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Knowledge and Skills Required for NZEB Project Construction

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Efficient project management is crucial to project success. As the construction industry changes, constructors face new issues and must undertake roles that have not traditionally been part of their responsibility. The aim of this study was to identify the Net Zero Energy Building (NZEB) project management challenges, and to determine the knowledge areas and skills that are necessary to respond to those challenges through surveys and interviews with NZEB constructors. NZEBs consume less resources than produced during operations of the building. Results revealed that the most important challenges were a general unawareness of the correct methods and procedures, reluctance to change from traditional practices, and the lack of the technical skills with NZEB technologies. The most important knowledge areas identified were communication management, schedule management and planning, and cost management. The most important skills were teamwork, leadership, and problem-solving. In addition, this study provides a summary of the importance of the various mechanisms for professional constructors' development of net zero construction knowledge and skills. This study is beneficial for the constructors' decision making in the NZEB project context. Educators are also expected to benefit from this study in the development of academic curriculum with a goal to meet the need.

Key Words: Green Construction, Net Zero, NZEB, Construction Knowledge and Skills.

Introduction

With the increasing global concern for the negative impacts brought upon the environment by human activities in recent years, many industries are turning towards implementing sustainability and green measures. The construction industry consumes a significant amount of energy and emits greenhouse gases (GHG), which are among the key factors for global warming. According to the United States Environmental Protection Agency's 2021 Annual Report (EPA, 2021), buildings are responsible for nearly 40% of the energy consumed and over 30% of GHG emissions in the United States. To mitigate the negative impacts on the environment, facility owners are looking to build facilities that will operate with reduced levels of energy consumption and natural resources across the building life cycle. As a result, many construction companies have integrated green concepts into their construction plans. Initially green buildings were intended to reduce the negative impacts on the environment caused by the building industry. In recent years, the design and construction industry has expanded its

green building efforts toward "net-zero", which simply means consuming less resources than produced (U.S. Green Building Council, 2014). As the green and net zero building construction continues to grow, there is a need to better understand what is needed by project constructors to manage net zero building construction. This study's aim was to identify the challenges of NZEB project management, and the essential knowledge and skills required for construction professionals to successfully deliver NZEB projects.

Background

Based on a comprehensive literature review, Hwang and Ng (2013) summarized the major challenges that project managers face in managing green construction projects. Those were 1) higher costs for green construction practices and materials, 2) technical difficulty during the construction process, 3) risk due to different contract forms of project delivery, 4) lengthy approval process for new green technologies and recycled materials, 5) unfamiliarity with green technologies, 6) greater communication and interest required amongst project team members, and 7) more time required to implement green construction practices on site. Additionally, Marcelino-Sádaba, González-Jaen, and Pérez-Ezcurdia (2015) identified communication, stakeholders, costs, risks and deadlines as the areas with the greatest impact on the project management of green construction.

The Project Management Institute documented nine knowledge areas in its Guide to the Project Management Body of Knowledge (PMBOK, 2017). Those areas are integration, time, cost, procurement, quality, communication, human resource, scope, and risk. Each of the nine knowledge areas contains processes that need to be accomplished within a discipline to achieve an effective project management program. For instance, project cost management encompasses processes that are required to ensure the project is completed within the approved budget and consists of resource planning, cost estimating, cost budgeting, and cost control. Likewise, project risk management is the process concerned with identifying, analyzing, and responding to project risk (Hwang & Ng, 2013). Dogbegah, Owusu-Manu, and Omoteso (2011) conducted a study on project management competencies for the construction industry and identified an additional six project management competencies, which were human resource management and project control, construction innovation and communication, project financial resources management, project risk and quality management, business ethics and physical resources, and procurement management.

Edum-Fotwe and McCaffer (2000) stated that acquiring the knowledge inputs for a particular type of project enables the project manager to develop two types of skills, which are specific skills and general skills. Specific skills relate directly, and only, to construction projects and the areas that reflect their specialty. Whereas, general skills are transferable from one type of construction project to another. According to Hwang and Ng (2013), most of the earlier research papers share similarities in that they identified direct and indirect skills that affect the construction professional's competencies. Direct skills are associated with one's technical competencies that have a direct influence on project performance. For instance, project planning is a specific direct skill that is utilized for scheduling construction activities. Indirect skills such as managerial effectiveness, for example, have an indirect influence on project performance and are needed as much as direct skills to ensure that workers on a job site execute their work to meet the project's deadline.

Previous studies focused on identifying the factors specific to the technical, cost, and organizational aspects of a green building project. A comprehensive study on the factors affecting the success and failure of managing NZEB building projects is lacking. This study identified the project management challenges, knowledge and skills needed to successfully deliver NZEB projects. The categories of professional development were also examined. Understanding the importance of these professional

development categories will provide information for use in the design and development of educational and training programs.

Methodology

A convergent mixed method study was conducted for an in-depth understanding of the NZEB project management challenges, and the knowledge and skills that construction professionals need to successfully deliver NZEB projects. The two parts of the study were: 1) a structured survey to generate the quantitative data, and 2) an interview using a semi-structured questionnaire to generate the qualitative data. Thus, both quantitative and qualitative data were collected and analyzed. After analysis of all the data was complete, the results of the analyses were compared for interpretation and explanation. Figure 1 shows a diagram depicting the convergent design of this study.

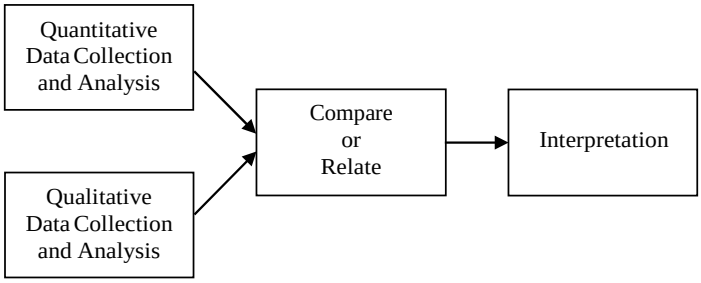

Figure 1. Convergent Parallel Mixed Methods Research Study

Participants

A directory of NZEB constructors and projects does not exist, therefore, the researchers first searched for literature on the NZEB construction projects in the United States from online sources, such as newbuildings.org, living-future.org, energy.gov, and usgbc.org. From the search, 21 completed NZEB projects were identified. Purposive sampling was then used to recruit industry professionals with NZEB project experience to participate in the study. The purposive sampling technique is the deliberate selection of a participant with particular characteristics or experiences, who will better be able to assist with the relevant research (Etikan, Musa, & Alkassim, 2016). For this study, the characteristic used was either residential or commercial NZEB project experience as a general contractor, subcontractor, project manager, estimator, architect, MEP engineer, energy consultant, sustainability consultant, project engineer, or project owner. In the search for participants with the appropriate experience, the assumption was made that if an individual did not have NZEB experience they would forward the request to a colleague who had NZEB experience within the organization. An email request to participate in the study was sent to 189 industry professionals, all of which had some role in the 21 NZEB projects identified through the online search of completed projects. The recruitment email explained the purpose of the study with a link to the Qualtrics™ survey questionnaire. A total of 27 completed surveys were received in a timeframe of 9 months. Five of the survey participants participated in the follow-up interviews. Seventy-four percent of the survey participants had industry experience of more than 20 years. Some of the participants mentioned more than one role on NZEB projects, which contributed in some part to the low number of participants given they had experience on more than one project. The demographic data for the participants is presented in Table 1.

Table 1

Participant Demographic Characteristics

Role on NZEB Projects	N
Energy Consultant	10
Project Manager	9
MEP Engineer	5
Architect	4
Owner	3
Owner's Representative	1
Estimator	1
Specialty Contractor/Subcontractor	1
Other (Sustainability Planner, NZE Coach, LEED Consultant, LBC Consultant, Design-Build Project Executive, Green Rater)	10

Data Collection and Analysis

The survey used for this study adapted a questionnaire previously developed for a 2013 study, *Project management knowledge and skills for green construction: Overcoming challenges* (Hwang & Ng, 2013). The questionnaire consisted of 24 questions, with 6 demographic related questions and 18 questions about the project management knowledge and skills needed to address the challenges of NZEB construction. A 5-point Likert scale was used for the questionnaire to measure participants' responses with a number between '1' to '5', where '1' indicated the lowest and '5' indicated the highest level of criticality. Numbers assigned to Likert-type items express a "greater than" relationship; however, how much greater is not implied. As the study had a series of individual questions that have Likert response options for the participants to answer, the analysis used mean *(M)* to measure central tendency, and standard deviation *(SD)* to measure dispersion. The responses were then numerically ranked based on their mean value. In the qualitative data collection, the semi-structured questionnaire was used that included three demographic questions, thirteen NZEB project management specific questions, followed up by additional probing questions, as necessary. All the qualitative data from the interview transcripts was input to MAXQDA, an analytical software, and further analyzed.

Results and Discussion

This section presents the results from the analysis of the quantitative and qualitative data collected for the study. In Table 2, the challenges that constructors face during NZEB construction project management are shown. In Table 3 and 4, the required knowledge and skills are listed. It is important to emphasize that although the list of challenges, knowledge areas and skills presented here are comprehensive, they are not exhaustive. Similar to traditional construction, the scope of challenges, knowledge areas and skills required for managing NZEB projects are also influenced by the context of the project. The development of the requisite knowledge and skills has traditionally relied on academic degree programs that focus on delivering general construction content instead of specialty construction. To further develop knowledge and skills in the sustainable construction industry, professional constructors often rely on training and professional certification. Table 5 lists the categories of professional development most frequently pursued.

Table 2

Analysis Summary: Challenges

Category	*Challenge*	*M*	*SD*	*N*	*RW*	*RA*
Planning-related	Difficulty in comprehending the NZEB specifications in the contract details	3.00	1.02	27	1	9
	Planning of NZEB construction technique	2.96	0.79	27	2	10
	Planning of NZEB construction sequence	2.56	0.79	27	3	19
	Lengthy approval process for new green/NZEB technologies within the organization	2.52	1.00	27	4	21
	Adoption of different forms of project delivery	2.22	0.96	27	5	23
Project-related	Difficulty in the selection of subcontractors in providing NZEB construction service	3.04	0.92	27	1	8
	More alteration and variation with the design during the construction process	2.78	1.03	27	2	11
	More time is required to implement green/NZEB construction practices onsite	2.74	1.07	27	3	13
	Difficulty in assessing the progress of completion in NZEB Construction	2.19	0.94	27	4	24
Client-related	Level of risk the client is willing to take in Green/NZEB technologies	3.19	0.86	27	1	4
	Client uses a lot of time in making decision	3.07	0.86	27	2	6
	Special request from client pertaining to specified Green/NZEB technologies to be used	2.73	0.86	26	3	14
	Required date of completion	2.63	0.99	27	4	16
	Objective of the building project	2.52	0.92	27	5	21
Project team-related	Lack of communication among project team members	2.78	1.1	27	1	11
	Frequent meeting with green specialists	2.59	0.95	27	2	18
	Conflict with the architect over the type of material to be used	2.56	0.83	27	3	19
	Conflict of interest between consultant and project manager	2.19	1.06	27	4	24
	Green consultant's delay in providing information	1.85	0.76	27	5	26
Labor-related	Workers' unawareness of methods and procedures	3.37	1.19	27	1	1
	Reluctance to change from traditional practices	3.33	1.15	27	2	2
	Lack of the technical skill regarding Green/NZEB technologies and techniques	3.30	1.18	27	3	3
Material and Equipment - related	High cost of green/NZEB material and equipment	3.11	0.74	27	1	5
	Uncertainty with green/NZEB material and equipment	3.07	0.94	27	2	6
	Decision on green/NZEB material and equipment	2.73	0.90	26	3	14
	Availability of green/NZEB material and equipment	2.63	0.82	27	4	16

In Table 2, challenges are organized into six categories: mean scores *(M)*, standard deviation *(SD)*, count *(N)*, ranks within *(RW)* and ranks across the categories *(RA)*. Based on the mean rank, the top three challenges faced by constructors executing NZEB construction projects are labor related.

Workers' unawareness of the correct methods and procedures yielded the highest mean scores *(M=3.37),* indicating that it is the most frequently encountered challenge. Reluctance to change from traditional practices was ranked second highest *(M=3.33),* while lack of the technical skill regarding Green/NZEB technologies and techniques was third ranked challenge *(M=3.30).*

The interview participants from this study verified that there is a tendency to revert to the old ways of doing things that people know and understand and have always done, whereas net zero energy building requires people to do things differently. One interview participant emphasized that the willingness to change is very critical, and people can learn better if they are not resistant to doing something different.

Workers' unawareness of the correct methods and procedures, and the lack of technical skills regarding green/NZEB technologies can be addressed by engaging contractors with knowledge on the environmental issues associated with construction activities and building materials during early stages of design. Forming interdisciplinary teams to work together throughout the project, increasing communication among team members, and implementing continuing professional develop training would be a good strategy in this regard. To address workers' reluctance to change from traditional practices, there must be a commitment to change the current mentality of employees. According to Shan, Liu, Hwang, and Lye (2020), senior management can have a major influence over their subordinates and the projects they are managing. Therefore, NZEB project managers should take an active role to raise the awareness of all employees about environmental issues, and knowledge about NZEB construction.

Table 3

Analysis Summary: Knowledge

Knowledge	*M*	*SD*	*N*	*Rank*
Cost Management	3.63	0.78	27	1
Schedule Management and Planning	3.63	0.82	27	1
Communication Management	3.63	0.87	27	1
Stakeholder Management	3.52	0.92	27	4
Materials Resource Management	3.30	0.81	27	5
Risk Management	3.15	0.89	27	6
Conflict and Dispute Management	2.85	0.93	27	7
Health and Safety Management	2.48	1.07	27	8
Claims Management	2.41	0.87	27	9
Human Resources Management	2.30	0.97	27	10

As shown in Table 3, the mean rank column indicates that there are three knowledge areas equally required for industry professionals to deal with the NZEB projects challenges. Those are cost management, schedule management and planning, and communication management *(M=3.63).*

Communication management was cited as the most important knowledge by the interview participants. One interview participant emphasized communication as the key factor in the NZEB construction process. Another interview participant discussed various methods of coordinating team members so that everybody had frequent communications. NZEB projects require a more holistic and integrated approach where communication plays a critical role to achieve the project goal. Livesey (2016) verified that effective communication management plan needs to be in place for NZEB

projects to facilitate collaboration in project teams, which also promotes active participation in decision making.

With regards to cost management knowledge, one interview participant emphasized understanding the relationship between the design decisions and their first cost implications compared to the cost over time as an important factor. When compared to conventional projects, green/NZEB projects tend to cost more to construct. Construction is a competitive industry dominated by price, therefore cost control is vital for contractors in the industry. A project manager's competency with cost management has considerable impact on the success of projects. Project managers must manage and deliver the project within the budget constraint. Shan et al. (2020) stated it is essential to appoint a capable project manager that can lead the implementation of the green building practices on NZEB projects.

Table 4

Analysis Summary: Skills

Skills	*M*	*SD*	*N*	*Rank*
Teamwork	3.93	0.77	27	1
Leadership	3.81	0.72	27	2
Problem Solving	3.74	0.84	27	3
Decision Making	3.63	0.87	27	4
Analytical	3.33	0.77	27	5
Human Behavior	3.19	0.82	27	6
Delegation	3.11	0.79	27	7
Negotiation	3.04	0.88	27	8
Chairing Meetings	2.81	0.90	27	9
Presentation	2.78	0.87	27	10

From the mean rank of Table 4, teamwork was found to be the most important skill required to address the NZEB project challenges *(M=3.93)*, followed by leadership skills *(M=3.81)* and problem-solving skills *(M=3.74)*.

Interview participants cited teamwork as an important management skill essential for success working on NZEB projects. One interview participant mentioned teamwork as the core skill. Another interview participant said that rather than working in traditional silos where mechanical, electrical, et cetera, were just working by themselves, a series of interdisciplinary component teams work together throughout the entire NZEB project. Another interview participant emphasized the role of a leader in understanding and having skills at managing stakeholders, managing groups of people and figuring out what they really want from an NZEB building.

Teamwork can be facilitated by training, when both training and on-the-job experience play a positive role in enhancing problem solving skills. Leadership skills can be developed by both education and training. To enhance teamwork and performance outcomes, Salas et al. (2015) suggested some interventions, such as, conducting team cross-training and team building prior beginning the project.

Table 5

Analysis Summary: Professional Development

Professional Development	*M*	*SD*	*N*	*Rank*
On the job experience	4.00	0.61	27	1
Training	3.67	0.77	27	2
Education	3.48	0.63	27	3
Professional Certification	2.67	0.82	27	4

This study focused on the categories of professional development that industry professionals should acquire to manage NZEB projects effectively. These categories include academic background and experience-related knowledge as well as skills. Based on the mean rank of Table 5, on-the-job experience is the most effective mean of professional development *(M= 4.00)* to work in NZEB construction. Training was ranked second *(M=3.67),* followed by education *(M=3.48).*

The importance of training and on-the-job experience were discussed by the interview participants. One interview participant mentioned about the system of mentoring where less experienced people were assigned with more experienced to facilitate one-on-one mentoring. The role of seasoned professionals in providing the needed information or the one-on-one coaching needed for a specific individual was also mentioned. Regarding the role of education, one interview participant mentioned that a graduate should have the knowledge of designing energy efficient building, if not net zero.

Limitations and Future Research

Although the sample size of this study is considered small with only 27, insights about the knowledge and skills necessary for NZEB construction were revealed. More research is needed and a future study with a larger sample size should result in a higher response rate for individual items of the study and be more generalizable for industry practitioners and educators.

Most of the survey participants of this study mentioned more than one role on NZEB construction projects. Constructors in different roles may have a different set of challenges to overcome. The future research can limit the scope of selecting more than one role by the survey participants so that the researcher can compare project managers, designers, engineers, energy consultants, owners, and contractors' perceptions. Finally, participants who have both NZEB and conventional construction project management experience could be requested to rate their perceptions of knowledge and skills to respond to the project challenges in both NZEB and conventional buildings for a comparative analysis.

Conclusion

Managing construction projects is a challenging job due to the significant impacts of construction activities on the environment, economy, and surrounding community. Concerns over these impacts have spurred the need for green/NZEB buildings in the construction industry. Since constructors play an important role in the success of construction projects, it is essential to identify the critical knowledge and skills that constructors require to deal with the challenges of NZEB construction project. The objectives of this study were to identify the knowledge areas and skills required to be a

competent constructor of NZEB construction projects, and to summarize the relative importance of the various mechanisms for professional development.

The analysis of the responses from the survey revealed knowledge areas and skills that are essential to respond to the challenges. The most important challenges were workers' unawareness of the correct methods and procedures, reluctance to change from traditional practices, and lack of the technical skill regarding Green/NZEB technologies. The most important knowledge areas were cost management, schedule management and planning, and communication management. The most important skills required to mitigate the challenges are teamwork, leadership, and problem-solving skills. The contribution of academic education to the competency of NZEB constructors was rated lower than that of formal industry training attended provided by employers. Similarly, the perceived contribution of industry training was outranked by that of experiences on the job site.

Based on the results from this study, it is evident that further development of competencies for NZEB construction is needed, both in higher education and in the construction industry. This research, therefore, advocates for a greater level of NZEB content in construction education and training programs. Collaboration with industry professionals who have NZEB project experience would provide a resource for knowledge and skill development.

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