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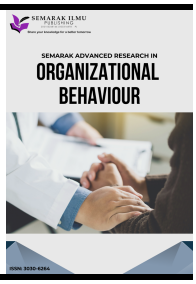

Redefining Safety Attributes: Essential Competencies for Project Managers in Green Construction

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ABSTRACT

Effectively managing safety considerations can significantly mitigate hazards and facilitate timely project completion within budgetary constraints. This study aims to investigate the safety attributes related to project manager competencies in green construction. Using a comprehensive study of the relevant literature, the authors identified the safety competency attributes that should be considered while practicing green construction. A table matrix was employed to precisely delineate the attributes of the suit for the project manager based on the relevant keyword search. The discussion reveals that the safety attributes were based on the competences of three project managers: safety knowledge, safety skills, and safety attitudes. The findings of this study may enhance safety performance in green construction. The project manager comprehends the roles related to safety to correspond with the sustainability objectives of green construction. It recommends appropriate management of safety issues that adhere with economic and environmental considerations while not ignoring the social aspect of green construction methods.

1. Introduction

It is imperative that the construction industry achieves net-zero carbon emissions by the year 2050 because it is a big user of non-renewable energy and a contributor to emissions of greenhouse gases. 36 percent of the world's total energy consumption and 39 percent of the world's total carbon dioxide emissions are attributed to construction activity [1,2]. Green technology innovation efficiency (GTIE) is a measurement that determines how effectively an industry uses its resources in the process of green technology innovation. In the current setting, where the environment is limited, the implementation of efficient environmental legislation is essential for the advancement of greener technologies [3]. Prior study in this field, on the other hand, has only examined the elevated safety hazards associated with green building construction projects with those associated with non-green construction projects. According to the comprehensive review carried out in previous study,

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substantially less attention has been paid to worker safety issues in green construction projects. Presently, there is no complete system in place to identify, analyze, assess, and manage the safety risks that affect the health and safety of Green Building Construction Workers (GBCWs). This highlights the need for more research in this field [4]. Despite earlier attempts by green construction research to promote and raise knowledge of sustainability in construction, several gaps remain in the literature. Previous studies have primarily focused on the environmental challenges affecting green construction adoption. Notably, there is a dearth of research on the social aspects of sustainability on construction sites [5]. Some new green construction procedures may appear unsafe to workers because they are complex or unfamiliar. However, greater reported injury rates (RIR) in green construction may not imply that green techniques necessarily contribute to increased accidents. Many other elements, such as contracting procedures, safety culture, and project type, influence worker safety [4]. The necessity of redefining safety competencies regarding construction in the era of sustainability stems from the realization that conventional safety training does not encompass the distinct issues surrounding green construction. Sustainable approaches to construction have the high potential to include new materials, techniques, and technologies that workers may not be acquainted with, generating a higher opportunity for accidents to occur without appropriate training. Incorporating sustainability in safety competencies enables project managers and workers to work with eco-friendly materials, use energy-efficient equipment, and adhere to green building standards, all without compromising job safety. In doing so, this method also fosters a strong safety culture that goes together with environmental stewardship, providing the best safe and sustainable practices to construction. Several studies on project managers' competencies on safety performance have been conducted within conventional construction [5,6]. Nevertheless, it was determined that the competencies of project managers and their correlations with safety performance in green construction have not been specifically examined in previous research. Research is scarce on strategies for addressing the safety concerns associated with green construction [7]. This study aims to bridge this gap by redefining safety competencies attributes to equip project managers with the essential skills for safe and successful green construction. It will explore the challenges posed by green construction practices and propose an updated safety competencies attributes framework that aligns with the principles of both safety management and environmental sustainability.

2. Safety Cases in Green Construction – A Malaysian Context

Safety concerns in the construction sector contribute to an unhealthy environment during project implementation. Scholars and industry practitioners have identified these issues in the field of construction research, and have been researching the best techniques to minimize these negative consequences [7-9]. The primary focus of these issues appears to be on various categories of fatalities. According to Hwang and Durdyev *et al*., the fatalities may have been associated with the implementation of unique architectural designs, green roofs, vertical gardens, or renewable energy systems such as solar panels or wind turbines. These characteristics often require workers to operate at significant heights, thereby increasing the risk of falls. As shown in Table 1, demonstrates that fatalities in Malaysian context associated with green elements during construction are not uncommon and require serious attention as a safety issue.

Table 1
Example of cases reported in Malaysia dealing with green features

Cases	Type of Accidents	Green Elements
Case 1	Worker falls from a height	Solar Panel Installation
Case 2	Workers Hit by H-Beam Structure	IBS Systems
Case 3	Worker was crushed by a precast concrete wall.	IBS Systems
Case 4	Workers Hit by H-Beam Structure	IBS Systems
Case 5	Worker falls from a height	Solar Panel Installation
Case 6	Workers Hit by	IBS System

Sources: [10]

Assessing the cases recorded in Malaysia incorporating green components found that human mistake or hazard factors on the construction site likely have contributed each fatality [12]. Consequently, each fatality can be categorized as either an unsafe condition-related risk or an unsafe act-related risk. Both of these selective attention and inattention are significant factors to human mistakes [11]. The involvement of employees in safety can consistently minimize the probability of human mistakes at the job site by enhancing participation and comprehension of tasks, environment, potential dangers, and erroneous traps [12]. Nonetheless, human mistake or negligence regarding surrounding concerns may not solely generate sources of hazard. The inadequate application of safety systems and the failure to adhere to safety protocols instituted by senior management—such as overseeing safety compliance, forming safety committees, disseminating safety policies to site personnel, engaging safety officers, and facilitating dialogue between safety officers and site staff—may adversely affect safety performance.

3. Evaluating the Role of Project Managers in Ensuring Safety in Green Construction: Recent Trends

The employer's failure to implement serious safety measures for the workers on site resulted in fatalities. A thorough analysis was conducted on managers' and supervisors' attitudes towards construction safety. The results showed that using daily supervision data to find low-severity safety risks can greatly improve efforts to make people better at recognizing hazards [15]. The dataset often includes comprehensive records detailing various identifiable unsafe acts and conditions occurring throughout the entirety of the construction process. Although these records pertain to projects that have not encountered significant accidents, they require comprehensive investigation. A series of frequent minor risky occurrences may serve as a warning regarding the probability, rather than merely the possibility, of a more significant event [13]. According to Wang *et al*., [14], the staff members occupying key positions in these important roles, such as the project manager, chief supervision engineer and safety officer. These individuals bear the responsibility for maintaining the safety standards on construction sites [14]. This study examines project manager competency as well as understanding of safety perspectives, caused by ambiguous responsibilities and overlapping job scopes with other personnel in this domain. It supported by Wang *et al*., [14] who highlighted the essential roles of the project manager in safety considerations. He stated that if the project managers observe the situation and implement prompt corrective measures, this early-warning system will facilitate the detection and correction of problems prior to the onset of a serious incident.

In this regard, Islam *et al*., [15] demonstrates that future research on the interrelationships among aspects and strategies for mitigation to reduce safety risks in green construction projects is vital [16]. This study emphasizes the significance of project manager competencies in reducing safety hazards in green construction, underlining the possible effect of top management on worker attitudes on safety procedures. Table 2 highlights the link between safety and green construction,

but there is still room for improvement in project managers' competencies focusing on safety performance.

Table 2
The undeveloped area of project managers competencies that focusing on the safety performance

Authors	Developed Area	Undeveloped Area
[17]	The study explores the distinction between safety concerns in conventional and green construction.	The study does not primarily focus on the roles of project managers even the aspect of safety and green construction are discussed in this study.
[18]	The study explores the importance of safety and health in ensuring client satisfaction with green projects.	This study emphasized safety and green project elements, but did not examine the competencies of project managers.
[19]	The study examined the key factors that should be taken into account to improve safety performance in green construction.	The study discussed safety in green construction but did not examine the safety competencies of project managers.
[20]	The study explores the correlation between energy, waste, and storm water management in relation to safety and health performance.	
[21]	The study investigates the correlation between critical safety risks and fall hazards in green construction.	
[22]	The study investigates the correlation between project manager competencies and green construction performance.	The study focused on project managers' competencies in green construction, but did not specifically address safety perspectives.
[23]	The study investigates the correlation between leadership competencies and safety performance.	The study does not adequately focus on the competencies of project managers in green construction practices.

2. Methodology

This article utilizes secondary data from websites, papers, and research reports to improvise the competences of project managers in green construction. This study employs a matrix table for classification, which underpins further content analysis. The study commences with the delineation of its scope and the identification of relevant keywords. Keywords such as "safety in green construction," "safety and sustainability," and "project manager's competencies" were employed to identify suitable publications and journals relating to the subject. The relevant studies were selected for the purpose of conducting thorough reading and determining the crucial terms. In the following step, the terms that were discovered were arranged into a matrix for purposes of comparison and systematic analysis. The findings and gaps were presented in the form of a table that was developed to identify the patterns that have emerged from current research. The analysis and conclusion were made based on the data and future study was next to be recommended. The flowchart in Figure 2 illustrates the methodology of this study.

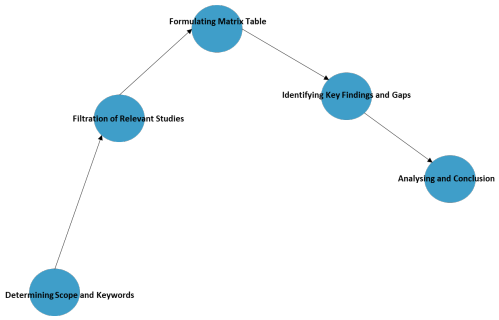

Fig. 1. Research methodology

3. Discussions on Project Managers Safety Competencies Attributes in Green Construction

As the senior leader of the project management team, project managers are responsible for ensuring the safety of their teams [24]. Effective methods and instruments for project management play important roles in the context of project management, and the achievement or failure of any project is highly related to an appropriate application of these methods and instruments. In the absence of support from the upper management, the implementation of a safety program becomes difficult. The establishment of a positive safety culture can be accomplished by the alignment of a safety culture across the various levels of the company. It is possible that a culture that prioritizes safety will have a beneficial impact on building costs and can lead to an increase in operational efficiency. Project managers appear to be the key controllers in construction projects, and their professionalism may explain the jobs that involve primary accountability for safety programs to constructing projects [25]. Thus, the integration of knowledge, skills, and attitudes which essential for project managers to support the maintenance of vital human and natural resources required for the social advancement of present and future green project development.

According to Chin *et al*., [26], the expertise to meet the GBI assessment criteria is still inadequate. In safety and health criteria, the tighter green requirements necessitate project manager enhance the knowledge on Health and Safety in the Workplace Rules. It is significant since the safety performance depending on the utilization of new materials, complexes construction methods and etc. It was recorded an accidents involved green project and proved the higher rate of accident compared to traditional construction [7,27]. Additional prevention planning was next approach to brace and assists the project manager set clear sustainability goals during the planning stage in order to prevent any hazards in other phases [28]. Robichaud and Anantatmula [29] suggest that setting sustainability goals during the planning stage can establish a framework for all future decision making. However, safety educational sessions also the high important factor for project managers that will enable them to foresee possible and potential problems that might occur in the sustainable construction projects. This will help them manage the possible risks before starting the project. The ability to understand the potential risks can facilitate project managers control the safety issues among labour and engineers. Thus, all of the safety knowledge that possessed by a trained project managers can hugely affect the project success [30]. Recent issues have arisen regarding the compatibility of safety devices with the current environmental construction method [31]. The project manager faces challenges in comprehending the appropriate safety devices that are compatible with the green construction system being utilized [32]. To address these issues, a qualified project manager that is totally knowledgeable with a broad spectrum of safety procedure and adheres to contract agreement is essential. When it comes to preparation during construction phase, a risk control procedure is another element that should be taken into consideration. It is important for the project manager to have a clear understanding of the procedures that are involved, such as inspecting and testing the required material and temporary work results to determine whether or not they are in line with technically stated environmental criteria [33].

Furthermore, construction management involves all areas of management and the general management practices requiring project management skills [25]. A project manager with skill in evaluating potential risks is crucial for green construction practices to ensure timely, cost-effective, and safe project completion without personal injury accidents. Additionally, success in the safety performance requires technical expertise, effective communication, and the ability to frame information and strategies to gain and maintain professional credibility with various constituencies. [34]. In each project that a Project Manager manages, the role of the project manager includes delivering safety information, encourage safety policies formulation in the project manager's

projects. This leadership characteristics implies huge impacts on the safety performance in handing green features. According to Khawam and Bostain [25], project managers who have not obtained the any credentials from Project Management Institute (PMI) may not be adequately prepared to apply health and safety policies and procedures in the projects.

Another, safety decision making is another element of safety competencies. A relevant emergency skills should possess by project manager for avoiding the event becomes worst [35,36]. The need for unique skills and competencies to effectively manage safety arrangements is significantly a great issue, especially in construction industry environments that are described as highly complicated, dangerous and uncertain [37]. Not all project managers have experience in sustainable construction and they often lack skills in implementing it. Even if they have a theoretical understanding of sustainability, lack of experience implementing it would create a major risk. Thus, the need for project and site managers to understand the changes in work environment resulting from the adoption of green practice need to be matched with specific green skills from site workers [38]. The challenges might happen will create some disputes among stakeholders during the construction phase, thus, conflict management skill is crucial for the success of sustainable construction projects, as it outlines a project manager's obligation to ensure project success [39].
In terms of attitudes, most studies addressed on individual's attention on safety aspect during handling a task. This attention on safety corresponds to a proactive mindset that encourages constantly awareness and organizing of workplace safety [40,41].

Green construction project managers confront enormous risks as new substances, techniques, and concepts are introduced. A safety-conscious project manager ensures that sustainable practices and safety work together to protect workers while executing high-quality, ecologically responsible projects. This responsibility should be in project manager because the green construction characteristics integrating three complicated components include carrying the responsibility for safety, environmental impact, and ethical decision-making. A fully accountable project manager intentionally ensures that green buildings are safe, sustainable, and useful for all stakeholders, rather than simply following the laws [42]. The positive mindset of a project manager is characterized by a focus on goals in green construction, refusing to settle for minimum requirements and instead striving for quality in safety, ecological responsibility, and successful completion of the project. Through proactive enhancement of processes, team engagement, and the implementation of innovative green solutions, they develop projects that comply with requirements and establish new industry standards [23]. Nonetheless, Empathy is an essential social component in construction, improving safety, sustainability, and human-centricity. It not only achieves objectives but also fosters trust, improves collaboration, and guarantees that sustainable constructions fulfil their intended mission [43]. Therefore, it is essential for project managers to be able to adapt to different circumstances. By maintaining a capacity for flexibility, being responsive to change, and focusing on finding solutions. Project managers may increase safety, boost sustainability, and guarantee efficiency even when faced with unforeseeable condition [40,41]. In other hence, when it comes to project management, project manger's ethics should go beyond the obligations of the law. Instead of only avoiding what is illegal, they should actively seek out solutions that are better, safer, and more sustainable [35].

Table 3
Matix table of project managers safety competencies attributes in green construction

Knowledge	[43]	[38],[44]	[45]	[46]	[47]	[35]
Health and Safety in the Workplace Rules	√	√	√		√	√
Prevention Planning	√	√	√	√	√	
Education on Safety	√	√	√		√	√
Safety Devices	√	√	√	√	√	
Environmentally Responsible Safety Procedures	√	√	√		√	√
Risk Control		√	√	√	√	
Skills	[43]	[28]	[27]	[35]	[36]	[37]
Evaluation of Potential Risks	√			√	√	
Safety Delivery Information		√	√	√	√	√
Leadership	√	√	√	√	√	√
Reacting to Emergencies	√	√	√	√	√	√
Records of Safety Procedures	√	√			√	√
Settlement of Disputes		√	√	√	√	
Attitudes	[35]	[42]	[23]	[43]	[40]	[41]
Attention to Safety	√	√	√	√	√	√
Responsibility of precautions	√			√		√
Focus on achievement	√	√	√	√	√	√
Emotional intelligence		√	√	√	√	
Ability to adapt	√		√	√	√	√
Ethical Behavior	√			√		√

4. Conclusions

Figure 4 integrates the findings from numerous studies regarding project managers' competencies in safety within the context of green construction practices. These three competences, which were referred to as knowledge, skills, and attitudes individually, served as the foundation for the competencies. The standardized framework is required for project managers to comprehend the clear picture of safety roles in this green construction practices. Besides that, it can be summarized that the competencies of project management in the overall perspective do not fully align with the competencies in safety aspect. There are more focused on the safety perspective that project manager can clearly observe the job's scope differences. In order to deploy environmentally friendly technologies and sustainable practices, project managers need to embrace green innovation. This is because sustainability is becoming a more essential concern. A thorough understanding of life-cycle assessment is required to ensure that all stages of a project, from inception to completion, consider the environmental and social implications. In light of this, the findings suggest a number of safety competency attributes that may be compatible with project managers' jobs. This clear competency attributes indicates that project managers must be able to adapt promptly to the unpredictable issues associated with sustainability. Furthermore, project managers must increase their level of skill

in the ethical management of safety operations in order to ensure the presence of sustainable values within their teams, and to coordinate with environmental regulations.

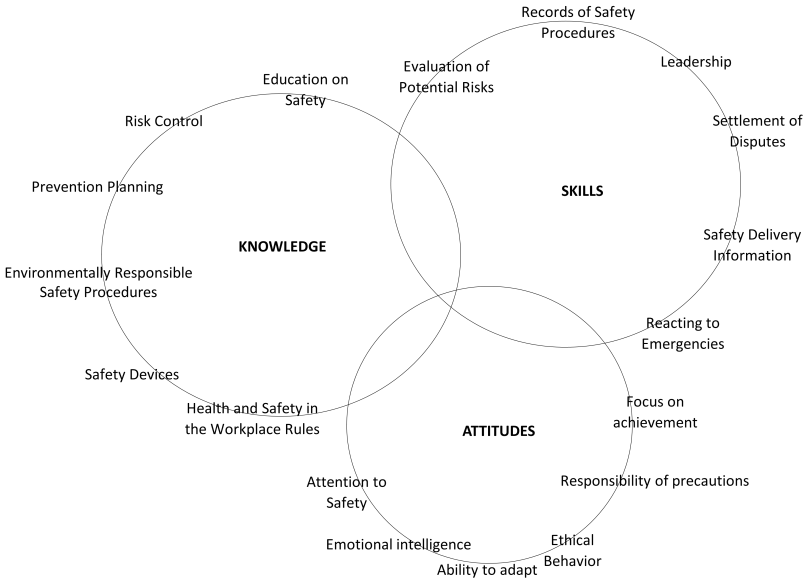

Fig. 2. Essential safety competencies for project managers in green construction

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