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Sustainability in the Software Industry: A Survey Study on the Perception, Responsibility, and Motivation of Software Practitioners

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While the topic of software sustainability is gaining increasing significance in academia, there is a need to explore its implementation in industrial practice. In this paper, we investigate how software practitioners assess sustainability as a topic within their profession. We conducted a survey study with 104 software practitioners, and the data provides evidence that companies assign moderate importance to sustainability. Different occupational roles indicate varying perceptions and levels of responsibility regarding the development of sustainable software products and services. Notably, technology-oriented roles (e.g., Software Engineers) exhibit lower valuation and responsibility of sustainability aspects compared to management-oriented roles (e.g., Project Managers). The motivation to engage with sustainability shows a connection to business factors such as profitability, competitive opportunities, and risk mitigation. Consequently, researchers should give greater consideration to the circumstances and requirements of businesses, incorporating them into practical approaches to contribute to sustainability.

Keywords: software sustainability, sustainability design, software engineering, software industry

1. INTRODUCTION

In the last decade, there has been a growing interest in the field of Information and Communication Technology (ICT) towards sustainability, particularly within the domains of Software Engineering (SE) and Requirements Engineering (RE). Several Systematic Literature Reviews have identified the significance of sustainability: Calero et al. [1] highlight sustainability as a key factor in SE, Gustavsson and Penzenstadler [2] advocate for a more interdisciplinary understanding of SE that goes beyond a narrow focus on technology, and Imran and Koster [3] acknowledge sustainability as one of the major challenges faced by the SE discipline.

While academia generates novel ideas, concepts, and technologies, industry possesses the expertise and resources required to transform these innovations into profitable products and services. Thus, fostering collaboration between academia and industry is crucial for translating new knowledge into practical applications that generate value for society, the environment, and the economy. Recognizing the importance of bridging this gap, Wolfram et al. [4], in their Systematic Mapping Study on industrial SE practices, advocate for enhanced understanding and collaboration between research institutions and industrial companies. The industry is faced with the dual challenge of grappling with the complexity associated with the multidimensional nature of sustainability, while also ensuring profitability and competitiveness in its implementation.

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To address these issues, we conducted a survey involving a total of 104 software practitioners from various industries in the field of software. The objective of this study is to examine the implementation of sustainability within the software industry, with a focus on answering three research questions:

- **RQ1:** How do software practitioners assess sustainability in the software company in general and in their field of activity in particular?
- **RQ2:** What role do different employee positions play in terms of responsibility for sustainability?
- **RQ3:** What motivates software practitioners to set sustainability goals?

Our findings indicate that the topic of sustainability is generally given a mediocre valuation within industry. However, it is crucial to distinguish between two employee roles: those with a more technology-oriented role, such as software engineers, and those with a more management-oriented role, such as project managers. Comparatively, the former role demonstrates a below-average level of engagement and responsibility with sustainability, whereas the latter role excels in terms of their overall commitment. Additionally, our study reveals variations in the prioritization of sustainability dimensions: The technical, environmental, and economic dimensions are considered more significant than the social and individual dimensions. Consequently, there appears to be less motivation to address negative social, ecological, and economic aspects within the context of the Triple Bottom Line (TBL) [5]. The motivation is also driven by market-related benefits, such as gaining a competitive advantage in marketing, reducing costs and risks, and attracting and retaining employees. Our study lays the foundation for future research endeavors aimed at bridging the gap between academia and industry.

In the chapter *Background and related work*, we first review relevant studies that bring together sustainability and software in an industrial context and then present related interview studies that provide first qualitative insights on how the paradigm shift is perceived by software practitioners. In the next chapter, we present our *Research design*. Our survey *Results* are presented in the fourth chapter along the three RQs. The fourth chapter, *Discussion*, is composed of an interpretation of our findings as well as the limitations (threats to validity) of our survey study. Finally, we summarize our results in a *Conclusion*.

2. BACKGROUND AND RELATED WORK

The Karlskrona Manifesto for Sustainability Design, endorsed in 2014 by an array of international scientists, brought significant attention to the imperative of encompassing the social, individual, environmental, economic, and technical impacts of software systems [6]. As part of their efforts, they introduced the Sustainability Awareness Framework (SusAF), a workshop tool designed to aid users in identifying the multifaceted impacts of software systems through guiding questions, a visual representation in a diagram, and ensuing discussions [7]. Seyff et al. [8] established connections between the SusAF questions and the descriptions of the United Nations' 17 Sustainable Development Goals (SDGs). Here, it becomes clear that software companies also share responsibility when it comes to achieving sustainability, as illustrated by Becker et al. [9]. The authors of this article describe the software engineering practice as a process for addressing "wicked problems" with which they express that technical and non-technical systems are intertwined. They emphasized that sustainable requirement engineering necessitates a mindset shift away from a "puzzle-solving attitude" focused on technical and economic issues towards a comprehensive consideration of impacts that require an interdisciplinary understanding of software systems.

In the software industry, the sustainability-related perspective on software has also arrived. Turning attention to empirical studies about the interplay of sustainability and the software industry, Bomfim et al. [10] observed that software companies have started recognizing the significance of cultivating a public image as a "sustainable organization," given the increasing consumer preference for sustainable products and services. Kwak et al. [11] corroborated this finding, stating that global companies have progressively embraced sustainability, with sustainable development being a subject of discussion in politics, business, and society as a long-term strategic goal and a prominent challenge for enhancing the quality of life. Kasurinen et al. [12] concluded that sustainability has become a prevalent trend across various industries, no longer regarded as an "extra feature" but rather as a "competitive advantage in the marketplace" and a critical consideration in the realm of global competition. It has the potential to generate revenue "for any type of organization."

Nonetheless, Karita et al. [13] underscored the lack of knowledge, particularly among software engineers, in their understanding of Sustainable Software Development (SSD). A thematically related survey study was conducted by Bambazek et al. [14]. The software practitioners surveyed ($n = 47$) rated the overall potential for addressing the sustainability impacts of software systems through the Agile method Scrum as high. This study is intended to serve as a basis for adding sustainability elements to Scrum. In total, our research led us predominantly to qualitative studies that address this issue. In the course of this, we would like to point to some interview studies. Chitchyan et al. [15] found in their interviews with requirement practitioners in software companies ($n = 13$) that this role lacks knowledge, experience, and methodological tools for dealing with sustainability. This is also in line with Groher and Rainer [16] who came to a similar conclusion in their interview study (n=10) on sustainability aspects in software development projects: "[Software] practitioners regard software sustainability as important but are technically minded with respect to sustainability." Oyedeji et al. [17] interview study with software practitioners ($n = 16$) showed that this role cannot deliver a definition of sustainability that combines social, environmental, and economic aspects in terms of the trinity of TBL.

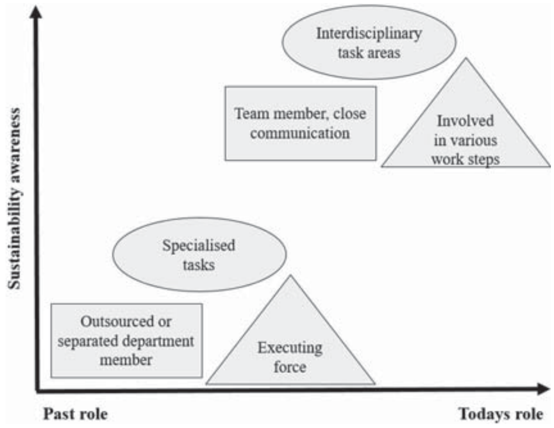

Figure 1 Role-attribution and sustainability awareness of SEs [17].

Lammert et al. [18] show in interviews with Software Engineers within industry ($n = 13$) that this group, especially due to the transition from the Waterfall Model to Agile Methods at the beginning of the 21st century, has evolved as a team member towards different work steps and thus an interdisciplinary scope of tasks, but has not yet arrived in the role. SEs tend to take on the role of the "executive force" with specialized tasks (mainly coding) withdrawing from team communication in the design process and slowing it down through a technical focus. They recognize the relevance of sustainability in software design but have insufficient knowledge and methods to meet the requirements. All in all, Figure 1 thus corresponds more to the academic understanding than to the industrial understanding of the self-role description and sustainability awareness of SEs.

Taking this study landscape into account, it becomes evident that the topic of sustainability has permeated both academia and industry. However, qualitative interviews with industrial software practitioners, particularly those of SEs an REs, reveal deficiencies in dealing with the topic of sustainability.

3. RESEARCH DESIGN

The data for this study is derived from a survey conducted among software practitioners in industry, with a total sample size of 104 participants. Our design is based on the process established by Pfleeger and Kitchenham [19]. Subsequently, we provide a detailed description of our research design.

3.1 Objectives and Content of the Survey

The goal of our survey is derived from the empirical knowledge gaps that were made abundantly clear in the interview studies (see Chapter 2). These were made abundantly clear in the interview studies. Qualitative studies provide valuable, in-depth insights into certain phenomena, but they often lack the ability to generalize the results to a larger population. By conducting a survey study with a larger sample size (n), we can collect quantitative data that allow for broader generalizations and statistical analyses. This quantitative approach complements existing qualitative research by providing a more comprehensive understanding of the topic under study.

The survey questionnaire covered three main areas based on the three RQs: First, participants were asked to rate the overall importance of sustainability in their company in general as well as their knowledge level. They were also asked to rate sustainability in relation to their task area and more specifically in relation to the five dimensions. The survey also asked whether, and if so, which tools are used to implement sustainability. Second, participants were asked if there is a responsible employee for sustainability in their company, and if yes, what that employee's role is. Thirdly, the survey aimed to identify the motivations behind setting sustainability goals within their companies.

3.2 Data Collection

As Pfleeger and Kitchenham describe, descriptive surveys are conducted with the intent, to explain characteristics of a particular population. This is made up of industrial software practitioners. All surveys were administered using Google Forms as the data collection tool. To reach a diverse range of software practitioners, the survey links were primarily shared through various channels such as social networks (e.g., LinkedIn) and online forums for software practitioners (e.g., Stack Overflow).

The participants in the survey can be categorized into 14 job areas, with an average work experience ranging from 5 to 10 years (30%) and over 10 years (33%) (see Table 1). Software Engineers account for 36% of the respondents, followed by Software Developers at 13%. Together, these two groups represent nearly half of the total participants. The surveyed companies span 13 different industry sectors (see Table 2). Approximately one-fourth of the companies (27%) belong to the Information and Communication Technologies sector. Regarding company size distribution, large companies with more than 250 employees constitute 35% of the sample, while medium-sized companies with 50 to 250 employees account for 27%. These two categories combined form the majority of the surveyed companies.

In addition to the overall analysis, we conducted a comparative examination of two specific roles:

Table 1 Overview of respondents' job positions ($n = 104$)

Job Position	*n*	*Years of exp.*	*n*
Software Engineer (*TR*)	37	> 10	34
Software Developer (*TR*)	14	5–10	31
Project Manager (*MR*)	14	3–5	24
IT Manager	9	0–3	15
CEO	5		
Product Owner (*MR*)	5		
UI/UX Designer	5		
CTO	4		
Requirements Engineer	3		
Software Architect (*TR*)	3		
Business Dev. Manager (*MR*)	2		
Data analyst	1		
Tech. Mananager Digital	1		
Webmaster/Content Manager	1		

Table 2 Overview of respondents' industry sectors ($n = 104$)

Industry sector	*n*	*Staff count*	*n*
Information and Communication Tech.	28	Large > 250	36
Media and Entertainment	13	Medium < 250	28
Finance and Insurance	10	Small < 50	24
Community, Social, Personal Activities	7	Micro < 10	16
Health and Social Work	7		
Manufacturing	7		
Transportation and Storage	7		
Electricity, Gas, and Water Supply	6		
Construction	3		
Agriculture, Forestry, and Fishing	2		
Public Administration	2		
Real Estate	1		
Other	2		

Table 3 Importance of sustainability in general and in the dimensions of one's own area of responsibility ($n = 104$)

Role	*General*	*Soc.*	*Ind.*	*Env.*	*Eco.*	*Tec.*
MR ($n = 21$)	2,8↑	3,0↑	3,0↑	3,6↑	3,9↑	3,4↑
Total ($n = 104$)	2,5	2,4	2,3	3,0	3,1	3,3
TR ($n = 54$)	2,4↓	2,2↓	2,1↓	2,7↓	2,7↓	3,1↓

- the **Technical Role (TR)**, which included Software Engineers, Software Developers, and Software Architects ($n = 54$) and
- the **Management Role (MR)**, comprising Project Managers, Product Owners, and Business Development Managers ($n = 21$).

This subgroup analysis allows for a more detailed understanding of the perspectives and differences between these two distinct roles within the surveyed software practitioners.

3.3 Data Analysis

In terms of the analysis process, we follow Pfleeger's and Kitchenham's tripartite division [19] into data *data validation* (checking consistency and completeness and identifying and processing responses to ambiguous questions), *partitioning of responses* (additional division of the total of responses: TR and MR), and *data coding*. Regarding this point, two types of closed-ended questions were utilized in the surveys: binary (yes/no/not sure) and a 5-point Likert scale. To analyze and evaluate the responses in relation to the research questions, the binary responses were mapped to numerical values (e.g., yes = 1, no = 0), while the Likert scale responses were assigned numerical values ranging from 1 to 5. This allowed for the calculation of average scores and the normalization of responses on standardized scales, facilitating the quantitative analysis of the data.

Table 4 Motivation for setting sustainability goals ($n = 104$)

Motivation	*MR* ($n = 21$)	*Total* ($n = 104$)	*TR* ($n = 54$)
Reduce neg. impacts	3,3↑	2,6	2,3↓
Long lasting software	3,3↓	3,5	3,6↑
Reduce risks	3,9↑	3,4	3,4→
Reduce costs	3,5↑	3,2	2,0↓
Profit	3,1↑	2,9	2,8↓
Image/reputation	3,7↑	3,1	2,9↓
Marketing	3,6↑	3,3	2,7↓
Acquire/bind employees	3,2↑	2,7	2↓
Receive fundings	2↓	2,1	2,1→

4. RESULTS

The structure of this chapter follows the three RQs.

4.1 Perception of Software Sustainability (RQ1)

Overall, the topic of sustainability received a medium-high rating of 2.8 on a scale from 1 to 5, with 1 representing very low importance and 5 representing very high importance. There was a noticeable difference in the ratings between the total respondents, the TR and the MR. The TR rated sustainability somewhat lower with a score of 2.6, while the MR rated it higher at 3.5, indicating a moderate to high level of importance. This difference is also reflected in the question of whether a higher workload related to sustainability was desired in the company. Among the total respondents, just over half (51%) answered in the affirmative, while 28% were unsure, and 21% answered negatively. In the TR, 49% favored a higher workload, while among the MR, the figure was 64%.

Regarding their own areas of responsibility, sustainability was given a medium weighting of 2.5 overall. The TR tended to view sustainability as “rather unimportant” with a score of 2.4. In contrast, the MR showed a stronger inclination towards moderate importance, with a score of 2.8. The weighting of individual sustainability dimensions did not differ significantly between the total respondents and the TR, with differences ranging from 0.2 to 0.4. However, the MR had higher scores across the dimensions, ranging from 0.1 to 0.8.

In terms of tools addressing sustainability, 28 different tools were mentioned, with the majority (11) being related to green server hosting (such as renewable energy usage, energy consumption reduction, and CO2 offsetting through climate projects). Two tools focused on reducing e-waste by utilizing used equipment. Additionally, usability/UX tools (4) and IT security or data privacy tools (3) were mentioned as addressing the social and individual dimensions of sustainability. Three tools explicitly addressed the multidimensional nature of sustainability, including the Sustainability Awareness Framework (SusAF) and the Flourishing Business Model Canvas. Some respondents indicated a high number of tools without providing specific details, while others mentioned that the choice of tools depended on the project. The remaining answers were too imprecise to be categorized.

4.2 Responsibility for Software Sustainability (RQ2)

According to the survey, 66% of respondents stated that there is no employee with primary responsibility for sustainability in their company. 28% answered affirmatively, while 5% were unsure. Among the 29 respondents who indicated a responsible employee, 41% mentioned the project manager as the role with sustainability responsibility. Other job roles mentioned as responsible included Business Development Manager, Product Owner, Requirements Engineer, and Chief Executive Officer, each accounting for 10% of the responses. Three respondents mentioned “Other” and emphasized that responsibility for sustainability lies with everyone in the company. No specific role within the Technical Role (TR) (Software Engineer, Software Developer, and Software Architect) was explicitly named.

This information corresponds to the estimation of knowledge levels regarding sustainability. Overall, respondents rated their knowledge as low with a score of 2.2 on a scale of 1 (very low) to 5 (very high). The TR scored slightly lower with 1.9, while the MR rated their knowledge significantly higher at 2.9, indicating a moderate level of knowledge.

Only one-third (33%) of the total respondents reported implementing sustainability tools, while the majority (60%) answered negatively, and a smaller proportion (7%) were unsure. Among the TR, 30% reported implementing tools, slightly below the overall group, while among the MR, the average was higher at 41.

4.3 Motivation for Software Sustainability (RQ3)

In the survey, respondents were asked to rate the importance of various areas for achieving sustainability goals within their company. Nine specific areas were provided for evaluation (refer to Table 4). Additionally, respondents had the option to provide additional reasons for motivation.

The results indicate that the TR rates only one motivation reason higher than the MR and the overall respondents: the importance of a long-lasting software system, referring to how well a piece of software system/service can adapt to changes. The MR shows a higher motivation for sustainability goals in seven areas, with only a slight deviation below the average in one area: receiving fundings.

Additionally, respondents provided motivations that were not included in the predefined list. These motivations include personal reasons, network cooperation with partners, investing in the future, surpassing the competition, receiving government project orders, and external demands.

Regarding interest in participating in a workshop on sustainable software design, the overall interest was rated as moderate with a value of 3.4. The majority (34%) rated their interest as "rather high," while the minority (7%) rated it as "very low." The TR showed slightly higher interest with a rating of 3.5, while the MR exhibited a higher interest with a rating of 4, indicating a "high" level of interest.

5. DISCUSSION

The findings are now discussed, providing insights and interpretations. In the final section, the limitations of the study design are addressed, acknowledging the constraints and potential factors that may have influenced the results.

5.1 Perception of Software Sustainability (RQ1)

Our findings align with the related interview studies mentioned in Chapter 2 [15]–[18] indicating a divergence in the understanding and valuation of sustainability between academia and industry. Sustainability appears to be moderately prioritized in the software industry. Besides this, we can observe a connection with business aspects such as profitability, competitive opportunities, and risk mitigation.

Although it makes sense in a second step to focus on individual areas (e.g., individual dimension) or aspects (e.g., privacy) depending on the software system, there is a risk that other dimensions will be overlooked. In the worst case, a software product or service can be classified as sustainable on the basis of a selective view, even though a comprehensive perspective reveals numerous weak points. In this sense, a holistic view of the topic of sustainability should first be taken, which gives importance to all dimensions.

Since there are deficits in the knowledge surrounding the topic of sustainability, it offers it is recommended to involve external stakeholders in requirements analysis through participatory design, as suggested by various studies (e.g., [13], [22], [23], [24], and [25]. This approach acknowledges the diverse levels of knowledge among individual employees and promotes collaboration.

5.2 Responsibility for Software Sustainability (RQ2)

In the planning and implementation of sustainability approaches, interdisciplinary professional roles in interface positions, such as project managers, are well-suited for the task. The MR is also most likely to be mentioned when identifying a person responsible for sustainability. The MR not only rates sustainability's relevance higher but also possesses a higher level of knowledge in this area.

Considering the importance of sustainability in planning and implementation across all fields of activity, it is recommended to enhance the inclusion of sustainability knowledge in the curriculum of software practitioner education, as already suggested in previous studies (e.g., [20] and [21]).

5.3 Motivation for Software Sustainability (RQ3)

The question is whether personal, intrinsic motivational factors alone are sufficient in an industrial context or whether extrinsic, commercially motivated motivational factors could exert a stronger force in achieving sustainability goals. When establishing sustainability goals based on models such as the TBL or the SDGs, it is important to consider the requirements of a profit-focused operation and its organizational structure, emphasizing the need for a balanced approach that incorporates both sustainability and financial considerations.

Like the Scrum-related study by Bambazek et al. [**?**], the results of our study could be used to link existing approaches in the field of sustainability design with business designs that target the outcome of extending existing artifacts.

5.4 Limitations

Construct validity: There is a potential threat to validity regarding the extent to which our survey questions fully capture the complexity of the subject matter, and it is possible that individual survey items, such as the scales used, may have limited it. Moreover, there is a risk that some participants may not have fully understood the questions, leading to potential misinterpretations during the follow-up step. To mitigate these concerns, we conducted multiple iterations of the survey, incorporating feedback to enhance the consideration of the topic and refine the wording of the questions.

Internal validity: It is important to acknowledge that there might be additional variables influencing the relationship between the independent and dependent variables in our survey. Factors such as personal circumstances (e.g., prior experience or cultural background) could lead to variations. Additionally, although we employed various common platforms for survey distribution to minimize selection bias, it is possible that software practitioners with a pre-existing interest in the topic were more inclined to participate. To address this, we employed a random sampling technique to provide an equal opportunity for software practitioners to be represented in the study.

External validity: While we made efforts to gather a large and diverse dataset during the recruitment process, certain characteristics of our sample may limit the generalizability of the results to the broader software industry. Although our study encompassed a wide range of occupational roles and business sectors, there may be industry-specific differences in the way sustainability is approached that were not fully captured in this study. Future research should consider these nuances to enhance the generalizability of findings.

Reliability: The evaluation process involved all researchers, ensuring that any discrepancies in classification were discussed and resolved through consensus. To mitigate potential reactive bias, where participants may provide responses influenced by social desirability, the surveys were conducted anonymously.

6. CONCLUSION

In our survey study, we have demonstrated notable disparities in the perception, responsibility, and motivation for sustainability between industrial software practitioners and the current academic theory. Our quantitative findings align with and substantiate previous qualitative interview studies, providing further validation to the existing body of knowledge.

The results of our study demonstrated that the subject of sustainability is accorded a moderate valuation by industrial software practitioners. Our analysis has revealed a discernible distinction between the professions that lean towards technical orientations (namely Software Engineer, Software Developer, and Software Architect) and those that adopt a more interdisciplinary approach in management (such as Project Manager, Product Owner, and Business Development Manager). The latter role places greater emphasis on sustainability, possesses more understanding of the topic, and assumes a higher level of responsibility when it comes to implementing sustainability into software products and services. The impetus to establish and attain sustainability objectives is intricately linked to business interests, including factors such as profitability, competitive advantages, and risk mitigation.

Our study highlights the significance of bridging the gap between academia and industry, enabling the translation of sustainability principles into tangible software products and services. It is through this synergy that we can collectively strive toward a more sustainable future for software systems.

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