Experiences from Applying the Karlskrona Manifesto Principles for Sustainability in Software System Design

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***Abstract*— Sustainability in software design is an evolving area that requires more practical guide on how software designers, developers and requirement engineers can elicit software sustainability requirements. The Karlskrona Manifesto for Sustainability Design (KMSD) principles serve as a common ground to guide and support sustainability in software design.**

However, there is little research as of now showing how these KMSD principles are applied in software requirements elicitation and software design in general. This paper presents some of our evaluation of how these KMSD principles, the software sustainability requirement template and software sustainability requirement best practice template were applied in two case studies by stakeholders (requirement engineers, CTO and software developers).

***Keywords*—Requirements engineering, Karlskrona Manifesto, software design, sustainability design**

I. INTRODUCTION

The United Nations highlight sustainability as one of the world's major challenges [1][2] and the United Nations Sustainable development Goals (SDGs) [3] show the global motivation for action towards sustainability. Sustainability has gained more attention as an important concern from many researchers in different research disciplines in software engineering and computing [4]. In the industry, sustainability has been on the agenda of many companies for decades, but their environmental, social and governance activities are often disconnected from their core strategy because they lack understanding of how to integrate sustainability into their business models [5]. Furthermore, sustainability is a key driver for innovations in companies by creating new opportunities to lower costs, add value and gain competitive advantages [6]. However, for software design, development and requirements engineering professionals in industry, there are few tools that wrap core principles of sustainability together [7] [8] for better understanding of software sustainability from the different sustainability dimensions (Economic, Environmental, Individual, Social and Technical) [9] . In requirements engineering there have been different research efforts to tackle the issue of sustainability in software design through workshops of researchers called the International Workshop on Requirements Engineering for Sustainable Systems (RE4SuSy) such as in 2013 [10], 2014 [11], 2015 [12], 2017 [13], 2018 [14]. One major outcome from RE4SuSy is the Karlskrona Manifesto for Sustainability Design (KMSD) [15] to guide and support the consideration of sustainability in software design.

Currently, there has been little research on applying the KMSD principles to software system design and reporting the application of those principles in comparison to other successful manifestos such as Agile manifesto [16] used for example in design practices to specify requirements [17] and agile in system design thinking [18]. The lack of research attention towards how the KMSD can be applied in software system design and development, most especially the requirement phase, has limited the understanding of stakeholders on how these principles can be effective in supporting and guiding requirement engineers to consider sustainability [19].

This paper presents early results from two case studies where the KMSD principles have been applied in the requirement gathering and design phase with different stakeholders. We present the usage of the software sustainability requirement template as well as the software sustainability requirement best practice template in the result section.

The next section provides an overview of related work. Section III describes the study design. Section IV covers results. Stakeholders' feedback are detailed in section V. Discussion is in Section VI. The concluding remarks are in Section VII.

II. BACKGROUND

Requirements engineering is the key to ensure sustainability in any software design and development project [20]. Requirement engineers have a role to play [21] because the requirements phase in any software design dictates and directs how any software will be developed [22]. Report by Mahaux et al. [23] and the proposed software requirements prioritization based on a multi criteria decision making model approach [24] shows requirements engineering has received some level of research attention promoting sustainability and proposing different solutions for sustainability in requirements engineering.

The Workshop series on Requirements Engineering for Sustainable Systems (RE4SuSy) [14] also has championed efforts to increase awareness about sustainability for researchers and interested stakeholders in this domain. This is to improve the narrow understanding of sustainability in requirements engineering as detailed in [25] which has limited the focus of sustainability to either one or two dimensions during requirement gathering.

However with continuous individual research efforts towards sustainability in requirements engineering approaches, the current practices by industry practitioners in software requirements engineering do not reflect these continuous research efforts due to less engagement for transfer of research to practice [26]. Promoting and increasing research engagement with industry practitioners will improve awareness about the benefits of sustainability in software requirements engineering. A study result shows requirements engineering practitioners attitude and perceptions with regards to sustainability are limited due to a narrow understanding of sustainability and poor organizational awareness about the positive opportunities for applying sustainability [7]. Furthermore, another major challenge of sustainability in software requirements engineering is that there is no single point of reference where different research works covering the application of sustainability in software requirement are gathered and exemplified which necessitated the authors in providing different techniques for handling sustainability in requirement engineering for all interested researchers and practitioners [27].

One of the major drivers for supporting sustainability during requirements engineering is the ability to discuss how sustainability can come into play with benefits for both end users and all stakeholders involved. For example the WinWin negotiation model with integrated sustainability concepts by Seyff et al. [8] supports negotiation and discussion of sustainability during requirements engineering to facilitate impact assessment of those requirements on sustainability. This can help improve sustainability consideration in the overall software design and also consideration of all sustainability dimensions during requirement engineering by requirements engineering practitioners.

The gap evident between the works cited above shows the need to channel research efforts towards the application of KMSD principles in requirements engineering and software design in general to foster better understanding of what sustainability means in software design and also support the adoption of sustainability as a key component in software design.

III. Study Design

This research is designed to show the impact of KMSD principles during software requirements gathering and design. We studied how KMSD principles reshaped the software requirements gathering process and the usefulness of applying the principles as guide for stakeholders; especially requirement engineers /software developers.

The research method applied is participatory action research [28] because it prevents a researcher from manipulation of the individual feelings and views of stakeholders. Participatory action research is also a method that best suit research where researchers (authors) are involved in supporting and making necessary decisions with stakeholders throughout the research process based on how stakeholders apply the KMSD principles.

A. Research Questions

1. How applicable are the KMSD principles during software requirement gathering?
2. What is the impact of the KMSD principles on stakeholders during software requirements elicitation?

In this paper, the focus is on answering these research questions, identifying issues and challenges of using KMSD principles during software requirement, and using feedback from stakeholders to offer others ways on how KMSD principles can be improved to support and guide stakeholders during software design and development.

B. Research Elements and Case Study

The main research element are the Karlskrona Manifesto for Sustainability Design (KMSD) principles detailed in Table I. The KMSD was initiated through an initiative to create a common ground and a point of reference for the global community of research and practice in software and sustainability to effectively communicate major issues, goals, values and principles of sustainability for the design and development of software systems [15].

The KMSD principles were used in the two case studies with support of the software sustainability requirements template (see Table III) and software sustainability requirements best practice documentation template [29] (Table VI). The KMSD principles were assign to different software development life cycle (SDLC) phases to explain what each of the KMSD principles means at each phase of the SDLC base on our understanding [30]. Table II details how the KMSD principles were translated to each software development life cycle phase and applied in the two case studies.

TABLE I. Description of the Karlskrona manifesto principles, adapted from [31].

Principle Number	Principle	Description
P1	Sustainability is systemic	Sustainability is never an isolated property. It requires transdisciplinary common ground of sustainability as well as a global picture of sustainability within other properties.
P2	Sustainability has multiple dimensions.	We have to include different dimensions into our analysis if we are to understand the nature of sustainability in any given situation.
P3	Sustainability transcends multiple disciplines.	Working in sustainability means working with people from across many disciplines, addressing the challenges from multiple perspectives.

P4	Sustainability is a concern independent of the purpose of the system.	Sustainability has to be considered even if the primary focus of the system under design is not sustainability.
P5	Sustainability applies to both a system and its wider contexts.	There are at least two spheres to consider in system design: the sustainability of the system itself and how it affects the sustainability of the wider system of which it will be part.
P6	System visibility is a necessary precondition and enabler for sustainability design.	Strive to make the status of the system and its context visible at different levels of abstraction and perspectives to enable participation and informed responsible choice.
P7	Sustainability requires action on multiple levels.	Seek interventions that have the most leverage on a system and consider the opportunity costs: whenever you are taking action towards sustainability, consider whether this is the most effective way of intervening in comparison to alternative actions (leverage points).
P8	Sustainability requires meeting the needs of future generations without compromising the prosperity of the current generation	Innovation in sustainability can play out as decoupling present and future needs. By moving away from the language of conflict and the trade-off mindset, we can identify and enact choices that benefit both present and future.
P9	Sustainability requires long-term thinking.	Multiple timescales, including longer-term indicators in assessment and decisions, should be considered.

Table I and II were provided to the stakeholders in the two case studies as guide for them to understand the KMSD principles and how they apply to different software development life cycle phases (SDLC). P1 to P9 represent the KMSD principles from 1 to 9 in Table I. The software sustainability requirements template (Table III) was used to collect information on how stakeholders relate each requirement to sustainability dimensions and their reasoning for associating each requirement to a particular dimension. The software sustainability requirements best practice template (Table VI) was applied in highlighting important key practices during the requirements gathering. These two templates offer researchers involved in the two case studies better understanding of how stakeholders translate all information provided to them into the software design.

The first case study is within a medium size company with the goal of developing a web application to replace manual handling of pension applications. The application is called pension benefit tracker. Figure 1 shows the use case diagram of the application in case study 1.

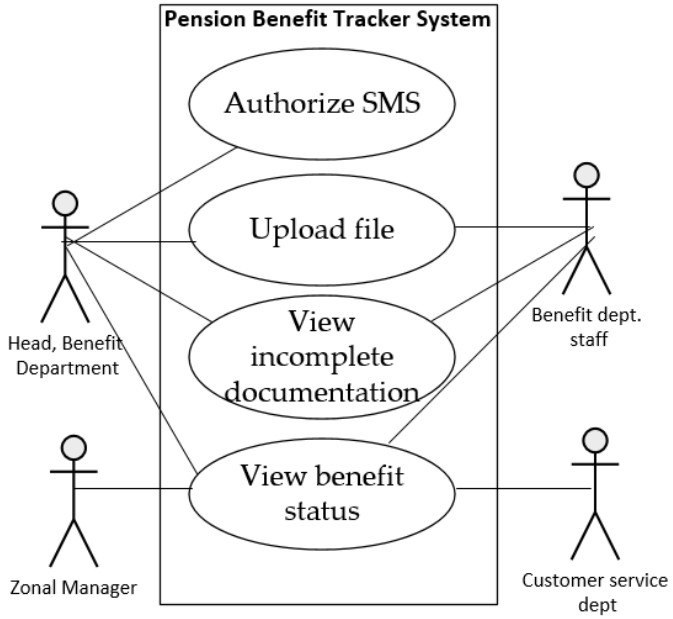

Figure 1. Use case for pension benefit tracker [19].

The second case study is in a university with the concern of how to display energy usage data within the university. The main requirement for the project is to transform energy usage data into CO2 emissions that will educate the university staff and students about sustainability. The project requires a web application interface which will display the energy usage and carbon emission. The goal is to let the public know more about the electricity consumption of each building in the university and understand the relation between the electricity consumption and carbon emission (CO2).

The KMSD principles were applied as guide during each of the case study (case study one and two) for requirement gathering and analysis. Stakeholders were able to use to the KMSD principles to cross check the sustainability aspect of each requirement and how to evaluate those requirements with consideration of each sustainability dimension. For better understanding of stakeholders thinking during classification of requirement into sustainability dimensions, the software sustainability requirements template was used to document stakeholders' explanations for each requirement mapped to a particular sustainability dimension. The software sustainability requirements best practice documentation template was provided to stakeholders to document what stakeholders perceived as a best practice during the case study.

TABLE II. KARLSKRONA MANIFESTO PRINCIPLES IN RELATION TO SOFTWARE DEVELOPMENT LIFE-CYCLE (SDLC) PHASES [30]

SDLC Phases	**Karlskrona Manifesto Principles**
Phase 1.	**P1-** This ensures that the project initiation considers sustainability in the overall project

Project Definition	definition from the beginning. **P2**- Software sustainability has different dimensions that have to be considered from the beginning for better project management with different stakeholders. **P3**- Software project usually involves stakeholders from different domains, incorporating their sustainability concerns provides better management of those concerns from multiple perspectives which can help the incorporation of sustainability for the software.
Phase 2. User Requirements Definition	**P2**- It is important to take note of user requirements in relation to each of the sustainability dimensions in order to have better sustainability analysis during the analysis and design phase
Phase 3. System Requirements Definition	**P4**- During elicitation of system requirements, requirement engineers should consider sustainability concerns for the system during the requirements definition even when it is not a core part of the user requirements. **P5**- Cross evaluate the consequential impacts of the system sustainability requirements and the environment in which the system will function.
Phase 4. Analysis and Design	**P2**- Applying this principle provides a blueprint for system evaluation from all sustainability dimensions (economic, environment, social, individual and technical). **P4**- At this phase, this principle helps to encourage analysis of system design based on sustainability in order to facilitate better sustainable system. **P6**- Application of this principle enables better visual and visible overview of the system from different levels of abstraction. **P8**- This will provide better understanding during analysis to make better choices that will help the potential users of the system in present and in future when the system evolves.
Phase 5. Development	**P2**- This will encourage developers during this phase to consider different sustainability dimensions, especially technical, social and individual dimensions. **P4**- Encourage the search for better avenues to make the system sustainable from the development perspective (developers) and also the functions of the system to aid longevity.
Phase 6. Integration and Testing	**P2**- Provides integration and for test team to have a sustainability template that can be used to test the system for all sustainability dimensions based on the sustainability requirement output from phases 2, 3 and 4. **P4**- Application of this principle will aid consideration of sustainability in this phase even if the primary focus of system is not about sustainability.
Phase 7. Implementation	**P5**- Provides beforehand reasoning for the development team to consider the sustainability of the system, its production environment and when pushing it live for use. **P7**- Based on principle 5 (P5), this principle will aid consideration of seeking the involvement of different stakeholders to make the actualization of the system sustainability possible in the production environment and when pushed live.
Phase 8. Sustainment/ Maintenance	**P9**- This principle at this stage help to create the conscious awareness so that when the system is in a live environment, there will be continuous evaluation to assess the system sustainability and think of ways for optimizing and improving the sustainability of the system from the different dimensions.

TABLE III. SUSTAINABILITY REQUIREMENT TEMPLATE

Requirement	**Sustainability Dimension**	**Explanation**
State each of the requirement in a way that makes it possible to associate the requirement to at least one or more of the sustainability dimensions	Highlight which of the sustainability dimension relates to all the stated requirements. These are the general explanation of the five sustainability dimensions based on the KMSD group [32]: • **Individual** sustainability refers to maintaining human capital (e.g., health, education, skills, knowledge, leadership, and access to services). • **Social** sustainability aims at preserving the societal communities in their solidarity and services. • **Economic** sustainability aims at maintaining capital and added value. • **Environmental** sustainability refers to improving human welfare by protecting the natural resources: water, land, air, minerals and ecosystem services. • **Technical** sustainability refers to longevity of information, systems, and infrastructure and their adequate evolution with changing surrounding conditions.	Provide an explanation for your decision to associate each requirement to a particular sustainability dimension.

IV. RESULTS

The first result is the use of KMSD principles for both case studies in which stakeholders explained their understanding of those principles with regards to each of their application. The KMSD principles applied in each SDLC phase were detailed in Table IV. The information contained in Table IV is all from stakeholders involved in the case studies with slight modification by authors to improve readability. This is to ensure that the exact understanding of stakeholders is documented and reported in this paper.

TABLE IV. KARLSKRONA MANIFESTO PRINCIPLES APPLIED IN THE TWO CASE STUDIES

SDLC Phases	Case Study 1	Case Study 2
Phase 1. Project Definition	**KMSD Principle 2** The technical, social dimension and individual dimensions was considered. 1. The technical dimension focused on the how well the final system can function effectively and efficiently to achieve all system goals. 2. Social dimension covers how different state branches can form a community to share pension application 3. The individual dimension center on the developer's satisfaction within the company throughout the development of the pension tracking system	**KMSD Principle 1** The project is centered around sustainability awareness base on energy usage and co2 emissions of university staff and students **KMSD Principle 2** The Sustainable Business Canvas provides thinking on different sustainability dimensions during the project initiations. **KMSD Principle 3** The project involves different stakeholders with different expertise and departments, they were all involve in using the Sustainable Business Canvas for the project in order to incorporate all concerns and sustainability ideas for the project
Phase 2. User Requirements Definition	**KMSD Principle 2** 1. Reduce pension processing time to decrease the stress and pain of pensioners covers the individual dimension. 2. Using the software sustainability requirement template provides an avenue to improve the overall performance of the application from different sustainability dimensions (economic, social, individual, technical and environmental)	**KMSD Principle 2 and 6** The user requirement was divided into different sustainability dimensions for better analysis namely: 1.Provide information on energy usage within the university (Economic and Technical) 2. Show the carbon emission (Environmental) 3. Allow weekly sustainability challenge and show winners (Social) 4. Section for user community to connect and discuss (Social) 5. Provide feature to share things to social media (individual)
Phase 3. System Requirements Definition	**KMSD Principle 4** The main goal of the application is to replace manual pension application; however, some sustainability concerns were also included such as: 1. Increase sustainability awareness among company staff using the application and customers (pensioners) 2. Reduce the use of paper for pension application 3. Decrease the amount of printing during pension application 4. Increase number of options for pension application notification	**KMSD Principle 4** The application main goal is about sustainability awareness in the university for staff and students. **KMSD Principle 5, 7 and 9** These are the following impacts of the system sustainability requirements: 1. Converting the energy usage in form of carbon emissions CO2 and presenting it as distance between two cities will help educate the users about sustainability and the users impacts on the environment. 2. Providing a community section with weekly challenge in the application will go a long to increase sense of belonging and foster better habits towards sustainability in the university. 3. The ability to share weekly challenge results by users will boost their interest and increase awareness about sustainability.

Phase 4. Analysis and Design		**KMSD Principle 2** The application will help economically because of reduce energy usage and cost. It will also help socially to bring people into a common community and environmentally to increase awareness about sustainability with the need for users to reduce their negative impacts **KMSD Principle 8** This principle encourages the use of API to allow different kind of users to interact and feed the application with data.

The second result is the preliminary evaluation of the sustainability requirement template showing how stakeholders categorized different system requirement based on their understanding of sustainability dimensions. Table V presents the use of the sustainability requirement template in case study one as documented by stakeholders with slight modification by researchers to improve readability.

TABLE V. SUSTAINABILITY REQUIREMENT TEMPLATE USED IN CASE STUDY ONE

Requirement	**Sustainability Dimension**	**Sustainability Dimension and Explanation**
The pension tracker application should be accessible online via web at any branch	Economic and Technical	It will save us money of using interstate courier to send, receive and track pension applications. (economic) To achieve this, a good functional system with no down time that will satisfy user needs is required (technical)
The application should have ability to enable Managers, pensioners and other stakeholders check application status	Technical, individual and social	Ease of use (individual) and also allows everyone using the system to be up to date about pension application status (Technical and social)
Provide automatic status communication and notification at each stage of benefit application	Individual and Social	It will keep clients (pension applicants) up to date about their application (individual and social)
Allow bulk or single file upload	Individual and Technical	More options to reduce time spent in uploading application files (individual, technical)
Provide SMS authorization from managers in benefit department	Individual	Provide ease of processing and approval for managers (individual)
Send Incomplete documentation notification to benefit department staff	Individual and economic	Reduce time of processing the pension application (individual, economic)
Provide email and SMS notification as an option for all users	Individual	Provide more options to increase user preference because some users might not have access to email (individual)
Provide option of different display to magnify fonts for users with visual problems	Individual	This promote inclusiveness especially with users with visual problem (individual)
Provide option to preview pension application and save electronically	Individual	Reduce amount of error in applications and saves time of double work (individual)
Add a tag message below each notification “Save the planet from environmental waste, print only when needed”	Environmental	Promote sustainability awareness among staff and clients (pension applicants)
Provide energy report for system usage	Environmental and Technical	This will enable users track the amount of energy consumed by the application and discuss how we can improve it

Table VI present the requirements best practice template documentation from case study two. It shows the use of the requirement elicitation best practice template [29]. This is an example of documentation and reporting of how sustainability was considered in this case study and showing the understanding of sustainability based on what is considered as a good sustainability practice during requirement gathering.

TABLE VI. SOFTWARE SUSTAINABILITY REQUIREMENT ELICITATION BEST PRACTICE FROM CASE STUDY TWO (SUSTAINABILITY AWARENESS VIA ENERGY DATA DISPLAY)

Element	**Description**
Title	Develop sustainability awareness in energy display application for the public
Date	12/08/2018
Authors	Mistretta Tom – Devinez Alexandre
Target Audience	Engineers / Developers
Objective	• Create awareness about sustainability requirements in a project • Encourage the development of ideas around sobriety
Location	Applicable worldwide
Stakeholders	Engineers / Developers / Users
Methodology	• Discussion among software development team on what sustainability means to them by going through the Karlskrona Manifesto principles, FSSSD and SSDC • Dialogue about which requirements can better influence users' awareness of sustainability • Dialogue about which requirements can better teach users to improve their daily habits, influenced by the information shown to them • Discussion of how to integrate sobriety awareness requirement in the project • Find a way to make the project attractive to users
Selected Karlskrona Manifesto principles	Principle 6: System visibility is a necessary precondition and enabler for sustainability design. Principle 7: Sustainability requires action on multiple levels. Principle 8: Sustainability requires meeting the needs of future generations without compromising the prosperity of the current generation. Principle 9: Sustainability requires long-term thinking.
Requirements	**<u>Functional Requirement</u>** REQ 1 – Interactivity (users must be able to interact with the application) • The interface must be simple to catch the user's attention. • Users can make actions on the interface with energy data and dynamically get eco feedback. REQ 2 – Display Information • The users should be able to understand the displayed data and information. • Energy usage data and carbon emission information should be displayed to users in relation to road distance between LUT University in Lappeenranta and other cities within Finland (this will provide a better understanding to users regarding their impact). REQ 3 – Community (users must be able to share ideas on sustainability and advice to the user community group) • Provide users with a sustainability challenge every week, dynamically based on energy usage to help users develop a sense of belonging with the idea of sustainability beyond the university. This can make them become more curious and choose to change their habits.
Validation	Engineers, developers and some end users validate these requirements with the best practice criteria.
Impact	Promote sustainability and sobriety awareness
Lessons Learnt	1. Test results from user interaction with the prototype design show users gain a sense of pride if their advice and suggestions help reduce energy usage in the community section 2. The prototype test result also shows the best way to influence public behaviour is to present energy and carbon emission information in relation to what users can easily relate to, which can offer better understanding for the public about their impact on the environment. This approach is why the equivalent of CO_2 emission, based on energy data usage, has been presented in the form of distance between one city and another to explain the impact on sustainability. This will encourage a change in users' habits over time instead of telling them to change their habits based on high energy usage data displays or CO_2 emissions.
Sustainability Dimensions	The requirements in this template cover the following: • Social sustainability • Environmental sustainability

	• Individual sustainability
Contact Details	mistrettatomjulien@gmail.com , devinez.alexandre@gmail.com

V. Stakeholders' feedback

The feedback from the stakeholders shows their interest in the KMSD principles for their system design, especially during requirement gathering. However, the challenge of understanding how to easily translate the KMSD principles into software design due to lack of tools or examples, shows there is need for more research providing tool support on practical usage of KMSD principles. This will further improve the usefulness of KMSD principles to other interested stakeholders in academia and industry.

According to the stakeholders in each of the case study, the software sustainability requirements template (see Table V) was useful as guide during requirement gathering because it supports discussion about sustainability during requirement gathering and categorizing requirements to each sustainability dimensions.

Stakeholders also states that using the software sustainability requirements best practice documentation template (Table VI) over time will provides enough knowledge base to show how KMSD principles have been applied in different software projects. Knowledge from this kind of documentation can be reused by other stakeholders which can offer better sustainability consideration during requirement engineering.

VI. Discussion

The two case studies presented in the paper shows the interpretation of KMSD principles by stakeholders involve based on their industry experience. Table IV presents the understanding from stakeholders on how the KMSD principles were applied the case study 1 and 2 from the Project Definition phase (Phase 1) to Analysis and Design (Phase 4). The remaining SDLC phases that were not covered in Table IV was because at the time of writing this paper those information were not at our disposal from stakeholders.

The following paragraphs summarize the answers to the research questions:

1. How applicable are the KMSD principles during software requirements gathering and design?
    a. The KMSD principle 2 (Sustainability has multiple dimensions) was used as a guide during requirements gathering as seen in Table IV presenting both case studies in the user requirements and system requirements definition phases.
    b. Principles 1 to 9 of the KMSD were also applied from the project definition to analysis and design phase of SDLC with sustainability consideration in each of the SDLC phases by stakeholders. The KMSD principles aided by the software sustainability requirements template create a sense of practicability with regards to applying sustainability in software design based on the outcome from both case studies in Table IV and the software sustainability requirements template for case study 1 detailed in Table V.
2. What is the impact of KMSD principles on stakeholders during software requirements elicitation?
    a. The main impact of the KMSD principles on the stakeholders is that at each phase of the SDLC, sustainability became a core aspect that was considered to improve the software application in the two case studies. Also, the KMSD principles brought some new awareness that there is a guiding principle that can support stakeholders during software requirement and design. A typical example is in case study 2 (Table IV): Using the principle 5,7, and 9 stakeholders were able to rethink how to present the energy usage data in a way that educates the university staff/students by showing the energy data in the form of C02 emissions from one city to another.
    b. In addition, the KMSD principles also pushed stakeholders to see each of the requirements from different sustainability dimensions with the aid of the software sustainability requirements template, thereby improving the overall evaluation of the software applications in the two case studies.

Despite the applicability and some positive results from using the KMSD in the two case studies, there is still the challenge of little evaluation research and practical guidance on using the KMSD in software requirement gathering and design. Currently the KMSD principles are presented as generic principles to serve all possible stakeholders, which means the principles are at high level of abstraction. It becomes difficult for novice stakeholder to properly understand how to use the principles without tangible practical examples of what and how to implement these nine principles in software design.

In order to increase the applicability of the KMSD principles, there is need to have more case studies and reporting on how these KMSD principles are applied for software design. This will improve stakeholders understanding of how the principles can be effective and efficiently used as guide during software design or enhancement.

One of the major challenges from stakeholders is the problem of understanding in what way the KMSD principles can be related to their application because of a lack of examples that could assist them. Table II was used to map the KMSD principles to SDLC phases in order to lessen the problem of understanding by the stakeholders about which principles are applicable to each SDLC phase.

VII. Conclusion

The Karlskrona Manifesto for Sustainability Design principles cover diverse aspects of sustainability to serve as a reference point and guide during software design. Our findings presented in this paper shows the benefits and challenges of using KMSD principles in software design projects via the two case studies.

The KMSD principles are useful as they provide the avenue for stakeholders to rethink the impact of their system and to take responsibility in improving or supporting the sustainability aspect of their software design. As noted on the Karlskrona Manifesto website, every stakeholder (Software practitioners, Researchers, Professional associations, Educators, Customers and End users) have a role to play in ensuring the sustainability of software that is designed, developed, used as well as the practices involved during the engineering of such software.

The major challenge currently is that there is lack of practical examples that exemplify the usage of KMSD principles during requirement gathering and software design. The lack of documentation or reporting on the KMSD principles usage have hindered the adoption of these principles in software design. One option for such documentation is the template for reporting software sustainability requirements best practice as shown in Table VI.

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