

CRESustain: Approach to Include Sustainability and Creativity in Requirements Engineering

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ABSTRACT: Requirements Engineering is an evolving field facing new challenges. One of the central conundrums is sustainability in software. The possibility of using known creativity techniques while introducing the dimensions of sustainability to help provide unexpected, original, practical, and sustainable answers in software development is challenging and motivating. This paper proposes an approach, CRESustain, incorporating sustainability dimensions when introducing creativity techniques in the Requirements Engineering process. CRESustain uses various creativity techniques considered appropriate for the different stages of the RE process. It is inspired by the Sustainable Development Goals, creative problem-solving methods, and the Karlskrona Manifesto. The methodology applied to give materiality to the outcome of this work was Design Science Research, a research paradigm that uses knowledge to solve problems, generate new knowledge and insights, and results in an artefact. The main results indicate that the approach stimulates discussion about sustainability in technical, economic, social, human, and environmental dimensions focusing on the Sustainable Development Goals and people's needs.

KEYWORDS: Creativity, Requirements Engineering, Sustainability, Sustainable Development Goals

1. Introduction

This work is an extended version of the paper [1] initially presented at the 16th Iberian Conference on Information Systems and Technologies (CISTI 2021).

Requirements Engineering (RE) has come a long way and is currently considered a set of good practices for pragmatic, results-focused critical thinking - applicable to any domain [2]. Agile development processes have also come to promote flexibility and adaptability in the face of inevitable changes in requirements, producing software in small increments and getting feedback in rapid iterations [3]. Recent studies [4] have identified that approaches that use creativity in requirements elicitation can be successfully implemented in real software projects. The possibility of using known creativity techniques, or adaptations, to mediate idea generation, help produce new combinations, and provide unexpected, original, practical, and satisfying answers in software development seems challenging.

This paper proposes an approach, CRESustain, for incorporating creativity and sustainability in the RE process, aiming at building more agile and sustainable software, which consequently allows for greater competitiveness and longevity. This paper also proposes integrating sustainability factors when introducing creativity in RE to overcome the barriers to incorporating sustainability in the RE process. The research works of [5] reinforce the need to incorporate creativity in the RE process. By looking at sustainability concerns, it is possible to incorporate guidelines into the requirements specification stages.

The paper is structured in six sections. The first section introduces the problem; the second presents the methodology used in the research; section three presents creativity and sustainability in RE; the proposed approach for incorporating sustainability and creativity factors in RE is presented in section four; section five describes the application of the approach; finally, in section six, the conclusions and perspectives for future work are discussed.

2. Methodology supporting the work

Based on the specificity of the subject under investigation, the Design Science Research Methodology (DSRM) was adopted to obtain scientific support for the study [6] that led to the design of the artefact - the CRESustain approach. The DSR process typically includes six steps or activities, illustrated in Figure 1. In selecting the methodology, the types of practical applications were also considered [7]. In this case, the focus is on applicable artefact development.,

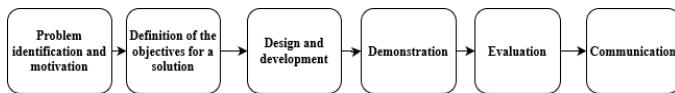


Figure 1: Design Science Research Methodology activities (adapted from [6])

The DSRM is a powerful tool for improving methods in engineering education research and provides specific guidelines for evaluation and iteration within research projects. DSRM focuses on artefact development with the explicit intention of improving the functional performance of the artefact [8]. In this context, it is considered that, given the specificity of the research under study, the DSRM allows the necessary iterations to identify the problem, define objectives, design, develop, demonstrate, evaluate, and communicate the artefact.

3. Background

Requirements Engineering [5] is the engineering discipline that includes all requirements definition and specification activities. RE concerns software systems' goals, functionalities, and constraints [9].

3.1. Creativity

Introducing creativity into the RE process seems to have enormous potential. The discussion about the potential of creativity in RE has been studied [10]; [11]; [12]. The importance of creative and heuristic techniques in solving engineering problems is recognized [13]. Problem-solving largely depends on innovation, creativity, intuitive design, correct analysis, and effective project management. In addition, experience from previous projects helps professionals in the early stages of identifying ideas [14].

Research into how the application of creativity occurs in RE has been neglected [13], [15]. Applying creative techniques will allow requirements engineers to work on problems, areas, and contexts with a combination of existing methods and techniques.

The scientific community has given importance to the incorporation of creativity in RE education [10] [16] [17]. Creativity workshops have been continuously held at major RE conferences such as the International

Requirements Engineering Conference and the Australian Workshop on Requirements Engineering.

The authors [18] refer to the importance of creativity during the requirements analysis phase. They suggest that several creativity techniques, such as brainstorming, scenarios, and simulations, can be used to promote creativity during this phase.

3.2. Sustainability

Sustainability assumes increasing importance. The concept of sustainability in Requirements Engineering has been analyzed and discussed at the International Workshop on Requirements Engineering for Sustainable Systems. In the same direction, the Karlskrona Manifesto has given excellent visibility to the concept of sustainability design [19]. This Manifesto contains sustainability guidelines for the design of software systems. In this context and to help with this sustainability task, the Karlskrona Manifesto proposes nine principles (Figure 2) and commitments.

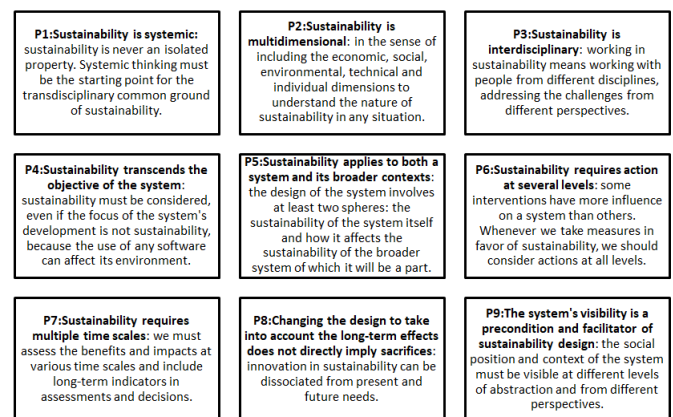


Figure 2: Principles of the Karlskrona Manifesto

One of the current challenges is the lack of practical examples that show the use of Karlskrona Manifesto principles during requirements gathering [20] and software design.

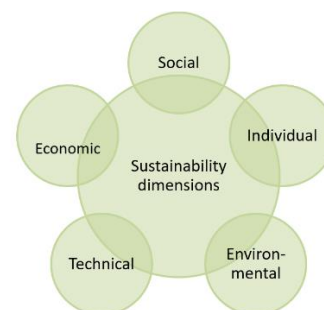


Figure 3: The five dimensions of sustainability

The Karlskrona Manifesto [21] argues that sustainability should be analyzed in five dimensions (Figure 3). The dimensions of Figure 3 are interconnected, providing a tool to analyze relevant sustainability issues for society [22]. In this sense, principle P2, "Sustainability is multidimensional," of the Karlskrona Manifesto

encourages the different dimensions of sustainability to be integrated into the RE process.

Since requirements define how and what a piece of software will do, the authors [21] argue that requirements engineering is the critical point in software engineering through which sustainability can be promoted. The introduction of sustainability during the RE process allows us to analyze the achievability of promoting and incorporating the United Nations' 17 Sustainable Development Goals (SDG) [23]. In fact, for the authors [24], sustainability is one of the pillars of software development.

According to [25], creativity is a fundamental element of sustainable development. In [26] perspective, the relationship between sustainability and creativity is very close, highlighting the need to place creativity as a resource at the center of sustainability. That is a renewable resource at the service of problem-solving.

In the authors' perspective, [20], [21], [27], [28], the need to include sustainability in RE is recognized. Research results from [29] indicate the importance of considering both technical and non-technical aspects of sustainability; putting one in contention and ignoring the other will threaten software products' sustainability [30]. The results of the study [31] on how to raise awareness of the potential

effects of software systems on sustainability indicate that the application of the SuSAF framework facilitates the discussion in terms of sustainability. This framework is intended to be used by requirements engineers to facilitate stakeholder engagement.

However, none of the cited approaches focused on applying creativity techniques to incorporate sustainability principles and dimensions during the RE process. The gaps found in the literature are centered on incorporating sustainability by applying creative processes during requirements specifications.

4. Approach to Sustainability and Creativity in Requirements Engineering - CRESustain

This section presents a strategy for incorporating sustainability factors when introducing creative techniques into RE and an approach to operationalizing it.

It is often assumed that the creative process that can be useful for RE is complex. It would be advantageous to have a structured approach that is powerful enough to generate results and flexible enough to be used and adjusted to any RE approach that includes sustainability. These considerations justified the creation of an approach, CRESustain, for introducing sustainability and creative processes in RE.

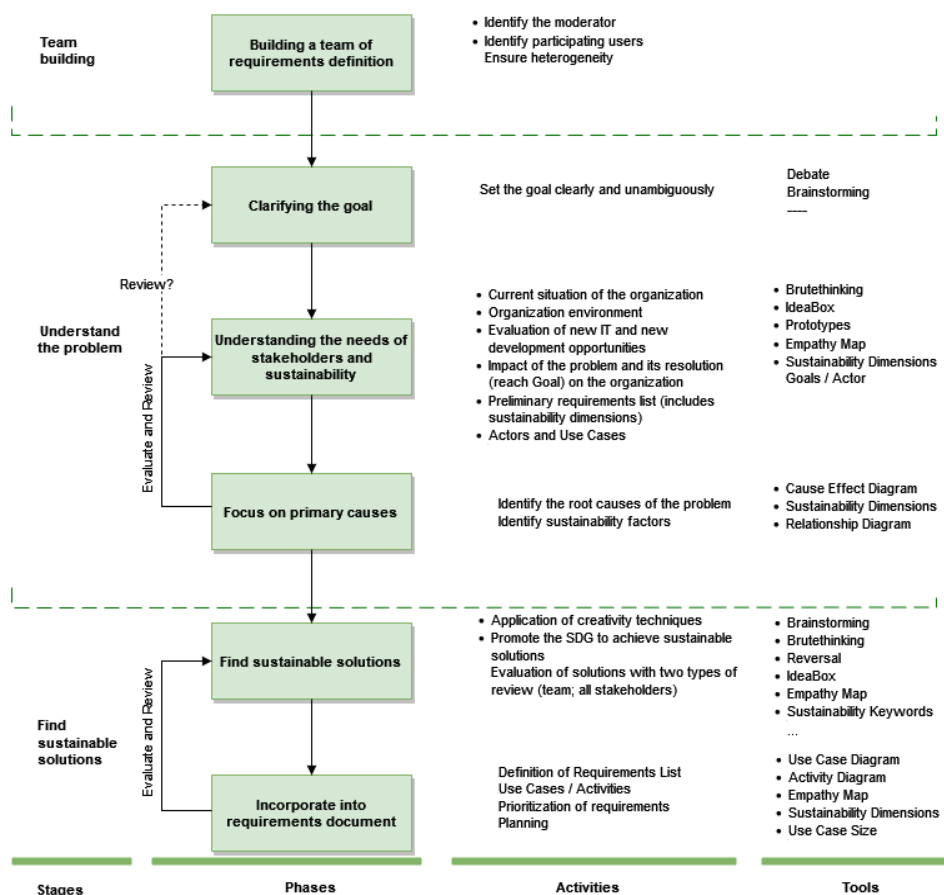


Figure 4: Approach to incorporating sustainability and creativity into RE - CRESustain

CRESustain, shown in Figure 4, is within the context of a more comprehensive methodology [1], [32], [33], [34]. It uses various creativity techniques considered appropriate for different activities and based on existing methods and techniques for creative problem solving, in particular the Creative Problem-Solving Process [35] and the Productive Thinking Model [36]. It incorporates the dimensions of sustainability and the principles of the Karlskrona Manifesto [19], in that requirements engineering is the crucial phase to promote sustainability.

As shown in Figure 4, the approach includes three stages: team building, understanding the problem, and finding sustainable solutions; and six linked phases indicating the flow of information between the steps. The first phase aims to set up a team that will apply the approach called "Building a team of requirements definition." Each phase contains several activities with supporting tools.

In phase 2, "Clarifying the goal," the formulation of a concrete goal is sought. The problem statement helps think about the general first and then the specific problem. In other words, it provides a structure for identifying the objectives that help to solve the problem. For this activity, "Clarify the goal," the Brainstorming technique is used to generate ideas without restrictions [32].

Phase 3, "Understanding the needs of stakeholders and sustainability," involves gathering requirements involving users/stakeholders in a spiral process to find creative solutions to achieve sustainability. Similar applications are used as prototypes to analyze and validate software requirements. In this step, empathy maps [37] help identify and understand the scenario where the end user is inserted, their vision, limitations, needs, and desires. The preliminary list of requirements is prepared, with actors and their objectives in a Use Case format [3]. The activity for analyzing prototypes by applying the IdeaBox creativity technique is also worth mentioning. This technique allows the combination of a challenge's parameters (characteristics, factors, variables, or aspects) into new ideas [32]. From this phase, the 17 SDGs and the five dimensions of sustainability are integrated.

In the "Focus on primary causes" phase, the root causes at the problem's origin are identified and highlighted. For effect, the elaboration of cause-effect diagrams and relationship diagrams is proposed; the sustainability factors are also identified, and the nine principles of the Karlskrona Manifesto [19] were incorporated. During the ER process, abstraction is used to manage the complexity of the problem and apply the Manifesto's nine principles.

The incorporation of sustainability factors takes place through the analysis of the five dimensions of sustainability: human, environmental, social, technical,

and economic. These sustainability dimensions are incorporated in the Karlskrona Manifesto [19] to address sustainability concerns in several areas, namely:

- Human/Individual Sustainability: concerns the maintenance of human capital (e.g., education, health, skills, knowledge, leadership, and access to services);
- Economic sustainability: aims to maintain capital and value-added;
- Environmental sustainability: refers to improving human well-being by protecting nature and its resources, such as water, earth, minerals, air, and ecosystem services;
- Technical sustainability: about the longevity of information, systems, and infrastructure and their adequacy to changing environmental conditions;
- Social Sustainability: aims to preserve social communities in solidarity and services.

In this phase, "Focus on primary causes," it is important to reflect on the Relationship Diagram of the principles of the Karlskrona Manifesto and the SDG.

Phase 5, "Finding sustainable solutions," is aimed at building and evaluating solutions considering the objective, the organization's needs, and sustainability factors, given the specificity of the business. Different creativity techniques are applied to obtain innovative solutions that address the primary causes and the five dimensions of sustainability. Thus, the creativity techniques proposed for this stage are Brutethinking and Reversal [32]. After applying the creative techniques, the sustainability keyword diagram is developed based on the human, environmental, social, technical, and economic dimensions, focusing on the SDG and people's needs. The empathy map is helpful during the validation of ideas.

The iterative process of CRESustain ends with phase 6, "Incorporate into the requirements document," whose purpose is to bring together all the elements of the process, namely: the documentation that results from the application domain information (phase 3); the list of requirements and supporting diagrams; the specific information with the requirements priorities (comprises the interaction with stakeholders to discover the most critical requirements); the empathy maps, to synthesize and organize the discussed contents; eventual prototypes of the system; the risk assessment and a project map.

The approach proposes validating requirements at two levels: within the team and in a general meeting with stakeholders. In other words, it corresponds to the TwoTierReview pattern [38], in which the full group should perform the review at least once.

It has already been possible to apply the approach in an academic context and a real-life context in a social organization.

5. Evaluation

A social organization providing services to a local community was selected to identify requirements that constitute added value in sustainability to evaluate the approach's applicability. A multidisciplinary team assessed the approach in a social organization. The social organization consists of a social center called São Domingos, which supports a Community (SDC).

The first phase, "Building a team of requirements definition," included elements from several areas, namely: the Project Manager with experience in information systems optimization; a Requirements Engineer with experience in the ER process; a Software Architect with development experience; and the Manager of the SDC (as end-user). The team also collaborated with the specialist engineer in applying creativity techniques to validate the approach.

After characterizing the community (in terms of gaps and opportunities for improvement), the team followed the steps underlying the process, namely: clarification of the goal, understanding of the needs of stakeholders and sustainability factors, focusing on primary causes, finding sustainable solutions and integrating into the requirements document.

It should be noted that to "Find sustainable solutions," the needs of the organization and the primary causes were considered, applying different creativity techniques to obtain innovative and sustainable solutions. At this point, we proceeded to select the most appropriate creative techniques given the specificity of the organization under study. Brutethinking and Reversal techniques were selected. Empathy maps were used to synthesize and organize the selected contents and ideas.

During the application of the Brutethinking creativity technique, the word sustainability associated with the problem was introduced. After analyzing the ideas obtained, the following SDGs were included (3 - Good Health and Well-being; 4 - Quality Education; 8 - Decent Work and Economic Growth; 9 - Industry, Innovation, and Infrastructure; 17 - Partnerships for the Goals) and the five dimensions of sustainability: human, economic, environmental, technical, and social.

The creative process was repeated to reflect and identify the connections between the five dimensions of sustainability. In this way, Figure 5 was created to present the result of this reflection in a diagram with keywords in the five dimensions of sustainability in the SDC. According to the representation in Figure 5, it was

possible to obtain the integration of the five dimensions of sustainability because of the reflection of the real situation of the social organization.

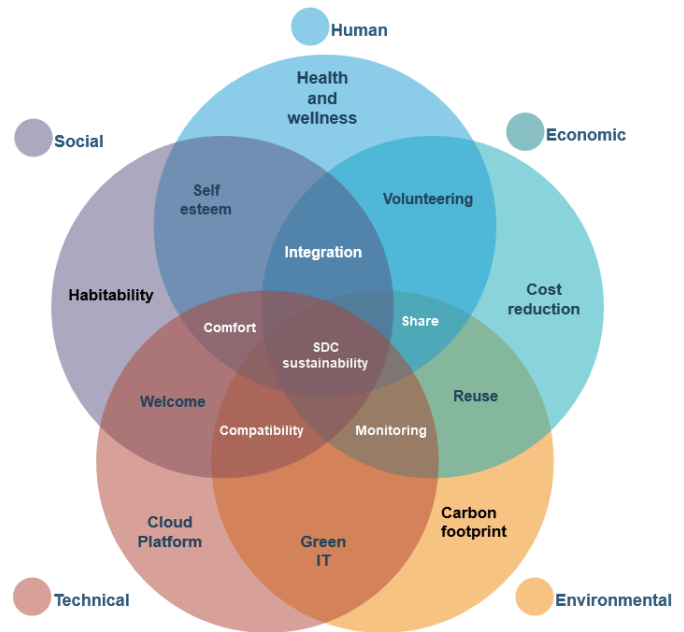


Figure 5: Sustainability dimensions in SDC

The main results focus on the visualization of the five dimensions of sustainability applied to the social organization under study. In this context, sustainability, particularly Sustainable Development Goal 17, encouraged the creation of partnerships to solve social problems. It should also be noted that the team was given sufficient guidance so that the actions do not seem mysterious, leaving room for innovation and participation.

The CRESustain approach was also applied in an academic context with a group of students in a Software Engineering course. The results underlying the interaction with students showed difficulties in relating the dimensions of sustainability to academic projects, namely the ability to visualize the benefits of the SDG after project implementation. On the other hand, it was observed that it is necessary to understand the concept of sustainability and its interconnection with software engineering.

Overall, it is concluded that creativity techniques were applied correctly, having achieved the objective of developing sustainable innovations in ongoing projects. It was possible to include sustainability factors in the creative approach by associating the five dimensions of sustainability and integrating the SDG.

The principles and commitments of the Karlskrona Manifesto are considered in applying the approach to provide a comprehensive view of sustainability and opportunities encouraging various stakeholders to include sustainable solutions during the RE process.

It is essential to mention that the sustainability factors incorporated in the RE process can be applied to other software products, referring to the following examples: smart home systems, washing machines or games [27]; digital signature of documents [22]; a platform for homeless people [40]; mobile applications for volunteering and insulin monitoring in diabetics [41]; taking medication [42]; agricultural land for cultivation [43].

6. Conclusion

The paper's innovative contribution concerns incorporating sustainability principles and dimensions with creativity techniques during the RE process, creating a CRESustain approach. Applying the specific structured CRESustain approach to introduce sustainability concepts and creative processes in RE focuses on three main stages: team building, understanding the problem and finding sustainable solutions. The word sustainability is introduced during the creative process by building the respective diagram and identifying sustainable solutions in its five dimensions: human/individual, economic, environmental, technical, and social. The study observed that this approach stimulates discussion about sustainability in its multiple dimensions, promotes the SDG, and focuses on people's needs.

The practical application of the CRESustain approach showed that it was possible to identify sustainability requirements that led to creating new services in the social organization. Another result obtained was the interconnection of the identified requirements to the SDG.

The difficulties were focused on the introduction of creativity techniques and sustainability dimensions. This difficulty was solved by training the whole team.

It is reiterated that innovation, creativity, and sustainability at the technical/non-technical and/or functional level are essential factors for the success of software products. Thus, the participation of elements with skills in these areas is also fundamental, allowing a reflection on the requirements and their effects on sustainability.

It is also observed that software professionals have shown interest in the sustainability issue, and there is a certain consensus that sustainability should be treated as a software quality attribute. Considering sustainability as an attribute of software quality allows incorporating the principles and commitments of the Karlskrona Manifesto and emphasizing the five dimensions of sustainability: individual/human, social, environmental, technical, and economical. The DSR methodology, applied in an iterative process, allowed the design of the artefact.

The study's limitations were at the level of surveying sustainability requirements to meet the principles of the Karlskrona Manifesto and thus contribute to promoting the SDG. The fact that it was only applied to a social project is also considered another limitation.

In future work, it is planned to continue the application of the approach in academic co-creation projects. Another operational perspective that can provide added value to extend the approach will be to analyze the organization's representation by its DNA and use the enterprise architecture structure for this purpose [44].

Conflict of Interest

The authors declare no conflict of interest.

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