Journal of Industrial Engineering & Management Research
Vol. 6 No. 3
http://www.jiemar.org
e-ISSN : 2722-8878

Agile project management and emerging technologies in concurrent engineering for sustainable and collaborative product design

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Abstract
Designing sustainable and innovative products today requires more than just good ideas as it demands speed, flexibility, teamwork, and smart use of technology. This study used a systematic review approach guided by PRISMA to examine how Agile project management and emerging technologies enhance concurrent engineering for sustainable and collaborative product design. Literature was sourced from five major databases using targeted search terms. After a rigorous three-phase screening and quality appraisal, relevant studies were thematically synthesized around Agile, AI, automation, cloud platforms, ethics, circular economy, and composite manufacturing. The result showed that revealed that integrating Agile project management into concurrent engineering enhances flexibility, collaboration, and design responsiveness. Design automation and AI tools improve accuracy and decision-making, while cloud-based platforms strengthen real-time teamwork. Generative design supports creativity and rapid iteration. Ethical concerns like transparency and inclusivity emerged as essential. Circular economy strategies help reduce waste and extend product life. In composite manufacturing, concurrent engineering and group design improve material efficiency, product quality, and speed, demonstrating strong potential for sustainable innovation. The findings suggest that integrating Agile practices with emerging technologies creates a powerful framework for building smarter, greener, and more collaborative products now and in the future.
Keywords: Agile project management, concurrent engineering, sustainable design, emerging technologies, collaborative product development.

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e-ISSN : 2722-8878

1. Introduction

In the dynamic and competitive industrial world that we currently live in, there has never been a higher need or necessity to develop products in as fast, innovative and sustainable a manner as possible. Every attempt to mix traditional sequential engineering may create time delays, communication failures and design overlapping. Therefore, as an alternative strategy to product development, concurrent engineering (CE), which focuses on parallel task completion and multidisciplinary cooperation, has come into interest. Examples of such systems are agile project management (APM), a flexible approach with iterative planning, change responsiveness, and continuous collaboration is a complementary principle of CE aimed at managing change and, through that, continuous collaboration and effective workflow management processes (Badran et al, 2025). The combination of APM and CE with the unique technologies and opportunities of the future, like artificial intelligence (AI), cloud computing, and generative design, can transform likeminded product creation and challenges on long-term sustainability intentions in producing sectors.

Although the benefits of concurrent engineering and agile approaches are well documented, most companies have not managed to attain a smooth collaboration and long-term continuity in the product development. The main issues are associated with the insufficient merging of design teams, ineffective interdisciplinary communication, and a failure of using emerging technologies effectively. Furthermore, expanding environmental and social grievances and accountabilities on industries require that they take into account the principles of the circular economy, waste minimization, and open design (Rodriguez-Espindola et al., 2022). The customary management and engineering tools do not necessarily possess the flexibility needed to create dynamic design conditions, and this situation does not favor supporting real-time decision-making, iteration, and eco-friendly innovation. Thus, there exists a pressing need to investigate how agile project management, along with the current development of advanced digital technologies, can be used in improving concurrent engineering to design more sustainable and collaborative products.

Agile project management started in software development but has become more common in the engineering and manufacturing environment. Stakeholder participation, adaptive planning, and iterative progression are features that APM highlights and go hand in hand with the goals of concurrent engineering (Hamad & Sabir, 2023). Different product development processes including the design, prototyping, and testing are performed simultaneously parallel, as opposed to sequentially in CE. The addition of agile practices assists in handling the complexity and dependencies found among these parallel work activities, thus reducing time-to-market and enhancing customer responsiveness to customer needs. Scrum, Kanban, and Lean frameworks support continuous learning and development in the letting teams respond rapidly to changes in the project design requirements and feedback on projects by allowing projects to improve rapidly (Zayat & Senvar, 2020).

Existing technological trends have greatly promoted the ability of CE to operate effectively and sustainably. Design automation tools and artificial intelligence (AI) increasingly are utilized to automate engineering efficiency and optimize engineering activity, foresee the performance of designs and lessen the human error (Adeyeye & Akanbi, 2024). Engineers are able to assess a variety of design configurations quickly using AI-driven simulations, which can save material and encourage smarter decision-making. Generative design is a type of AI-driven innovation innovation that builds design alternatives with set restrictions and targets, enabling environmentally friendly resource utilization and maximum performance optimisation (Schwartz et al, 2021). Cloud technologies are also beneficial in facilitating CE, since they allow geographically distributed teams to share and work on data in real-time. Software like Autodesk Fusion 360 and Onshape have integrated systems that allow several stakeholders to work on and change the design in real time. This minimises communication barriers and improves co-creation. Those sites also accommodate version control, task tracking, and management of resources, which are key requirements to working agilely on a project.

Sustainability is an imperative goal in engineering design, and agile methods can support the creation of ongoing review of environmental impacts taking place across the product lifecycle. Within life cycle assessment (LCA) tools being used during the agile development cycle, the design teams will be keeping track of resources used, as well as emissions at any level or step. Concurrent engineering further contributes to sustainability through minimization of rework activities and redundancies hence waste of resources. In modern products and their

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development, both in terms of the complexity of development and the speed of development, the impetus to develop a study of agile project management and emerging technologies in concurrent engineering in crafting sustainable and collaborative product design is driven by the understanding that modern products require a sustainable and collaborative product design process. Conventional approaches to engineering are usually linear models that cannot scale to move quickly with the demands of the market and environmental limits, resulting in inefficiencies, long development time, and unsustainable solutions (Eidenskog et al, 2023). Although concurrent engineering creates a more comprehensive process, it is sometimes less adaptive and responsive to changing environments (Othman & Ali, 2024).

Moreover, the phenomenon of the introduction of agile methodologies into engineering practice is insufficiently studied, particularly in terms of the objectives of sustainable development and the circular economy. AI, cloud-based tools, or even generative design can be substantial advantages to the collaboration effort, yet most organizations underutilize these tools and have highly disjointed processes and designs. Ethical considerations, such as transparency in AI-assisted decisions and equitable stakeholder participation, are also inadequately addressed in current literature. Thus, there is an urgent need to investigate how agile project management and emerging technologies can be systematically applied in concurrent engineering to enhance sustainability, foster real-time collaboration, and close existing technological and ethical gaps in product design.

1.1 Research Questions

1. How is Agile Project Management implemented in Concurrent Engineering to enhance team coordination and project adaptability?
2. What roles do design automation and artificial intelligence-assisted tools play in improving design efficiency and decision-making in concurrent engineering processes?
3. How do cloud-based design and collaboration platforms support real-time group design and concurrent product development?
4. In what ways are generative design techniques applied in group design to foster innovation, performance optimization, and collaboration?

5. What are the prevailing ethical considerations in group design and concurrent engineering, particularly in the use of AI and shared digital platforms?
6. How is the concept of design for circular economy and waste reduction being integrated into concurrent engineering practices?
7. What are the applications and outcomes of group design and concurrent engineering in the development of reinforced composite products?

2. Methodology

This study adopted a systematic review approach to critically explore the integration of agile project management and emerging technologies within concurrent engineering for sustainable and collaborative product design. The review process was structured according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines, ensuring a transparent, replicable, and methodologically rigorous process. The systematic review aimed to synthesize existing literature and provide insights into the roles of design automation, artificial intelligence (AI), cloud-based collaboration, generative design, ethical practices, circular economy, and applications in composite product manufacturing within the broader scope of concurrent engineering and agile methodologies.

The study was guided by 7 research questions. To gather relevant literature, a comprehensive search was conducted across five major academic databases—Scopus, Web of Science, IEEE Xplore, ScienceDirect, and Google Scholar. These databases were selected for their extensive coverage of engineering, design, and project management research. The search was limited to peer-reviewed journal articles, book chapters, and conference proceedings published between 2014 and 2025, ensuring the inclusion of recent and relevant studies. Keywords and Boolean search phrases such as "Agile project management AND concurrent engineering", "AI-assisted design AND sustainability", "cloud-based collaboration platforms AND group design", and "generative design techniques AND circular economy" were used to identify relevant sources. Only publications written in English and directly related to engineering design and management were considered.

After completing the database search, all retrieved articles were subjected to a three-phase screening process. The first phase involved title screening to remove clearly irrelevant

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publications. The second phase included an abstract screening to assess the relevance of each study to the research objectives. In the final phase, full-text screening was performed on the remaining articles to evaluate their methodological quality and alignment with the review's scope. Duplicates were identified and removed using Mendeley reference manager. The PRISMA flow diagram was used to visually represent the selection process, indicating the number of records identified, screened, excluded, and included.

Data extraction from the selected studies focused on author information, publication year, research context, applied technologies or frameworks, key findings, and thematic relevance. This information was organized into a data matrix to enable thematic synthesis. The extracted data were analyzed qualitatively, with recurring themes grouped according to the main focus areas of the study: agile project management, concurrent engineering, design technologies, sustainability, collaboration, and ethics. Special attention was given to studies that presented empirical evidence of the benefits and challenges associated with these themes. To ensure the quality and credibility of the review, each included study was appraised using a modified version of the Critical Appraisal Skills Programme (CASP) checklist. It was possible to evaluate each of the studies based on clarity, relevance, methodology, and knowledge contribution using this checklist. Research papers that did not satisfy at least 70 percent of the appraisal criteria were avoided in the final analysis. In this way, only studies of high quality and synthesizing perfectly aligned with the theme of the thesis were synthesized, which augmented the reliability of the conclusions made. Only English-language sources and databases that had been available to the researchers were subjected to the review..

3. Results

3.1 Agile project management in concurrent engineering

Agile Project Management (APM) in Concurrent Engineering (CE) has become more applicable in contemporary engineering within manufacturing domains, requiring the dynamics of quick innovations, responsiveness to the customer, and multidisciplinary combinatory efforts. APM is an iterative, flexible choice of dealing with complex projects, whereas CE thinks about parallelization of work and sharing of communication between multidisciplinary teams. The recent literature has discussed the possibilities risks, and consequences of implementing agile in CE systems, particularly in product development, manufacturing, and designing of industrial systems. Agile project management focuses on flexible, successive design, stakeholder interaction, responsiveness to change, and constant delivery (Santoso et al., 2015). These values fit the goals of CE to shorten the product development time and improve the quality of the products through parallel execution of work and working together to solve the problems. Both approaches recommend early adoption of design, engineering, and product creation cycles, which means quicker feedback and less reworking. Chukwunweike and Aro (2024) noted that agile and CE overlaps have the benefit of making an organization generate value sooner and adapt to changing project needs, thereby decreasing the iteration of design cycles and increasing customer satisfaction.

Among the greatest opportunities of the integration of APM in CE is that departmental collaboration now occurs in real time. Agile brings transparency and visibility, and this is vital in CE where design, testing and production processes may be intertwined. Andersson (2022) reveals that agile impediments addressed through daily stand-ups, informal meetings, and sprint reviews contribute to effective team communication and decision-making capabilities, thus ensuring that tasks can be undertaken simultaneously. Moreover, the incremental model of agile delivery assists in discovering any flaws in the design or integration mishaps in the early stages, which follows the precept of CE that focuses on early error detection. However, the literature also points to several challenges. Agile methodologies were originally designed for software development, where physical constraints and regulatory requirements are minimal compared to traditional engineering fields (Figure 1). In CE environments, particularly in industries such as aerospace, automotive, and defense, rigid compliance structures, documentation standards, and hardware dependencies limit the adaptability of agile approaches (Dikert et al., 2016). Conforto and Amaral (2016) also observed that many engineering teams struggle to balance agile's lightweight processes with the rigorous demands of physical product development, leading to partial or inconsistent implementation.

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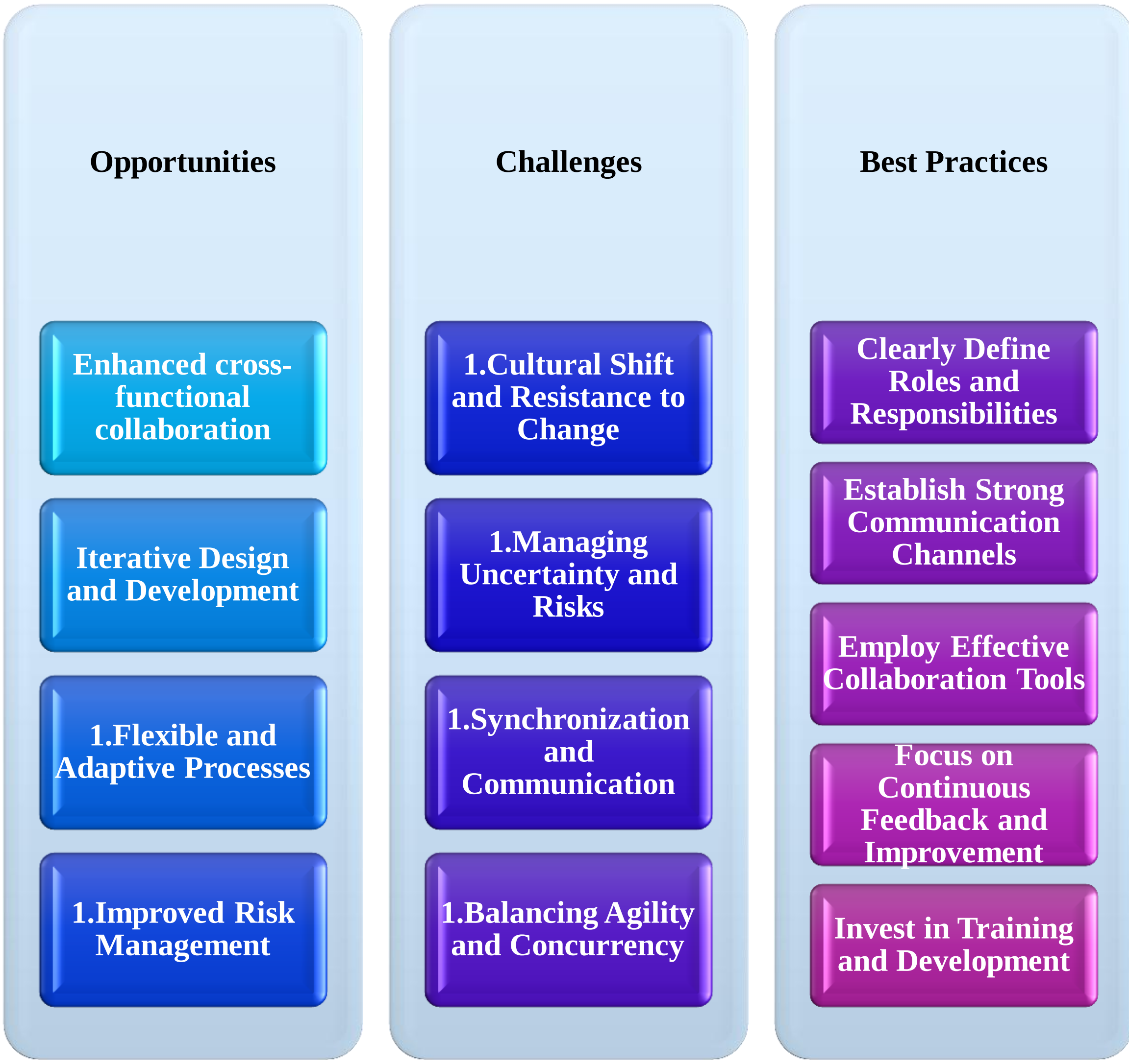

Figure 1: Opportunities, Challenges, and Best Practices for Integrating Agile Project Management in Concurrent Engineering.

Organizational culture and resistance to change are other significant barriers. In many engineering organizations, hierarchical structures and legacy project management practices hinder the collaborative and self-organizing team structures that agile requires (Serrador & Pinto, 2015). Further, there is also a mismatch between the training or experience of technical leads and project managers on agile principles, which also impacts how faithfully agile is adopted. Álvarez and Roibas-Millan (2021) are adamant that the success in the integration of agile-CE should not only be about adaptation of processes, but also a change of culture toward openness, experimentation, and continuous learning. In order to solve them, new works propose a hybrid approach to these issues, which allows integrating agile practices with established engineering standards. Cooper and Sommer (2018) introduced the AgileStage-Gate model that has the same formal design of stage gate reviews but incorporates agile iterations into each state. In this model, there is flexibility and speed, coupled with regulatory compliance and design rigor. It is likewise presented in Bohmer et al. (2020) who reported the applications of Scrum in a manufacturing setting, demonstrating that agile could be adapted to the development of hardware when coupled by clear documentation practices and stakeholder inclusion.

3.2 Design automation and artificial intelligence-assisted design in concurrent engineering

The recent development of artificial intelligence (AI) and design automation is significantly transforming concurrent engineering (CE) across the product life cycle and actualizing more integration, quicker loop times, and real-time across the product life cycle. Intelligent systems allow automation of routine processes and support decision-making and this is an important advantage of CE, which focuses on parallel design, analysis and manufacturing activities. Among the most important advancements in this regard is the use of generative AI in engineering design. According to a research conducted by Li et al (2025) AI integration in CAD/CAE pipelines resulted in shorter average design cycles, particularly with mechanical components like wheel rims.

In addition to generative design, the concept of multi-agent systems has cropped up as a powerful solution to the complexity of design in CE settings. Chen et al. (2025) characterized an AI-driven multi-agent system that can independently and concurrently address a variety of aesthetical design challenges: e.g., geometry generation, aerodynamics simulation. These agents operate simultaneously in agreement with the parallelism of human engineers within a CE environment. They helped with a major decrease in turnaround time and a better intra-departmental modeling, which makes them relatively adaptable in quick speed product development teams. Continuing with this trend, Jiang et al. (2025) coined the term of "Intelligent Design 4.0" that outlines the shift to the concept of full autonomy and agenticity of AI systems capable of planning, reasoning, and adapting throughout the design process. Their model also encompasses autonomous agents capable of self-learning depending on the results of the design, which is what CE focuses on because it will minimize delays and maximize efficiency of parallel task execution. This type of agent-based coordination enables higher loop feedback between design, testing and manufacturing planning.

At the same time, additive manufacturing (AM) is also emerging in CE in combination with design automation tools. AI-based topology optimization algorithms are demonstrated to demonstrate the capability of generating manufacturing-ready geometries alongside takes into account sustainability, cost and material constraints (Xu et al., 2023). It is especially helpful in CE where it is critical to reduce downstream rework. On the same note, He et al. (2023) have offered a pipeline integrating BIM (Building Information Modeling) and generative AI to automate structural design within a construction setting. Such integration assists designers to make informed choices during early-stage planning which is one of the most influential stages in CE. One of the enabling technologies throughout these advancements is the digital twin, an environment of real-time simulation that can be interacted with through AI-powered design systems. Digital twins, combined with generative models, can be used to update the product designs and the manufacturing strategies in real-time and co-optimize them (Xu et al., 2023). This enables CE teams to work in a more predictive manner identifying design issues prior to building any physical prototypes.

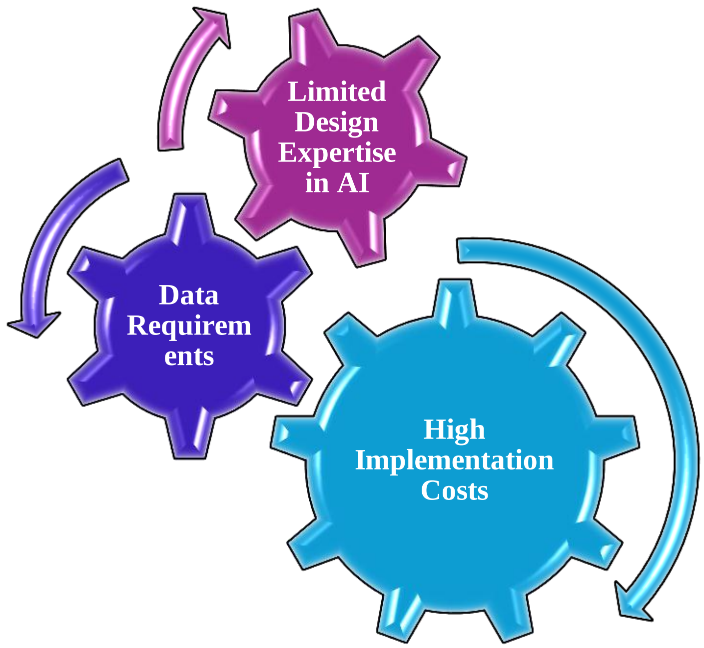

Figure 2: Challenges faced in integrating design automation and AI in Concurrent Engineering

However, the integration of AI in CE is not without challenges. Data interoperability, the complexity of legacy systems, and resistance to new tools remain barriers to widespread adoption (Mishra et al, 2023). Integrating design automation and AI into Concurrent Engineering is further challenged by high costs, limited AI literacy among designers, and the need for large, quality datasets for training algorithms—factors that hinder widespread and effective implementation across industries (Figure 2). Additionally, explainability remains a concern, especially in safety-critical industries like aerospace or civil engineering.

3.3 Cloud-based design and collaboration platforms in group design

Cloud-based design and collaboration platforms have become pivotal in enabling distributed and synchronous group design, especially as engineering and architecture projects shift toward remote and multi-stakeholder environments. These platforms leverage cloud computing to centralize data, facilitate real-time interaction, and support concurrent workflows among geographically dispersed teams. Onshape, a cloud-native CAD platform, exemplifies this shift by enabling multiple users to view and edit a single CAD model simultaneously from any device (iOS, Android, desktop), obviating the need for file version control or local installations (Onshape, 2025). Marion et al. (2021) analyzed Onshape's collaborative affordances and noted that engineers particularly leverage real-time visibility and community-shared resources, although full synchronous editing—akin to code collaboration on GitHub—remains underutilized.

Educational applications also highlight cloud CAD's collaborative impact. Cuperman, Verner, and Rosen (2024) incorporated Onshape into a collaborative prototyping course, finding that analytics tools offered by Onshape Education Enterprise improved teamwork, design iterations, and reflective practices among engineering students. Their study showed enhanced engagement in group-based redesign tasks, attributed to accessible cloud-based version tracking and shared workspaces. Beyond CAD, cloud-based BIM (Building Information Modeling) platforms serve as comprehensive collaboration hubs. Zhou et al. (2021) reported on P-BIM systems built on cloud architectures that support version control, clash detection, and cross-disciplinary design across civil, structural, and architectural domains. Similarly, Australian architects and students considered cloud BIM essential during the pandemic, noting its expansive ecosystem—integrating modeling, documentation, and analysis tools—as key to remote collaboration's effectiveness.

Customized private cloud systems are also increasing in adoption. Xu et al. (2023) described a bespoke private cloud platform that supports domain-specific workflows, embedding design standards, process tracking, and real-time data sharing tailored to the organization. This indicates that off-the-shelf cloud platforms may be insufficient for some contexts, prompting organizations to develop tailored solutions. Collaborative cloud-based CAM systems have also been devised in the manufacturing sphere with lending to CRDT (Conflict-free Replicated Data Types), allowing synchronous multi-user editing on 2D designs, messaging, and backend integration with the manufacturing information systems. Such environments illustrate the expansion of cloud collaboration to other downstream applications beyond CAD. By different fields there are three dominant themes of cloud-based design platforms; real-time concurrency, data and analytics centralization and integrational customizability. Concurrency in real time present in Onshape and CAM systems enables collaborative design to be synchronous and minimizes conflicts. The centralization of data creates single sources of truth and allows tracking activity and analytics (Marion et al., 2021; Cuperman et al., 2024). The custom integration means that platforms can be combined with workflows in a domain-specific process, like in the case of the private cloud and BIM systems (Xu et al., 2023).

3.4. Generative design techniques in group design

Generative design processes gained momentum over the last couple of years, presenting effective solutions to collaborative design efforts. Generative systems have been embraced in the group design process in areas as diverse as engineering, architecture, and learning; improving speed, collaboration, and creativity in many aspects, including AI-assisted brainstorming and visual prototyping. The application of large language models (LLMs) to group ideation has become one such innovation area. In the study by Shaer and others (2024), the authors investigated the opportunities of using LLMs during brainwriting sessions a creativity tool in which members of a group exchange ideas. Their evidence indicated that AI integration did not only enhance the volume of the ideas generated but also drove the improvement in novelty and variety of the ideas. The LLM was not designed to replace human creativity, but it was a teammate, assisting the participants to think in new directions or reframe ideas. A third fascinating change is that of multi-agent systems, with various AI agents created to fulfill roles normally the work of team members. As an example, Ding et al. (2023) proposed DesignGPT where three AIs could be used, one proposing a design, one assessing it, and one improving it. The system replicates the way actual design teams operate, and initial experiments indicate that it has the potential to increase performance as well as creativity when combined with human teams. Generative design is another way to innovate group design allowing a user to explore more design possibilities, enable collaborative ideation, facilitate trade-offs, and involve stakeholders as shown in Figure 3. Its graphic and dynamic process promotes an inclusionary decision-making environment and allows teams to explore numerous solutions as new ideas find their way into the ultimate design..

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http://www.jiemar.org
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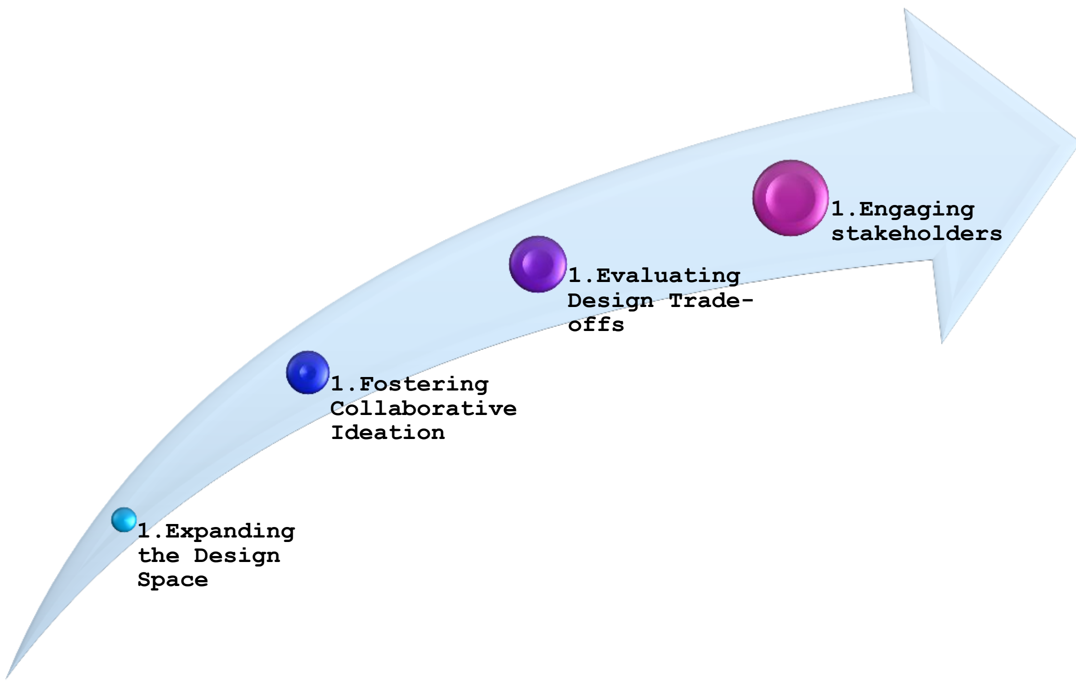

Figure 3: Benefits of Generative Design in Group Collaboration

Generative design has been used in architecture and construction industry by integrating with Building Information Modeling (BIM) tools that enable teams to experiment and quickly test a broad spectrum of structural possibilities. Abrishami, Goulding, and Rahimian (2021) targeted teams working on building layouts by coming up with G-BIM, which is a generative design workspace allowing project teams to experiment with alternative building layouts at the early stages of the design process. Notably, this system allows design intent, which is important especially in group work when many individuals are working on the final product. At the same time, Ko, Ajibefun, and Yan (2023) went even further and integrated generative AI, BIM, and parametric modeling into a single workflow. Powered partly by ChatGPT, the system assisted the architects in creating 3D models of their creations, using natural language descriptive---in other words, the team discussions were transformed into visual prototyping. This enabled design teams to go concept-to-visualization in much shorter time and enabled everyone to be on the same page with the vision.

Visual AI platforms such as Midjourney are finding their place in design education as well. This technology has been used in urban design studios by Yildirim (2023), who discovered that it has enabled students to create visuals on a timely basis, which are easily debated and ameliorated during group discussions. The common visualizations allowed making abstract concepts concrete and opening up to a more in-depth collaboration and inclusion in the discussion. It is possible to note certain regularities even in these very different applications. First, effective group generative design can have a feedback-loop of prompting, assessing, and refining ideas, which both AI and humans can engage in. Second, assigning AI particular roles (as evaluator, visualizer) allows teams to concentrate on innovative decision-making. Lastly, using generative tools with established platforms such as BIM or CAD will make it consistent and practical.

3.5 Ethical considerations in group design and concurrent engineering

Ethical issues have gained prominence as engineering and design teams have since been moving towards more collaborative and concurrent work models. Other studies focus on a need to be concerned about autonomy, justice, transparency, and trust, particularly within the domain of AI-intensive, human-centered industrial environments. Among the most notable ones is the idea of human autonomy and a sense of agency in collaborative settings with automation or robots. A Delphi study composed by European ethicists suggested a framework in which the decision authority remains within a worker involved in factory-floor human-robot collaboration, paying their attention to human dignity and resilience (Callari et al., 2024). This is in line with fundamental values of ethics, which should dominate design choices, namely beneficence, non-maleficence, autonomy, and justice, and automation should complement human workers, rather than replace them.

Information security, monitoring, and trust are issues introduced by the use of concurrent engineering/group design, whereby the behaviors of users are tracked by AI systems. Liang et al. (2024) used systematic reviews of ethical issues in AI in the AEC sector and reported the concerns of data privacy, transparency, and monitoring fear. Cociancig, Heuer, and Breiter (2024) also emphasized the importance of integrating ethical values (including fairness, accountability, and contestability) into collaborative ideation tools, to stay transparent and human-centered in the course of group sessions. Value-sensitive design (VSD) and value-based engineering (VBE) provide systematic implementations of systematic inclusion of ethics in design. Umbrello (2020) generalized VSD to AI systems, making them conform to human well-being, justice, and dignity. VBE also implements IEEE 7000 standards by employing value elicitation that involves stakeholders, risk analyses, and ethical requirement evolutions in an iterative manner. These frameworks facilitate parallel design because they make sure that the values of various stakeholders are taken into account during development.

Professional and social ethics is also a key factor. Hsu (2021) discovered that more ethically sensitive in collaborative design environments were enjoyed by engineering students with a greater appreciation of user needs, supporting the view that stakeholder input in real-time environments can contribute to engineering ethical awareness. Similarly, Ondrusch and Quandt (2025) pointed out the importance of collaborative, user-oriented learning environments in ethical reflection as opposed to simple compliance, which makes students develop an image of the effect of their designs in the society. To the extent AI and automation are incorporated into the concept of concurrent engineering, responsible AI governance frameworks are critical. A catalogue of responsible AI patterns proposed by Lu et al. (2024) aims to enable teams to apply fairness, explainability, and accountability in a more systematic manner at the design and deployment stages: including governance, process, and product-level patterns. Researchers propose systems like interdisciplinary discussion, ethical reflection milestones and clear data policies as a way of operationalizing these principles. This intersection of ethics on the technical, professional, and social levels needs constant consideration and active adaptation.

3.6 Design for circular economy and waste reduction in concurrent engineering

The circular economy concepts in concurrent engineering have gained traction over the past few years, and industries are showing more concern over the sustainability angle. Circular economy considerations embrace reuse, recycling, and resource productivity, and concurrent engineering provides an ideal environment where such aspects can influence the product development at its initial phases. One of the primary topics of the literature is material efficiency and dematerialization of structure. Spreafico (2022) reviewed how component structures can be optimized during the design process to minimize the amount of materials used and the resulting wastes. The research made it clear that streamlining design geometry made improvements in reducing environmental loads, a more conservation-friendly stance of design to production. The other necessary factor is the designing of products to be dismantled and modular. Gasparri et al (2021) reaffirmed the fact that recovering material and prolongation of product life is easier when it is designed, and selected product parts are detachable and reusable. When other disciplines must interact in concurrent engineering environments, this plan would help teams to think through end-of-life planning during the initial phases, rather than treating them as an afterthought.

Digital technologies have been another source of facilitation. Technologies like Building Information Modeling (BIM), digital twins and cloud-based simulations give real-time estimation on used resources and environmental conditions. As demonstrated by Lim et al. (2020), digital twins assisted design teams in monitoring the movement of materials, environmental impact, and potential reuse, some of the advances made during the development process. This move to real-time feedback enables more circular goals-driven design information. The application of Industry 4.0 tools together with the thinking of the circular economy has yielded encouraging results in the construction and manufacturing industries. According to a research article by Flores-Lara et al. (2025), the case studies featured in the article concerns the use of smart technologies and cloud systems in the UAE, which helped to improve resource use and minimize wastage and embrace reuse. How these tools helped teams to easily collaborate in different stages of the design and production cycle is also discussed in their work.

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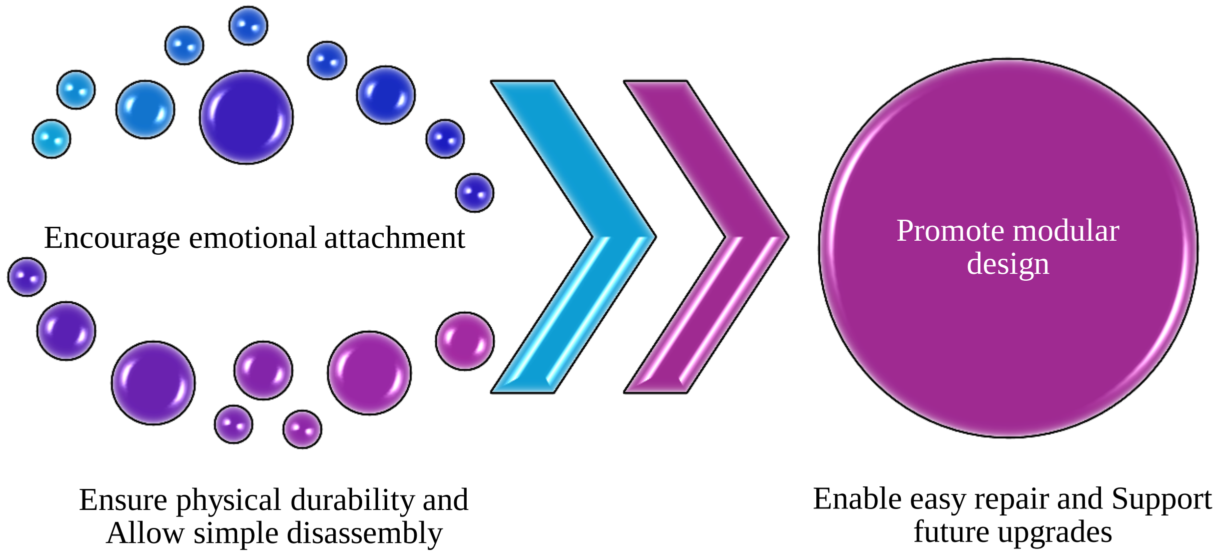

Figure 4: **Strategies for Circular Product Design and waste reduction**

Circularity can also be established at the system level beyond product-level improvements with industrial symbiosis. As explained by Ginga et al. (2020), industries can share waste streams, and use by-products of one process as input of another process. This kind of thinking will promote a more holistic, environmentally responsible planning in a concurrent engineering environment where cross-functional collaboration is already a standard. Automation is also involved in the closure of material loops. High-level waste-sorting machines use AI and deep learning to better detect and separate recyclable material. Such technologies aid attempts to recycle recovered material back into the design chain so that valuable resources do not needlessly tend to run out. Circular product design strategies give attention to the period of increased product life cycle and production waste through emotional durability, physical resilience, modularity, ease of maintenance, upgradability, and dismantling (Figure 4). These innovations assist in combating obsolescence in different dimensions, so that the products stay useful, fixable, flexible to the changing requirements of customers (Cura, 2016).

3.7 Application of group design and concurrent engineering in reinforced composite product manufacturing

Over the years, researchers have made significant progress in composite product development using natural and hybrid fibers. Ihueze, Obiafudo, and Okafor (2016) explored plantain fiber-reinforced polyethylene for auto body fenders, while Okafor and Metu (2019) discussed fatigue response in structural applications. Similarly, Okafor et al. (2022) developed carbonized wood/silicon dioxide composites for shoe soles, and Ihueze et al. (2024) examined the quality characteristics of miscanthus fiber-reinforced polypropylene. While these studies offer solid material information, most focus heavily on modeling, mechanical testing, or material performance in isolation. Okafor et al. (2025) proposed a framework for optimizing composite product design for sustainability, yet the practical integration of collaborative, real-time design approaches remain underdeveloped. Other studies, such as robust modeling for armor applications (Ihueze, Okafor, & Obende, 2024), electrical cable insulation process optimization (Ihueze et al., 2023), and hybrid composites for hardness and wear resistance (Okafor et al., 2023), still lean toward experimental modeling over system-level collaboration. Even in works focused on natural fiber piping systems (Ihueze et al., 2021) and automotive hybridization (Okafor et al., 2021), concurrent engineering and group design principles are largely missing. Such technologies as Automated Fiber Placement (AFP) or Tailored Fiber Placement (TFP), when used together with collaborative design can reduce this gap.

The finer placement of materials is offered by automated fiber placement (AFP) and tailored fiber placement (TFP) systems, which enable less waste and the proper level of reinforcement in the place where it is most needed. Such technologies enable collaborative design spaces in combination with structural, process, and material engineers sharing information simultaneously (Fascio et al., 2025; Kukwi et al., 2025). Machine learning and digital tools have also been able to enhance concurrent workflows. A team at NASA partnered with the University of Texas to use real-time data and machine learning to adjust autoclave curing cycles for composite parts. The method resulted in more accurate temperature control, shorter curing times, and improved part consistency (Humfeld et al., 2021). Digital platforms like CrossTrack also help coordinate tasks across departments, from design and nesting to material usage and expiry tracking. As see in Figure 5, Group design and concurrent engineering in reinforced composite manufacturing offer benefits such as faster development, improved product quality, reduced manufacturing costs, and optimized designs. Collaboration among multidisciplinary teams helps identify design flaws early, ensures manufacturability, enhances communication, and minimizes waste, ultimately leading to efficient, cost-effective, and high-performance composite product development (Simões, 2024).

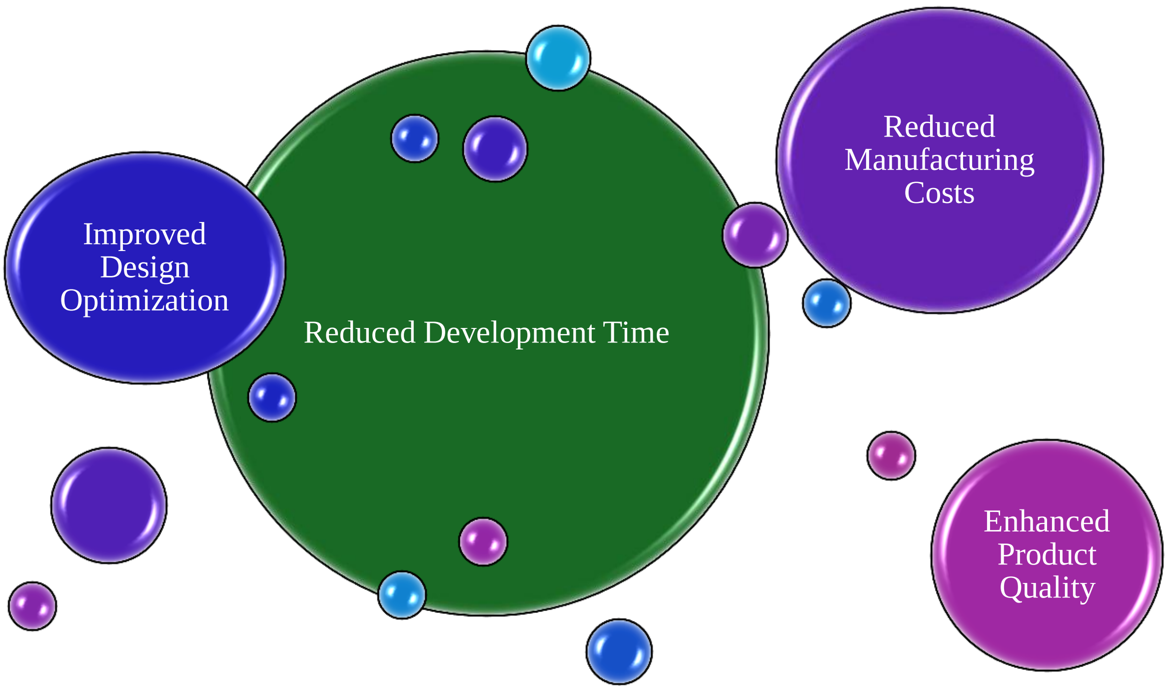

Figure 5: Benefits of Group Design and Concurrent Engineering in Reinforced Composite Manufacturing

Additive manufacturing introduces new opportunities for collaboration. Ho et al. (2024) introduced a workflow combining topology optimization with continuous carbon fiber printing. Through this approach, teams created high-strength composite structures with less material and better load-bearing capacity. Zhang et al. (2023) also worked on robot-assisted additive manufacturing that aligned fiber orientations with complex curved geometries. It was used so that design and fabrication teams could collaboratively develop tooling paths and structural layout to ensure the design process remained flexible and efficient. The group design is successful in environments where groups handle various magnitudes of modeling simultaneously. The study by Castricum et al. (2022) covered multi-scale modeling, which bridges the gap between the fiber orientation at a micro scale (micro-scale mechanical behavior) and the macroscopic-level mechanics. This provided the engineers with a common language in the material behavior so that they would be able to make informed decisions without having to rely on frequent prototyping.

A number of studies have demonstrated just how such cooperative efforts cut down on time, resource expenditure. The design was optimized through simulation to reduce more material and keep the strength. One example is the Materials waste reduction where teams were able to reduce the weight and material waste by early-stage ply optimization (Hughes, 2023). Similar advantages were provided in TFP systems by fiber placement accuracy and controlled scrap. One of the most important trends in these inventions is the relevance of common digital infrastructure. The synchronization of CAD models as well as real-time dashboards and traceable material data helped teams to become more communicative. These tools allowed each contributor, whether interested in design, simulation or production, to remain on the same page and to progress together in the same direction.

Conclusion

This paper has discussed the use of concurrent engineering, in which Agile project management, in combination with novel technologies, provides sustainable and cooperative development of products. Agile embraces flexibility, quicker feedback, and collaboration, which are the major strengths that align with concurrent engineering that is based on cross-function cooperation. New tools such as AI-based design automation and generative design tend to enable teams to make more informed decisions, iterate through many possibilities, and eliminate early errors. With cloud-based platforms, collaboration is simpler, with real-time input of various stakeholders, irrespective of their location. These instruments enable groups to remain diverted and effective during the design process. The generative design is also one that fosters creativity and group discussion and provides a range of design options. Ethics are crucial here, especially as design will rely more on automation. Groups are required to be transparent, even handed, and accountable in their operations. Sustainable design principles, like modularity, durability, and disassembly, are essential to help cut down wastes. These strategies should be woven into activity rather than added as additional features related to the circular economy requirements and the value of products throughout their lifetime. Group design and concurrent engineering in composite manufacture have resulted in superior product quality, lower cost, and less wastage of materials. Combined with Agile and technology, teamwork establishes a robust base of fast, responsible, and future-proof offers.

Acknowledgement

We would like to graciously appreciate the encouraging advice and support of Engr. Christian Emeka Okafor, Ph.D., Department of Mechanical Engineering, Faculty of Engineering, Nnamdi Azikiwe University, Awka, Anambra State Nigeria throughout this study work. His engaging and insightful delivery of the course *group design and concurrent engineering (MEC 939)* sparked our interest and laid the foundation for this research. We are especially grateful for his encouragement, constructive feedback, and genuine dedication to our academic growth. This work would not have taken shape without his mentorship, and we truly appreciate the role he played in making it a success.

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