Sustainable Software Development: An ADKAR-Based Framework for Project Managers and Teams

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Abstract: This ongoing preliminary research addresses the growing need for environmentally conscious practices in Information Technology (IT), specifically in software development. It aims to develop a generic framework for sustainable software development (SSD) tailored to IT project managers and teams, through leveraging the ADKAR change management model and its five pillars (Awareness, Desire, Knowledge, Ability, Reinforcement). This work combines two complementary research methodologies: interviews and participatory action research. The current findings include the overall structure of the framework and suggest an alignment of the proposed framework with the Agile project management methodology. Further research is under progress to develop the detailed content of the framework, and test it. The main contribution expected from this work is to promote the democratization of sustainable practices in software development.

1 INTRODUCTION

The world is currently addressing crucial challenges, threatening the delicate balance of our planet's ecosystem (United Nations Environment Programme, 2023). In this context, the impact of Information technology (IT) on the environment is mixed. On the one hand, IT-enabled solutions and tools addressed various environmental issues in multiple sectors and supported eco-friendly initiatives and transformations. On the other hand, IT has introduced new set of environmental challenges, as studies indicated in 2020 that IT industry could be responsible for up to 4% of global carbon emissions (Freitag et al., 2021) and accounts for 7% of global electricity consumption (Andrae, 2020). Reports anticipate a rapid increase of these numbers as IT demand, usage and manufacturing are expected to grow in the coming years (Belkhir & Elmeligi, 2018; Ross & Christie, 2022).

Among the most crucial solutions to address this issue, "Green IT" has gained growing interest over the past decade. Green IT refers to the process of developing, operating and disposing of IT in a manner that minimizes harm to the environment (adapted from Elliot (Elliot, 2007) and Dalvi-Esfahani et al. (Dalvi-Esfahani et al., 2020)). This process involves a set of principles, methodologies and tools at the software and the hardware levels. This paper focuses on software Green IT, also referred to as sustainable software development (SSD). According to academia and practice, SSD techniques have proven to lead to energy efficiency and thus to less carbon emissions (e.g. (Capra et al., 2012; Katal et al., 2023; Kravets & Egunov, 2022; Ournani et al., 2021; Verdecchia et al., 2021)). Approaches in SSD range from virtualization and cache management, to coding efficiency, optimized need and requirements definition, among others.

At the project level, SSD requires the involvement of all stakeholders, including project managers, architects, designers and software engineers. Each of them can contribute to SSD as part of their respective scope, by introducing impactful changes to their daily activities throughout the lifecycle of the project.

To be able to do so, these changes need to be motivated, acknowledged and deployed while being aligned to the existing software development

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methodology used in the project. With their holistic project view, project managers could be seen as guarantors of SSD deployment and success. However, those project managers who aim at conducting software development with a view to sustainability and carbon emissions reduction, lack visibility on the "how" question.

There is indeed little available and structured knowledge and guidance on these relatively new issues. Some of the existing frameworks are sketchy and lack detail and operability. Although maturity grids for SSD governance were explored by literature, they do not offer concrete methodologies for deployment. In the same respect, some described approaches, despite proposing best practices and key performance indicators, lack details on the control elements to make these indicators operational, and their scope may not be adapted to the practical needs of project managers. Some recommendations are neither detailed nor sequenced, thus limiting their practical application.

In short, although some contributions exist, they lack detailed and operational approaches to the effective deployment of SSD, underlining the need for a more comprehensive and structured methodological framework.

This research tries to fill this gap. It is a work-in-progress as our findings have not yet been tested and applied in real settings, which is planned as our next research step. Our objective, eventually, is to propose a validated methodological framework that will enable project managers to deploy SSD in their projects and help them engage their teams in this approach. In concrete terms, this will involve answering the following questions:

- What methodological framework should be adopted for SSD?
- What concrete actions should be taken to deploy SSD?
- How can we support project teams in implementing SSD?

We aim to answer these questions while ensuring that our framework could be adapted to different usage situations and considers the expectations of project managers, both in form and content. One of the use contexts that we consider in this work is the Agile methodology.

Our position in this research is to view SSD as a major change to existing practices. Hence, we rely upon a well-known change management framework, namely ADKAR, to build our project framework for SSD. ADKAR stands for Awareness, Desire, Knowledge, Ability and Reinforcement. Our idea is to align these ADKAR pillars to the project lifecycle for SSD deployment.

The remaining sections are organized as follows. First, in the literature review section, we present some related work and the ADKAR model that structures our developed framework. Then, we describe our methodology, which is based on a qualitative method (i.e. interviews) and participatory action research. Afterwards, we present the findings of our study, namely the content of the SSD framework and a suggestion of alignment with agile methodology. In the last section, we conclude with intended actions to validate our framework, and expected implications of our exploratory research.

2 LITERATURE REVIEW

In this section, we will present an overview of existing SSD methodologies and frameworks as well as the ADKAR methodology upon which we propose to build our Green IT methodological framework.

2.1 SSD Methodologies and Frameworks

Various frameworks and methodologies have been developed to address SSD, each focusing on distinct aspects such as energy efficiency, waste reduction, and the integration of sustainable practices into IT operations.

The Green IT readiness framework provides a structured method for assessing an organization's Green IT practices and maturity (Molla et al., 2009). It integrates five dimensions: technology, organizational, environmental, people and governance readiness. This model provides a holistic framework to identify gaps and to design targeted strategies for sustainable IT adoption.

The GreenSoft model (Naumann et al., 2011) is a conceptual framework designed to enhance software sustainability across its lifecycle phases (development, use, and disposal). The model conceptualizes components such as sustainability metrics, procedural guidelines for stakeholders, and tools for green practices. It suggests how "conventional" processes could be enriched with a view to sustainability.

Wati & Koo (2011) developed a strategic management tool based on a balanced scorecard approach to highlight how businesses can integrate environmental considerations into IT strategy. This model evaluates IT performance from economic,

social, and environmental perspectives, promoting sustainability alongside business objectives.

Bose & Luo (2012) developed a step-by-step process management approach for Green IT adoption. This approach is cyclical in nature and relies on four different phases: plan, design, implement and measure the performance of the process. For each phase, generic-level guidance is provided to assist IT managers in their efforts to bring greener practices to their organizations.

Mahmoud & Ahmad (2013) proposed a two-level framework to enhance sustainability in software engineering processes. The first level defines a hybrid green software engineering process that combines sequential and iterative methods, incorporating green practices at each stage. The second level focuses on using software as a tool for resource monitoring and energy efficiency.

Through exploratory and confirmatory factor analysis of large Mauritian companies, the study from Hardin-Ramanan et al. (2018) developed a Green IT governance model that outlines the accountabilities, decisions, mechanisms, and practices necessary for sustainable IT management.

The Green-agile maturity model provides a framework to assess the integration of environmental sustainability and agile practices in global software development (GSD) (Rashid et al., 2021). The model outlines maturity levels to help organizations progress from basic awareness of green practices to their comprehensive implementation in agile workflows.

The Environmental Sustainability Computing (ESC) framework is a holistic approach that addresses operational energy consumption and carbon emissions (Pazienza et al., 2024). It includes the entire lifecycle of computing systems and considers regulations, accounting and culture issues.

Although these methodologies and frameworks are well-developed and studied, gaps remain in their application from a project management standpoint. Indeed, many frameworks focus on organizational or strategic levels, with limited guidance on embedding Green IT into individual project lifecycles. This high-level granularity of analysis might pose integration challenges. Especially as some models lack actionable steps or detailed methodologies for implementation in IT projects. Moreover, some of the available frameworks do not address quantitative and qualitative metrics to assess Green IT adoption and impact during specific project phases, and neglect return on investment analysis.

2.2 ADKAR Framework

The ADKAR framework, developed by Prosci founder Jeff Hiatt, is a widely-used goal-oriented change management framework designed to guide individuals and organizations through successful transformations (Hiatt, 2006). The model is structured around five sequential building blocks: Awareness, Desire, Knowledge, Ability, and Reinforcement, each representing essential guidelines and outcomes for managing change at different levels, starting from individuals and teams.

- **Awareness:**

This stage focuses on recognizing the need for change, emphasizing effective communication to address resistance and misconceptions. Successful awareness fosters understanding of why change is necessary and the consequences of inaction (Angtyan, 2019).

- **Desire:**

Building motivation and commitment to participate in and support the change is the second step. Factors such as individual goals, organizational culture, and perceived benefits influence this stage. It highlights the challenge of fostering intrinsic motivation while aligning it with external drivers (Angtyan, 2019; Picado Argüello & González-Prida, 2024).

- **Knowledge:**

This stage centers on equipping individuals with the information and skills required to implement the change. Training, mentorship, and access to resources play a critical role in translating theoretical understanding into actionable change (Angtyan, 2019; Picado Argüello & González-Prida, 2024).

- **Ability:**

The ability stage transitions theoretical knowledge into practical application. Continuous coaching and feedback help individuals overcome barriers and demonstrate the desired behaviors necessary for the change to be effective (Angtyan, 2019; Picado Argüello & González-Prida, 2024).

- **Reinforcement:**

To sustain the change and prevent regression, reinforcement mechanisms such as rewards, accountability structures, and post-change performance evaluations are essential. This phase ensures that changes are institutionalized within the organization (Angtyan, 2019).

The ADKAR model's emphasis on individual-centric change differentiates it from other frameworks. It has been applied in diverse contexts, including technology adoption, industry 5.0, and organizational restructuring. Research demonstrates its effectiveness

in reducing resistance to change and enhancing the success of digital transformations by addressing both human and technical aspects of change (Angtyan, 2019; Picado Argüello & González-Prida, 2024). Hence, we decided to rely on ADKAR to build our SSD methodological framework.

3 METHODOLOGY

This work used two complementary methodological approaches: first, interviews for initial input and understanding, and then participatory action research for development and refinement of the methodological framework.

3.1 Interviews

Initial input was collected by means of interviews. The purpose of data collection was twofold. First, the interviews tried to understand the expectations of project managers on SSD deployment and the fit of ADKAR as a framework for SSD. Second, the interviews gathered suggestions on SSD framework requirements, actions, crucial steps and warning points. The interviews were divided into 5 topics, namely covering the 5 ADKAR pillars. An interview guidelines was prepared accordingly.

19 semi-structured interviews were conducted with IT project managers between January 2023 and June 2023. The interviewees were employees of the same IT consulting company, each assigned to different projects and client organizations across various sectors, enriching and diversifying the insights gathered.. Interviewees were randomly selected from the company directory based on their profiles and were invited to participate after completing a brief survey to confirm their Green IT awareness. None of the interviewees had prior knowledge of the ADKAR framework. All interviewees had more than 3 years of experience.

Our sample size (N=19) is close to the 20-30 range recommended by state-of-the-art qualitative research authors Creswell & Poth (2018). A larger sample could not be secured due to constraints of availability and convenience. However, we believe that data saturation was achieved within our sample, supported by the complementary research method detailed below.

With the consent of interviewees, all interviews have been taped and transcribed. Notes were also taken during the interviews. The duration of each interview was between 30 to 60min.

Based on notes and transcriptions, collected textual data was coded according to the 5 ADKAR pillars. Then, further sorting and analysis allowed initial categorization of data within each pillar. Each category represented a set of SSD actions and themes to cover by the framework. To support traceability, analysis was conducted in a versioned Excel spreadsheet, resulting in almost 70 categories and over 650 entries. To enhance reliability, each categorization decision was the result of a double coding approach and discussions to harmonize the few differences (Miles et al., 2014; Vaughn & Jacquez, 2020).

3.2 Participatory Action Research

Participatory action research was the second stage of our methodology. It could be defined as the active participation and collaboration of individuals being studied in research phases (Vaughn & Jacquez, 2020). As such, our work involved the direct and collective participation of project managers in the development of the Green IT methodological framework. These project managers work at the same IT consulting company cited in 3.1, and have different profiles, backgrounds, and expertise sectors.

The approach started on December 2023 and is still ongoing. A team of 5 project managers, in average, worked on the SSD framework, in collaboration and under direct and daily supervision of the authors. The team of project managers continuously changed over time, with more than 25 different participants so far. The outcome benefits from the diversity of the contributors' profiles.

The project managers brought all their field expertise to review, propose and refine the SSD methodological framework. The starting point was the initial categorization obtained from the interviews' analysis. The team added to it, refined it and assessed the practical relevance and clarity of the content. After few versions, a draft structure for the framework was built. For each ADKAR pillar, different categories of SSD actions were proposed, and for each category, different sub-categories were proposed as well. These categories and sub-categories encompass all 450 isolated entries stemming from our textual interviews' dataset and the teams' suggestions. A glossary was defined to describe the different categories and sub-categories.

Then, a backward effort was made to regroup the entries into macro-actions and provide enough descriptions and detail to ensure the potential of implementation. A Word document was created afterwards for each macro-action (i.e. action sheet).

In each document, the content of the underlying actions was built and developed by specifying implementation stages and topics, means, tools and stakeholders.

Throughout this process, multiple iterations were necessary due to the scale of the content, and to check for clarity, redundance and relevance. All incorporated content was cross-reviewed and validated by the team. As new input arose, the global structure of the methodological framework evolved, as well as the detailed content of each action sheet.

4 FINDINGS

First, we will present our proposed ADKAR-based framework for SSD and then we will suggest an alignment of our framework with the agile methodology.

4.1 Sustainable Software Development: An ADKAR-Based Framework

The presentation of the findings will consist of an overview of the main tasks for each ADKAR stage. Detailed and personalized (depending on stakeholders profiles) content is currently still under development for each of the actions. The framework, when deployed in IT projects, will consist of detailed sheets and a quick-read summary for each of the main actions,

4.1.1 Prerequisites and Pre-ADKAR Stage

We consider that three prerequisites are important to be available at the company level before engaging into SSD projects. First, all interviewees and participants agree that the company needs to implement a sustainability driven strategy, incorporating operations (projects), but also all other departments. Second, a sustainability or SSD sponsor is needed to provide support for such projects. Third, a carbon footprint assessment of the company's IT operations, services and architecture could be beneficial for the teams' engagement in SSD efforts.

Moreover, to prepare Green IT deployment, it was deemed necessary to consider a pre-ADKAR stage to prepare the teams and analyze the pre-deployment situation.

The suggested content of this stage includes:

- **Preface:** It aims to introduce the upcoming SSD change, identify stakeholders and provide an overview of the inherent framework.
- **Project managers' training and information:** is the purpose is to specifically train project managers who will coordinate the SSD approach.
- **Stakeholders' questionnaire:** To evaluate stakeholders' maturity for sustainability matters, their understanding of SSD, and their attitude towards this change.

4.1.2 Awareness

The awareness stage is divided into three main actions aimed at raising Green IT awareness among the project teams:

- **Introduce Green IT:** Here, the goal is to define Green IT and its key aspects, as well as the stakes and issues related to it. These should be adjusted depending on the stakeholders' profiles. Additional resources (links, success stories…) should be provided for further information.
- **Understand the impact:** Through workshops, stress is made on the environmental impact of IT. The idea is to address each and all stakeholders to prove the necessity for action. Current and future norms and regulations are also presented at this stage.
- **Communicate on carbon footprint and questionnaire:** To ensure stakeholders engagement, efficient and targeted communication to inform on the carbon footprint assessment and stakeholders' questionnaire results is proposed. We suggest interactive and sober means of communication.
- **Ensure continuous communication:** Further SSD communication and interactive events should be maintained across the project lifecycle, to inform for instance on measured KPIs, SSD news, feedback and success stories.

4.1.3 Desire

This stage is composed of three main actions:

- **Create community engagement:** An SSD community could be built to foster SSD efforts. It can rely on workshops, gamified challenges or other interactive digital events.
- **Highlight the operational benefits:** For each stakeholder's profile, insist on the advantages related to SSD application in day-to-day project activities.

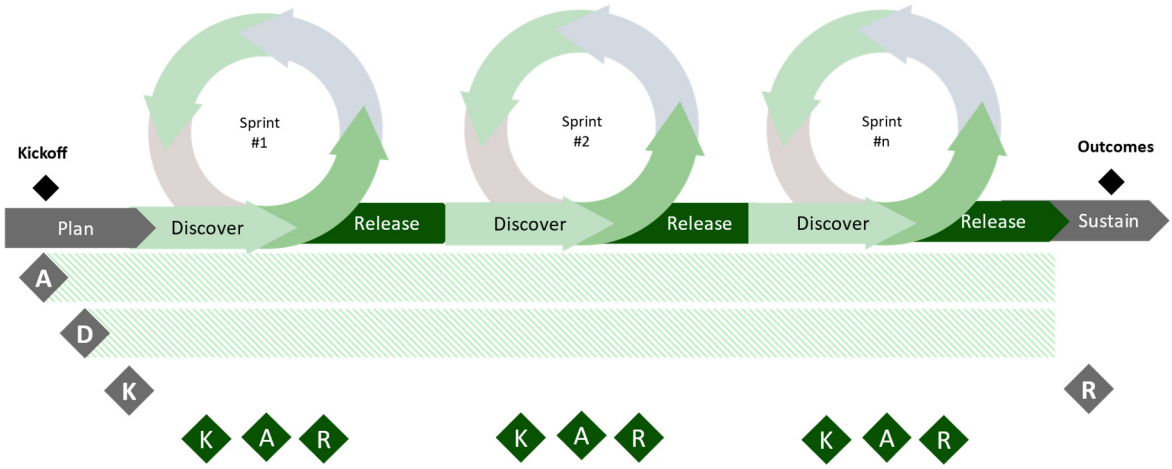

Figure 1: Alignment between our SSD ADKAR framework and Agile methodology.

- **Initiate recognition and rewards:** Encourage SSD adoption by putting in place a rewards system, including at least symbolic rewards and prices (digital badges, goodies…).
- **Ensure engagement upholding:** Develop initiatives to ensure that stakeholders are supported and that their engagement is maintained throughout the project.

4.1.4 Knowledge

We propose to carry out the following three main actions for the Knowledge pillar:

- **Identify SSD compatible activities:** For each stakeholder profile, a list of project work tasks that are compatible with software sustainability will be developed. Depending on project specificities, the list will need to be prioritized based on the best quick win/ impact ratio.
- **Structure and map the competencies:** Identify here the required competencies to conduct the project in an SSD manner, linking them to green-compatible project tasks. A set of competencies for different project activities and stakeholders is being developed and could be used as a checklist. An evaluation is then needed to assess the competencies situation and prioritize the training.
- **Provide the training courses:** our framework will include a set of generic trainings. The format and content of the training will be adapted to each stakeholder's needs. Trainings objective is adjusted depending on the assessment of competencies situation. Users of the framework could complement the generic set according to their specific needs. After trainings completion, feedback will be collected for format & content improvement purposes.

4.1.5 Ability

We suggest conducting two main tasks for the Ability pillar:

- **Deploy:** At the beginning of this stage, each project stakeholder starts applying the Green IT's best practices they were trained on, focusing on prioritized SSD compatible activities. This will be done according to the project or task planning.
- **Follow-up and adjust:** Define metrics thresholds and follow-up on them. SSD metrics cover the operational, adoption and financial levels. Adjust the course of action, if necessary, while balancing functional needs and SSD issues.

4.1.6 Reinforcement

The reinforcement stages conclude the SSD ADKAR framework. We propose to conduct the following main tasks:

- **Continuous improvement:** Collect data and feedback from the previous pillars, to assess them based on factual KPIs and perception of the stakeholders. It also refers to the development of a prioritized action plan to improve the methodology and bridge the gaps.
- **Technology watch:** Identify innovations in SSD field, and update the SSD competencies

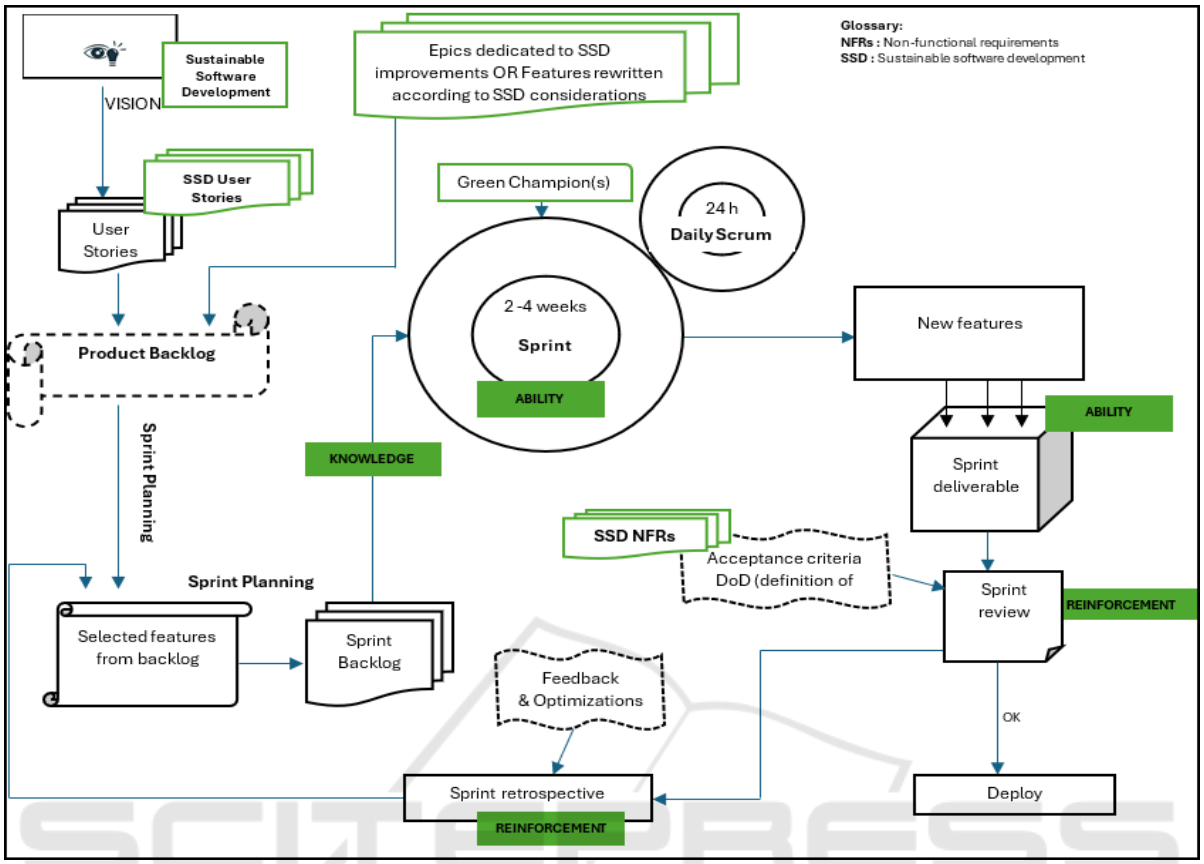

Figure 2: Complementary view of our framework alignment with Agile methodology.

best practices, and SSD compatible tasks. The latter should be considered for inclusion in the framework.

- **Promotion:** Here, it is about promoting the collective and individual actions, highlighting the successes (even the smallest ones), communicating to sponsors and at the company level, and gathering and sharing key knowledge and best practices acquired during the project

4.2 ADKAR-Based Framework: a Focus on Agile Methodology

To confront our framework with project lifecycle and timeline, we chose to focus on one of the most used project development methodologies, namely agile. Agile methodology is a flexible and iterative approach for project management and software development, emphasizing collaboration, customer feedback and incremental delivery. It splits projects into small manageable units called sprints, allowing teams to adapt to changes quickly. Agile promotes continuous improvement through regular reviews and embraces principles such as prioritizing individuals and interactions over processes and tools.

Figure 1 presents our suggestion of alignment between agile software development and our SSD ADKAR framework. We suggest that Awareness and then Desire stages for SSD need to intervene at the project planning phase. However, continuous communication (Awareness) and engagement upholding (Desire) need to be ensured throughout the whole project lifecycle (A and D lines in Figure 1).

Also at the planning phase, global Knowledge activities that address the entire project's perimeter could already be deployed (greyed K in Figure 1).

Then, at each sprint, we suggest successively conducting Knowledge, Ability and Reinforcement stages that specifically address the sprint perimeter (greened K, A and R in Figure 1). We believe that these iterations are necessary to enhance the relevance of our framework. It would allow us to have proper, targeted and only necessary training, to adjust SSD KPIs and prioritized activities according to a sprint backlog, and to improve SSD deployment from one sprint to another. This agile approach stresses the need for short, modulable and pre-configured training

content, a set of customizable KPIs, and adjustable checklists of SSD activities and best practices per stakeholder profile.

At the end of the project, a global Reinforcement stage would be needed, allowing an exhaustive retrospective on all sprints (greyed R in Figure 1).

With a focus on the sprint perspective, Figure 2 presents a complementary view on how we suggest our SSD ADKAR framework could be integrated into agile methodology. First, aside from the ADKAR framework, we suggest stressing the need to consider SSD issues since the development of the project vision, and then integrate these into the user stories and product backlog. We suggest considering epics that are dedicated to SSD improvements or at least rewrite relevant features according to SSD considerations.

Once the sprint backlog is set, we enter the Knowledge-Ability-Reinforcement cycle of the sprint. Knowledge activities are conducted before sprint starts and could be resumed if needed for a specific feature. Development, architectural, and design decisions and actions will align with the prioritized SSD tasks and activities, with follow-up guided by the selected SSD KPIs. Finally, Reinforcement will be conducted alongside the sprint review and retrospective.

During each sprint, we recommend incorporating sustainable non-functional requirements into the definition of done and the acceptance criteria. Additionally, we propose establishing a 'Green Champion' role, to be undertaken by the project manager and one or more technical team members, depending on the project's complexity and task requirements. This role involves providing guidance on SSD-related matters.

5 CONCLUSION

This ongoing research aims to address the gap in operational guidance for deploying SSD, specifically by leveraging the ADKAR model as a structured change management framework. In this paper, we presented an overview of the methodological framework we propose to be adopted for SSD. This provides a preliminary answer to our first research questions.

Comprehensive materials are currently under development and refinement, including training resources, checklists, quantitative and qualitative KPIs, lists of SSD-compatible tasks and best practices for project teams, white book for project managers and an ROI assessment framework. This will allow to develop concrete actions and fully support project teams in implementing SSD, as stated in our other research questions.

Besides the work-in-progress character of this research, our study comes with some limitations. First, the framework is built upon the ADKAR change management model, which is initially a linear model that might oversimplify the complexities and iterative nature of projects. Confronting our methodological framework to the Agile methodology helps mitigate this risk. In the same sense, this paper does not address potential conflict between our ADKAR-based framework and agile practices. Methodologically speaking, since all interviewees and participants are employees of the same company, the questions of organizational bias might be posed. We note however that the company is a consultancy one, and its employees are assigned to different client companies.

Looking ahead, we plan to validate the framework and its detailed content through multiple pilot projects, while evaluating its effectiveness and potential for operationalization and generalization. This process will include iterative refinements informed by stakeholder feedback and empirical KPI measurements. The practical implications of this work include equipping project managers and teams with a detailed, adaptable methodology, enabling broader, more structured and lower-risk risk deployment of SSD.

This approach ultimately bridges the gap between high-level sustainability goals and day-to-day project execution, providing organizations with a clear pathway to achieve environmental objectives within their IT operations.

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