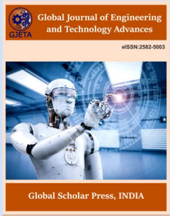
Global Journal of Engineering and Technology Advances

eISSN: 2582-5003

Cross Ref DOI: 10.30574/gjeta

Journal homepage: https://gjeta.com/



(RESEARCH ARTICLE)

Check for updates

Optimizing agile collaboration frameworks for carbon-efficient digital twin deployment in oil and gas: strategies, tools, and challenges in the planning phase

Alliy Adewale Bello [1,*], Mobolaji Fakeyede [2], Ogochukwu Gold Abaneme [1], Vincentia Eshun[1], Chukwuka Junior Akibor [3] and Frederick Owusu [4]

[1] *Department of Project Management, Northeastern University, Roux Institute, Portland, Maine, U.S.A.*

[2] *Department of Information Technology, Chevron Corporation, Nigeria.*

[3] *Department of Management, University of Texas Rio Grande Valley, U.S.A.*

[4] *Department of Earth Sciences and Geological Resources, Stephen F. Austin State University, U.S.A.*

Global Journal of Engineering and Technology Advances, 2025, 22(02), 034-045

Publication history: Received on 25 December 2024; revised on 02 February 2025; accepted on 05 February 2025

Article DOI: https://doi.org/10.30574/gjeta.2025.22.2.0025

Abstract

Integrating Agile frameworks into the planning phase of digital twin deployment provides a unique opportunity to improve operational efficiency and achieve carbon reduction goals in the oil and gas industry. This article investigates the use of Agile methodologies, such as Scrum and Kanban, to address the complexities of deploying digital twins while embedding sustainability into project workflows.

The report reveals several major problems, including stakeholder misalignment, resource restrictions, and restricted collaboration across varied teams. To address these constraints, practical techniques such as training and capacity building, implementing Agile frameworks, and utilizing energy *modelling* tools such as EnergyPlus and OpenStudio are offered. Agile approaches, such as iterative feedback loops and real-time dashboards, are cited as enablers of continuous improvement and alignment with carbon efficiency goals.

Key findings show that Agile frameworks enhance stakeholder collaboration, the incorporation of sustainability data, and adaptive planning to accommodate fast changing plans. The article also discusses the roles of Product Owners, Scrum Masters, and Technical Leads in integrating technical efforts with business objectives for sustainability.

This study emphasizes the significance of Agile frameworks in improving the planning processes for digital twin projects, providing practical guidance for decreasing carbon footprints and meeting long-term environmental goals in the oil and gas sector.

Keywords: Agile Frameworks; Digital Twins; Carbon Efficiency; Oil and Gas Industry; Sustainability; Planning Phase

1. Introduction

Digital twins (Figure I) are virtual duplicates of physical systems that allow for real-time monitoring, modelling, and predictive analytics [1]. Digital twins have transformed operational efficiency in the oil and gas industry, optimizing output, minimizing equipment downtime, and assuring better resource allocation [2]. These systems use advanced data analytics and IoT technology to monitor operations, simulate possible outcomes, and drive decision-making in a virtual environment. Digital twins enable firms to improve safety, anticipate future disruptions, and save operating expenses by matching physical assets [3].

* Corresponding author: Alliy Adewale Bello.

The oil and gas industry, known for its enormous carbon footprint, is under increasing pressure to adopt more sustainable practices [4]. Here, digital twins emerge as an important instrument for attaining carbon efficiency by optimizing energy consumption, lowering emissions, and extending asset life. Companies such as British Petroleum and Shell are already using digital twins to improve energy efficiency and minimize environmental impact [5].

However, as use grows, difficulties like as integration costs, cybersecurity, and data standardization continue to prevent widespread implementation [6]. Overcoming these issues, especially during the planning stage, is critical for incorporating carbon efficiency into digital twin deployment strategies and harmonizing with global sustainability goals.

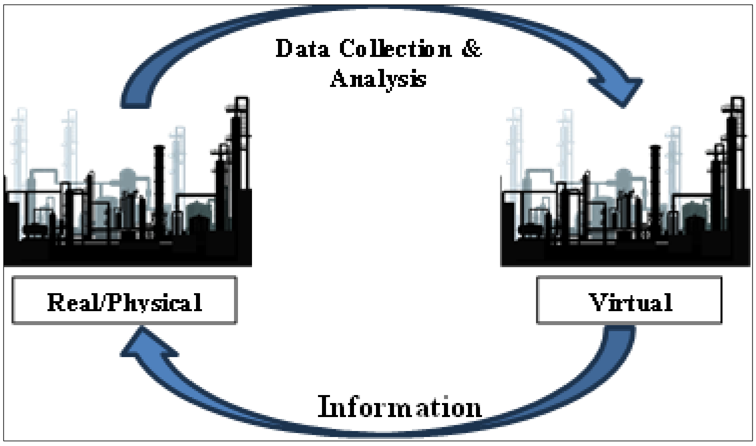


Figure 1 Digital Twin

1.1. Significance of Agile Methodologies

Agile methodologies or frameworks in project management are an array of methodologies that promote a flexible, iterative strategy to project delivery, with a focus on collaboration, customer feedback, and rapid releases of working product features to respond quickly to changing requirements [7]. Agile approaches, which were originally designed for software development, have altered how cross-functional teams work and adapt to changing project needs. Popular Agile frameworks include Scrum (the most extensively used), Kanban (flow-based), Lean, Feature-Driven Development (FDD), Extreme Programming (XP), and Scaled Agile Framework (SAFe) for big teams [7]. Scrum and Kanban frameworks, which emphasize iterative development, continuous feedback, and stakeholder involvement, are suited for dealing with the complexities of digital twin deployment.

In the oil and gas business, where projects involve various teams and quickly changing objectives, Agile techniques provide a structured yet flexible approach to planning and implementation. Agile frameworks promote regular communication and iterative improvements, which increases transparency and allows teams to align on carbon efficiency targets [5].

Agile's iterative nature guarantees that sustainability is a continuous concern. Sprint reviews and retrospectives provide opportunity to evaluate and improve carbon efficiency measures at each level of planning. Integrating Agile approaches into the planning phase can greatly increase collaboration among technical teams, business leaders, and environmental specialists, propelling projects to operational and environmental success [8].

2. Research problem

Integrating sustainability into the deployment of digital twins in the oil and gas industry, especially during the planning phase, poses major obstacles. While digital twins have enormous potential to increase operational efficiency and lower carbon footprints, combining these benefits with sustainability goals frequently necessitates overcoming technological, organizational, and financial constraints. A major difficulty is incorporating carbon efficiency concerns early in the design phase, when decisions about resource allocation, energy usage, and lifetime implications are made.

Furthermore, achieving smooth coordination among project managers, technical teams, and sustainability experts can be challenging. Misaligned priorities, insufficient training on carbon-efficient methods, and a scarcity of standardized instruments exacerbate these problems. Also, the high initial costs and complexity of integrating digital twins with legacy systems impede the implementation of sustainable plans. Addressing these problems necessitates a bespoke approach that uses Agile collaboration frameworks to unify disparate teams and build sustainability into the project's basis.

2.1. Objectives and Scope

The present research investigates how Agile collaboration frameworks can be adjusted to the planning phase of digital twin deployment in the oil and gas industry to achieve carbon efficiency while meeting business requirements. It investigates techniques for improving collaboration, including sustainability, and overcoming obstacles in large-scale projects.

The investigation addresses four key research questions: (1) How can Agile frameworks improve collaboration among stakeholders? (2) What strategies ensure carbon efficiency during planning? (3) Which roles and tools are most effective in supporting carbon-efficient planning? (4) What challenges arise in applying Agile to digital twin deployment, and how can they be mitigated?

3. Methodology

This study takes a qualitative approach to investigating the incorporation of Agile frameworks into the planning stage of digital twin deployment for carbon efficiency in the oil and gas industry. It draws on current research, industry reports, and case studies to point out the essential problems, tactics, tools, and responsibilities associated with Agile deployment. The study is organized around four important questions: enhancing stakeholder communication, guaranteeing carbon efficiency during planning, identifying effective roles and tools, and overcoming barriers in Agile adoption.

The study emphasizes an overall examination of Agile techniques, focusing on stakeholder alignment, iterative feedback loops, and sustainability measures. Practical examples from sectors that use Agile for energy modelling and carbon footprint reduction are presented to demonstrate successful framework customization. Stakeholder misalignment and resource restrictions are among the key difficulties addressed by recommended mitigation techniques such as capacity building, leadership engagement, and the use of advanced tools such as EnergyPlus and real-time dashboards.

4. Agile framework collaboration and its role in digital twin deployment

Agile methods, such as Scrum, Kanban, and SAFe, offer flexible and iterative approaches to project management, making them ideal for complex and dynamic contexts like digital twin deployment. These frameworks enable teams to respond swiftly to changing requirements and emerging technologies, which are critical components of digital twin projects that frequently involve real-time data updates and fluctuating project scopes [9]

Scrum is an Agile framework that prioritizes short, focused work cycles known as sprints. Teams collaborate and hold regular meetings, such as daily stand-ups and sprint reviews, to ensure alignment and make quick improvements [10]. This structure is very useful in settings where requirements change often, like in digital twin deployments. Scrum's iterative structure encourages stakeholders to provide ongoing input, guaranteeing that each sprint builds on the preceding one, which is critical for retaining momentum and relevance in a quickly changing field [11].

Kanban uses a more visible approach, concentrating on improving the flow of work through the system. Teams use boards to track progress, limiting work in progress and identifying and addressing bottlenecks. This visual method allows teams to focus on making tiny, incremental improvements, which is critical for digital twin deployments that require frequent updates and modifications. Kanban's flexibility allows teams to readily modify priorities without affecting the overall flow of the project [12,13].

According to Pavlíčková et al. (2024), SAFe (Scaled Agile Framework) is intended for large enterprises that need to coordinate across several teams working on complicated projects. By combining lean thinking with Agile principles, SAFe offers an organized method for expanding Agile practices over sizable teams and departments. SAFe maintains Agile's adaptability to change while guaranteeing alignment for digital twin projects in sectors like manufacturing, energy, or healthcare where many teams must work across numerous roles [14].

These Agile frameworks are particularly relevant to digital twin deployment because they promote continuous delivery, real-time feedback, and stakeholder collaboration. Digital twin projects often require input from various disciplines including engineering, data science, and business strategy, making Agile’s flexibility and emphasis on collaboration highly beneficial. This helps teams address unexpected challenges, innovate more effectively, and ensure that the digital twin models evolve in line with real-world changes, ultimately reducing the risks associated with large-scale implementations.

4.1. Enhancing Collaboration Between Stakeholders

Agile methodologies are fundamentally designed to foster collaboration among stakeholders, which is essential in ensuring successful project outcomes. Central to Agile's collaborative nature are its ceremonies: stand-ups, retrospectives, and sprint reviews (Figure 2).

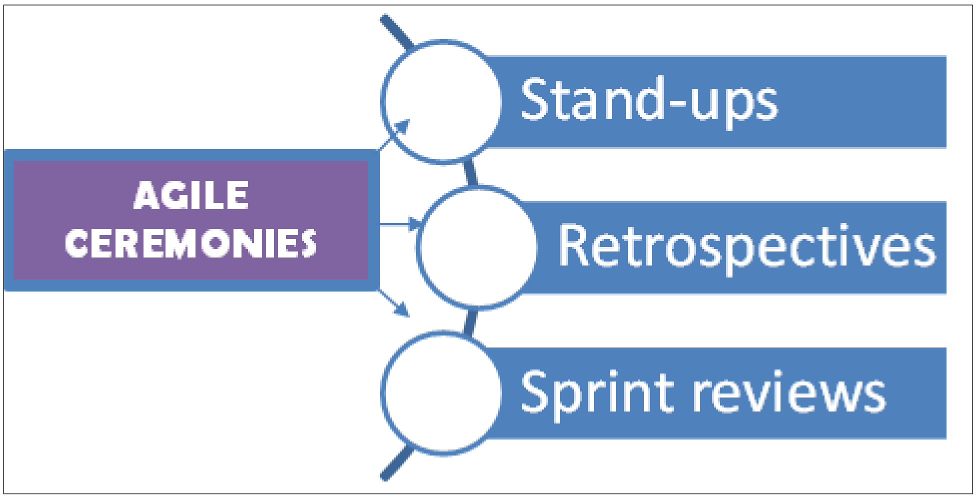


Figure 2 Agile Ceremonies

Stand-ups, held daily, are quick meetings where team members briefly share updates on their progress, discuss roadblocks, and set priorities for the day [15]. This short, focused interaction ensures that everyone is on the same page, facilitates transparency, and allows for real-time adjustments [16]. In cross-functional teams, where stakeholders from different areas such as engineering, data science, and business are involved, stand-ups encourage open communication and help avoid misunderstandings by providing a regular touchpoint for alignment [17].

Retrospectives are held at the end of each sprint and offer a dedicated space for teams to reflect on what went well and what could be improved. This ceremony encourages continuous improvement, allowing technical teams and business stakeholders to adapt and refine processes, workflows, and collaboration strategies. Retrospectives ensure that teams can resolve any friction points or gaps in understanding, which is especially critical when working with diverse stakeholders who might have different priorities and working styles [18,19].

Sprint reviews are another key Agile ceremony where teams demonstrate what has been accomplished during the sprint. This provides an opportunity for stakeholders including business leaders, project managers, and clients to provide feedback. Through the inclusion of business and technical teams in this collaborative process, sprint reviews ensure that project goals, such as carbon efficiency, are continuously reassessed and aligned with stakeholder expectations [20]. This helps maintain focus on delivering outcomes that support both technical advancement and business objectives [21]

Agile frameworks in digital twin deployment play a critical role in aligning technical teams with business goals, particularly those related to carbon efficiency. It ensures that both technical and business stakeholders are involved throughout the project lifecycle, making it easier to adjust and refine the project's direction as new information and feedback become available.

One example is in the continuous evaluation of energy usage during the deployment of digital twins in smart cities or industrial facilities [22]. Agile teams can break the project into smaller, manageable sprints, each focused on optimizing specific aspects of energy efficiency. At the end of each sprint, technical teams can assess the impact of their work on carbon emissions, with business stakeholders reviewing the results to ensure that the project is meeting sustainability targets. If carbon reduction goals aren't being met, business stakeholders can adjust priorities or suggest alternative solutions, which are then incorporated into the next sprint cycle. For instance, if a digital twin model of a building's energy consumption doesn't show the expected reduction in carbon emissions, the Agile process allows for quick identification of where improvements can be made. During sprint reviews, both technical teams and business stakeholders can discuss the model's performance in terms of energy use, carbon emissions, and cost-effectiveness. If the carbon reduction target is not being achieved, adjustments can be made, such as recalibrating sensors, changing algorithms, or updating operational strategies to improve energy savings.

Agile's emphasis on regular stakeholder collaboration ensures that the technical team remains focused on the business's overarching goal of carbon efficiency. The continuous feedback loops created by Agile ceremonies ensure that the technical team receives constant input from business stakeholders, allowing them to adjust their work in real-time to meet carbon reduction objectives.

4.2. Addressing Communication Barriers

Communication problems are frequent in large-scale initiatives, particularly when team members are spread out geographically. Communication problems are made worse by the digital gap, which is exacerbated by differences in access to technology and digital literacy. Inequities in information exchange and participation may result from certain stakeholders' inability to use technology efficiently or their lack of access to fundamental communication tools. Promoting inclusive communication requires bridging this digital divide through investments in technical infrastructure, training, and capacity-building programs [23].

Variations in technology adoption rates among stakeholders can impact communication effectiveness. While some organizations may embrace cutting-edge communication technologies and digital tools, others may be more resistant to change or constrained by legacy systems [24]. Mismatched technology capabilities and preferences can complicate collaboration efforts and hinder interoperability between systems, leading to inefficiencies and communication breakdowns [25]

To address these challenges, various tools can be employed to foster transparency and accountability in communication. Project management software like Jira, Trello, and Confluence can facilitate real-time communication and information exchange. These tools offer features such as task tracking, document sharing, and collaboration spaces, enabling team members to stay informed and engaged. It helps ensure that all stakeholders have access to the same information, reducing the risk of misunderstandings and miscommunications [26].

Furthermore, video conferencing and instant messaging technologies can connect geographically separated team members, enabling real-time conversations and decision-making [27]. These solutions can also help with language translation and interpretation services, encouraging inclusivity and effective communication across varied teams.

5. Strategies for carbon-efficient digital twin planning: integrating sustainability in the planning phase

Integrating sustainability into the planning phase of digital twin deployment is critical for achieving carbon efficiency and ensuring alignment with broader environmental goals. This integration requires adopting methodologies like Lifecycle Assessment (LCA), engaging sustainability experts, and leveraging advanced data analytics to predict and optimize energy consumption effectively [28].

5.1. Lifecycle Assessment (LCA): Importance and Application during Planning

Lifecycle Assessment (LCA) is an important tool for integrating sustainability into the planning process. It assesses the environmental impact of a project or product throughout its lifecycle, from raw material extraction to end-of-life disposal [29]. LCA is used as a decision-making framework in digital twin deployment, delivering a full perspective of potential carbon emissions at various stages of the project. For example, in the building business, digital twins are used to simulate energy use and optimize material choices, ensuring that resource use is minimized while retaining efficiency [30]. Identifying high-emission phases early will make planners to adjust project specifications, adopt eco-friendly materials, and implement energy-saving measures. This predictive capability of LCA fits closely with the digital twins, where adjustments can be modelled and tested before implementation, thus preventing costly rework or oversights that could compromise sustainability.

5.2. Engaging Sustainability Experts and Stakeholders to Set Carbon Efficiency Goals

Involving stakeholders, such as sustainability specialists, in the planning stage guarantees that carbon efficiency targets are clear and attainable. A common understanding of sustainability priorities is fostered by cooperative conversations including engineers, data scientists, corporate executives, and environmental professionals [31]. Digital twins, for example, let stakeholders to view scenarios of energy usage, evaluate environmental implications in real time, and collaborate to devise emission reduction plans. Stakeholder input guarantees that carbon reduction strategies are workable within operational and financial restrictions, while the involvement of sustainability specialists guarantees that these strategies are grounded in scientific principles. A balanced approach to attaining carbon efficiency is provided by this cooperative approach, which improves the alignment of technological solutions with long-term economic and environmental objectives [31, 30].

5.3. Leveraging Data Analytics to Predict and Optimize Energy Consumption

When digital twins are paired with powerful data analytics and IoT sensors, they provide unprecedented prospects for predicting and optimizing energy use. Digital twins help planners detect inefficiencies and implement targeted interventions by processing real-time data on energy usage, temperature, and equipment performance [3, 33]. For example, in the manufacturing industry, data analytics may estimate peak energy demand and recommend changes to production schedules, saving waste and pollution. Similarly, in building operations, digital twins can replicate HVAC (heating, ventilation, and air conditioning) system performance, assuring maximum energy efficiency while maintaining occupant comfort [34]

6. Framework customization for carbon efficiency: defining sustainability metrics and their role in agile sprints

Customizing carbon efficiency frameworks is crucial for using digital twin technologies to cut carbon emissions in a variety of businesses. Firms can link their Agile processes with sustainability goals by identifying sustainability criteria, implementing iterative feedback loops, and reviewing successful case studies [30].

Sustainability metrics give quantifiable indicators for evaluating environmental effect and connecting project objectives with carbon efficiency targets. These measures could include carbon emissions per operational hour, energy intensity per output, and waste reduction percentages. In Agile sprints, these metrics are included into the sprint planning and review processes, allowing teams to incrementally track their progress toward sustainability targets. As an illustration, in a digital twin deployment for building retrofitting, measures such as energy savings % or reduction in operational carbon footprint influence decision-making throughout each sprint. By establishing explicit, actionable sustainability targets, Agile teams may prioritize work that directly contribute to environmental goals.

6.1. How Iterative Feedback Loops Can Ensure Incremental Improvements in Carbon Efficiency

The Agile philosophy of iterative development, paired with feedback loops, is extremely successful in ensuring continuous progress in carbon efficiency. Feedback loops allow teams to evaluate the impact of their decisions on a regular basis and adjust depending on real-time data and stakeholder input. For instance, digital twin systems combined with IoT sensors provide real-time data on energy use and emissions. This data may be examined after each sprint, allowing teams to fine-tune their plans for the following iteration. If a proposed solution does not match sustainability parameters, the feedback loop indicates areas for improvement and allows course changes. Such periodic changes ensure that carbon reduction targets are gradually met, with lessons learnt from one cycle feeding into the next.

6.2. Case Examples of Successful Customization

Applications in the real world show how successful it is to modify frameworks for carbon efficiency. The construction industry's employment of digital twins to maximize building retrofits is one noteworthy example. Agile methodologies and digital twin technology were recently used to track and lower the operational carbon footprint of commercial buildings. Agile sprints were organized around reaching predetermined carbon reduction goals, like integrating renewable energy sources and improving HVAC systems. A 30% decrease in energy use and a notable drop in carbon emissions resulted from the team's ability to assess the effects of each intervention and modify their tactics in response thanks to feedback loops [30, 35, 36]

Another example comes from the manufacturing industry, where digital twins were used to model production workflows and identify energy-intensive processes. The team was able to reduce peak energy demand by 20% by rearranging equipment usage schedules through the use of sustainability metrics in Agile sprints, and regular stakeholder feedback ensured that these changes were in line with operational requirements while maintaining carbon efficiency [37].

7. Roles, tools, and techniques in agile planning

The successful planning and implementation of digital twin projects require key roles within Agile teams to function collaboratively, ensuring that the project achieves both its technical and sustainability goals. Each role plays a distinct part in driving carbon efficiency and maintaining alignment with project objectives.

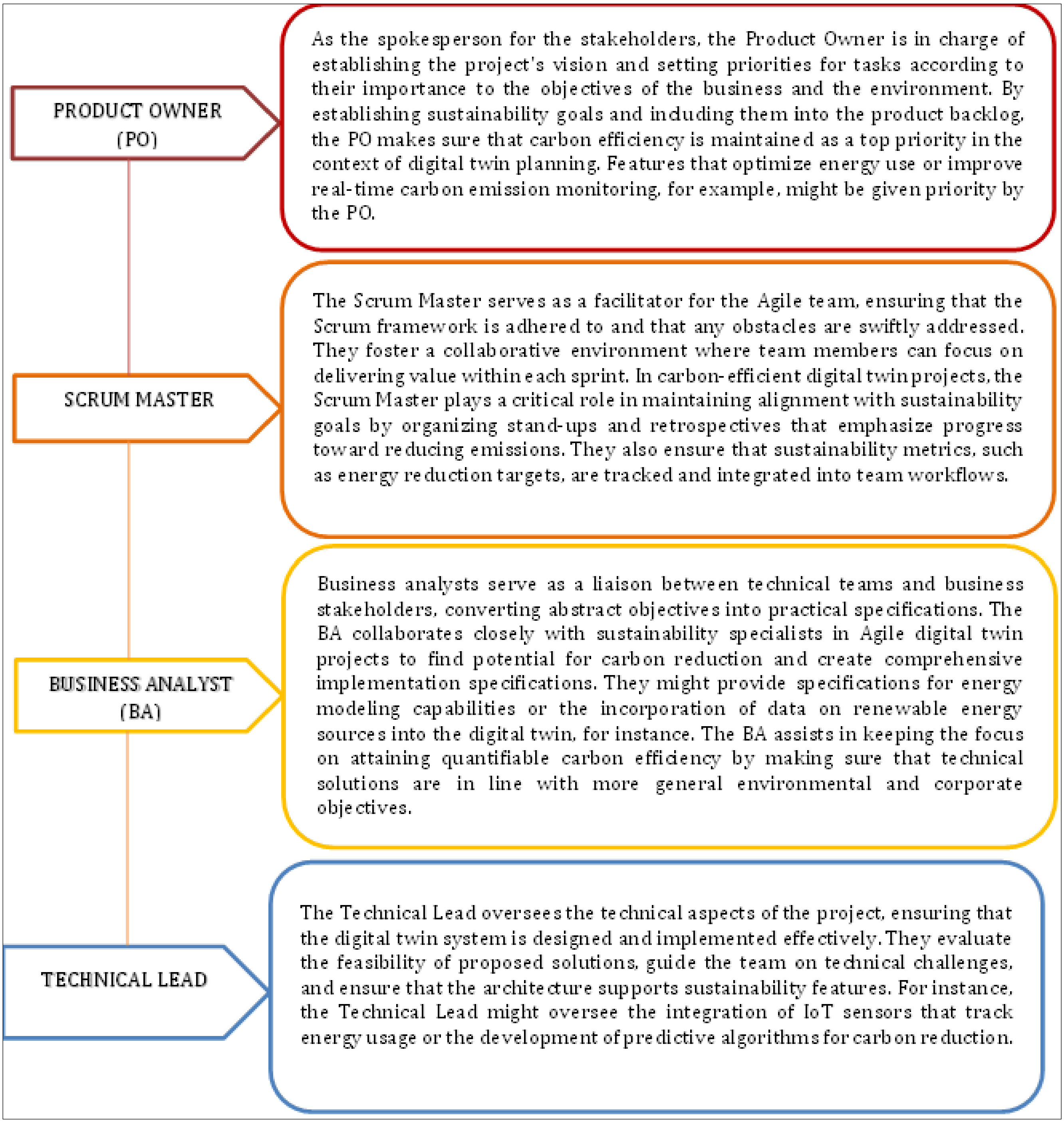


Figure 3 Agile Roles

Together, these responsibilities guarantee that sustainability is ingrained throughout the course of the project. Carbon-efficient features are defined and prioritized by the Product Owner, team alignment is facilitated and obstacles are removed by the Scrum Master, sustainability goals are translated into actionable tasks by the Business Analyst, and system architecture support is ensured by the Technical Lead. When combined, they provide a framework in which Agile processes are not only effective but also significantly improve environmental stewardship and carbon reduction.

7.1. Tools and Techniques

Effective tools and techniques are integral to Agile digital twin planning, ensuring seamless collaboration, accurate energy modelling, and continuous monitoring of sustainability goals. Leveraging on modern project management software, energy modelling platforms, and real-time dashboards, teams can optimize processes to achieve both technical and environmental objectives.

7.2. Project Management and Collaboration Tools

Tools like Jira, Asana, and Confluence are widely used in Agile workflows to manage tasks, foster collaboration, and streamline communication among stakeholders (Table I). These platforms allow teams to break down complex projects into manageable tasks, assign responsibilities, and track progress in real-time.

Table 1 Project Management tools and their functions

Tools	Functions	Source
Jira	Supports Agile practices such as sprint planning and backlog prioritization	[38]
Asana	Offers visual workflows to monitor project timelines.	[39]
Confluence	Serves as a centralized documentation hub, enabling teams to share knowledge and align on project objectives.	[40]
ScrumWise	Supporting both daily work and agile planning and management. ScrumWise seems to offer all the features needed to run a Scrum project.	[41]

While these tools are not specific to digital twin projects, their integration into Agile frameworks helps ensure that carbon efficiency goals remain a consistent focus across all tasks. These platforms also provide visibility to all stakeholders, making it easier to identify bottlenecks and course-correct in alignment with sustainability metrics.

7.3. Energy Modelling Software for Simulating Carbon Impacts

Energy modelling tools, such as EnergyPlus and OpenStudio, are critical for simulating and optimizing carbon impacts during digital twin deployment. These platforms enable teams to analyze energy consumption patterns and evaluate the environmental performance of proposed designs or operational strategies. Using these tools into Agile sprints will help teams to prioritize features that contribute to energy efficiency and validate their impact through iterative testing. This ensures that digital twin systems are optimized for sustainability from the planning phase onward.

Table 2 Energy Modelling software and their functions

Software	Functions	Source
EnergyPlus	Allows for the detailed simulation of HVAC systems, lighting, and renewable energy integration, providing actionable insights for reducing carbon emissions.	[42]
OpenStudio	Offers a user-friendly interface for energy modelling, making it accessible to both technical and non-technical stakeholders.	[43]

7.4. Real-Time Dashboards for Visualizing Progress

Real-time dashboards are critical for tracking and visualizing progress toward sustainability objectives in digital twin initiatives. These dashboards combine data from IoT sensors, energy modelling software, and other sources to provide a complete picture of key performance indicators (KPIs) [44]. Dashboards, for example, can provide indicators like real-time energy consumption, carbon emissions, and operational efficiency, allowing teams to track their progress toward specific goals. The ability to visualize data in real-time allows Agile teams to quickly discover deviations from carbon reduction targets and implement remedial actions in succeeding sprints. Furthermore, dashboards improve stakeholder participation by presenting clear, understandable visualizations of project outcomes, creating a shared commitment to sustainability.

8. Challenges and mitigation strategies in agile framework implementation

Table 3 Challenges and Mitigation strategies in Agile framework implementation

S/N	Challenges	Mitigations
1.	Stakeholder Misalignment and Knowledge Gaps	Training and Capacity Building: Offer training sessions and workshops to educate stakeholders on Agile principles, their roles, and the importance of alignment to project goals.
		Clear Communication Channels: Establish frequent communication touchpoints (e.g., sprint reviews, retrospectives) to ensure shared understanding of objectives.
		Collaborative Goal Setting: Involve all stakeholders in defining project objectives, ensuring buying and reducing conflicts caused by differing priorities.
2.	Resource Constraints and Scalability Issues	Resource Planning: Prioritize tasks based on value and resource availability during sprint planning to optimize resource utilization.
		Piloting Agile Frameworks: Begin with small-scale pilots to identify resource bottlenecks and refine processes before scaling Agile across the organization.
		Flexible Budgeting: Adopt an iterative budgeting approach to allocate resources dynamically as project requirements evolve.
3.	Resistance to Change and Cultural Barriers	Leadership Commitment: Secure strong support from senior management to model Agile values and create a culture of collaboration and adaptability.
		Gradual Transition: Implement Agile practices incrementally rather than overhauling the entire process at once.
	.	Change Management Initiatives: Use change management strategies to address resistance by highlighting the benefits of Agile frameworks through case studies, success stories, and pilot results
4.	Inconsistent Team Collaboration Across Functions	Cross Functional Training: Train teams to collaborate effectively across disciplines, breaking down silos and fostering a shared sense of purpose.
		Team Alignment Rituals: Use Agile ceremonies like standups and sprint planning to align cross functional teams.
5.	Limited Feedback Mechanisms for Continuous Improvement	Establish Feedback Loops: Integrate regular retrospectives and sprint reviews to gather team insights and stakeholder feedback.
		Data Driven Decision Making: Use metrics and dashboards to evaluate progress and inform adjustments.
6.	Technology Adoption Challenges and Tool Overload	Simplify Toolsets: Identify and adopt a core set of tools (e.g., Jira, Trello, Confluence) that meet project needs without overwhelming the team.
		Training on Tools: Provide hands on training on the selected tools to ensure proper usage and adoption.
		Technical Support: Establish a support structure for resolving technical challenges with Agile tools quickly.
7.	Unrealistic Expectations of Agile Results	Set Realistic Goals: Manage expectations by communicating those Agile focuses on incremental improvements rather than instant transformations.
		Frequent Progress Reviews: Share small wins and milestones regularly to demonstrate progress toward goals.

9. Conclusion

This paper focuses on the transformative power of Agile frameworks in tackling the issues of incorporating sustainability into the planning phase of digital twin deployment in the oil and gas sector. Agile methods, with their iterative and collaborative nature, present a structured yet adaptable approach to overcoming technological, organizational, and financial hurdles. Agile ensures that carbon efficiency targets are entrenched at all stages of planning by integrating tools such as EnergyPlus and real-time dashboards, as well as fostering stakeholder alignment.

The study demonstrates that Agile frameworks are more than just tools for managing complexity; they also promote long-term innovation. Regular feedback loops, collaborative ceremonies, and clearly defined roles let teams adapt swiftly to change objectives while remaining focused on lowering carbon footprints. For the oil and gas industry, which is notorious for its significant environmental impact, adopting Agile techniques provides a path to match operational excellence with global sustainability goals.

The findings suggest for more research on how emerging technologies like as AI and machine learning might improve Agile frameworks in digital twin deployment. Research should concentrate on creating standardized methods and measurements for evaluating carbon efficiency and scaling Agile adoption in resource-intensive industries. Cross-industry cooperation and longitudinal research on the environmental and economic effects of Agile-driven digital twin projects will also yield useful results.

Incorporating Agile frameworks into the planning phase of digital twin deployment in the oil and gas industry may minimize its carbon footprint, improve cooperation, and achieve commercial and environmental objectives.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

References

[1] Raj P, Surianarayanan C. Digital twin: The industry use cases. In: Advances in Computers. 2020. p. 285–320. Available from: https://doi.org/10.1016/bs.adcom.2019.09.006

[2] Fantozzi IC, Santolamazza A, Loy G, Schiraldi MM. Digital Twins: Strategic Guide to Utilize Digital Twins to Improve Operational Efficiency in Industry 4.0. Future Internet. 2025;17(1):41. Available from: https://doi.org/10.3390/fi17010041

[3] Attaran M, Celik BG. Digital Twin: Benefits, use cases, challenges, and opportunities. Decision Analytics Journal. 2023;6:100165. Available from: https://doi.org/10.1016/j.dajour.2023.100165

[4] Bello A, Magi F, Abaneme O, Achumba U, Obalalu A, Fakeyede M. Using Business Analysis to Enhance Sustainability and Environmental Compliance in Oil and Gas: A Strategic Framework for Reducing Carbon Footprint. ITEGAM-JETIA. 2024;10(50):76–85. Available from: https://doi.org/10.5935/jetia.v10i50.1303

[5] Dada MA. Digital Twins in the Upstream Oil and Gas Industry: Trends, Applications, and Challenges. North Africa Petroleum Exhibition and Conference (NAPEC), Oran, Algeria 2024. Available from: https://doi.org/10.5281/zenodo.14250614

[6] Weil C, Bibri SE, Longchamp R, Golay F, Alahi A. Urban Digital Twin Challenges: A Systematic Review and Perspectives for Sustainable Smart Cities. Sustainable Cities and Society. 2023;99:104862. Available from: https://doi.org/10.1016/j.scs.2023.104862

[7] Daraojimba CE, Nwasike C, Adegbite A, Ezeigweneme C, Gidiagba J. Comprehensive review of agile methodologies in project management. Computer Science & IT Research Journal. 2024;5:190–218. Available from: https://doi.org/10.51594/csitrj.v5i1.717

[8] Ekechi CC, Okeke CD, Adama HE. Enhancing agile product development with scrum methodologies: A detailed exploration of implementation practices and benefits. Engineering Science & Technology Journal. 2024;5(5). Available from: https://doi.org/10.51594/estj/v5i5.1108

[9] Popoola OA, Adama EH, Okeke CD, Akinoso EA. Conceptualizing Agile Development In Digital Transformations: Theoretical Foundations And Practical Applications. Engineering Science & Technology Journal. 2024;5(4). Available from: https://doi.org/10.51594/estj/v5i4.1080

[10] Hidalgo ES. Adapting the scrum framework for agile project management in science: Case study of a distributed research initiative. Heliyon. 2019;5(3):e01447. Available from: https://doi.org/10.1016/j.heliyon.2019.e01447

[11] Alencar B, Darli RV. Digital Twin Technology as a Tool to Enhance the Performance of Agile Project Management. Intech Open; 2023. DOI: 10.5772/intechopen.112489

[12] Afzal M, Li RYM, Shoaib M, Ayyub MF, Tagliabue LC, Bilal M, et al. Delving into the Digital Twin Developments and Applications in the Construction Industry: A PRISMA Approach. Sustainability. 2023;15(23):16436. DOI: 10.3390/su152316436

[13] Damij N, Damij T. An Approach to Optimizing Kanban Board Workflow and Shortening the Project Management Plan. IEEE Trans Eng Manag. 2021.

[14] Pavlíčková M, Mojžišová A, Bodíková Z, Szeplaki R, Laciak M. Integration and Implementation of Scaled Agile Framework and V-Model in the Healthcare Sector Organization. Electronics. 2024;13(11):2051. DOI: 10.3390/electronics13112051

[15] Stray VG, Moe NB, Sjøberg DI. Daily Stand-Up Meetings: Start Breaking the Rules. IEEE Softw. 2018;37:70-77.

[16] Abson E, Schofield P, Kennell J. Making shared leadership work: The importance of trust in project-based organisations. Int J Proj Manag. 2024;42(2):102575. DOI: 10.1016/j.ijproman.2024.102575

[17] Yin Z, Caldas C, De Oliveira D, Kermanshachi S, Pamidimukkala A. Cross-functional collaboration in the early phases of capital projects: Barriers and contributing factors. Proj Leadersh Soc. 2023;4:100092. DOI: 10.1016/j.plas.2023.100092

[18] Lucidchart. How to Conduct a Sprint Retrospective. 2024 [cited 2025 Jan 26]. Available from: https://www.lucidchart.com

[19] Schwaber K, Sutherland J. The Scrum Guide: The Definitive Guide to Scrum: The Rules of the Game. Scrum.org; 2020 [cited 2025 Jan 26]. Available from: https://scrumguides.org

[20] Adrielle CS, Isabela AA, Tábata N, Fernandes P, Milena SO. Scrum: A Systematic Literature Review. Int J Adv Comput Sci Appl. 2023;14(4). DOI: 10.14569/IJACSA.2023.0140420

[21] Bello A. CSA implementation strategies unraveling success and challenges. ITEGAM-JETIA. 2024;10(47):42-49. DOI: 10.5935/jetia.v10i47.1070

[22] El-Agamy RF, Sayed HA, Akhatatneh AMA, Aljohani M, Elhosseini M. Comprehensive analysis of digital twins in smart cities: a 4200-paper bibliometric study. Artif Intell Rev. 2024;57(6). DOI: 10.1007/s10462-024-10781-8

[23] Yu J, Bekerian DA, Osback C. Navigating the Digital Landscape: Challenges and Barriers to Effective Information Use on the Internet. Encyclopedia. 2024;4(4):1665-80.

[24] Roberts R, Flin R, Millar D, Corradi L. Psychological factors influencing technology adoption: A case study from the oil and gas industry. Technovation. 2021;102:102219. DOI: 10.1016/j.technovation.2020.102219

[25] Daramola GO, Adewumi A, Jacks BS, Ajala OA. Navigating Complexities: A Review Of Communication Barriers In Multinational Energy Projects. Int J Appl Res Soc Sci. 2024;6(4). DOI: 10.51594/ijarss.v6i4.1062

[26] O'Daniel M, Rosenstein AH. Professional communication and team collaboration. Patient Safety and Quality - NCBI Bookshelf. 2008 [cited 2025 Jan 26]. Available from: https://www.ncbi.nlm.nih.gov/books/NBK2637/

[27] Lane JN, Leonardi PM, Contractor NS, DeChurch LA. Teams in the Digital Workplace: Technology's Role for Communication, Collaboration, and Performance. Small Group Res. 2023. DOI: 10.1177/10464964231200015

[28] El Haouat Z, Essalih S, Bennouna F, Ramadany M, Amegouz D. Environmental optimization and operational efficiency: Analysing the integration of life cycle assessment (LCA) into ERP systems in Moroccan companies. Results Eng. 2024;22:102131. DOI: 10.1016/j.rineng.2024.102131

[29] Hariyani D, Hariyani P, Mishra S, Kumar Sharma M. Leveraging digital technologies for advancing circular economy practices and enhancing life cycle analysis: A systematic literature review. Waste Manag Bull. 2024;2(3):69-83. DOI: 10.1016/j.wmb.2024.06.007

[30] Zhang Z, Wei Z, Court S, Yang L, Wang S, Thirunavukarasu A, Zhao Y. A Review of Digital Twin Technologies for Enhanced Sustainability in the Construction Industry. Buildings. 2024;14(4):1113. DOI: 10.3390/buildings14041113

[31] Fallah Shayan N, Alavi S, Zahed MA. Sustainable Development Goals (SDGs) as a Framework for Corporate Social Responsibility (CSR). Sustainability. 2021;14(3):1222. DOI: 10.3390/su14031222

[32] Moshood TD, Rotimi JO, Shahzad W, Bamgbade J. Infrastructure digital twin technology: A new paradigm for future construction industry. Technol Soc. 2024;77:102519. DOI: 10.1016/j.techsoc.2024.102519

[33] Arsecularatne B, Rodrigo N, Chang R. Digital Twins for Reducing Energy Consumption in Buildings: A Review. Sustainability. 2023;16(21):9275. DOI: 10.3390/su16219275

[34] ElArwady Z, Kandil A, Afiffy M, Marzouk M. Modeling indoor thermal comfort in buildings using digital twin and machine learning. Dev Built Environ. 2024;19:100480. DOI: 10.1016/j.dibe.2024.100480

[35] Sebastian A, Jradi M. A review of building digital twins to improve energy efficiency in the building operational stage. Energy Informatics. 2024;7(1):1-31. DOI: 10.1186/s42162-024-00313-7

[36] Yang Z, Tang C, Zhang T, Zhang Z, Doan DT. Digital Twins in Construction: Architecture, Applications, Trends and Challenges. Buildings. 2024;14:2616. DOI: 10.3390/buildings14041116

[37] Zahedi F, Alavi H, Majrouhi Sardroud J, Dang H. Digital Twins in the Sustainable Construction Industry. Buildings. 2024;14(11):3613. DOI: 10.3390/buildings14113613

[38] Sarhadi P, Naeem W, Fraser K, Wilson D. On the Application of Agile Project Management Techniques, V-Model and Recent Software Tools in Postgraduate Theses Supervision. IFAC-PapersOnLine. 2021;55(17):109-14. DOI: 10.1016/j.ifacol.2022.09.233

[39] Jihan SK, Muhammad FM. Asana and Trello: A Comparative Assessment of Project Management Capabilities. Int J Inform Visualization. 2024;8(1).

[40] Sanugommula H. Exploring Confluence: Enhancing Collaboration and Knowledge Management in Modern Organizations. Int J Multidiscip Res. 2023;5(4).

[41] Wannes A, Ghannouchi SA. KPI-Based Approach for Business Process Improvement. Procedia Comput Sci. 2019;164:265–70. DOI: 10.1016/j.procs.2019.12.182

[42] Garwood TL, Hughes BR, Oates MR, O'Connor D, Hughes R. A review of energy simulation tools for the manufacturing sector. Renew Sustain Energy Rev. 2017;81:895–911. DOI: 10.1016/j.rser.2017.08.063

[43] Campamà Pizarro R, Bernardo R, Wall M. Streamlining Building Energy Modelling Using Open Access Databases—A Methodology towards Decarbonisation of Residential Buildings in Sweden. Sustainability. 2022;15(5):3887. DOI: 10.3390/su15053887

[44] Stogia M, Naserentin V, Dimara A, Eleftheriou O, Tzitzios I, Papaioannou C, et al. A Scalable and User-Friendly Framework Integrating IoT and Digital Twins for Home Energy Management Systems. Appl Sci. 2023;14(24):11834. DOI: 10.3390/app142411834