Benchmarking in Stealth Construction: A Drive Towards Sustainable and Resilient Construction Industry at the Pre-construction Stage

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Abstract

In the context of increasing environmental concerns and the demand for resilient infrastructure, there is a pressing need to explore innovative practices in the construction industry. The study emerged as a critical investigation towards mitigating these concerns by focusing on benchmarking in stealth construction to promote sustainability and resilience. It utilised a qualitative approach through a systematic literature review to present a novel practice in stealth construction. It brings resilience and sustainability into construction through building cross-section areas, safety features, radio frequency emission, and efficient countermeasures. The findings indicate that integrating stealth techniques can significantly reduce environmental impact, enhance durability, and improve overall project efficiency. This was achieved through combining technological practices in construction 4.0/5.0 and sustainable practices, energy efficiency, safety protocols, and innovative construction methods. The research implications underscore the potential for stealth construction to lead the industry towards more sustainable and resilient methodologies, providing a roadmap for future developments and policymaking in construction practices.

Keywords

Benchmarking, Environmental protection, Resilient construction, Stealth construction, Sustainability

1. Introduction

The construction industry faces increasing pressure to address environmental sustainability and enhance resilience in the face of climate change and natural disasters, as illustrated by Shamout et al. (2021). Traditional construction methods often fail to meet these demands, necessitating exploring innovative approaches. The construction industry significantly contributes to global economic and physical development, with its value projected to grow from USD 7.28 trillion in 2021 to USD 14.41 trillion by 2030 at a CAGR of 7.3% (Opoku et al., 2024). This growing demand has spurred competitiveness, prompting companies to adopt new management tools and practices, such as benchmarking, to systematically enhance performance by comparing against peers (Harris et al., 2021).

Stemming from stealth technology, discussed by Zohuri and Zohuri (2020), stealth construction is a novel approach that blends multiple construction techniques (including lean construction, value management, supply chain management, smart construction, and others) with the latest advancements in Construction 4.0/5.0. This method is applied throughout all major stages of construction—pre-construction, during construction, and post-construction. The primary objective is transforming industry standards and promoting greater resilience and sustainability. Stealth construction, which emphasises minimal environmental impact and maximised efficiency, offers promising solutions. Tian and Ketsaraporn (2013) stated that benchmarking allows organisations to systematically implement performance improvements by comparing their performance with industry peers, and by applying these techniques, the construction industry can identify best practices and set standards for greater sustainability and resilience. The study, therefore, established that benchmarking can guide the construction industry in adopting sustainable and resilient practices as it helps it move towards a stealth construction industry.

2. Literature

2.1 Benchmarking for Stealth construction (at pre-construction)

Previous research has highlighted the significance of benchmarking in improving organisational efficiency, aligning project plans with industry standards, and fostering best practices. However, most studies focus on general construction without specifically addressing the unique needs of stealth construction, which integrates environmental protection, safety enhancement, and quality improvement while maintaining aesthetics. Existing literature like Costa et al. (2006), Presley and Meade (2010), Dong et al. (2021), and He et al. (2021), amongst others, discusses various aspects of benchmarking, such as optimising building design for energy efficiency, visibility reduction, advanced RF technology adoption, and sustainable construction methods. Despite these insights, comprehensive research on benchmarks tailored to stealth construction's specific requirements is lacking. This gap suggests that while benchmarking is a well-established practice in general construction, its application in stealth construction remains underexplored. This study aims to fill this gap by developing benchmarks that address the unique challenges and opportunities in stealth construction, guiding the industry toward more sustainable and resilient practices.

Construction benchmarking is a crucial management practice for enhancing organisational efficiency and performance (Kim & Huynh, 2008). Massa and Testa (2004) emphasise its importance during project planning to align with industry trends and best practices, monitoring aspects like project schedule, cost, and design against industry standards and past projects. Hopkinson (2017) added that this proactive approach in the pre-construction phase optimises planning, resource management, risk mitigation, and overall project success, fostering efficiency and effectiveness through insights from previous experiences or industry leaders. In stealth construction, which prioritises environmental protection, safety enhancement, and quality improvement without compromising aesthetics, benchmarking aids in identifying sustainable practices and cutting-edge technologies across construction phases (Opoku et al., 2024).

In stealth construction, benchmarking helps identify techniques that reduce environmental impact, improve safety protocols, and increase quality standards, as shown in Figure 1 below. This section explores the idea of stealth construction, examining how benchmarking can improve construction principles through tools such as building cross-section areas, safety features, radio frequency emission, and efficient countermeasures, which ultimately contribute to a balanced combination of advancement and appearance. The tools for benchmarking stealth construction can be explained explicitly below.

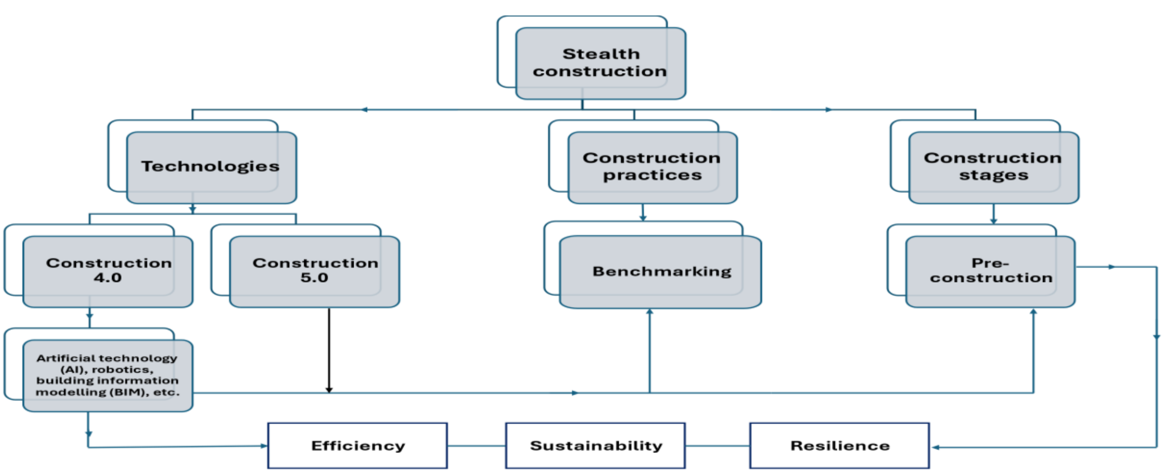

Fig. 1. Benchmarking framework in stealth construction (authors')

Table 1 summarises various benchmarking initiatives to enhance stealth construction practices across different areas. To begin, building cross-section development focuses on optimising energy efficiency, natural lighting, and ventilation in stealth construction, using benchmarking to improve security, reduce environmental impact, and enhance operational efficiency. Furthermore, visibility benchmarking influences architectural design to integrate functionality with surroundings, improve user experience, and select eco-friendly materials and camouflage techniques for sustainability. Also, Radio Frequency (RF) technology benchmarking enhances construction productivity, safety, and cost efficiency while ensuring compliance with energy efficiency and environmental standards. In addition, countermeasures benchmarking involves strategic actions to improve stealth construction practices, focusing on systems like occupancy sensors and smart security. Finally, construction methods benchmarking promotes efficiency and sustainability through innovative techniques like modular construction and rubberised concrete, aligning with evolving building standards. Overall, the diverse benchmarking initiatives detailed in Table 1 underscore the critical role of systematic comparison and adaptation in enhancing construction practices, ensuring improved efficiency, sustainability, and resilience across various facets of the industry.

Table 1. Summary of benchmarking initiatives for enhanced stealth construction (authors' summary)

Benchmarking initiated practice	**Summary variables**	**Benefits**	**Authors**
Building Cross-Section Development	Energy efficiency, natural lighting, and ventilation	Building cross-section development is crucial for stealth construction, optimising the design for energy efficiency, natural lighting, and ventilation, using benchmarking to compare practices against industry standards to enhance security, reduce environmental impact, and improve operational efficiency.	Keshavarzian et al. (2021), Mittal et al. (2019), Roque et al. (2020), Hu et al. (2023)
Visibility	Strategic location, interaction with surroundings and inhabitants,	Benchmarking architectural design accessibility impacts functionality integrates with the environment, enhances user experience, and guides strategic location selection, eco-friendly materials, and camouflage techniques to achieve reduced visibility and sustainability in stealth construction.	Abshirini and Koch (2013), Askar et al. (2021), Aksha and Emrich (2020), Alamry (2024), Umoh et al. (2024)
Radio Frequency (RF) Technology	Productivity, safety, and cost efficiency	Benchmarking advanced Radio Frequency (RF) technologies in construction enhances productivity, safety, and cost efficiency while minimising detectability and interference risks, ensuring alignment with innovations, energy efficiency, and environmental standards for optimised project performance.	Egea-Lopez et al. (2005), Koppel and Haldre (2015), Lessmann (2015), Wang et al. (2020)
Countermeasures	Strategic actions, collaboration	Effective deployment of countermeasures ensures continuous improvement in stealth construction, systematically addressing gaps to meet or exceed industry standards. Benchmarking in stealth construction focuses on specific systems like occupancy sensors,	Jin et al. (2013), Ding et al. (2023), Moudgil et al. (2023), Cano-Suñén et al. (2023)

		adaptive lighting, integrated HVAC, climate control, and smart security systems.	
Construction Methods	Foundation techniques, modular construction, robotic beam	Benchmarking these innovations ensures construction practices are efficient and environmentally conscious, aligning with evolving standards for sustainability and resilience in building practices. Furthermore, rubberised concrete, which incorporates waste tyres to improve concrete performance and address tyre disposal challenges, exemplifies innovative solutions that reduce environmental impact.	Esmaeilpour et al. (2022), Spagnoli and Tsuha (2020), Hossain et al. (2020), Ahmad et al. (2023)

3. Study's method

The study employed a qualitative research method through a systematic literature review (SLR) to investigate benchmarking in stealth construction through contextual understanding. This approach was adopted because it allows for a comprehensive synthesis of existing knowledge, providing a detailed understanding of complex phenomena (Hennink et al., 2020). Saini and Shlonsky (2012) added that when research is systematically identified, evaluated, and interpreted across relevant studies, a qualitative method ensures a robust analysis of current practices and trends in the construction industry. The qualitative method is particularly suited for exploring aspects of stealth construction, such as environmental impact and structural resilience, which quantitative methods might overlook (Barker & Pistrang, 2021). Furthermore, a systematic review facilitates the identification of gaps in the previous literature, guiding future research and practical applications (Tranfield et al., 2003). This methodology underpins our study's aim to establish effective benchmarks for sustainable and resilient construction practices.

4. Discussion

In the ever-changing world of construction, stealth construction highlights the importance of benchmarking, a systematic process of measuring and improving performance against recognised standards. It aims to achieve construction that is not only efficient but also environmentally sustainable, safe, fast, cost-effective, and visually pleasing. Moving toward resilience, the literature from the previous studies showed the significance of integrating benchmarking in construction. Further discussions show that it can be effective towards environmental protection, safety, speed, economy, and aesthetic considerations are the core benchmarks that guide the construction industry toward more effective and resilient practices. It can thus be said that benchmarking in construction has the ability to bring resilience even to a novel practice in construction like stealth.

4.1 Environmental protection

Environmental protection is paramount in stealth construction, emphasising sustainable practices, energy-efficient systems, waste reduction strategies, and environmentally conscious site management to minimise ecological impact (Hossain et al., 2020). Starting with Sizirici et al. (2021), benchmarking successful projects that prioritise sustainability allows construction teams to adopt eco-friendly materials with lower carbon footprints and recycled content. Furthermore, integrating energy-efficient systems, including renewable energy sources and smart technologies, improves overall project sustainability by reducing energy consumption (Metallidou et al., 2020). Kabirifar et al. (2020) added that effective waste reduction strategies, informed by benchmarked projects with robust waste management plans, optimise resource utilisation and minimise construction waste. Implementing environmentally conscious site management practices, such as preserving natural habitats and minimising soil disturbance, enhances environmental protection efforts (Li et al., 2020). Finally, Olatunde et al. (2024) identified that benchmarking in smart water management guides the adoption of water-efficient practices like rainwater harvesting and low-flow fixtures, contributing to water conservation and reducing environmental impacts.

4.2 Safety

In stealth construction, safety is paramount, necessitating rigorous measures to minimise risks and ensure a secure environment. Implementing benchmarking practices in safety protocols allows construction teams to glean insights from successful projects and industry standards to establish and refine best practices effectively. This approach includes adopting comprehensive safety protocols with clear guidelines, robust emergency response plans, and personal protective equipment (PPE) protocols based on benchmarks from projects with exemplary safety records (Simpeh & Amoah, 2022). Learning from projects integrating advanced safety technologies such as wearable devices and real-time monitoring systems enables construction teams to enhance safety monitoring and hazard mitigation efforts (Nnaji et al., 2021). Moreover, benchmarking helps implement rigorous safety training programs that ensure all workers are well-versed in safety procedures and emergency response, fostering a proactive safety culture (Ahn et al., 2020).

4.3 Construction speed (duration)

In stealth construction, duration is prioritised alongside efficiency, revolutionising traditional construction models by integrating advanced technologies and streamlined processes to expedite project timelines effectively. Xing et al. (2021) illustrated that benchmarking lean construction practices allows construction teams to optimise resource utilisation, minimise waste, and enhance project efficiency through principles like just-in-time delivery and collaborative planning. Furthermore, benchmarking against projects employing advanced technologies such as Building Information Modelling (BIM), drones, and robotics identifies automation and productivity enhancement opportunities. BIM, for instance, enables digital project simulations that streamline planning and coordination, setting benchmarks for accelerated project delivery by minimising errors and improving efficiency (Chen et al., 2022). Prefabrication benchmarks also play a crucial role in reducing on-site assembly time and expediting construction processes through off-site fabrication of components (Smith & Quale, 2017).

4.4 Economy

In stealth construction, achieving economic efficiency involves balancing cost-effectiveness and quality by strategically benchmarking successful projects and methodologies. Supply chain management benchmarks focus on optimising procurement processes through strategies like bulk purchasing and just-in-time delivery, which can significantly reduce costs (Blanchard, 2021). Debele et al. (2024) added that value engineering benchmarks highlight successful applications of cost optimisation principles, enabling construction teams to maximise value while minimising expenditures. Lean construction practices, such as lean scheduling and continuous improvement, streamline workflows and eliminate waste, enhancing project efficiency and cost-effectiveness.

4.5 Aesthetics

In stealth construction, aesthetics is crucial in achieving visual harmony and design excellence through strategically benchmarking successful projects and methodologies. Nature-inspired designs are a benchmark for integrating natural elements into construction, using shapes, colours, and patterns in the environment to seamlessly blend structures with their surroundings (Purwaningsih et al., 2024). Benchmarking discreet architectural features guides construction teams in minimising visual impact while maintaining elegance by carefully using angles, shapes, and materials. Additionally, studying benchmarked colour palettes helps teams select tones that complement the natural environment, promoting visual cohesion in stealth construction projects. Insights from benchmarked innovative materials, such as those with unique textures and light-reflective properties, inform construction teams on functional and aesthetically pleasing solutions. Effective lighting design benchmarking aids in creating visually appealing structures, particularly enhancing nighttime aesthetics and overall project visual appeal in stealth construction.

5. Conclusion

Stealth construction exemplifies a transformative approach in the building industry, prioritising security, efficiency, sustainability, aesthetics, and safety. Construction benchmarking is crucial for enhancing organisational efficiency and performance. It optimises planning, resource management, risk mitigation, and overall project success by monitoring project schedules, costs, and designs against industry standards and past successes. In stealth construction, benchmarking is critical in identifying and adopting sustainable practices, cutting-edge technologies, and efficient construction methods that minimise environmental impact, enhance safety protocols, and improve quality standards. This study showed that this proactive approach ensures compliance with stringent security requirements and fosters advancements in construction methodologies that prioritise speed, economy, and aesthetic integration. Through strategic benchmarking, the construction industry continues to evolve towards more efficient, sustainable, and visually harmonious building practices, shaping a future where construction projects achieve heightened operational excellence while meeting stringent environmental and aesthetic standards.

Considering Sustainable Development Goals (SDGs) and the African Agenda 2063, the study aligns in significance. Specifically, it contributes to SDG 9 (Industry, Innovation, and Infrastructure) by promoting sustainable and resilient infrastructure development through efficient construction practices. It supports SDG 11 (Sustainable Cities and Communities) by advocating for environmentally conscious building designs that minimise ecological footprints and enhance urban resilience. Moreover, the study aligns with SDG 13 (Climate Action) by emphasising energy-efficient systems and sustainable materials in construction. In African Agenda 2063, the study supports aspirations for infrastructure development, industrialisation, and sustainable growth across the continent, aiming to foster inclusive economic development and environmental stewardship through benchmarked construction practices. In terms of the study's limitations, there is a need for more extensive empirical validation across diverse geographical contexts and construction project scales. Also, future studies should explore longitudinal assessments to gauge the long-term effectiveness of benchmarking initiatives in sustaining enhanced construction practices and adapting to evolving industry standards.

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