software sustainability measures.

A total of 82 measures were extracted from these papers.
* 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.
* There are only measures for: 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.
* Reusability and Time behavior are two subcharacteristics that we consider closely related to sustainability however no measures have been founded in this SLR to assess them.

**CONCLUSIONS AND FUTURE WORK**
There are several **future works** we are interested to develop.

- First, we must continue to review the quality model and discuss in depth if it is necessary to change any definition, add some new subcharacteristic and, specially, if sustainability must appear explicitly in it as a specific characteristic of quality.

- We must define measures and indicators with the required properties of a good measure: should be objective, automatic and realistic. They should also be empirically validated to ensure that "they really measure what they claim to measure." Getting these measures is a long and difficult work.

- A third line of work, we have to build a useful Bayesian Network that helps us analysing sustainability of software products.
Sustainability as a Software Quality Factor

THANKS. QUESTIONS??

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