Investigating and determining the crucial construction site supervisory competencies influencing the effectiveness of building construction project activities

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Abstract

Purpose – Sources highlight that insufficient skills of site supervisors considerably influence the progress of many construction projects in numerous countries. This study intends to identify the crucial supervisory competencies that influence the effectiveness of building project operations in the context of developing countries.
Design/methodology/approach – The crucial construction site supervisory competencies were qualitatively identified through a comprehensive literature survey and a series of expert interviews with the use of thematic analysis approaches. A questionnaire survey was then carried out among 154 building project

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firms to quantify the impacts of the competencies on the effectiveness of project tasks with the use of the relative importance index approach. Additionally, industry-consultative meetings were held using problem-focused communication strategies to scrutinise the necessary actions.

Findings – Overall, 22 cognitive elements and 24 skills/abilities of supervisors were determined as being critical according to their impact values, where the site supervisors cognitive domains in construction planning and construction materials were determined as the top-ranking competencies in the list, with their manual skills/abilities in labour management and labour performance evaluation. Accordingly, a group of key competency outcomes were produced for the considerations in developing new site supervisory training components. Relevant statistical analysis results and the industry consultative outcomes substantiated the validity and dependability of the overall results.

Research limitations/implications – Although the study's focus was to site supervision procedures used in Sri Lankan building construction projects, the overall findings/outcomes might be put to the test in related situations in other emerging industries in other countries.

Originality/value – The study has constructed a base that shows how the significant site supervisory competencies influence the effectiveness of building construction operations, contributing to making a big difference in the methods of reskilling/upskilling in the industry associated with construction labour, supervision, efficiency management and productivity enhancement.

Keywords Built environment, Construction supervision, Work-based competencies, Productivity improvement, Training development

Paper type Research paper

1. Introduction and background

The construction industry makes a substantial contribution to the accomplishment of a nation's socioeconomic goals by creating a variety of investment opportunities (Mistri *et al.*, 2019). The productivity of construction industry operations has an imperative impact on a nation's gross domestic product (Durdyev and Mbachu, 2011). Principally, the construction sector is labour-intensive when compared to other industries since it employs the most people over an extended period of time (Manoharan *et al.*, 2022c). Therefore, labour efficiency has a big impact on how effective construction organisations are (Tuan and Tam, 2019). However, in many developing countries, the construction sector has encountered a number of challenges related to the quality and quantity of work outputs because of the ineffectiveness of labour work (Silva *et al.*, 2018; Shoar and Banaitis, 2018). This results in construction organisations facing various challenges associated with unprofitability and project delays (Nwosu, 2018). The primary element influencing productivity gains in construction operations is labour efficiency, which is influenced by a variety of factors (Tuan and Tam, 2019).

Effective supervision is significant in managing construction labour tasks, and construction site supervisory staff play an essential role to link labour with employers in general (Nwosu, 2018). But in recent decades, the low efficiency of labour has been largely attributed to the insufficient competencies of site supervisors in the construction sector of numerous nations, including Australia, Iran, New Zealand, Nigeria, Sri Lanka, Trinidad and Tobago and Vietnam (Hickson and Ellis, 2013; Hughes and Thorpe, 2014; Durdyev and Mbachu, 2011; Ghoddousi *et al.*, 2015; Nwosu, 2018; Tuan and Tam, 2019; Manoharan *et al.*, 2022c). These studies emphasise the need for polishing the role of labour supervision with new skills in order to implement beneficial methods for managing labour operations at worksites. To add new characteristics to a job role, it is crucial to note that education and training components should be well-connected to regular work tasks (Manoharan *et al.*, 2022a). Accordingly, this study highlights the necessity for the construction sector in different developing nations to determine the significant supervisory competencies affecting labour efficiency in construction.

Recent studies (Tertiary and Vocational Education Commission, 2017; Nwosu, 2018; Silva *et al.*, 2018; Mistri *et al.*, 2019; Manoharan *et al.*, 2022b) and interviews with experts in the construction industry and relevant skill sector authorities revealed that many developing countries lack appropriate reskilling and upskilling methods/procedures on enhancing supervision traits connected to the efficiency and sustainability of site operations in

building projects. The significance of resolving this problem is found in its effects on the chain of inadequate training infrastructure, supervisory competency gaps and skill shortages that have been the main factors affecting the effectiveness of building construction operations in such developing countries (Windapo, 2016; Tertiary and Vocational Education Commission, 2017; Nwosu, 2018; Mistri *et al.*, 2019; Manoharan *et al.*, 2022b). The background analysis of the current study emphasises that such stated challenges were not fully addressed in earlier investigations. The current study reveals a knowledge gap in the field regarding determining what supervisory traits are crucial, what causes are associated with such influences of supervisory traits, how such influences break the flows of project effectiveness and what kinds of actions the appropriate authorities should take. In light of these essential aspects, the current study emphasises the need to restructure the construction supervision characteristics connected to this knowledge gap.

As per the above-highlighted gaps and needs, this study intends to pinpoint the critical competencies of construction site supervisors that affect the efficiency of labour in building project tasks. At its beginning, the study qualitatively identifies those components. Additionally, it makes an effort to quantify the degree to which those factors affect the effectiveness of labour operations and to pinpoint the necessary future actions from relevant authorities to improve the practices currently used in supervision. This will aid the construction sector of different developing nations in overcoming obstacles to productivity brought on by evolving challenges of the industry. Importantly, the discussions with the officials from the Construction Industry Development Authority (CIDA) reveal that many firms do large investments in building projects than others in developing nations. Accordingly, the scope of the study is limited to the construction site supervision practices in building construction project practices and the contexts of developing countries. This study is essential because the industry lacks the knowledge required to create the protocols and application procedures needed to reshape construction supervisory job roles in this environment. In order to predict, comprehend and quantify what levels of supervisory capabilities can practically be applied and theoretically be considered in actual operations, the study aims to open a gate that receives potential knowledge attributes to the industry sector along with the necessary comparison of a wide range of supervisory traits.

Within the scope and significance of the study stated in the preceding paragraphs, the rest of the paper is structured as follows: Section 2 reviews the relevant literature taking into account the settings of various nations. Next, Section 3 provides the necessary illustrations of the methodology employed for the study's aims using both qualitative and quantitative approaches. In particular, the influence levels of supervisory competencies on the efficiency of building project operations are described using relevant analysis and results in Section 4. Additionally, Section 5 discusses the findings, making the necessary comparisons with earlier studies from the contexts of various developing nations to the key findings while also outlining the contributing elements that led to the current state of the findings relating to other elements and the kinds of actions that the appropriate authorities should take. Conclusively, Section 6 summarises the study's findings, which crucially describes how the study's findings relate to numerous implications, contributions, limitations and recommendations.

2. Literature review

Studies conducted in recent decades highlight a wide range of skills that need to be enhanced for construction site supervisors working in many countries (Oseghale *et al.*, 2015; Nwosu, 2018; Montaser *et al.*, 2018). The site management abilities of the construction site supervisors were identified as one of the key elements that have significant impacts on labour efficiency in construction projects in Trinidad and Tobacco (Hickson and Ellis, 2013). Notably, leadership ability is an influencing factor in the site management practices of construction supervisors,

according to a survey conducted by Jarkas *et al.* (2012) among 84 construction firms in Qatar. Construction site supervisors' strong leadership and decision-making abilities bring out the best qualities of their labourers. However, these abilities were found to be insufficient among the supervisors working on numerous construction projects in India (Saurav *et al.*, 2017). On the other hand, the supervisors' site coordination abilities were found to be the main factors limiting on-site labour efficiency in the construction industry in New Zealand (Durdyev and Mbachu, 2011). They were also discovered to be a crucial delay factor affecting construction productivity in Malaysian residential projects more than a decade ago (Kadir *et al.*, 2005). Site coordination is crucial for coordinating labour and material resources during construction activities, especially for maximising resource utilisation (Kadir *et al.*, 2005).

In a survey conducted by Nwosu (2018) among 49 Nigerian construction firms, the interpersonal skills of construction site supervisors were examined, and it was discovered that the leadership, planning and communication skills of construction site supervisors need to be specifically improved. Nwosu (2018) further highlighted the poor compliance between Nigerian construction site supervisors and the labourers affecting the efficiency of work operations. Notably, an increase in labour motivation and engagement results in higher productivity in construction when there is effective communication between construction site supervisors and labourers (Nwosu, 2018). On the other hand, planning abilities are the key performance indicators of construction site supervisors that have been found to significantly affect labour efficiency in many Indian construction projects (Murari and Joshi, 2019). Effective construction planning boosts efficiency, productivity and resource management practices towards the reduction of costs and project delays (Kesavan *et al.*, 2014).

Taking on many construction projects in Iran, it has been determined that construction site supervisors' ethical behaviour need to be specifically improved (Ghoddousi *et al.*, 2015), where honesty, integrity, fairness and many other virtues are the key elements of ethical behaviour. Importantly, the level of organisational commitment and work satisfaction of labourers to performance enhancement may considerably increase when supervisors act ethically (Mahan, 2019).

Hughes and Thorpe (2014) sought to understand how project managers in the Australian state of Queensland perceived the variables influencing construction productivity. It demonstrates the need for enhancement in the health, safety and quality inspection-related competencies of the construction site supervisors. Numerous construction projects in India reported the poor quality control skills of construction site supervisors (Shashank *et al.*, 2014). Hughes and Thorpe (2014) highlight that occupational safety and the risk of making expensive mistakes are considerably influenced by quality control procedures (Hughes and Thorpe, 2014). On the other hand, Oseghale *et al.* (2015) stated that the Nigerian building contractors' main issues against productivity improvement were the construction site supervisory staff's poor cognitive skills in health and safety procedures.

Quality control, leadership, attendance, resource management and labour handling are accentuated by Soekiman *et al.* (2011) as the pivotal supervisory skills that affect the productivity of the workforce in Indonesian construction projects. Construction site supervisory staff in the Indonesian construction industry were advised by Adi and Ni'am (2012) to improve their cognitive skills in conducting industrial surveys and research. By conducting surveys and research, supervisory employees may be able to pinpoint issues at the workplace and take immediate action to address them.

Taking on the construction sector in Sri Lanka, there were not enough studies that looked at enhancing construction site supervision procedures from the perspective of Sri Lanka. According to Fernando *et al.* (2016), many construction firms need to significantly enhance their labour supervision procedures. The cognitive skills of site supervisors in health and safety practices were found to be a significant factor affecting labour efficiency in Sri Lankan building construction projects (Halwathura, 2015). According to Halwathura (2015), the Sri

Lankan construction site supervisors' cognitive abilities need to be improved in order to perform performance evaluations of labour skills at work sites.

Based on prior studies, Table 1 and Table 2 map out the key construction site supervisory competencies that have a considerable impact on the effectiveness of building project operations.

3. Methodology

The study methodology used qualitative and quantitative methods to pinpoint the crucial supervisory competency components influencing the efficiency of building project activities. In-depth approaches were also used in the study to evaluate the reliability and accuracy of the results. As per the sequential process shown in Figure 1, Sections 3.1–3.5 describe each component of the methodological progression used in this work.

3.1 Literature investigation

As shown in Figure 1, a comprehensive literature review was carried out by looking through relevant scholarly academic articles from many different countries. The majority of the academic articles were initially selected by well-known online search tools, namely, "ResearchGate", "Google Scholar", "Scopus" and "ScienceDirect", based on their reputation, impact rankings and subject contents. On the basis of suggestions made by subject-matter specialists, some of the articles were located. The article titles, abstracts and keywords were then carefully examined, and a table was prepared to compile the data obtained from the literature study after a thorough review process.

3.2 Interviews

To learn about the most recent practices in the industry, construction experts from Sri Lanka participated in structured interviews. More than 40 professionals from the construction industry were interviewed in total. Considering the professional backgrounds of those interviewees, directors, project managers, engineers, quantity surveyors, institutional specialists from training providers, supervisors and technical officers were involved in these interview sessions. All the interviewees had been employed for a minimum of five years in the construction field, and the majority of them fell into the category of work experience between 5 and 10 years. It is noteworthy that more than 30% of them had work experience in foreign countries. Notably, more than 80% of the interviewees agreed that the competencies of construction site supervisors are inadequate to enhance the efficiency of construction activities in Sri Lankan building projects in the recent scenario.

3.3 Qualitative analysis and identification of significant competencies of construction site supervisors

The data gathered from the literature investigation and expert interviews were subjected to thematic analysis to qualitatively identify the significant competencies of construction site supervisors controlling construction efficiency. Thematic analysis is a well-suited method for examining respondents' perspectives, experiences, knowledge and values using qualitative data, as recommended by Caulfield (2019). Considering these aspects, this qualitative approach was used to look at the recurring themes and patterns in the data that had been gathered. In this qualitative thematic analysis process, the identified competencies were checked for particular characters, and the codes were issued as necessary. With the basis of the themes created, the corresponding codes were then established between the groupings of competencies found through literature reviews and interviews. The repetitive characters of competencies were eliminated using the identified corresponding codes. After a second evaluation of the themes and codes, the final set of competencies was derived from this

Table 1.
Mapping of key supervisory cognitive elements determining the effectiveness of building processes based on previous investigations

Cognitive (knowledge in)	Past studies																
	Tuan and Tam (2019) - Vietnam	Murari and Joshi (2019) - India	Montaser *et al.* (2018) - Egypt	Nwosu (2018) - Nigeria	Silva *et al.* (2018) - Sri Lanka	Dixit *et al.* (2017) - India	Fernando *et al.* (2016) - Sri Lanka	Kesavan *et al.* (2015) - Sri Lanka	Hughes and Thorpe (2014) - Australia	Robles *et al.* (2014) - Spain	Shashank *et al.* (2014) - India	Jarkas *et al.* (2012) - Qatar	Adi and Ni'am (2012) - Indonesia	Jarkas and Bitar (2012) - Kuwait	Durdyev and Mbachu (2011) - New Zealand	Soekiman *et al.* (2011) - Indonesia
Site management						X		X			X					
Resource management								X								X
Health and safety in construction	X		X						X		X					
Construction planning		X				X				X						
Performance evaluation on labour skills							X									
Industrial research													X			
Construction materials			X													
Construction procedures and technology				X				X								
Material and equipment handling	X		X									X		X	X	
Waste management															X	
Water management							X									

(*continued*)

Table 1.

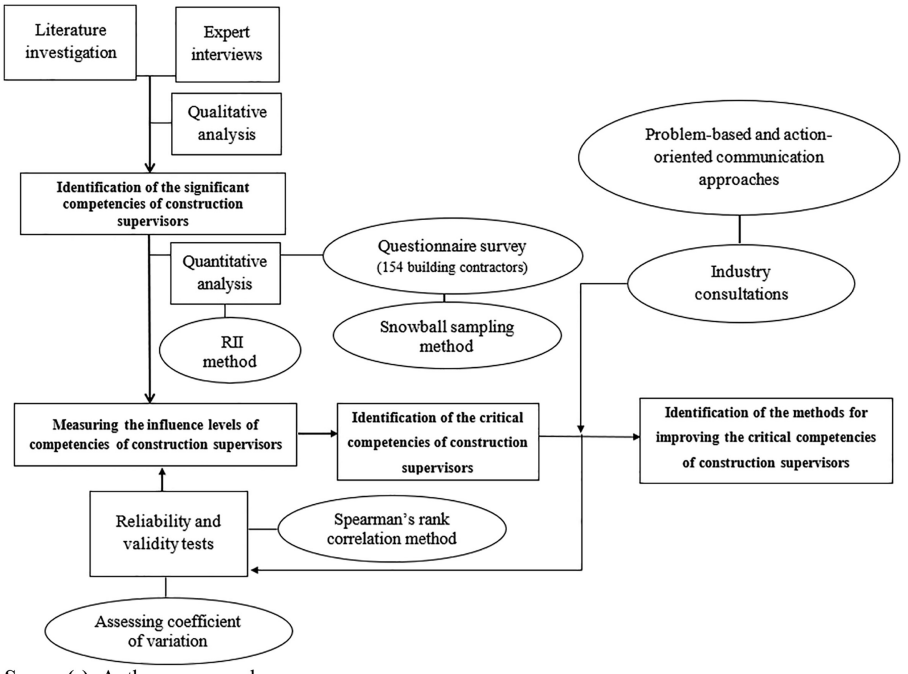
Cognitive (knowledge in)	Past studies: Tuan and Tam (2019) - Vietnam	Murari and Joshi (2019) - India	Montaser *et al.* (2018) - Egypt	Nwosu (2018) - Nigeria	Silva *et al.* (2018) - Sri Lanka	Dixit *et al.* (2017) - India	Fernando *et al.* (2016) - Sri Lanka	Kesavan *et al.* (2015) - Sri Lanka	Hughes and Thorpe (2014) - Australia	Robles *et al.* (2014) - Spain	Shashank *et al.* (2014) - India	Jarkas *et al.* (2012) - Qatar	Adi and Ni'am (2012) - Indonesia	Jarkas and Bitar (2012) - Kuwait	Durdyev and Mbachu (2011) - New Zealand	Soekiman *et al.* (2011) - Indonesia
New technologies in construction					X											
Quality assurance and control									X		X					X
Environment and society										X	X	X		X		
Financial knowledge		X	X	X												X

Source(s): Authors own work

Table 2. Mapping of key supervisory skills/ abilities determining the effectiveness of building processes based on previous investigations

Skills/ Abilities	Past studies																	
	Tuan and Tam (2019) - Vietnam	Murari and Joshi (2019) - India	Montaser *et al.* (2018) - Egypt	Nwosu (2018) - Nigeria	Silva *et al.* (2018) - Sri Lanka	Dixit *et al.* (2017) - India	Fernando *et al.* (2016) - Sri Lanka	Kesavan *et al.* (2015) - Sri Lanka	Hughes and Thorpe (2014) - Australia	Robles *et al.* (2014) - Spain	Shashank *et al.* (2014) - India	Jarkas *et al.* (2012) - Qatar	Adi and Ni'am (2012) - Indonesia	Jarkas and Bitar (2012) - Kuwait	Durdyev and Mbachu (2011) – New Zealand		Soekiman *et al.* (2011) - Indonesia
Planning		X		X		X			X								
Supervision of operations	X		X		X			X	X			X		X	X	X	
Labour management	X				X	X	X	X			X				X		
Relationship with labourers				X													
Efficient site management and coordination						X			X		X		X	X	X		
Performance evaluation on labour skills							X										
Leadership				X	X							X				X	
Decision making						X											
Resource management	X					X	X	X								X	
Motivational skills								X									
Quality inspection									X		X					X	
Ability of conducting industrial research													X				
Participation																X	

Source(s): Authors own work



Source(s): Authors own work

Figure 1.
Sequential process of the study methodology

qualitative analysis process. Figure 2 shows the sequential methodology used in this study's qualitative thematic analysis.

3.4 Quantitative analysis and measuring influence levels of competencies of construction site supervisors

A questionnaire-based survey was conducted among 154 building project firms covering all nine provinces of Sri Lanka to assess the impact levels of the identified competencies of site supervisors on building construction operations. Because of the difficulty in determining the exact size of the sample given the desired characteristics, the method of snowball sampling was applied to identify the survey respondents. According to Showkat and Parveen (2017), the technique used in snowball sampling is a non-probability approach for choosing survey sample sizes, and it can be applied when it is difficult to locate potential participants. Starting with a small group of well-known contractors, the sample size of the survey was then increased by identifying additional contractors who took part in it.

The main structure of the questionnaire was divided into two segments (Segment A and Segment B), with Segment A covering the backgrounds of the survey respondents and Segment B including the significant competencies identified through the qualitative process. Survey participants were asked to rate each element's level of influence on the efficiency of construction operations using a Likert scale ranging from 1 (representing "very low effect") to 5 (representing "extremely high effect"). In particular, the questionnaire included all the necessary instructions and information to guarantee that respondents understood the scope of the study and the aspects associated with the importance of efficiency and sustainability in construction practices. In the initial stage of the survey, eight survey respondents participated in cognitive interviews to support the validity of the questions that were created for the questionnaire design.

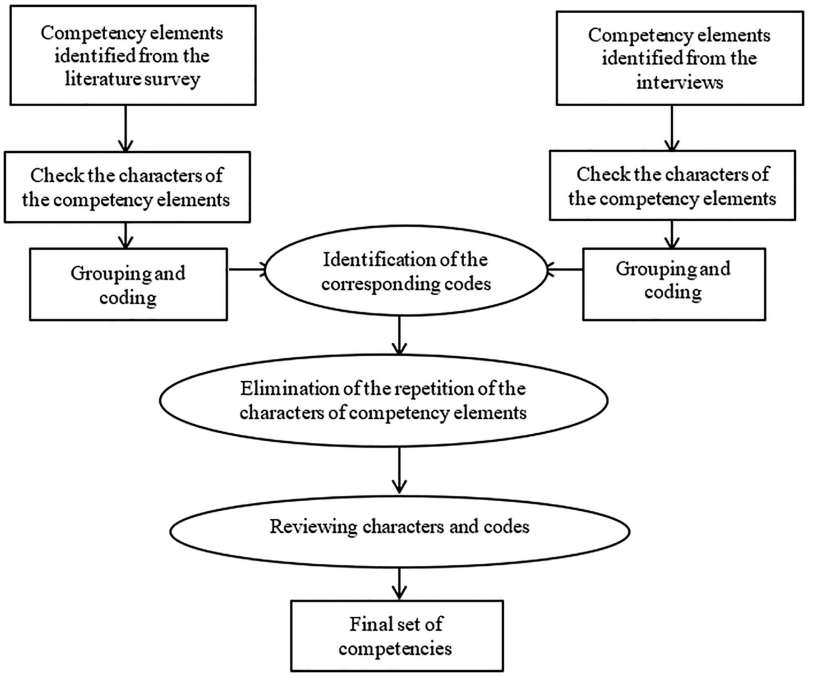


Figure 2.
Sequential process of the study methodology associated with qualitative thematic analysis

Source(s): Authors own work

Only the construction contractors who work on building projects with a minimum CIDA registration grade of "C4" were taken into account in this survey. In Sri Lanka, the CIDA grants the necessary grades for a contractor's registration by assessing the financial availability, technical proficiency and work experience of the contractors. In Sri Lankan Rupees, 50–150 million are the permitted financial limits for the "C4" grade, as mentioned in the Construction Development Act 33 (CIDA, 2014). The discussions with the officials of CIDA highlighted that the above-stated needs are crucial for the firms that have "C4" or above registration grade since such construction firms usually run the projects within a sustainable scope, whereas most of the firms having less than "C4" registration grade can be considered less important for this study's scope considering their weak organisational structures and resource availabilities to apply suitable actions for a long stage. A total of 154 Sri Lankan building construction contractors responded to this survey. Considering the methods of questionnaire distribution, the majority (56%) of the questionnaires were received through direct handover. On the other hand, notable percentages of questionnaires were received by posts (34%) and email (10%). According to the job designation of the respondents, they were divided into two working categories, which are Directors/Managers/Engineers (named "DME") and Assistant Engineers/Technical Officers/Supervisors (named "ATS"). Table 3 displays the survey respondents' detailed profiles. Notably, a 3:2 ratio between DME and ATS work categories was reported among the survey respondents. The classification based on the job designation of the survey respondents was considered important to assess the dependability of the results by measuring the degree of agreement between the perspectives of different working categories. Among the survey respondents, the majority (48%) were "C4" grade registered contractors, whereas all the respondents particularly had a minimum of

Profile	Variables	No. of responses	Percentage (%)
CIDA grade of contractors (X: Financial limit of the projects - LKR in million)	CS2/CS1 (X > 1,500)	07	05
	C1 (1,500 ≥ X > 600)	23	15
	C2 (600 ≥ X > 300)	25	16
	C3 (300 ≥ X > 150)	25	16
	C4 (150 ≥ X > 50)	74	48
Experience in the construction field	Less than 5 Years	02	01
	5–10 Years	70	45
	11–15 Years	39	25
	16–20 Years	15	10
	21–25 Years	18	12
	More than 25 Years	10	06
Job category	DME	90	58
	ATS	64	42

Source(s): Authors own work

Table 3. Detailed information about survey respondents who responded

five years of experience working in the construction industry, with the majority (45%) of respondents having between 5 and 10 years of experience.

As per the importance of quantitative approaches in interpreting the collected data in a scientific and numerical manner, the relative importance index (RII) approach was used to quantify the influences of the identified competencies on the efficiency of building project works. As suggested by Shoar and Banaitis (2018), RII values were calculated using Equation (1).

$$\mathrm{RII} = \frac{\sum \mathrm{W}}{\mathrm{A} * \mathrm{N}} \tag{1}$$

Where

W reflects the weight that each component received from the response range (1 – "Extremely low", 2 – "Low", 3 – "Moderate", 4 – "High", 5 – "Extremely high").

A reflects the highest weight given.

N is the number of total responses.

The greater RII value shows that the corresponding element/factor has significant influences on the efficiency of building project operations. According to the recommendations provided by earlier investigations (Shanmuganathan *et al.*, 2014; Shoar and Banaitis, 2018), the following RII value ranges were taken into consideration when determining the levels of effects of the competencies, and a minimum RII value of 0.7 was required to determine whether a given competency was critical. The coefficient of variation (CV) values for each competency were computed in order to assess the validity and reliability of the results. The ratio of standard deviation to RII is known as the CV value (Solly and Gezani, 2017), whereas the dependability of the outcome is guaranteed by a CV value of less than 0.3 for each element/factor, according to Statistics Canada (2020).

RII ≥ 0.9: Extremely High (EH)

0.9 > RII ≥ 0.8: High (H)

0.8 > RII ≥ 0.7: High – Moderate (HM)

0.7 > RII ≥ 0.6: Moderate (M)

0.6 > RII ≥ 0.5: Moderate – Low (ML)

0.5 > RII ≥ 0.3: Low (L)

0.3 > RII: Extremely Low (EL)

The degree of agreement/relationship between the perspectives of DME and ATS levels of working categories on the competencies of construction site supervisors working in building construction projects was determined using Spearman's coefficient of rank correlation. As suggested by Kesavan *et al.* (2015), this can be determined using Equation (2).

$$\rho = 1 - \left[6\,\Sigma D^2 / n\left(n^2 - 1\right)\right] \tag{2}$$

Where

ρ reflects Spearman's rank correlation.

D reflects the difference between the ranks of two variables.

n is the count of observations.

The values of Spearman's rank correlation were examined in the following ranges to ascertain the effects of the level of agreement.

$\rho > 0$: Positive degree of agreement (Positive relationship)

$\rho = 0$: Neutral (No correlation)

$0 > \rho$: Negative degree of agreement (Negative relationship)

3.5 Industry consultative meetings and workshops

To identify the methods for enhancing the critical construction site supervisory competencies, a series of industry consultative discussions and meetings were held among industry experts/specialists from different work categories. Importantly, 25 academic and industry experts, including project directors, planners, management specialists, engineering experts and institutional representatives, took part in this. Problem-based and action-oriented communication methods were mainly applied in the consultative sessions and tasks. The results of the consultative outcomes further supported the validity and dependability of the research findings.

4. Analysis and results

Based on the RII values, the influence levels of competencies were determined, as shown in Table 4 and Table 5. The findings indicate the degree to which each competency of the site supervisors has an impact on how well building project operations are performed.

Overall, 22 knowledge elements and 24 skills/abilities of construction site supervisory competencies were determined as being crucial according to their RII values. Considering the cognitive elements of the construction site supervisory competencies, their knowledge in construction planning, construction materials, performance evaluation methods on labour skills, basic concepts of structures and site management were found in the top five rankings. When it comes to their skills and abilities, labour management, planning, performance evaluation on labour skills, leadership and decision-making were the elements in the top five rankings.

A total of 17 cognitive elements and 24 skills/abilities were determined to be the crucial competencies of construction site supervisors when looking at DME-level workers' perspectives. Based on the viewpoint of ATS-level workers, 22 knowledge elements and 24

Table 4. Levels of effects of construction supervisors' cognitive elements on the effectiveness of building construction operations

Cognitive elements (knowledge)	DME level workers' perspective					ATS level workers' perspective					Overall				
	RII	SD	CV	#	LE	RII	SD	CV	#	LE	RII	SD	CV	#	LE
Construction planning	0.83	0.15	0.18	1	H	0.92	0.17	0.18	2	EH	0.87	0.16	0.18	1	H
Construction materials	0.82	0.16	0.20	2	H	0.92	0.15	0.16	2	EH	0.86	0.17	0.20	2	H
Performance evaluation on labour skills	0.81	0.16	0.20	3	H	0.92	0.15	0.16	4	EH	0.86	0.17	0.20	2	H
Basic concepts of structures	0.80	0.16	0.20	5	H	0.93	0.16	0.17	1	EH	0.85	0.15	0.18	4	H
Site management	0.80	0.16	0.20	4	H	0.87	0.20	0.23	6	H	0.83	0.15	0.18	5	H
Resource management	0.79	0.15	0.19	7	HM	0.87	0.14	0.16	7	H	0.82	0.20	0.24	6	H
Construction procedures and technology	0.80	0.21	0.26	6	H	0.86	0.15	0.17	8	H	0.82	0.14	0.17	6	H
Industrial research	0.77	0.14	0.18	11	HM	0.89	0.17	0.19	5	H	0.82	0.13	0.16	6	H
Health and safety in construction	0.79	0.14	0.18	8	HM	0.84	0.17	0.20	9	H	0.81	0.15	0.19	9	H
Material and equipment handling	0.78	0.16	0.21	9	HM	0.80	0.13	0.16	11	H	0.79	0.11	0.14	10	HM
Quality assurance and control	0.77	0.12	0.16	10	HM	0.80	0.13	0.16	10	H	0.78	0.12	0.15	11	HM
New technologies in construction	0.76	0.17	0.22	12	HM	0.77	0.13	0.17	15	HM	0.77	0.16	0.21	12	HM
English/Languages other than mother tongue	0.73	0.12	0.16	13	HM	0.79	0.14	0.18	12	HM	0.76	0.11	0.14	13	HM
Basic labour laws and regulation	0.72	0.12	0.17	14	HM	0.79	0.15	0.19	12	HM	0.75	0.13	0.17	14	HM
Financial knowledge	0.71	0.11	0.15	17	HM	0.78	0.13	0.17	14	HM	0.74	0.16	0.22	15	HM
Waste management	0.71	0.13	0.18	16	HM	0.76	0.15	0.20	16	HM	0.73	0.13	0.18	16	HM
Simple architecture	0.72	0.15	0.21	15	HM	0.74	0.14	0.19	19	HM	0.73	0.12	0.16	16	HM
Information and communication technology	0.70	0.14	0.20	18	HM	0.73	0.12	0.16	21	HM	0.72	0.15	0.21	18	HM
Water management	0.69	0.14	0.20	20	M	0.74	0.13	0.18	19	HM	0.71	0.13	0.18	19	HM
Environmental sustainability	0.68	0.12	0.18	23	M	0.75	0.14	0.19	18	HM	0.71	0.13	0.18	19	HM
Environment and society	0.68	0.11	0.16	24	M	0.75	0.12	0.16	17	HM	0.71	0.12	0.17	19	HM
Estimation	0.70	0.13	0.19	19	HM	0.72	0.12	0.17	22	HM	0.71	0.13	0.18	19	HM
Simple measurements	0.69	0.12	0.17	22	M	0.67	0.12	0.18	23	M	0.68	0.13	0.19	23	M
Numeracy	0.69	0.12	0.17	21	M	0.63	0.13	0.21	25	M	0.67	0.13	0.19	24	M
Basic electricity	0.67	0.14	0.21	25	M	0.64	0.14	0.22	24	M	0.66	0.15	0.23	25	M

Note(s): μ: Mean; σ: Standard Deviation; CV: Coefficient of Variation; RII: Relative Important Index; LE: Level of Effect; #: Rank; EH: Extremely High; H: High; HM: High-Moderate; M: Moderate; ML: Moderate-Low; L: Low; EL: Extremely Low

Source(s): Authors own work

Table 5.
Levels of effects of construction supervisors' skills/abilities on the effectiveness of building construction operations

Skills/Abilities	DME level workers' perspective					ATS level workers' perspective					Overall				
	RII	SD	CV	#	LE	RII	SD	CV	#	LE	RII	SD	CV	#	LE
Labour management	0.86	0.16	0.19	1	H	0.95	0.15	0.16	1	EH	0.90	0.15	0.17	1	EH
Planning	0.85	0.15	0.18	2	H	0.94	0.16	0.17	2	EH	0.89	0.15	0.17	2	H
Performance evaluation on labour skills	0.83	0.16	0.19	5	H	0.94	0.16	0.17	2	EH	0.88	0.16	0.18	3	H
Leadership	0.84	0.15	0.18	3	H	0.93	0.15	0.16	5	EH	0.88	0.15	0.17	3	H
Decision making	0.84	0.15	0.18	4	H	0.93	0.15	0.16	5	EH	0.87	0.15	0.17	5	H
Communication	0.82	0.17	0.21	7	H	0.91	0.17	0.19	7	EH	0.86	0.16	0.19	6	H
Critical thinking	0.83	0.16	0.19	6	H	0.90	0.14	0.16	10	EH	0.86	0.17	0.20	6	H
Supervision of operations	0.82	0.17	0.21	7	H	0.91	0.15	0.16	8	EH	0.86	0.16	0.19	6	H
Analytical skills and abilities	0.80	0.20	0.25	11	H	0.93	0.16	0.17	4	EH	0.86	0.15	0.17	6	H
Efficient site management and coordination	0.82	0.14	0.17	10	H	0.90	0.14	0.16	11	EH	0.85	0.15	0.18	10	H
Problem solving	0.82	0.15	0.18	9	H	0.87	0.13	0.15	15	H	0.84	0.15	0.18	11	H
Motivational skills	0.80	0.19	0.24	14	H	0.88	0.15	0.17	12	H	0.84	0.16	0.19	11	H
Relationship with labour	0.80	0.15	0.19	11	H	0.87	0.13	0.15	15	H	0.83	0.20	0.24	13	H
Ability of conducting industrial researches	0.76	0.14	0.18	22	HM	0.91	0.14	0.15	8	EH	0.82	0.18	0.22	14	H
Conflict resolution	0.79	0.13	0.16	16	HM	0.87	0.12	0.14	15	H	0.82	0.14	0.17	14	H
Resource management	0.80	0.15	0.19	11	H	0.84	0.16	0.19	20	H	0.82	0.13	0.16	14	H
Quality inspection	0.78	0.15	0.19	18	HM	0.87	0.18	0.21	14	H	0.82	0.15	0.18	14	H
Innovative thinking	0.78	0.15	0.19	18	HM	0.87	0.15	0.17	15	H	0.82	0.16	0.20	14	H
Optimisation	0.77	0.14	0.18	20	HM	0.87	0.21	0.24	13	H	0.81	0.15	0.19	19	H
Impersonal skills	0.77	0.16	0.21	20	HM	0.84	0.14	0.17	19	H	0.80	0.15	0.19	20	H
Technical skills and abilities	0.79	0.14	0.18	17	HM	0.81	0.14	0.17	21	H	0.80	0.14	0.18	20	H
Time and priority management	0.79	0.13	0.16	15	HM	0.80	0.14	0.18	22	H	0.80	0.14	0.18	20	H
Ethical behaviour	0.75	0.14	0.19	23	HM	0.79	0.14	0.18	23	HM	0.77	0.14	0.18	23	HM
Information technology skills	0.67	0.17	0.25	25	M	0.73	0.15	0.21	24	HM	0.70	0.16	0.23	24	HM
Participation	0.73	0.16	0.22	24	HM	0.60	0.16	0.27	25	M	0.67	0.17	0.25	25	M

Note(s): μ: Mean; σ: Standard Deviation; CV: Coefficient of Variation; RII: Relative Important Index; LE: Level of Effect; #: Rank; EH: Extremely High; H: High; HM: High-Moderate; M: Moderate; ML: Moderate-Low; L: Low; EL: Extremely Low

Source(s): Authors own work

skills/abilities of construction site supervisory competencies were identified as being crucial. The degree of agreement/disagreement between DME and ATS work categories on the construction site supervisory competencies influencing the efficiency of building construction operations was assessed using Spearman's rank correlation coefficient. The findings show that these two working categories have a degree of agreement (positive relationship) of 91.7% on the cognitive domains of construction site supervisory workers. They agree (have a positive relationship) to an extent of 78.6% with respect to skills/abilities of construction site supervisory competencies. The findings show that there are not many conceptual contrarieties between the perspectives of DME and ATS working categories on the identified competencies of construction site supervisors affecting the efficiency of building construction operations.

5. Discussion

Taking on the top 10 rankings of competencies in each category compared to past studies, most of those were found that substantially influenced the efficiency of construction activities in many nations, namely, Australia (Hughes and Thorpe, 2014), Egypt (Montaser *et al.*, 2018), India (Shashank *et al.*, 2014; Dixit *et al.*, 2017; Murari and Joshi, 2019), Indonesia (Soekiman *et al.*, 2011; Adi and Ni'am, 2012), Kuwait (Jarkas and Bitar, 2012), Nigeria (Nwosu, 2018), Qatar (Jarkas *et al.*, 2012), Sri Lanka (Manoharan *et al.*, 2022a) and Vietnam (Tuan and Tam, 2019). Taking on the methods for enhancing the critical competency elements of supervisory workers in construction, the relevant actions were identified through industry consultation discussions and literary analysis on the characteristics of those competencies and the current/future scopes of the industry practices. Accordingly, considering the construction site supervisors' competencies related to site management, resource management and construction planning, effective skill development practices need to be introduced with a specific focus on enhancing the construction site supervisors' cognitive and manual skills/abilities in applying project management principles and techniques in construction operations, scheduling project tasks, upholding quality assurance and control procedures, creating cash flow statements for construction sites and understanding of construction contract laws. In particular, the experts' discussions and a few studies (Soekiman *et al.*, 2011; Kesavan *et al.*, 2015; Dixit *et al.*, 2017) emphasised such a potential action. In addition to these, Manoharan *et al.* (2022b) accentuate that the construction site supervisors' abilities in applying labour management practices on construction sites, measuring labour productivity and evaluating labour performance will make them identify effective paths for improving the efficiency of labour operations in construction.

Additionally, the other critical competencies of construction site supervisors listed in the top 10 rankings can be addressed by upgrading the industrial and institutional practices focusing on the enhancement of the following competency elements of outcomes of construction site supervisors, as per the discussions with the industry experts on the results and the needed actions on competency enhancement.

(1) Applying fundamental scientific and technological principles

(2) Applying fundamental engineering and technological principles

(3) Performing construction site work by adhering to health and safety regulations

(4) Performing supervision on building construction work with well-improved technical abilities, especially in the tasks related to the substructure, superstructure and finishing stages

(5) Applying efficient material management strategies

(6) Utilising green practices in construction

(7) Providing opportunities for hands-on learning to workers at construction sites

(8) Developing labour training tasks and applying work-based training methods to construction labourers

(9) Involving in simple research applications on enhancing labour operations

Taking on applying fundamental scientific and technological principles, the study emphasises the need for enhancing the site supervisory competency elements in taking accurate measurements in construction tasks at first. In particular, it is important for the site supervisors to be very familiar with the fundamental units used, formulas and concepts applied, as well as error calculations while carrying out various physical, mechanical, thermal and electrical measurement tasks. In particular, when it comes to surveying and setting out tasks, the industry experts revealed that the work qualities of site supervisors have not been at an adequate level in taking linear and angular measurements, taking measurements of sloping ground, levelling and theodolite surveying, traversing, error calculations and the use of the total station. Next, this study highlights the importance of enhancing site supervisory competency elements in estimating aspects. The site supervisors' involvement in the preparatory tasks of the bill of quantities for various construction tasks will add additional benefits to avoid unnecessary constraints related to time, quality and quantity. The competencies associated with generating drawings and designs using manual techniques or computer-aided software tools also add additional strength to the site supervisory practices associated with measurements and estimations. Further, the industry experts stated that most of the site supervisory staff employed in building construction projects in numerous developing countries are not familiar with keeping records and documentation within computerised systems in order to avoid unnecessary expenses, time delays and communication issues. Compared to the supervision roles in many developed countries, the industry experts highlighted the poor understanding level of competencies of site supervisors in classifying computer operating systems, data storage, wired/wireless/optical data transmission technologies, network classifications and topologies, Internet protocols, usage of emails and Microsoft Office packages. Such actions associated with skill enhancement focus on the fundamental scientific and technological principles are also considerably replicated in a few studies representing different countries, such as Egypt (Montaser *et al.*, 2018), Nigeria (Nwosu, 2018) and Vietnam (Tuan and Tam, 2019).

When it considers the application of fundamental engineering and technological principles, the expert discussions highlighted the importance of supervisory competencies in solving simple structural-related problems at first. Here, the expert discussions emphasised ensuring the understanding and applying level competency domains of construction site supervisors in structural mechanics and analysis related to force systems and equilibrium, sketching free body diagrams, stability and determinacy of different structures, the structural behaviour and actions for tensile, compressive, shear, bending and torsion effects, load path/distribution in building structural elements, structural concepts for different types of supports and connections, identification of axially loaded members, shape and effects of shear force/stress and bending moment/stress distributions in structural elements, elastic buckling in compression members, deflection shape/profile of structural elements and the concepts related to structural modelling. Further, the expert discussions highlighted the importance of the site supervisory competencies associated with the fundamentals of fluid properties, such as viscosity, surface tension, compressibility, pressure variation in fluids, stability of immersed/floating bodies, velocity measurements, flow rate measurements, flow visualisation, flow measuring devices, head losses in multiple pipe

systems, surface and groundwater hydrological properties and other relevant measurement properties on regional water sources. On the other hand, the site supervisors' cognitive abilities related to fundamental properties of soil mechanics, such as the basic composition of the soil, soil classification, soil compressibility, water content and hydraulic properties of soil, soil compaction, investigations and testing experiments, will lead to significantly influence the work qualities of geotechnical aspects in building structures. It is significant to note that no potential studies emphasised such actions recommended by the industrial experts on the supervisors' work attributes focusing on handling structural, hydrological and geotechnical aspects in the recent scenarios. The major reason behind this can be the lack of attention to recent studies on conducting expert consultations, and this signifies the need for a change in the regular approaches to industrial investigations.

In order to perform construction site work by adhering to health and safety regulations, recent studies (El-Nagar *et al.*, 2015; Wijewantha, 2018; Min *et al.*, 2019) emphasise that adequate cognitive and manual skills are required for site supervisors in the aspects related to safety policies, safety foundation, safety culture, safety monitoring, controlling principles, risk assessment, accident investigation/reporting, insurance and legislation procedure, material and machinery movement, machinery/tool handling, fire hazards, electrical hazards, biological/chemical hazards, mining safety, first aid regulations, occupational health and disease, environmental control and traffic control safety. Further, the industry expert discussions highlighted that the cognitive and manual skills of site supervisors employed in many developing nations need to be widely expanded in modern building technologies associated with earthwork, formwork, bar-bending, concreting, masonry, plastering, tiling, waterproofing, plumbing, carpentry, welding, electrical installations, pre-cast and pre-stressed structural work and machinery operation techniques in different stages of construction phases.

When it takes to the site supervisory competencies for applying efficient material management strategies, the site supervisors' cognitive and manual skills in the industrial usage of construction materials are highly essential, particularly the behaviour of construction materials like cement, concrete, steel and timber materials, the concrete material properties associated with strength, workability, compaction, bleeding and segregation effects, tests for checking concrete material quality (compacting factor test, slump test and cube test) and concrete mix design aspects under various conditions/requirements. Moreover, the site supervisors' understanding level cognitive abilities in the mechanical behaviour of metals, especially stress-strain variations, the concepts and properties associated with ductility, necking, brittleness, toughness and tensile strength, tensile test, hardness test, impact test and the types of metal failures, are the other notable areas in the part of material handling strategies. It can also be notable that even though a few studies (Durdyev and Mbachu, 2011; Jarkas and Bitar, 2012; Jarkas *et al.*, 2012; Montaser *et al.*, 2018; Tuan and Tam, 2019) emphasised the need for enhancing material management strategies, but none of them presented what strategies need to be considered for enhancing material handling competency traits of site supervisory workers.

Considering the site supervisory abilities in utilising green practices, the expert discussions and a few past studies (Durdyev and Mbachu, 2011; Fernando *et al.*, 2016) accentuated that the site supervisors need to have proper awareness and readiness to respond to the concepts and applications related to water management, waste management, environmental management system, environmental sustainability, usage of sustainable resources and other relevant green tools. Importantly, the concept of green practices increases resource utilisation efficiency in order to lessen the negative effects of building on the environment and on human health during all phases of construction, including design, construction, operation and maintenance. Green practices often have a positive impact on the environment by generating their own energy or boosting biodiversity in addition to reducing or eliminating negative environmental effects.

In addition to the above-highlighted aspects, providing opportunities for hands-on learning to workers at construction sites, developing labour training tasks and applying work-based training methods to construction labourers will lead to adding new characteristics to the job roles of site supervision, as emphasised by Manoharan *et al.* (2022b). Additionally, the expert consultations highlighted that site supervisors' involvement in simple research applications on the enhancement of labour operations, especially assisting in identifying problems, conducting field surveys, collecting information and analysing data, will add some advanced value to the site supervision attributes.

The reliability and accuracy of the results are guaranteed by the CV values of the competencies. For all categories of competencies, the CV values were found below 0.3, as shown in Table 4 and Table 5. These CV values ensure that the accuracy and dependability of the findings are at a satisfactory level for the purpose of this study, according to Statistics Canada (2020). In addition to these, the degree of agreement found between the perspectives of two different working categories and the industry consultation outcomes further support the trustworthiness of these results. The outcomes of the discussions with the industry experts on the results and the required actions on competency enhancement also replicate the dependability of the current research findings in overcoming impediments to production imposed by shifting industry challenges.

6. Conclusions

The study has identified the critical competencies of construction site supervisors that affect the efficiency of workflows in building project tasks with severity values. The overall study has established a foundation layer for understanding how important site supervisory competencies affect the efficiency of building construction operations, making a significant difference in the approaches to reskilling and upskilling in the sector related to construction labour, supervision, efficiency management and productivity improvement. The current study emphasises the need to restructure the construction supervision characteristics associated with the knowledge gap in the area with regard to identifying what supervisory traits are essential, what causes are associated with the influences of supervisory traits on project efficiency, how such causes and influences disrupt the flows of project effectiveness and what types of actions need to be implemented.

The study started off by qualitatively identifying those elements, and then it quantified the extent to which those elements influence the efficiency of building construction operations and identified the future steps that the appropriate authorities must take to enhance the practices currently employed in supervision. The study emphasises the urgent need to upgrade the current training programmes for the construction site supervisors employed in developing nations. Based on the crucial competencies determined in this study, the necessary workplace training activities and experimental exercises should be developed to apply constructive approaches to construction site supervision practices. For the purpose of making the necessary adjustments to the current training programmes, the training providers and skill development authorities will find the levels of impact of the supervisory competencies obtained in this study to be of great assistance. The study has further proposed some important elements of competencies that carry pertinent actions for enhancing the critical competencies of construction site supervisors through training development practices. These findings will be highly useful for developing new apprenticeship programmes based on industry needs, particularly for designing learning outcomes, learning content and delivery strategies.

The study outcomes open a window to flow potential knowledge attributes to the industry sector along with the necessary comparison of a variety of competency elements to comprehend what levels of supervisory abilities can be practically applied and

theoretically considered in site activities. It is crucial to assure the sustainability of project participants' workflows and job outputs due to the additional implications that these enhancements or changes in supervision outcomes may have on the job characteristics of engineers and project managers. In turn, this improves the working relationship between diverse job roles, assuring the long-term viability of the construction industry. Also, the study's conclusions may contribute to the transition of supervisory employees from temporary to permanent employment in many construction organisations. As a result, this study helps local businesses reduce the use of foreign staff and increases the quality of jobs at construction sites strengthening the self-sustainability and economic structure of the industry.

Though the study's scope is restricted to supervision practices used in building construction projects in Sri Lanka, other emerging construction industries might test these findings in similar circumstances. Future studies are advised to concentrate more on enhancing practices based on the crucial competencies of construction site supervisors depicted in this research. Moreover, this research suggests that future studies may focus on developing new proactive training models/programmes and assessing the efficiency and productivity of various construction flows within building projects. This may lead to expanding the generalisable outcomes more scientifically and practically within the basis of the findings of the current study.

References

Adi, H.P. and Ni'am, M.F. (2012), "Improving skill's strategies of Indonesian construction labours to have global competitiveness", *International Journal of Civil and Structural Engineering*, Vol. 3 No. 1, pp. 150-157, doi: 10.6088/ijcser.201203013014.

Caulfield, J. (2019), "How to do thematic analysis?", available at: https://www.scribbr.com/methodology/thematic-analysis/ (accessed 16 October 2019).

CIDA (2014), "National registration and grading scheme for construction contractors", Construction Industry Development Act No. 33 Sri Lanka, available at: http://www.cida.gov.lk/sub_pgs/con_registration.html (accessed 12 November 2019).

Dixit, S., Amit, K.P., Satya, N.M. and Sanjeev, B. (2017), "A study of enabling factors affecting construction productivity: indian scenario", *International Journal of Civil Engineering and Technology*, Vol. 8 No. 6, pp. 741-758.

Durdyev, S. and Mbachu, J. (2011), "On-site labour productivity of New Zealand construction industry: key constraints and improvement measures", *Australasian Journal of Construction Economics and Building*, Vol. 11 No. 3, pp. 18-33, doi: 10.5130/ajceb.v11i3.2120.

El-Nagar, R., Hosny, H. and Askar, H.S. (2015), "Development of a safety performance index for construction projects in Egypt", *American Journal of Civil Engineering and Architecture*, Vol. 3 No. 5, pp. 182-192, doi: 10.12691/ajcea-3-5-5.

Fernando, P.G.D., Fernando, N.G. and Gunarathna, M.A.C.L. (2016), "Skills developments of labourers to achieve the successful project delivery in the Sri Lankan construction industry", *Civil and Environmental Research*, Vol. 8 No. 5, pp. 86-99.

Ghoddousi, P., Pourafshar, O., Chileshe, N. and Hosseini, M.R. (2015), "Labour productivity in Iranian construction projects", *International Journal of Productivity and Performance Management*, Vol. 64 No. 6, pp. 811-830, doi: 10.1108/IJPPM-10-2013-0169.

Halwathura, R.U. (2015), "Critical factors which govern labour productivity in building construction industry in Sri Lanka", *PM World Journal*, Vol. 4 No. 4, pp. 1-13.

Hickson, B.G. and Ellis, L. (2013), "Factors affecting construction labour productivity in Trinidad and Tobago", *The Journal of the Association of Professional Engineers of Trinidad and Tobago*, Vol. 42 No. 1, pp. 4-11.

Hughes, R. and Thorpe, D. (2014), "A review of enabling factors in construction industry productivity in an Australian environment", *Construction Innovation*, Vol. 14 No. 2, pp. 210-228, doi: 10.1108/CI-03-2013-0016.

Jarkas, A. and Bitar, C. (2012), "Factors affecting construction labor productivity in Kuwait", *Journal of Construction Engineering and Management*, Vol. 138 No. 7, pp. 811-820, doi: 10.1061/(ASCE)CO.1943-7862.0000501.

Jarkas, A.M., Kadri, C.Y. and Younes, J.H. (2012), "A survey of factors influencing the productivity of construction operatives in the State of Qatar", *International Journal of Construction Management*, Vol. 12 No. 3, pp. 1-23, doi: 10.1080/15623599.2012.10773192.

Kadir, M.R., Lee, W.P., Jaafar, M.S., Sapuan, S. and Ali, A. (2005), "Factors affecting construction labour productivity for Malaysian residential projects", *Structural Survey*, Vol. 23 No. 1, pp. 42-54, doi: 10.1108/02630800510586907.

Kesavan, M., Gobidan, N.N., Gobishanker, R. and Dissanayake, P.B.G. (2014), "Proper project planning in avoiding construction project delays", *Proceedings of the Special Sessions on Sustainable Design and Construction, 5th International Conference on Sustainable Built Environment*, Kandy, pp. 77-84.

Kesavan, M., Gobidan, N.N. and Dissanayake, P.B.G. (2015), "Analysis of factors contributing civil engineering project delays in Sri Lanka", *Proceedings of the Session on Construction Management and Tall Building and Urban Habitat, 6th International Conference on Structural Engineering and Construction Management*, Vol. 4, pp. 40-46.

Mahan, T. (2019), "How to define ethical behavior & why it's important in the workplace", available at: https://workinstitute.com/how-to-define-ethical-behavior-why-its-important-in-the-workplace-2/ (accessed 7 November 2019).

Manoharan, K., Dissanayake, P., Pathirana, C., Deegahawature, D. and Silva, R. (2022a), "A guiding model for developing construction training programmes focusing on productivity and performance improvement for different qualification levels", *Construction Innovation*, pp. 1-24, doi: 10.1108/CI-10-2021-0194.

Manoharan, K., Dissanayake, P., Pathirana, C., Deegahawature, D. and Silva, R. (2022b), "Assessing the performance and productivity of labour in building construction projects through the application of work-based training practices", *Construction Innovation*, pp. 1-26, doi: 10.1108/CI-05-2022-0126.

Manoharan, K., Dissanayake, P., Pathirana, C., Deegahawature, D. and Silva, R. (2022c), "Labour-related factors affecting construction productivity in Sri Lankan building projects: perspectives of engineers and managers", *Frontiers in Engineering and Built Environment*, Vol. 2 No. 4, pp. 218-232, doi: 10.1108/FEBE-03-2022-0009.

Min, J., Kim, Y., Lee, S., Jang, T.W., Kim, I. and Song, J. (2019), "The fourth industrial revolution and its impact on occupational health and safety, worker's compensation and labour conditions", *Safety and Health at Work*, Vol. 10 No. 4, pp. 400-408, doi: 10.1016/j.shaw.2019.09.005.

Mistri, A., Patel, C.G. and Pitroda, J.R. (2019), "Analysis of causes, effects and impacts of skills shortage for sustainable construction through analytic hierarchy process", *International Journal of Technical Innovation in Modern Engineering and Science*, Vol. 5 No. 5, pp. 168-176.

Montaser, N.M., Mahdi, I., Mahdi, H.A. and Rashid, I.A. (2018), "Factors affecting construction labour productivity for construction of pre-stressed concrete bridges", *International Journal of Construction Engineering and Management*, Vol. 7 No. 6, pp. 193-206, doi: 10.5923/j.ijcem.20180706.01.

Murari, S.S. and Joshi, A.M. (2019), "Factors affecting labour productivity in precast construction industry", *Proceedings of Fourth National Conference on Road and Infrastructure*, Bengaluru, pp. 163-169.

Nwosu, O.V. (2018), "Impact of low labour characteristics on construction sites productivity in EBONYI state", *International Journal of Advanced Research in Science, Engineering and Technology*, Vol. 5 No. 10, pp. 7072-7087.

Oseghale, B.O., Abiola-Falemu, J.O. and Oseghale, G.E. (2015), "An evaluation of skilled labour shortage in selected construction firms in Edo State, Nigeria", *American Journal of Engineering Research*, Vol. 4 No. 1, pp. 156-167.

Robles, G., Stifi, A., Jose, L.P. and Gentes, S. (2014), "Labour productivity in the construction industry - factors influencing the Spanish construction labour productivity", *World Academy of Science, Engineering and Technology International Journal of Civil and Environmental Engineering*, Vol. 8 No. 10, pp. 1061-1070.

Saurav, D., Satya, N.M., Anil, S. and Subhav, S. (2017), "Relationship between skill development and productivity in construction sector: a literature review", *International Journal of Civil Engineering and Technology*, Vol. 8 No. 8, pp. 649-665.

Shanmuganathan, A., Disaratna, V. and Francis, M. (2014), "A study of procurement selection for bridge construction", *FARU Journal 2014*, Vol. 6 No. 1, pp. 112-121.

Shashank, K., Hazra, S. and Pal, N.K. (2014), "Analysis of key factors affecting the variation of labour productivity in construction projects", *International Journal of Emerging Technology and Advanced Engineering*, Vol. 4 No. 5, pp. 152-160.

Shoar, S. and Banaitis, A. (2018), "Application of fuzzy fault tree analysis to identify factors influencing construction labour productivity: a high-rise building case study", *Journal of Civil Engineering and Management*, Vol. 25 No. 1, pp. 41-52, doi: 10.3846/jcem.2019.7785.

Showkat, N. and Parveen, H. (2017), *Non-probability and Probability Sampling*, E-PG Pathshala, Gujarat.

Silva, G.A.S.K., Warnakulasuriya, B.N.F. and Arachchige, B.J.H. (2018), "A review of the skill shortage challenge in construction industry in Sri Lanka", *International Journal of Economics, Business and Management Research*, Vol. 2 No. 1, pp. 75-89.

Soekiman, A., Pribadi, K.S., Soemardi, B.W. and Wirahadikusumah, R.D. (2011), "Factors relating to labour productivity affecting the project schedule performance in Indonesia", *Procedia Engineering*, Vol. 14, pp. 865-873, doi: 10.1016/j.proeng.2011.07.110.

Solly, M.S. and Gezani, R.M. (2017), "Construction and application of a statistical test for coefficient of variation on normal distributions", *American Journal of Applied Sciences*, Vol. 14 No. 11, pp. 1024-1030, doi: 10.3844/ajassp.2017.1024.1030.

Statistics Canada (2020), *Guide to the Labour Force Survey 2020*, Statistics Canada.

Tertiary and Vocational Education Commission (2017), *Construction Industry Sector Training Plan 2018-2020*, Tertiary and Vocational Education Commission, Colombo.

Tuan, D.H. and Tam, N.V. (2019), "Analysis of affected factors on construction productivity in Vietnam", *International Journal of Civil Engineering and Technology*, Vol. 10 No. 2, pp. 854-864.

Wijewantha, P. (2018), "Occupational health and safety (OHS) and organizational commitment: evidence from the construction industry of Sri Lanka", *Studia i Prace WNEiZ US*, Vol. 51 No. 2, pp. 273-282.

Windapo, A.O. (2016), "Skilled labour supply in the South African construction industry: the nexus between certification, quality of work output and shortages", *SA Journal of Human Resource Management*, Vol. 14 No. 1, pp. 1-8.

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