Quantification of Social Sustainability in Software

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***Abstract*—Software is an essential element in the modern (largely) digitized world. Yet, social sustainability topics are, so far, under-researched in the software engineering discipline. Currently, there is neither a clear method for evaluating social sustainability of a software system at the requirements level, nor a comprehensive set of metrics for social sustainability assessment in requirements analysis. This research aims to develop a set of such metrics and an accompanying method for analyzing social sustainability requirements of software systems.**

***Index Terms*—Software engineering, social sustainability, metrics.**

I. Introduction and Motivation

As defined by the United Nations report on sustainable developments [1] "Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs." [1]. There are three pillars of sustainability that are commonly agreed on namely, environmental, economic and social sustainability. There are also additional (less considered) issues, such as human [2], cultural and religious. Some authors consider cultural and religious aspects as part of the social pillar [3]. The same could be said about the human aspect of sustainability.

Software is an essential element in our modern (largely) digitized world; it is playing an important part in all spheres of our daily lives - from entertainment, communication, to business. Until recently, however, the consequences of software use on sustainable development have not been considered. Having conducted the first review of sustainability-related topics in software, authors in [2] note that software sustainability is usually supported via developing models, frameworks, methods and metrics, the majority of which are currently focused on energy-efficiency, waste reduction, and cost-effective ways of software development. The social sustainability topics are, so far, under-researched in software engineering discipline.

Yet, social sustainability is an important aspect of sustainable development that is concerned with personal and communities' well-being [3-5]. The effect of software on social sustainability is ever growing, as more and more aspects of our life migrate into the digital domain (as evidenced by cybercrime, e.g. cyber stalking [6], internet fraud and cyber-pornography [7], loss of money and emotional hurt, e.g., through "online romance scam" [8], etc.). Social sustainability has a number of traditional themes (e.g., employment) and emerging ones (e.g., empowerment) [9]. The emerging themes are found to be qualitative in nature, as opposed to the traditional quantitative ones [9]. These different themes result in different definitions (and observable indicators) tailored to fit specific domains [9]. Thus, there is a need for consensus for a set of social sustainability indicators as well as for methods to quantify social sustainability and integrate it into the everyday practice of software engineering.

The aim of this research is to support identification and quantification of social sustainability effects of software in requirements engineering in order to enable development of software systems that are conducive for social sustainability. The specific objectives of this work are to:

1) Produce metrics that measure the impact of software on social sustainability and

2) Design a method for incorporating social sustainability concerns into software requirements engineering and design (including study of how such concerns can be identified, analyzed, and modeled).

II. State of the Art

"Sustainable Software is software whose direct and indirect negative impacts on economy, society, human beings, and the environment resulting from development, deployment, and usage of the software is minimal and/or has a positive effect on sustainable development."[10]

Social sustainability is slowly gaining grounds in computer science research [11] but much more effort is still needed in this area. In order to appraise the state of the art on topics of social sustainability and software, we have undertaken a systematic literature review (SLR) of this topic. Some of our findings are discussed below.

There are different frameworks for assessing social sustainability such as the life cycle assessment (LCA), social impact assessment and vulnerability assessment techniques.

Some of the mentioned methods were not originally developed for social concerns but were later adjusted to include social dimensions. An example is the life cycle assessment (LCA) framework which was initially used to evaluate the environmental impacts of products throughout their life cycle [12]. In [13], social dimensions were added to the LCA and used for assessing the social sustainability of biofuel industry in Indonesia. This study used such social criteria as human

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rights, working conditions and cultural heritage. Another study used LCA framework and focused on the public's social acceptance of energy technologies [14]. Authors in [15] utilized the LCA model to asses food system in US. The used social indicators were associated with different stages of the food system. For example, the average age of farmers was an indicator associated with the planting and production stage [15] while the percentage of food wasted to the donated food indicator used to assess social sustainability during the end of life phase [15].

Social impact assessment refers to the analysis of the social impacts resulting from development projects [16]. In [17], the social impact assessment was part of the suggested framework for evaluating construction projects. The impacts can be related to the culture, new social classes, population changes, zoning decisions and access to public transportation [17].

Vulnerability assessment technique depends on pinpointing the most vulnerable populations and finding the social effects on them resulting from a development project [18].

Social sustainability indicators vary depending on the assessment framework used and the studied domain. Indicators are related to employment, equity, education, public services, resilience, social ties and networks, etc. Those indicators are tailored in most cases to fit a specific domain or case. The indicators will also vary depending on the level of study or granularity. For example, social sustainability of an industry can be related to social effects on the employees (internal effect) or social effects on consumers (external effects). In [19-21], indicators were derived in association with projects internal human resources and external population.

Social indicators can overlap and interchange. For instance, health can be considered an indicator on its own [22] or it can be part of public facilities indicator [23].

Software can influence a huge set of areas in social sustainability. For instance a prototype of a communication software was developed in [24] to support data sharing and communication in virtual teams and virtual organization. In order to achieve this, the authors suggested that the content should be usable and available in different contexts. The response time and scalability was measured to evaluate the achievement. In another study, software was used as a social sustainability assessment tool for biotechnological modeling [25]. In [26] software was employed as an educational game to educate students on social sustainability.

Several studies have highlighted the role of stakeholders in the process of developing or selecting suitable social sustainability indicators for their domain [13, 25, 27, 28]. This suggests the importance of involving community members, domain experts and academics in social sustainability evaluation projects.

Our SLR shows that social sustainability indicators discussed in papers discussing software (or software engineering) are much fewer than social sustainability indicators discussed for other domains. This indicates that, so far, the software engineering discipline has not adequately engaged with this topic. Thus, our research will be building the knowledge by combing software metrics knowledge and social sustainability assessment in other domains. Here we are applying the method suggested in [29]. It was suggested that there are two approaches of achieving sustainable development. One approach is to build innovation from external knowledge to the software engineering field and the other is to create innovation from internal knowledge of the field [29].

In [11] the authors' reviewed a set of 122 papers related to sustainability in UbiCom and CHI. It is reported that 51% of the top 100 papers were derived from UbiComp/HCI community. It was also reported that social questions appeared just in twenty percent of the top 100 papers [11]. It is noticed that some of the social indicators are actually used as human computer interaction (HCI) designs evaluation. For instance, bad ergonomics has direct effect on individuals' health. As we have mentioned above, health is an indicator to social sustainability. At the same time, ergonomics was used in [30] to evaluate the usability of e-readers technology. The indicator was used but not associated to social sustainability concern.

III. Research Questions and Challenges

The research questions addressed in our work are (1) how can social sustainability requirements be identified? (2) What metrics can be used for measuring software's social sustainability? (3) What social sustainability indicators are pertinent to software?

The first question will give insights on requirements engineering and design approaches that will allow elicitation of social sustainability concerns. This will help software engineers to analyze the social sustainability aspects of software in future projects. The last two questions will provide methods for evaluating software's effects on social sustainability.

We have currently catalogued around 600 social sustainability indicators through the SLR. Reducing these (or relevant sub-set of) indicators to a reasonable set of metrics is the first challenge to be addressed. This is because we must reconcile a number of the different views on what social sustainability is and what indicators are to be used to measure social sustainability. Substantial challenge is also attributed to the qualitative nature [9] of some emerging concepts in social sustainability – these will be very difficult (if at all possible) to quantify.

Another challenge is to ensure that the method and metrics developed in this work are acceptable to the requirements engineering practitioners. Thus, the metrics and method should be light-weight yet informative. Considering the large number of indicators that we have already catalogued, producing a light-weight method for their application will not be an easy task.

Social effects are indirect and take long time to manifest [31], yet, for requirements engineering, we must be able to identify and measure social effects of software even before that software is developed. Reconciling these apparent contradictions is yet another challenge to us.

IV. Progress, Research Methods and Contributions

This research will contribute to the software and social sustainability field by:

1) developing a comprehensive catalogue of social sustainability concerns that originate from the systematic literature review,

2) building a set of metrics that support quantification of social sustainability in software requirements and design and

3) establishing a method to integrate social sustainability concerns into systems' requirements and design.

To the best of our knowledge, this is the first effort aiming to capture a holistic view of social sustainability and to provide a method to engineer it into software. As noted before, due to the ever increasing penetration of software in all spheres of life, it is important to understand and consider its social effects. We have already witnessed substantial change imposed through software on the traditional communication (e.g., Facebook and WhatsApp applications), shopping (e.g., eBay and Amazon), dating, learning (from YouTube videos to free online courses), political (e.g., protest and riot organization through Facebook and Twitter during Arab Spring [34] and London Riots [41]) and other practices. We are also facing such negative social consequences of software as online child bullying [36], online romance scams [8], and radicalization of youth [35]. By providing a method and metrics for engineering social sustainability into software, this work will facilitate the anticipation and prevention of such undesired consequences [37].

To accomplish the above contributions, the following research will be carried out (table 1):

Stage 1: conduct systematic literature review. The aim here is to discover the common social sustainability indicators, social sustainability metrics, the role of software in social sustainability and the indicators of software's social sustainability. A set of about 600 indicators has already been catalogued through SLR. These indicators are to be aggregated into coherent groups. The grouping will be done through light-weight grounded theory analysis (which is to say that grounded theory coding will be applied to extracts from documents, rather than their whole texts).

Stage 2: explore software metrics used in requirements engineering and design, study and how they are built and used. This is to be done through additional literature review as well as by extracting information on software sustainability metrics from stage 1.

Stage 3: develop a set of metrics that support quantification of social sustainability in software requirements and design. This will be achieved through application of the software engineering metric construction techniques (obtained from stage 2) to the set of social sustainability indicators (obtained from stage 1). The work at stages 1 and 2 has no particular restrictions on data collection and study domain. However, we foresee that each indicator group developed in stage 1 will be substantial enough to define a domain (e.g., we can provisionally identify such groups as security, equality, etc.). In stage 3 each indicator group will be considered a separate domain. Thus, at this stage, domain-specific stakeholders will also be consulted, as their knowledge and perspectives on relevance of a particular metric are essential. We expect to conduct focus groups and workshops with such stakeholders on per-indicator-group basis.

Stage 4: construct a method to incorporate social sustainability concerns into systems' requirements engineering and design. This stage should address 2 distinct issues:

a) generalizing the metric construction method worked on stages 1-3, and

b) integration of metrics developed in stages 1-3 into the framework of requirements engineering and design methodologies in current practice (i.e., primarily agile development).

The generalization of the metric development work into a method is necessary as – due to the expected substantial number of indicator groups - it will not be possible to work thought all the groups within this PhD project. Yet, having provided the complete (currently available through SLR, stage 1), set of social sustainability indicators and a validated method for metric construction for a given indicator group, we will enable further metric development for the remaining indicator groups.

Integration of developed social sustainability metrics into a software engineering methodology is also necessary if these metrics are to be used by others. Here such issues as social sustainability concern identification, modeling, and treatment would be considered. Identification, for instance, could be potentially supported through a natural language processing (NLP) tool to capture social sustainability indicators from software requirements document [32]. Another potential method is the use of software patterns to provide guidelines for elicitation of social sustainability requirements [33]. We do not intend to provide any new concepts or techniques here, but to demonstrate how the existing ones can account for the social sustainability concerns.

Stage 5: conduct case studies on several e-government initiatives in Oman to evaluate the effectiveness of the metrics. The case study approach will be used to evaluate the completed work, however, we are also aware of a number of validity concerns related to the case study methodology. One such concern is, for instance, related to the selection of representative cases reflecting larger population. This is due to the in-depth investigation that will lead to limited number of cases that makes results generalization an issue [38]. According to [39], this can be resolved by analytic generalization (theoretical generalization) and theory testing. Analytic generalization is "the extraction of a more abstract level of ideas from a set of case study findings − ideas that nevertheless can pertain to newer situations other than the case(s) in the original case study. For case study evaluations, the analytic generalization should aim to apply to other concrete situations and not just to contribute to abstract theory building." [38] This can be achieved by relating the findings to literature and finding overlaps and gaps as well as by conducting additional case studies to reproduce findings [38].

TABLE I. RESEARCH STAGES AND METHODS

Stage	Task	Method
1	Collect social sustainability indicators	Systematic literature review
2	Discover software metrics	Reading and results from stage 1
3	Develop set of metrics	Integrating results from stage 1 and 2
4	Construct software method	Use natural language processing tool and software patters.
5	Evaluate the metrics	Case study (e-government)

Currently, we are in the first stage of the project. A systematic literature review is in progress. We have taken advantage of the digital libraries to conduct our search. We focused on computer science and engineering digital libraries and decided to use ACM digital library, IEEE, Scopus and Springer link. We have also used Web of science and ASSIA to derive the social concern of our research. The search terms used were social sustainability and metrics, social sustainability and indicators and software and social sustainability. Studies were selected based on their relevance to the defined research questions. Some primary results have informed the work outlined in this paper. A further paper on the systematic literature review is currently in submission [40].

V. CONCLUSION

As discussed above, sustainable development is slowly taking a center stage in research. Software engineers are also increasingly focusing on sustainable development issues for software applications [4].

We are currently developing a catalogue of software's social sustainability indicators, which will lead to development of a set of social sustainability metrics and evaluation method for social sustainability in software requirements. We are facing a number of challenges in our project, including the task of folding numerous indicators into a manageable set of metrics, estimating/measuring long-term effects of software which is not even developed yet, and integrating social issues into the normally functionality- (and quality) focused engineering discipline. We are looking forward to discussions and feedback on avenues of potential progress with these (and possibly other, unnoticed by us) challenges.

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