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The impact of implementing Sustainable Development Goals in Agile Software Development

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Abstract

Many software development companies are currently moving towards producing sustainable software that contributes to reducing waste of manufactured materials, preserving the environment, and supporting sustainable innovation. Software and various computer systems in general contribute to global greenhouse gas emissions and are a source of electronic waste, so it is necessary to integrate sustainable development goals into software development processes. Integrating sustainable development goals into agile software development represents an ideal opportunity to align software engineering practices with sustainability principles. This research explores the integration of sustainable development goals into Agile methodologies, highlighting potential strategies to enhance development efficiency and reduce waste in the development process. It also highlights the iterative and adaptive nature of Agile to achieve sustainable goals and enhance innovation in software projects, and provides a framework that represents an enhanced approach to achieving sustainable development goals in Agile.

The study shows that agile software development is a tool for achieving sustainable development goals by promoting environmental and social responsibility concepts in work environments with complex and changing requirements.

Keywords: Development, Agile, Software, Sustainable Development , Prototype

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تأثير تنفيذ أهداف التنمية المستدامة في تطوير البرمجيات الرشيقة

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المستخلص

تتجه العديد من شركات تطوير البرمجيات حاليًا نحو إنتاج برمجيات مستدامة تُسهم في تقليل هدر المواد المُصنّعة، والحفاظ على البيئة، ودعم الابتكار المُستدام. تُساهم البرمجيات وأنظمة الحاسوب المُختلفة بشكل عام في انبعاثات غازات الاحتباس الحراري العالمية، وتُعدّ مصدرًا للنفايات الإلكترونية، لذا من الضروري دمج أهداف التنمية المُستدامة في عمليات تطوير البرمجيات. يُمثّل دمج أهداف التنمية المُستدامة في تطوير البرمجيات الرشيق فرصةً مثاليةً لمواءمة ممارسات هندسة البرمجيات مع مبادئ الاستدامة. يستكشف هذا البحث دمج أهداف التنمية المُستدامة في منهجيات الرشيقة، مُسلّطًا الضوء على الاستراتيجيات المُحتملة لتعزيز كفاءة التطوير وتقليل الهدر في عملية التطوير. كما يُسلّط الضوء على الطبيعة التكرارية والتكيفية لمنهجية الرشيق لتحقيق أهداف الاستدامة وتعزيز الابتكار في مشاريع البرمجيات، ويُوفّر إطارًا يُمثّل نهجًا مُعزّزًا لتحقيق أهداف التنمية المُستدامة في البرمجيات الرشيقة. تُظهر الدراسة أن تطوير البرمجيات الرشيقة هو أداة لتحقيق أهداف التنمية المُستدامة من خلال تعزيز مفاهيم المسؤولية البيئية والاجتماعية في بيئات العمل ذات المُتطلبات المُعقدة والمُتغيّرة.

الكلمات المفتاحية: تطوير، البرمجيات الرشيقة، التنمية المستدامة، النماذج الاولية

انتساب الباحثين

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Introduction

Sustainable development is one of the most important concerns of many population groups, as it is essential to balance economic growth and social justice and maintain a suitable living environment surrounding humans [1]. In the same context, information technology and software development are fundamental axes in achieving the sustainable development goals set by the

United Nations in 2015. [2]These goals are considered a roadmap for many economic and social projects, including software development projects[3]. They are considered among the most critical projects because of their importance in preserving the environment and the social and economic situation. One of the most essential methodologies in software development is the agile software approach because of its ability to adapt to changing requirements and find solutions simultaneously and flexibly[4]. It also relies on the iterative method of the development process based on variables, as it is divided into small units[5]. These units enable work teams to provide usable models of the product, allowing continuous interaction with users to improve the final product. The agile software approach is practical in many different sectors [6]. This approach aligns with achieving sustainable development goals, as it creates many productive solutions from a technical, social, and environmental standpoint**.**

Agile Software

Agile software is one of the most critical practices and methodologies that aim to improve the efficiency of the development process and achieve the best product quality [7]. The development process in this approach always focuses on continuous and close cooperation between work teams, continuous delivery, response, and finding quick solutions to continuous variables during the development process. Agile software emerged as a reaction to the traditional software development approach, often characterized by inflexibility and slow response variables[8]. Agile software relies in the product development process on a set of fundamental principles that were established by experts in this field in 2001 and were published in a unique statement that included a set of principles specific to the development process to facilitate work[9], the most important of which is emphasizing and relying on work teams and the importance of continuous communication and interaction between these teams and stakeholders throughout the development process, documenting and evaluating the development process, and giving importance to rapid response to stakeholders' requirements. In addition to the 12 principles (gaining customer satisfaction through continuous delivery of the program[10], facilitating the process of accepting changes at any time during the development process, delivering usable versions of the program, close and constant communication between work teams, direct conversations between work teams, continuous motivation to create a work environment free of doubts and appreciation, a usable product, encouraging work teams to develop their skills and continuously improve their technical and development capabilities, increasing attention to the quality of work, simplicity in reducing work and tasks in the development process, enhancing self-organization and encouraging teams to think and adapt to improve effectiveness and control behaviour), it is noted on the statement of the principles of agile software that it enhances the achievement of sustainable goals by eliminating waste by reducing the waste of resources and time[11].

Sustainable development:

Sustainable development is a socio-economic term defined by the United Nations, and a roadmap for global environmental, social, and economic development has been drawn. Its primary goal is to improve the living conditions of the planet's inhabitants and develop and manage means of production in many ways that do not lead to the

depletion, waste or overuse of natural resources so as not to cause an imbalance in the environmental balance and a shortage of resources currently available to future generations[12]. The United Nations identified seventeen interconnected global goals to create a more peaceful and sustainable future for humanity. These goals cover a wide range of development issues for all countries with explicit recognition of the integrated nature and the integration of policies to drive the process of progress[13]. To achieve these goals, exceptional efforts are required to cooperate with governments, companies, civil society, and stakeholders. Sustainable development can be defined in its general concept as the development that meets the needs of the current generation without exceeding the capabilities of the next generation in meeting the unique needs, as every variable in the growth content becomes less material and energy-intensive and more just [14].

Goal and purpose

To highlight the importance of agile software development and its effectiveness in achieving sustainable development goals, and to work on some technical solutions to create a broad positive scope in the information society, master the environment, sustainable innovation and participation in sustainability to ensure the quality of the final product.

Research Methodology

The research topic imposes a descriptive and analytical methodology. The aim is to highlight achieving sustainable development goals in developing agile software and demonstrate evidence by reviewing the most important general rules related to the topic.

The function of agile software in sustainable development:

Through its core principles, practices, and methodologies, agile software can align with the requirements of sustainable development by employing its adaptability and focusing on continuous improvement. This can be summarized in a set of aspects that highlight the potential of agile software in supporting sustainable development goals.

1- Enhancing development efficiency and reducing waste:

Applying the principles of agile software development enhances product efficiency and focuses on receiving a high-quality product through continuous improvement. This, in turn, reduces the waste of material resources and the development process time [15]. For example, the development process costs can be reduced by correcting errors in the final stages and before the project is delivered.

2- Supporting innovation and responding to changes:

One of the most essential features of agile software is the ability to adapt to requirements during the development process. This feature supports the process of providing sustainable solutions that meet customer variables more effectively, as responding to variables is one of the exciting factors in supporting sustainable development goals by modifying the development process based on requirements. This feature is compatible with environmental and social standards [16].

3- Improving the quality of work-life:

Agile software enhances the quality of work life by supporting the work environment [17]. This may lead to an increase in customer satisfaction, employee satisfaction, and production quality. This achieves the goal of social sustainability through a

balance between the work environment and personal life, enhances the well-being of individuals, and improves professional quality.

4- Supporting transparency

Agile software features work transparency, constructive collaboration, and communication between work teams[18]. These features build trust between all parties and are essential in achieving sustainable development goals. They also enhance the efficiency of development processes and reduce cost waste.

Principles of Sustainable Development in Agile Software:

The ideas of sustainable development in Agile software development seek to establish systems that are efficient, durable, and adaptable to change while reducing environmental, social, and economic implications [19]. Here are some Applications of sustainable development principles in Agile software:

1- Improving the designs of environments:
   System design should prioritize environmental protection to improve resource efficiency and reduce energy consumption. By integrating green computing technologies and circular design principles, we can recycle resources effectively and work towards the sustainable development goal of minimizing environmental impact.
2- Enhancing social sustainability:
   The goal of social sustainability can be achieved by developing a plan for flexible and continuously improving work policies. This can be done by developing professional skills, achieving equal job opportunities among individuals, equality in available opportunities, and respecting workers' rights to enhance social justice.
3- Sustainable innovation process:
   Modern technological techniques effectively improve environmental and social quality by encouraging all parties to the development process to use modern technologies, motivating the development factor, and allocating part of the costs allocated to the development process to research sustainability.

At the beginning of each project, sustainable development goals that are appropriate to the project requirements must be identified. In software development projects, we can identify the seventh goal of the sustainable development goals, which can be cleaned in the process of managing and reducing energy consumption, the twelfth goal (software development supports the reduction of resource consumption) and the thirteenth goal to achieve a suitable climate environment for development work.

Agile software can apply sustainability principles by balancing performance improvement and sustainable development goals. as shown in Figure (1).

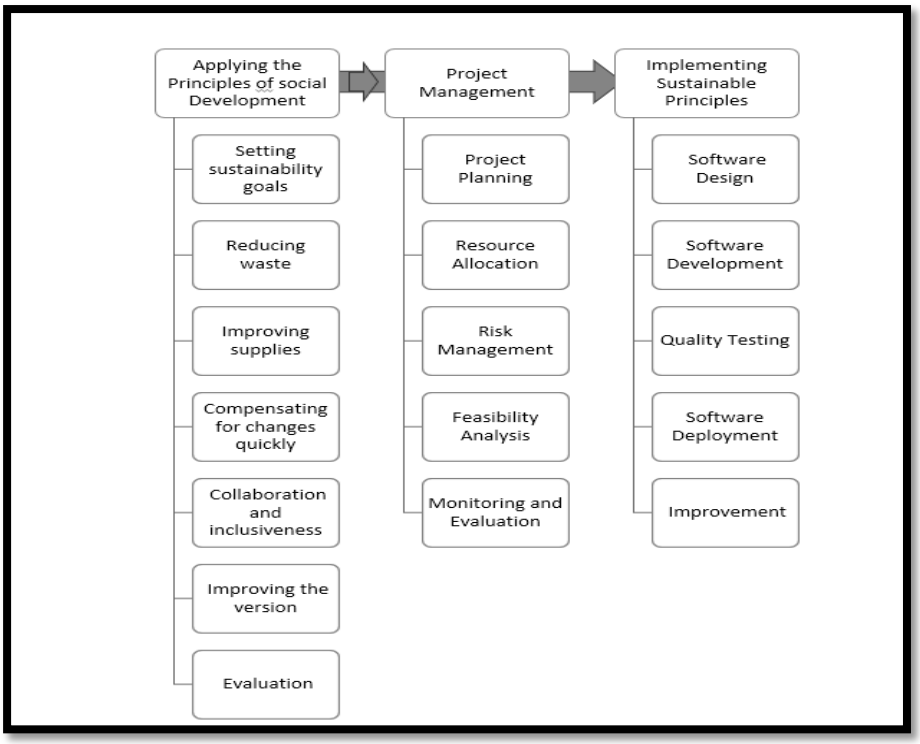

Figure (1): Applying Sustainable Development Principles in Agile Software

Achieving Sustainable Development Goals in Agile Software Development Process

To achieve the sustainable development goals in the agile software development process, each stage of development must be considered, and the necessary steps must be taken to achieve them. Sustainable development methods and practices can be integrated into the steps of the development process as shown in Figure (2).

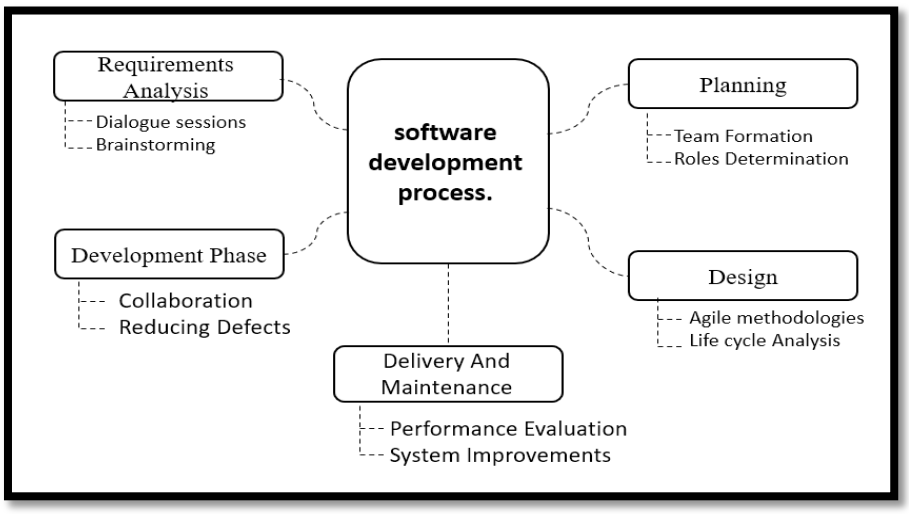

Figure (2): Development stages path

Requirements Analysis: During the process of analyzing the requirements of the development process, sustainable development methods and requirements analysis are integrated according to the determination of sustainability goals that can be achieved in the development process. Dialogue

sessions can also be added with different work teams and clients, including a brainstorming process to achieve sustainability requirements with work goals, and then evaluate the results of the analysis of sustainability requirements on the design.

Planning: The basis of any production or development process is the planning stage [20]. To ensure the achievement of sustainable development goals, sustainability goals must be identified at the beginning of the planning stage according to the requirements of the development process and a vision for the development process must be developed that includes identifying the desired goals of the project and how they support sustainability, in addition to forming specialised teams to ensure integration. In this stage, the requirements of users and stakeholders are planned and documented with the requirements of sustainable development (environmental and social), roles are defined among team members, those responsible for sustainability aspects are appointed, and appropriate solutions are found for the integration process. After the role definition process, timetables are prepared that specify the development stages and delivery dates for the initial and final versions, as well as allocating periods within the timeline to review and evaluate the sustainable development goals. The planning process continues in terms of identifying resources, selecting tools and methodologies for the development process that support sustainable development, preparing a plan for communication between work teams, preparing periodic reports, and following up and evaluating the development process in a way that achieves the integration of sustainable development goals.

Design: At this stage, agile methodologies and principles are used to achieve flexibility and adapt to changes. The environmental impact of software should be one of the most important aspects of design. To reduce work and determine the project's impact on the environment, life cycle analysis tools can be used. In software design, there should be the ability to develop and update to avoid wasting resources and time, while ensuring the use of efficiency standards in design, energy use, and recycling.

Improving the designs of environments: System design should prioritize environmental protection to improve resource efficiency and reduce energy consumption. By integrating green computing technologies and circular design principles, we can recycle resources effectively and work towards the sustainable development goal of minimizing environmental impact.

Enhancing social sustainability: The goal of social sustainability can be achieved by developing a plan for flexible and continuously improving work policies. This can be done by developing professional skills, achieving equal job opportunities among individuals, equality in available opportunities, and respecting workers' rights to enhance social justice.

Sustainable innovation process: Modern technological techniques effectively improve environmental and social quality by encouraging all parties to the development process to use modern technologies, motivating the development factor, and allocating part of the costs allocated to the development process to research sustainability. Through the above, sustainability principles can be applied in agile software by creating a balance

between performance improvement and sustainable development goals.

Development Phase:

Sustainable development practices should be intertwined with the development phase, such as continuous development, continuous testing, and continuous delivery, to ensure best practices in achieving sustainable development goals. This can be achieved by encouraging collaboration between teams and partners through meetings or workshops to introduce sustainable development principles, and relying on defect reduction techniques using clean code tools.

Delivery and Maintenance Phase:

At this stage, the software is deployed, improved, and continuously evaluated for performance (environmental and software) and necessary improvements are implemented to ensure system stability and continued sustainability. The software that is produced must meet the sustainable goals set at the start of the project, provide ongoing support to users, and minimize environmental impact.

Integrating Sustainability with Agile Development

Integrating sustainable development and its goals with agile software development projects is important and necessary to build a sustainable software future. This integration ensures the software's sustainability and effectiveness in achieving many societal [21], environmental and economic benefits. Given the compatibility of many agile methodologies with the principles of sustainable development, it is possible to link a relationship between agile and sustainable development by focusing sustainable development on the environmental, social and economic dimensions and meeting the needs of the present without compromising the needs of previous generations. This approach is focused on by agile through the development methodology in the process of iteration, gradual development, rapid response to variables, and continuous cooperation between development teams and customers [22]. This link achieves many factors:

1- Waste: Focus on reducing costs and unnecessary work.
2- Improvement: Reviewing and identifying opportunities for continuous improvement in social and environmental aspects.
4- Cooperation: Involving business owners in all axes of the development process.
5- Transparency: Discuss variables, new requirements, and sustainable development issues with stakeholders during the development process. as shown in Figure (3).

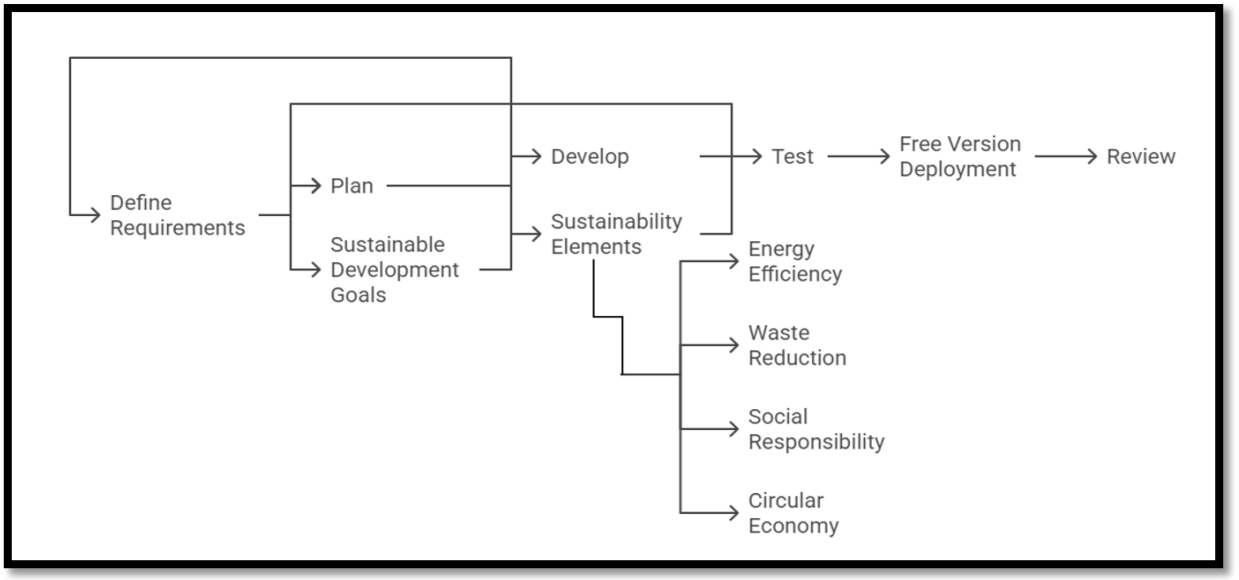

Figure (3): Integrating Sustainability with Agile Development

Applying sustainable development goals in agile software development requires a combination of scientific and technological innovation. Figure (3) shows that the relationship between sustainable development and agile software development effectively achieves many goals.

1- Adaptation and response: Agile allows for processes of responding to changes based on emerging requirements during the development process, which allows work teams to improve the product based on feedback. This practice achieves sustainability by reducing resource waste and ensuring high-quality product development based on user desires. This is what was confirmed by (Lago et al. 2015): agile supports and enhances the principles of sustainable development in the ability to integrate changing requirements sustainably.

2- Waste Reduction: (Baker et al.,) state that agile practices contribute to waste reduction through optimal use of resources and minimizing unnecessary practices. Agile practices emphasize simplifying processes, implementing necessary features, reducing resource consumption, and reducing the environmental footprint, which aligns with sustainability goals.

3- Stakeholders and collaborative collaboration: Agile values collaborative work and stakeholder engagement in the development process. This collaborative approach focuses on sustainable development to embrace social, inclusiveness, and long-term sustainability. Salah et al. (2018) state that collaborative engagement with stakeholders promotes transparency and trust, essential for sustainable development.

4- Process Efficiency: Agile enhances the efficiency of the necessary processes in the software development process, and this enhancement, in turn, reduces waste in the production increase, which achieves integration with the sustainable development goals in managing the production of maintainable systems and developing them with future requirements and reducing the need to replace these systems.

5- Process Efficiency: Agile enhances the efficiency of the necessary processes in the software development process, and this enhancement in turn, reduces waste in the increase in productivity, which achieves integration with the goals of sustainable development in managing the production of maintainable systems and developing them with future requirements and reducing the need to replace these systems. Processing and improving software proactively ensure software sustainability (Kazman et al. 2017).
6- Environmental Impact: Indirect (remote) collaboration supports environmental sustainability. (Penzenstadler et al., 2014)) Environmental integration is achieved in agile practices through indirect team collaboration and communication via electronic meetings, reducing material and environmental resource waste during the development process.

Strategies for Integrating Sustainable Development Goals into Agile Software Development

To apply strategies that can effectively achieve the goals of sustainable development and agile software methodologies and integration through a set of steps that can be used in software development:

1. Determine the goals: When starting the process of developing agile software, we can determine the goals that we want to achieve in the sustainable project to reduce, improve and enhance (energy consumption, resource efficiency, environmental awareness, waste)
2. Methodologies: Adopt agile software methodologies appropriate for the development process such as Scrum for project management, development and improving project efficiency, reducing losses and continuous interaction, and Kanban to improve the efficiency of managing tasks and resources in the workflow.
3. Design: Innovation in sustainable software design by building the program with less software code. Writing innovative codes with clean code reduces resource and energy consumption.
4. Modern technologies: Modern technologies contribute to achieving sustainable development goals when applied in agile software development. Among these technologies is the use of storage/cloud computing to reduce the need for physical devices.
5. Performance and Evaluation: Measuring performance and evaluating development processes using key performance indicators (KPIs) (measuring energy consumption, resources, environmental impact).
6. Team Development: Training and introducing teams to sustainable development practices by providing introductory and educational workshops on the principles application of the Sustainable Development Goals in Agile Software Development requires a combination of scientific and technical innovation, and this innovation can currently be achieved by using artificial intelligence and machine learning techniques. The tremendous scientific steps and scientific breakthroughs in artificial intelligence applications can improve software efficiency, and this improvement contributes to reducing energy consumption. The design based on sustainable development contributes to the best use of resources, and the best use of resources can be achieved through cooperation between work teams to exchange ideas and

techniques through indirect communication, this improves environmental performance and reduces environmental pollution. as shown in Figure (4).

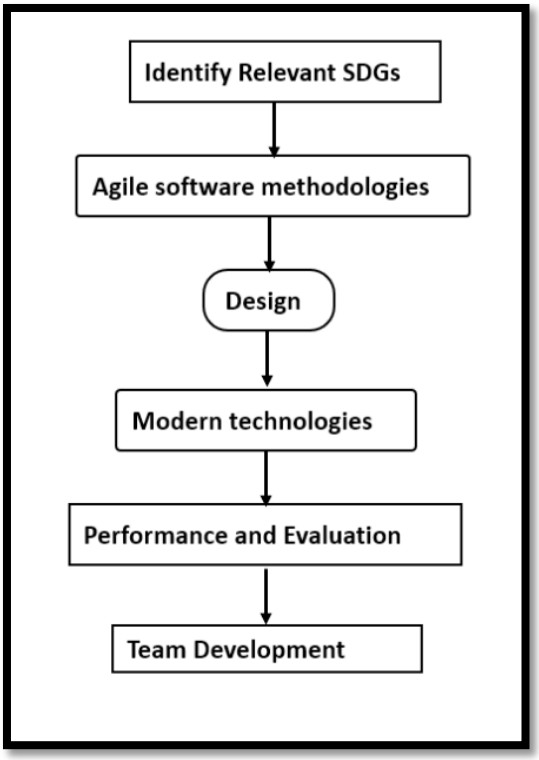

Figure (4): Strategies Integrating

Sustainable Innovation

Agile software development in sustainable development is a complex process that requires the integration of many factors to achieve a balance between efficiency, innovation, and sustainability [23]. Stimulating innovation in agile development processes enhances environmental and social sustainability as it aims to achieve the best efficiency in the use of resources and reduce environmental impact, as well as enhance social and economic benefits. And finding innovative technical development solutions that contribute to improving product efficiency. To achieve sustainable innovation in agile software, the planning process can begin by identifying sustainability goals from the beginning of the project in conjunction with development requirements and testing these goals in the implementation process by building them into project prototypes and reviewing performance and measuring the efficiency of these goals in the improvement phase [24].

Since flexible software allows teams to quickly adapt to changes during the development process (economic or environmental), this flexibility enhances the ability to innovate and provide sustainable solutions that better meet customer requirements. Rapid response to change is a critical factor in supporting sustainable development, as products and services can be modified to suit changing environmental and social standards. Teams are encouraged to experiment with new ideas and make adjustments based on continuous feedback to enhance innovation.

Some mathematical equations can be formulated to achieve best practices in innovation-based sustainable development to measure the ability of teams to innovate and provide new sustainable solutions. As shown in equation No. 1

$$I = \frac{impact^N ideas^{\times Q}}{iterations^N} \quad (1)$$

Whereas:

I Sustainable Innovation Index

$ideas^N$ It is the number of new ideas that have been developed.

$impact^N$ It is the quality of each idea's impact on sustainability (measured on a scale of 1 to 10).

$iterations^N$ It is the number of development iterations.

Since the sustainable innovation process depends on environmental, economic, and social factors, **As shown in equation No. 2**

$$I = \frac{eW}{E} + \frac{cW}{C} + \frac{sW}{S} \quad (2)$$

Whereas:

E Environmental impact (carbon emissions, resource consumption).

C Economic impact (costs, financial return, resource efficiency).

S Social impact (job creation, improved quality of life).

EW,CW,SW Relative weights of the above factors (determined based on the importance of each factor in the project)

To use the above equation, the units of measurement of the factors must be specified. For example, environmental factors are defined as carbon emissions, economic factors are defined as financial returns such as dollars, and social factor is defined as the number of people.

Framework for agile software development in sustainable innovation

This framework aims to achieve work that contributes to achieving the goals of sustainable innovation by combining the advantages of agile software with the basic principles of sustainability and innovation, which in turn achieves a balance between social, environmental, and economic goals through a set of tools and practices. This framework also aims to enhance and support joint collaboration between work teams and stakeholders, give utmost importance and priority to sustainable practices, reduce social, economic, and environmental impacts through continuous delivery, and measure the impact of improving the integration of sustainability into agile software development projects. as shown in Figure (5).

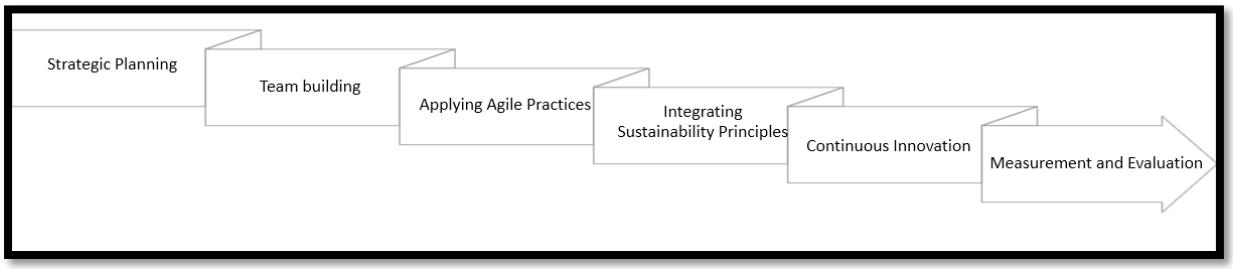

Figure (5): Framework for agile software development in sustainable innovation Plan Stages

1. Strategic planning:

- Objective setting: Define the strategic objectives for sustainable innovation in the project.
- Risk analysis: Assess potential environmental and social risks.
- KPIs: Identify appropriate indicators to measure progress towards achieving the objectives.

2. Team building:

- Form a multidisciplinary team: Ensure the presence of experts in software, sustainability, and innovation.
- Team training: Provide the necessary training to the development team on the principles of agile software and sustainability.
- Build a culture of innovation: Encourage a work environment that promotes creative thinking and problem solving.

3. Applying agile practices:

- Iterative planning: Use agile planning techniques such as Scrum or Kanban.
- Iterative delivery: Break work into short time frames and deliver reusable products.
- Continuous collaboration: Encourage collaboration between team members and customers.
- Adapting to change: Be prepared to adapt to variables and changes in requirements.

4. Integrating sustainability principles:

- Software life cycle assessment: Analyze the environmental and social impacts of software throughout its life cycle.
- Selecting sustainable technologies: Use software and hardware technologies that consume less energy and reduce waste.
- Design for Maintainability: Design software to be easy to maintain and update, which extends its productive life.
- Encourage Reuse: Reuse codes and software components as much as possible.

5. Continuous Innovation:

- Allocate time for innovation: Allocate a portion of the team's time to work on new ideas and improve the product.
- Encourage Risk-taking: Create an environment that allows taking risks and learning from mistakes.
- Collaboration with Partners: Collaboration with universities, research institutions and other companies to share knowledge and expertise.

6. Measurement and Evaluation:

- Tracking Indicators: Follow up on the indicators identified in the first phase.
- Continuous Evaluation: Conduct periodic assessments to ensure that goals are being achieved.
- Continuous Improvement: Make the necessary adjustments to improve performance.

Conclusions

Integrating the SDGs into Agile software development presents both opportunities and challenges. By enhancing stakeholder engagement, boosting team motivation, driving innovation, and ensuring long-term sustainability, organizations can create a positive impact on society and the environment. However, teams must also navigate the complexities of balancing short-term goals with long-term sustainability objectives. Ultimately, successful implementation of the SDGs into Agile development can lead to more responsible and impactful software solutions that

contribute to a sustainable future. The proposed framework provides a comprehensive approach to sustainability in agile, bridging the gap between Agile methodologies and the urgent need for sustainability in modern projects. By integrating strategic planning, multidisciplinary team building, iterative practices, sustainability principles, continuous innovation, and performance evaluation.

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