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A structured investigation on the site supervisory traits in applying science and technology related fundamental concepts in construction operations

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Abstract

Purpose – Productivity increase is correlated with profitability, sustainability and competitiveness of the construction firms. Recent studies reveal that the primary causes of productivity decline are poor usage of scientific and technological advances, ineffective supervision strategies and poor apprenticeship facilities/opportunities. Accordingly, the purpose of this study was to evaluate how well construction supervisors can utilise fundamental science and technological concepts/ideas to increase the efficiency and productivity of construction activities.

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Design/methodology/approach – A new strategic layout was designed with the use of potential training guide tools. Based on the designed layout, a new supervisory training programme was developed, and 62 construction supervisors were selected, trained and evaluated in line with six parts of competencies and the relevant learning domains. An assessment guide with different levels of descriptions and criteria was developed through literature analysis and expert interviews. The research tools were verified using comprehensive approaches.

Findings – The overall mean values of supervisors' performance scores indicate proficient-level grades in the competency characteristics related to taking measurements, generating drawings/designs using manual techniques and computer-aided tools, involving Bill of Quantities (BOQ) preparations and preparing training plans/materials for improving the competencies of labourers on estimation, measurements and understanding drawings. Their proficiency was notably lower in the use of information and communication technology application tools in construction tasks compared to others. The findings point to a modern generalised guideline that establishes the ranges of supervisory attributes associated with science and technology-related applications.

Research limitations/implications – The study outcomes produce conceptualised projections to restructure and revalue the job functions of various working categories by adding new definitions within the specified scope. This may result in constructive benefits to upgrading the current functions associated with urbanisation, sustainability and society. The implementation of the study's findings/conclusions will have a significant impact on present and future practices in other developing nations and developing industries, even if they are directly applicable to the Sri Lankan construction industry.

Originality/value – Up to certain limits/stages, the study fills not only the knowledge gap in the field of creating protocols and application techniques connected to lifelong learning and skill enhancement/upgrading but also the existing gaps in work attributes and roles of construction supervisors associated with the utilisation of fundamental science and technological concepts/ideas towards reinforcing sustainable and productive site operations.

Keywords Construction technology, Developing countries, Performance evaluation, Productivity enhancement, Work-based training

Paper type Research paper

1. Introduction and background

The global economy was transformed from an agriculture-based system into an industrial economy throughout the 18th and 19th centuries due to the industrial revolution (Min *et al.*, 2019). Together with recent scientific and technological developments, this has caused the industrial sector to flourish globally (Manoharan *et al.*, 2022a). Although these technological advancements have improved comfort and efficiency, numerous construction firms in many developing countries do not properly use science and technology related applications to enhance work productivity and associated outcomes (Min *et al.*, 2019). Such behaviour of construction firms has a significant influence on the quality, productivity and safety results of construction processes (Dinh and Nguyen, 2019). This has been the major cause for many industrial firms experiencing a variety of troubles associated with capital flows, cost overruns, project delays and competitiveness, leading to substantially affecting the overall gross domestic product of a nation (Onyekachi, 2018; Silva *et al.*, 2018; Mistri *et al.*, 2019). For instance, sources indicate that such problems were found that critically influenced the economy of the countries, namely, Trinidad and Tobago (Hickson and Ellis, 2013), Iran (Ghoddousi *et al.*, 2015), Nigeria (Onyekachi, 2018), Vietnam (Dinh and Nguyen, 2019) and Sri Lanka (Manoharan *et al.*, 2020, 2021b).

In the context of Sri Lanka, the construction industry accounts for roughly 60% of the nation's gross domestic fixed capital formation and contributes 8% to its gross domestic production (Darshana, 2017). The construction industry in Sri Lanka has seen significant growth after the end of the Eelam War in 2009, which has led to the vast range of infrastructure development projects currently underway in the nation, as well as making the construction industry claiming the country's fourth-largest sector out of 13 (Tertiary and

Vocational Education Commission, 2017; Wijewantha, 2018; Manoharan *et al.*, 2020). The demand for the construction job market in Sri Lanka has increased due to the construction industry's ongoing growth (Darshana, 2017). According to the expert consultations, the construction industry is continuing to grow as a result of the numerous infrastructure development projects and investment schemes currently underway in Sri Lanka. The expert discussions also made clear that a large number of residential and commercial development projects are operating locally under soft-loan programmes offered by state and private banks. As a result, the Sri Lankan construction industry has tremendous development potential (Darshana, 2017). Wijewantha (2018) highlights that the rapid increase in construction employment vacancies has underscored the industry's importance to the growth and economy of the country. Estimates show that the construction industry in Sri Lanka has created more than 600,000 direct employment opportunities across four major professions, namely, engineering professionals, supervisory/technical staff, artisans (masons, plumbers and others) and machine operators (Wijewantha, 2018). Yet, poor application of science and technology-based concepts have contributed significantly to the efficiency and productivity issues that many Sri Lankan construction companies have been facing on a number of those development projects (Tertiary and Vocational Education Commission, 2017; Silva *et al.*, 2018; Manoharan *et al.*, 2022a). According to studies, fundamental problems with the country's vocational education and training system are the primary causes of these challenges in the Sri Lankan construction sector (Tertiary and Vocational Education Commission, 2017; Silva *et al.*, 2018). The current practices of the vocational education sector in the country are drastically out of sync with addressing the current/future needs of the industry sectors (Silva *et al.*, 2018; Manoharan *et al.*, 2020, 2022a). Another concern in this regard is the lack of emphasis on work-based training procedures in the industry (Tertiary and Vocational Education Commission, 2017; Silva *et al.*, 2018; Manoharan *et al.*, 2021a).

The efficiency and productivity of construction operations are impacted by a number of elements (Onyekachi, 2018; Dinh and Nguyen, 2019; Mistri *et al.*, 2019). Even though the skill shortage, poor material- and equipment-handling practices, lack of worker motivation and other challenges associated with technological advancement are among such elements, the supervision approaches are the key to offering effective answers and connections between these elements to address the work efficiency-related issues and produce improvements in job outputs substantially (Hickson and Ellis, 2013; Ghoddousi *et al.*, 2015; Windapo, 2016; Tertiary and Vocational Education Commission, 2017; Onyekachi, 2018; Silva *et al.*, 2018; Dinh and Nguyen, 2019; Manoharan *et al.*, 2022c). The competence of construction supervisors is the primary determining element in how effectively site operations are directed to perform for handling the constraints and close the gaps between labour and organisations (Onyekachi, 2018; Dinh and Nguyen, 2019). Modern circumstances in developing nations like Sri Lanka demonstrate a very high level of impact of construction supervision systems on construction productivity (Dinh and Nguyen, 2019; Onyekachi, 2018; Manoharan *et al.*, 2020, 2021b). According to studies, construction supervisors from such countries need to practice enhancing their application-based learning approaches to supervise site operations, especially managing tools, materials and equipment more skilfully (Onyekachi, 2018; Manoharan *et al.*, 2021a). Nonetheless, it is crucial to keep in mind that competencies are the outcomes of knowledge, skills and attitude because they directly affect aspects of the job process, learning demand and responsibilities (Manoharan *et al.*, 2021a). The ability of construction supervisors in applying the fundamental concepts/theories of science and technology-based practices has a significant impact on enhancing the efficiency and productivity levels of construction activities, according to recent studies (Onyekachi, 2018; Silva *et al.*, 2018; Dinh and Nguyen, 2019; Manoharan *et al.*, 2021b) and interviews with industry experts in the construction sector. Notably, recent studies highlight that the role of construction supervisors is mainly handling labour operations, whereas the labour operations are like the blood of the construction process flows (Tertiary and Vocational Education Commission, 2017; Silva *et al.*, 2018; Manoharan *et al.*, 2021b). Compared to other construction work categories, such as engineers, architects, quantity surveyors, etc. construction supervisory resources have a direct influence in directing labour works and site processes. However, recent studies point out that the abilities of construction supervisors in applying the fundamental concepts/theories of science and technology-based practices are relatively lower than other work categories in many developing countries (Tertiary and Vocational Education Commission, 2017; Silva *et al.*, 2018; Manoharan *et al.*, 2021b). The major reason behind this status is the lack of focus on the science and technology-related aspects in the construction site supervisory vocational training programme curricula and poor work-based apprenticeship facilities in the industry sector of those countries, as recent studies pinpoint (Tertiary and Vocational Education Commission, 2017; Silva *et al.*, 2018; Manoharan *et al.*, 2021b).

The significance of resolving the above-highlighted problems lies in its effects on the chain of inadequate training infrastructure, supervisory competency gaps and worker skill shortages that have been the primary factors affecting the efficacy of construction operations in Sri Lanka and many other developing countries (Windapo, 2016; Tertiary and Vocational Education Commission, 2017; Onyekachi, 2018; Mistri *et al.*, 2019; Manoharan *et al.*, 2020). The background analysis emphasises that these problems were not sufficiently addressed by earlier studies. To improve the supervisory competencies related to the application of science and technology-based approaches with a direct scope of increasing the effectiveness, productivity and safety of construction operations, this study identifies the knowledge gap in the industry regarding how apprenticeship practices, competency assessment and performance evaluation tasks need to be systematically handled in construction supervision practices and aims to evaluate the abilities of construction supervisors in understanding theories related to science and technology as well as in implementing their applications/functions. Accordingly, the study focused on the achievement of the following objectives:

- Develop a new apprenticeship system containing the required competency element categories relevant to proficiency in applying science and technology-related fundamental concepts in work operations.
- Classify the construction supervisors into different groups/grades for the relevant competency element categories.
- Measure the construction supervisors' performance scores under the required competency characteristics.
- Generalise the supervisory attribute levels in applying science and technology-related fundamental concepts in work operations.

A variety of supervisory practice competencies connected to the study's aim are the main focus of the study. This study is significant and differs from other studies in that it highlights the industry's knowledge gap regarding the development of protocols and application methodologies needed to assess the capabilities of construction supervisors and track their performance in this setting. The study aims to open a window that inflows knowledge attributes to the industry sector along with the necessary comparison of the relevant competency elements and respective weights to predict and comprehend what levels of supervisory capabilities can be practically applied in real operations. This might lead to the development of more advanced scientific and technical approaches to comprehending the regulations, agreements and adherence to workforce employment limits in the construction industry.

2. Literature review

According to industry's viewpoints, construction enterprises face various challenges to competing worldwide due to low productivity in recent years, particularly in Australia, India, Nigeria, South Africa, Vietnam and Sri Lanka (Rami and David, 2014; Windapo, 2016; Onyekachi, 2018; Silva *et al.*, 2018; Dinh and Nguyen, 2019; Mistri *et al.*, 2019). All of these studies identify a lack of systematic skill enhancement practices as the root of such challenges in the industry.

2.1 Useful models and methods for evaluating the efficacy of construction activities and construction supervision practices

A conceptual model was designed by Uwakweh and Maloney (1991) for manpower planning in the construction industry more than 30 years ago. This model accentuates the need to enhance work-based training practices to create a more qualified pool of construction supervisors with a variety of skills. Noticeably, Uwakweh and Maloney (1991) emphasise the importance of cooperation abilities in supervisory approaches and the proper course of action when carrying out duties and using tools. Besides, with a focus on fostering interaction and situational awareness in the work-based training and skill assessment components, different sets of digitalised models were developed by Pham *et al.* (2018) in the past ten years. Importantly, the intention of Pham *et al.* (2018) was to make smart and studio-based training rooms using a variety of modern technologies. On the other hand, it is significant to note that a construction supervisory training guiding model, a construction labour training guiding tool and a system for scoring and grading the performance of construction labour have been presented in recent studies (Manoharan *et al.*, 2021a, 2021b, 2022b). Importantly, the models presented by Manoharan *et al.* (2021a, 2021b, 2022b) can be useful practical training tools/systems that directly focus on enhancing the productivity and efficiency of construction operations. A variety of well-developed labour training exercises (LBEXs) that construction supervisors might provide to workers are included in the labour training guide model of Manoharan *et al.* (2021a). Based on the traits of each LBEX, Manoharan *et al.* (2022b) established the necessary labour training elements of outcomes (LBEOs). In their extensive examination of such LBEXs and LBEOs, Manoharan *et al.* (2022b) also created a labour performance score (LBPS) system and a labour grading scheme (LGS) with generalised approaches to evaluate the effectiveness of construction operations inside of a systematic mechanism. This study emphasises the significance of improving construction supervision skills in the application of theories and practices linked to science and technology for the methodical execution of the required tasks associated with these LBEXs, LBEOs, LBPS and LGS.

2.2 Critical supervision skills that are essential to the efficiency and productivity of construction operations

Supervision strategies are the primary impetuses behind the provision of work-based training components for labourers at construction sites (Manoharan *et al.*, 2021a, 2021b). Strong leadership, planning, site management, decision-making and communication abilities in construction supervisors enable their staff to work at their best (Hickson and Ellis, 2013; Onyekachi, 2018). Such supervisory abilities were found to be crucial components in the site management tactics associated with technological applications, according to a study conducted by Jarkas *et al.* (2012) of 84 Qatari construction firms. On the other hand, one of the crucial performance factors that significantly affect labour efficiency in many Indian construction projects has been recognised as the planning abilities of construction supervisors on the use of technological advancement (Mistri *et al.*, 2019). To reduce expenses and project delays, such supervisory abilities boost productivity, efficiency and resource management aspects (Manoharan *et al.*, 2020, 2021b). Moreover, efficient use of scientific methods is necessary when combining labour and material resources for construction operations, especially to maximise resource utilisation (Durdyev and Mbachu, 2011). Costs drop, productivity rises and time-saving can be resulted consequently (Manoharan *et al.*, 2021b).

Together with the above-mentioned supervisory abilities, estimating and measuring skills are crucial elements in construction supervision procedures linked to the use of science and technologically based approaches (Ghoddousi *et al.*, 2015; Onyekachi, 2018). Noticeably, Manoharan *et al.* (2021b) point up poor cognitive skills of supervisory resources in the use of fundamental units for taking physical, mechanical, thermal and electrical measurements in many developing countries' perspective. On the other hand, the weak cognitive abilities of the construction supervisors in quality control procedures were discovered to be a key influencing factor on construction productivity in a range of building projects in Australia (Rami and David, 2014). Project operations can be made safer, and the possible expensive mistakes can be decreased by improving quality control systems (Rami and David, 2014). Another significant barrier to contractors' efforts to boost efficiency in Australian building projects was the poor cognitive areas of construction supervisors in health science and safety aspects (Rami and David, 2014).

Apart from the above, the supervisory attributes in the use of relevant manuals and computer-aided tools for generating drawings and designs have been highlighted that impede a large number of construction projects in Nigeria (Onyekachi, 2018). Manoharan *et al.* (2021b) reveal that the construction supervisory workers in many countries are familiar with the procedures for the usage of software for generating drawings and designs, but their poor cognitive skills in understanding relevant manual techniques, theories and concepts are the major resistance against their work standards associated with generating drawings and designs. Furthermore, Adi and Ni'am (2012) found the poor work qualities of Indonesian construction supervisors associated with the Bill of Quantities (BOQ) practices. On the other hand, the supervisors' cognitive and manual skills in the use of information and communication technology tools need to be strengthened to enable their work qualities associated with technology-focused procedures in numerous developing countries (Hickson and Ellis, 2013; Manoharan *et al.*, 2021b).

In light of the Sri Lankan construction environment, only a few studies have attempted to develop construction supervision attributes. Enhancing Sri Lankan construction supervisors' cognitive capabilities in terms of applied science and advanced technological aspects is important for the sustainability of the industrial flows (Tertiary and Vocational Education Commission, 2017). It is important to draw attention to the study results of Manoharan *et al.* (2020), which pinpointed the issues with supervisory techniques that have an impact on the efficiency of work operations in the Sri Lankan construction sector. Lack of awareness and readiness for the rapid changes in technology, lack of knowledge and experience in designing and drawing, lack of familiarity with technical specifications, poor material handling abilities, poor understanding skills on design complexity and changes and poor cognitive skills in equipment maintenance, tool safety, health science and quality controlling aspects are the significant problems associated with supervisory attributes highlighted by Manoharan *et al.* (2020). Moreover, Manoharan *et al.* (2020) identified 20 key attributes of construction supervision, which should be addressed while developing new training programmes for construction supervisory resources. Such attributes led to the development of 20 programme outcomes (POs), adding a supporting layer to the creation of more effective training programmes for construction supervisors (see Table 2). In terms of project operations, such as building, road, highway, bridge, water supply, irrigation and dredging project works, these POs clearly show what the industry anticipates from construction supervisors.

2.3 Overview of the flaws, restrictions and gaps in the literature findings

Despite the fact that the current study's literature review identifies a wide range of construction supervisory competencies that influence construction productivity, only a small number of studies have offered tools and models to enhance skill-development procedures and evaluate productivity at construction sites. However, the current study demonstrates that there are significant limits when employing such tools/models in accordance with industrial requirements and characteristics. Even though they rarely address the issue of productivity enhancement, the major drawbacks of such tools and models are their lack of specialised competency features and performance evaluation procedures. If it takes on the primary causes of this constraint, many construction processes in developing countries are unable to adapt to the usage of such modern technologies, and they have a limited amount of funding available. Pham *et al.* (2018) provided digitalised environment models that can be mostly applied in the construction sector of industrialised nations. Another significant flaw in the design of these models and tools is that they disregard techniques for improving the efficiency and safety of construction activities.

By the performance evaluation of construction supervision procedures, the literature analysis of this study also demonstrates that there are still substantial knowledge gaps that must be filled to improve the efficacy and productivity of construction operations. The industry has difficulty in predicting/understanding what levels of capabilities can be theoretically considered and practically applied in supervision characteristics because there is a knowledge gap in the field regarding the creation of protocols and application methodologies necessary to assess the capabilities of construction supervisors and track their performance.

2.4 The importance of the guidance tool of Manoharan *et al.* (2021b) for the adaptation and applicability in light of the purpose of the current study

Manoharan *et al.* (2021b) have provided a paradigm for developing new construction supervisory training programmes that methodically address the challenges of the industry as they change in more detail. To improve the productivity of construction operations, the guidance tool of Manoharan *et al.* (2021b) specifically comprises 12 competency units and 64 competency elements (CEs), with one of those competency units emphasising the use of methodologies connected to science and technology. Five of the 64 CEs specifically handled the necessary supervisory characteristics as part of the execution of efficient science and technology-related ways for boosting the productivity of construction operations. Importantly, the supervisory competencies associated with science and technology aspects discussed in Section 2.2 are well-covered in these five CEs of Manoharan *et al.* (2021b). These CEs replicate the characteristics of the fundamental competency elements associated with the science and technology aspects, which play a pivotal role in improving the efficiency, quality, productivity and safety of a construction site's operational flows and outputs. Importantly, they provide the base in ways for simplifying construction tasks, saving time, integrating powerful planning and scheduling tools, making hypothetical changes and cost-effective decisions, detecting errors, optimising materials, controlling risks, etc. Accordingly, the concepts behind the expected outcomes of these CEs are the key to pushing the industry forward, fostering innovation and advancement, developing economy and ecology and ensuring sustainability. They notably contribute in large part to revolutionising the way that construction projects are planned, carried out and completed and how the structural, automation, energy and interactive systems function.

The weight distribution of these CEs in reference to Bloom's taxonomy of learning domains is also provided by Manoharan *et al.* (2021b), as shown in Table 1. This weighting system offers a means of developing competency assessment techniques and offers a distinct cross-section of the CEs.

In addition, it is significant to note that the construction supervisors' involvement in the preparation of training plans and training materials for improving the competencies of labourers on estimation, measurements, simple ICT applications and understanding drawings will not only improve the labourers' working patterns but also add enhanced attributes and new values to the supervisors' job role and site management practices. Accordingly, the construction supervisors' competency aspects associated with CE-v are rarely looked at in the industry sector of many countries. The concept behind CE-v is novel, powerful and essential in upgrading the construction practices to address the evolving challenges and opportunities in the current and future circumstances.

As shown in Table 2, the levels of mapping between the six CEs of Manoharan *et al.* (2021b) and the POs of Manoharan *et al.* (2020) were demonstrated using the following descriptions:

- *Introduced (I) Level*: The learning contents would give an overview of the intended outcome.
- *Emphasised (E) Level*: The learning contents would emphasise the desired result/outcome.
- *Reinforced (R) Level*: The learning contents would act as reinforcement for the materials in the direction of the desired result.
- *Advanced (A) Level*: The learning materials would represent an advanced level of interaction with the resources to achieve the desired results.

During the mapping process, the capabilities of the supervisors, the industry's expectations and practical factors were all carefully taken into account. The mapping findings of the complete competency unit under the POs were established in accordance with the following statements, given the levels of mapping that emerged between the CEs and POs:

- The mapping level denotes that the competency unit is prominently (P) or considerably (C) or moderately (M) or slightly (S) fulfilling the relevant characteristics of the PO.

3. Methodology

Figure 1 depicts the layout of the strategy used to achieve the study aims/objectives. A number of discussion sessions, workshops and reviews were held among academic and industry experts (including project directors, civil engineers, construction managers and senior technical officers) throughout the process, with a focus on the necessary actions in construction site practices to face the evolving challenges and opportunities of the industry in new normal situations. Problem-focused approaches were used at all stages of the study process, particularly for understanding the challenges, exchanging ideas and identifying solutions. Significantly, the study methodology was based on the application of the construction supervisory training guidance tool provided by Manoharan *et al.* (2021b).

Competency elements (CEs)/ Competency unit (CU)	Weight (%)	Learning domain and Domain levels: Cognitive/Knowledge levels (C)				Psychomotor/Skill levels (P)							Affective/Attitude levels (A)				
		C1	C2	C3	C4	P1	P2	P3	P4	P5	P6	P7	A1	A2	A3	A4	A5
CE-i: Take accurate measurements in construction works	25	5	8			2	1	2	5				2				
CE-ii: Generate drawings and designs using manual techniques and computer aided tools	20	5	6			3	2	2					2				
CE-iii: Involve in Bill of Quantities (BOQ) preparation for the construction works	20	6	6			4	2	2									
CE-iv: Use information and communication technology (ICT) application tools in construction activities	15	2	6			2	1	2					2				
CE-v: Prepare training plans and training materials for improving the knowledge, skills and abilities of labourers on estimation, measurements, simple ICT applications and understanding drawings	20	2	4			4	4	2					4				
CU: Proficiency in applying science and technology related fundamental concepts in work operations	*100*	*20*	*30*	*0*	*0*	*15*	*10*	*10*	*5*	*0*	*0*	*0*	*10*	*0*	*0*	*0*	*0*

Notes: C1 = remembering and Understanding; C2 = applying; C3 = analysing and Evaluating; C4 = creating; P1 = perception; P2 = set; P3 = guided Response; P4 = mechanism; P5 = complex Over Response; P6 = adaptation; P7 = origination; A1 = receiving Phenomena; A2 = responding to Phenomena; A3 = valuing; A4 = organisation; A5 = characterisation
Source: The mapping and weight distribution of CEs mentioned in Table 1 were produced by Manoharan *et al.* (2021b)

Table 1. Mapping and distributed weights of competency elements (CEs) and competency unit (CU) relevant to proficiency in applying science and technology-related concepts in work operations, along with learning domains of Bloom's taxonomy, presented by Manoharan *et al.* (2021b)

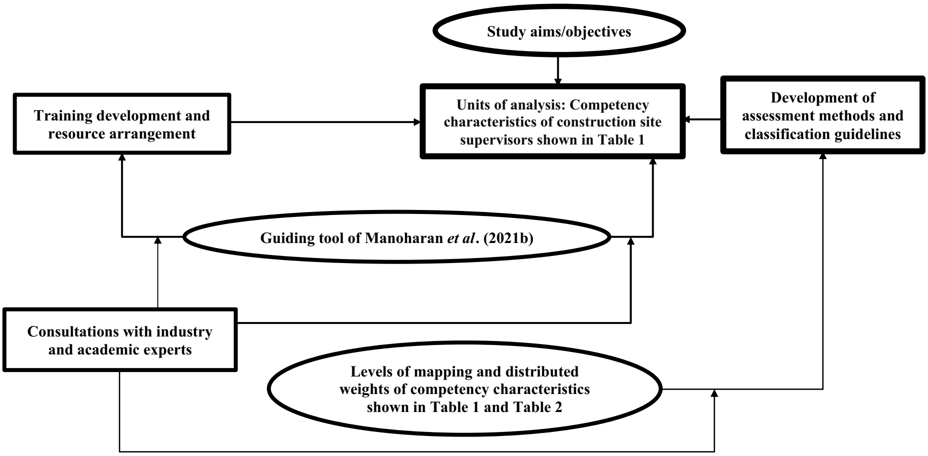


Figure 1.
The flow of the mechanism associated with the study methodology

Source: Authors' own work

Expert consultations, assessments and reviews confirmed that this training guidance manual can be used while taking the current study's goals and other relevant factors into account.

Taking on the mechanism shown in Figure 1, the competency elements (CE-i–CE-v) highlighted in Table 1 can be considered as the units of analysis to evaluate the case of the supervisors' proficiency in applying science and technology related fundamental concepts in work operations. Accordingly, the guiding tool of Manoharan *et al.* (2021b) was considered as the basis for developing a new apprenticeship system containing those competency element categories, leading to achieving the primary objective of this study. The levels of mapping and distributed weights of competency characteristics shown in Tables 1 and 2 were used to develop assessment methods and guidelines for the achievement of the next two objectives of this study, which are the measurement of the construction supervisors' performance scores under the required competency characteristics and then the classification of the construction supervisors into different groups/grades for the relevant competency element categories. Accordingly, the generalisation of the supervisory attribute levels in applying science and technology-related fundamental concepts in work operations can be evaluated based on the results obtained under the classification/grading of supervisors for the achievement of the last objective of this study.

3.1 Development of a new supervisory training programme

Based on the competency components described in the apprenticeship guidance model of Manoharan *et al.* (2021b), a new occupational and vocationally specific construction supervisory training programme was methodically constructed to attain the diploma level of the National Vocational Qualification Framework (NVQF) of Sri Lanka. The Sri Lankan Qualification Framework (SLQF) Level 3 criteria, which is comparable to NVQF Level 5, served as the entry criteria for the selection of candidates. NVQF is a nationally consistent framework that protects the authenticity of degrees and certificates awarded in Sri Lanka based on internationally benchmarked norms and procedures. Noticeably, NVQF is authorised by the Tertiary and Vocational Education Commission (2021) of Sri Lanka. On

Table 2. Mapping levels of competency elements (CEs) and competency unit (CU) relevant to proficiency in applying science and technology related concepts in work operations, along with the programme outcomes (POs) of Manoharan *et al.* (2020), presented by Manoharan *et al.* (2021b)

Competency elements (CEs) / Competency unit (CU)	Programme outcomes (POs) of Manoharan *et al.* (2020)																			
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
CE-i		I	I	E										E	E	E				
CE-ii							E							E						
CE-iii		E		E										I		E				
CE-iv		I		I			E							I	E	E		I		
CE-v			I			I	I		I	I	I							I	I	I
CU: Proficiency in applying science and technology related fundamental concepts in work operations		S	S	M		S	C		S	S	S			M	M	M		S	S	S

Notes: POs of Manoharan *et al.* (2020): Demonstrate the ability of monitoring usage, storage, delivery and operations of construction materials and equipment (PO1); Demonstrate the ability of planning and managing the resources at the site effectively (PO2); Apply effective supervision methods on the labour operations at the construction site (PO3); Assist in developing budgets and estimates of the construction activities effectively (PO4); Demonstrate the ability of overcoming health and environmental related challenges during the construction activities (PO5); Implement the possible practices on improving labour performance in the construction projects (PO6); Carryout self-learning on modern theories, advanced technologies and practices related to construction works (PO7); Demonstrate brainstorming techniques to the labourers in construction (PO8); Demonstrate competency-based training techniques for the labourers in construction (PO9); Instruct basic theories and applications of the construction principles to the labourers in construction (PO10); Provide experimental learning exercises to the labourers in construction (PO11); Assess the performance of labourers in the construction field (PO12); Implement the possible labour rewarding mechanisms in the construction sector (PO13); Apply necessary mathematical applications to solve related problems in the construction activities (PO14); Assist in conducting field investigations, surveys and tests required for feasibility studies of construction works (PO15); Maintain the records of the construction tasks and help in preparing the reports effectively (PO16); Demonstrate the ability of applying sustainable development and green practices on labour operations at the construction site (PO17); Be a good communicator and team player among the construction workers (PO18); Be a positive-thinker to face the challenges effectively (PO19); Be a good guide for the labourers in construction (PO20)
Source: The mapping levels of CEs and POs mentioned in Table 2 were produced by Manoharan *et al.* (2021b)

the other hand, SLQF is a framework authorised by the University Grant Commission (UGC) of Sri Lanka to recognise higher education qualifications granted by both public and private higher education institutions (University Grant Commission, 2015).

Sequential methods were followed while taking into account fresh characteristics in the context of the industry's new normal conditions during the training and development practices. The training institution was chosen for the implementation of the construction supervisory training programme after expert deliberations using the SWOT analysis. Through a series of meetings with the academic committees of the chosen institution that are pertinent to curriculum development, academic planning, ethics, finance and scholarships, the required approvals were obtained for starting the proposed construction supervisory training programme. To assure the systematic training delivery at the institution with an emphasis on the long-term run, the establishment of a Board of Study, the nomination of teaching resources and other key resource arrangements were formed. Notably, the newly developed construction supervisory training programme included a specific course unit that incorporated a number of work-integrated learning techniques to apply better practices to supervision skills based on the primary objectives of the current study. Significantly, each of the components stated in Table 1 and 2 was addressed in the relevant course/competency unit.

Two academic heads, two institutional directors and four industry professionals made up a panel of experts that evaluated the specific course unit's particular curriculum. These assessors were selected based on their level of involvement in education and training development approaches and their vast experience in the construction industry sector. It is significant to note that they all had more than ten years of experience in their specialised industries, whereas three-quarters of them had chartered engineering qualifications too. In addition, all six experts had a minimum master's level educational qualifications in the construction engineering and technology field, whereas half of them had the doctor of philosophy qualification. The review of the proposed competency unit was performed through the necessary observations, documentation and discussions that focused on the course unit's title, academic credit weight, time allocation, learning outcomes, training contents, teaching and learning strategies, assessment strategies and resource requirements within a particular analysis of the application and viability of those elements illustrated in Tables 1 and 2.

3.2 Selection of the construction supervisors

The method of snowball sampling was used to locate construction supervisors. Importantly, the snowball sampling method is a non-probability sampling strategy that can be used in situations where it is challenging to gather samples with the required attributes (Baltar and Brunet, 2012; Showkat and Parveen, 2017). The sample was initially expanded through a small group of well-known construction supervisors to identify more supervisors who could be interested in applying to the designed training programme. According to the guidelines outlined in the by-laws for the programme, 62 construction supervisors were ultimately selected based on their qualifications and performance in the selection interviews. The interviewing panel was composed of eight academic experts with backgrounds in construction engineering. The interviewers developed an evaluation system that is split into two categories (A and B), with Category A assessing the applicants' qualifications in relation to the entry requirements and Category B assessing their subject knowledge, interest, work experience, self-discipline, communication skills, attitude and capacity to apply contemporary practices. The majority of the selected candidates (construction supervisory personnel) worked on projects linked to buildings (40%), while a considerable percentage of the supervisors worked on projects related to roads and highways (35%) and water supply (20%), respectively. Significantly, 30% of them had experience ranging from six to ten years, with all of them having at least one year's worth of expertise in the construction sector. Each of the nine provinces of Sri Lanka is well-represented among the chosen construction supervisors. Every one of the chosen construction supervisors received the training components following the instructions detailed in the guidance model developed by Manoharan *et al.* (2021b).

3.3 Development of competency assessment guide

Following consultations with academic authorities, a marking guide was created to evaluate the five CEs, as indicated in Table 1. The developed marking guide makes sure that the weight distribution of CEs about the learning domains of Bloom's taxonomy listed in Table 1 is satisfied. When developing the marking guide, the mapping of those CEs with the 20 POs of Manoharan *et al.* (2020) (shown in Table 2) was also taken into account. In this competency unit, 50% of the training content was devoted to enhancing the cognition (knowledge) of construction supervisors, specifically in terms of evaluating how they define terms and approach problems. On the other hand, 40% of the training content was intended to evaluate the supervisors' abilities with an emphasis on the relevance of sensory information, readiness to act, demonstrating behaviour and turning taught reactions into habitual behaviour. The supervisors' attitudes are the focus of the final 10% of the training content, which promotes active engagement in assessments. The construction supervisors who were the topic of the study had a cognitive (knowledge), psychomotor (skills) and affective (attitude) level ratio of 5:4:1. According to the descriptions and criteria, each construction supervisor was evaluated for each CE under each area and given a score that was within the range presented in Table 3. The final performance scores were then produced using the weights given to the CEs across all of the domains (as indicated in Table 1). Based on discussions among the panel of assessors, the levels of descriptions and standards of CEs with the range of scores were created, as shown in Table 3.

3.4 Data collection through the training delivery

The above-described training components were delivered to the selected construction supervisors by the training institution. The teaching contents, learning contents/materials and necessary assessment components were designed and delivered based on the developed training elements and assessment guide discussed in Section 3.1 and Section 3.3, respectively. Noticeably, the assessment components included tutorial sessions, design/drawing sessions, laboratory practical sessions, quizzes, in-class tests, assignments and the final examination to evaluate the required competencies of supervisors based on the

Group/grade	Descriptions/standard	Score range
A+	Superior level	≥85
A	Excellent level	75–84
B	Proficient level	60–74
C	Satisfactory/pass level	45–59
D	Conditional pass level	35–44
E	Fail	≤34

Source: Authors' own work

Table 3. The developed criteria for the classification of construction supervisors into different groups/grades

elements discussed in Section 3.1 and Section 3.3. The competency scores of each supervisor under each category were recorded in a score maintaining system. Accordingly, the data relevant to the supervisory competency scores were collected through this continuous and systematic process with the support of academic resources of the training institution.

3.5 Verification of the research tools

An evaluation procedure incorporating observations, written evidence, interviews, workshops and discussions was carried out by a panel of eight experts, including academic and construction professionals, with an emphasis on the research plans and instruments used, as described in the aforementioned sections. Noticeably, the same experts mentioned in the third paragraph of Section 3.1 were involved in this process.

4. Results and discussion

4.1 Classification of construction supervisors into different groups/grades based on their performance under each competency element category

Figure 2 illustrates the percentages of supervisors in the construction industry at various descriptions and levels of standards for each competency element while also taking into account the entire competency unit.

A quarter of the supervisory workers demonstrated their expertise at an excellent or above level when it comes to taking measurements in construction works (CE-i), and the remaining three-quarters showed their relevant skills at a proficient level. None of the supervisors was found in the other grades/groups for CE-i. When it comes to the competencies in generating drawings and designs using manual techniques and computer-aided tools (CE-ii), around 30% of the supervisors were at excellent or above level, whereas nearly half of them were superior. Furthermore, 60% of the supervisors demonstrated their proficient level skills in

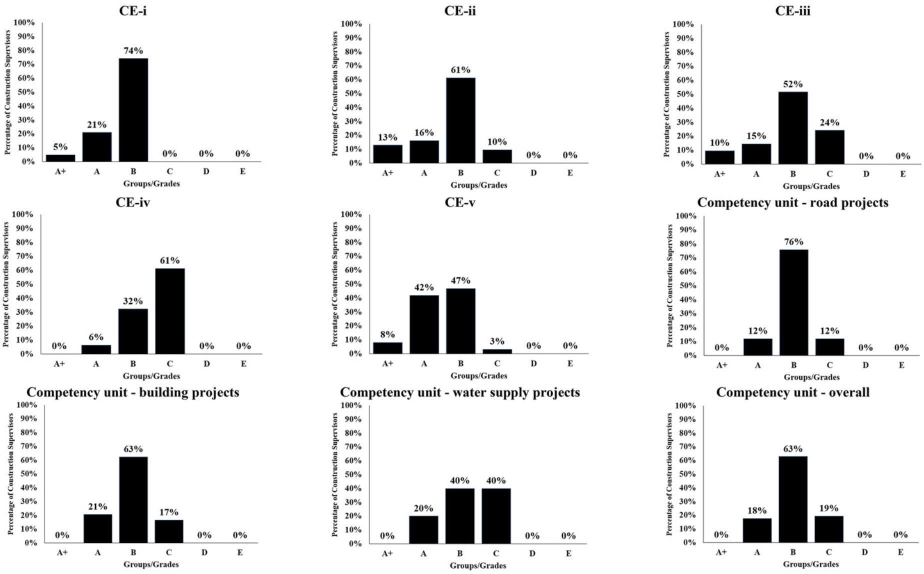


Figure 2. Classification of construction supervisors into different groups/ grades

Source: Authors' own work

CE-ii, and the competency level of the remaining 10% of the supervisors was found at a pass/satisfactory level. On the other hand, a quarter of the supervisory staff showed their abilities at an excellent or above level when it came to BOQ preparation tasks for construction works (CE-iii), where 40% among them were at a superior stage. Considering the remaining three-quarters of the supervisors, the 2:1 ratio can be applied among the groups/grades of proficient and satisfactory levels, respectively.

Compared to the above-described three CEs, the overall performance of supervisors was found to be significantly lower in using ICT application tools in construction activities (CE-iv). Here, only 6% of the supervisors demonstrated their skills at an excellent level, whereas none of them was found at a superior level. Even though a notable portion of the supervisors (32%) were at a proficient level, the grade/group of the majority of the supervisors (61%) was at a satisfactory/pass level. Apart from these, none of the supervisors was found in the other grade/group for CE-iv. The expert discussions on this disparity revealed that the working patterns of the current construction site practices lack the use of ICT tools, even though the industry's needs expand wider towards the application of modern ICT tools. The expert discussions further highlighted that the existing training programmes of the school and vocational education sectors fail to sufficiently expose knowledge elements related to the fundamental use of ICT applications. Moreover, the expert discussions emphasised that curricula of such training programmes need to have more special attention on enhancing the trainees' fundamental knowledge and understanding of computer generations, classification of computer systems, data representation and storage, data transmission technologies, internet and email facilities, operating systems, network topologies, classification of network protocols and the uses of Microsoft Office package. It is also notable that the supervisors' performance in the use of ICT application tools influences taking measurements, generating drawings and designs and preparing BOQs for the construction works. Accordingly, it is expected that taking actions to enhance the supervisory performance under CE-iv based on the expert discussion outcomes will further lead to significant increases in their performance levels in CE-i, CE-ii and CE-iii as well.

Taking on the last competency element (CE-v) in the list, which is about preparing training plans and training materials for improving the knowledge, skills and abilities of labourers on estimation, measurements, simple ICT applications and understanding drawings, the supervisors showed better performance than the above-discussed four CEs. Here, 50% of the supervisors showed their competencies at excellent or above levels, whereas 47% of the supervisors demonstrated their skills at proficiency level, and only the remaining 3% were at satisfactory/pass level. The in-depth analysis of the cross-section of CE-v revealed that the weight of cognitive domain elements in CE-v is relatively lower than the other CEs, rather CE-v covered a substantial amount of weight with an emphasis on the psychomotor domains, especially relevance of sensory information, readiness to act, demonstrating behaviour and turning taught reactions into habitual behaviour. Furthermore, it is noticeable that the weight of CE-v focused on affective domains of receiving and responding phenomena was relatively two times higher than the other CEs focused on the same domains. Such features of domain elements connected with the supervisory work characteristics can be the major reasons for the performance of supervisors being quantitatively higher in CE-v compared to other CEs.

Taking on the overall competency unit associated with the supervisory proficiency in applying science and technology-related fundamental concepts in work operations, an approximate ratio of 1:3:1 was found to be between the supervisors falling into the grades of excellent, proficient and satisfactory levels, respectively. The same ratio was reported between such three grades when it only considers the supervisors employed in building project works. The ratio was 1:6:1 and 1:2:2 in road construction and water supply project works, separately.

4.2 Construction supervisors' scores under the required competency characteristics relevant to proficiency in applying science and technology-related fundamental concepts in work operations

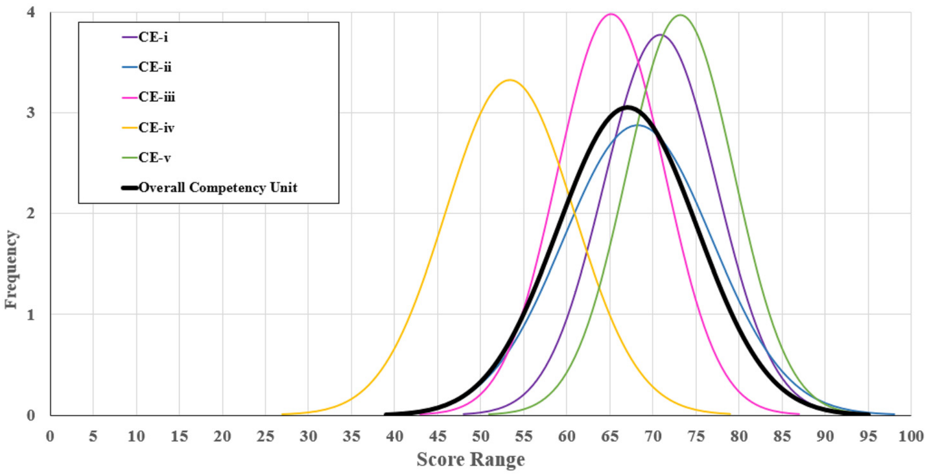
Table 4 shows the mean performance ratings that construction supervisors received for each relevant competency aspect, and Figure 3 displays the frequency distribution curves of those ratings. Overall, CE-v had the greatest mean score (73), which is almost closer to the excellent level of competency standards. On the other hand, CE-iv had the lowest mean score (53), which denotes the satisfactory level of competency standards. The mean score of supervisors' performance in the overall competency unit was around 67 (denoting the proficient level of competency standard). It is notable that such overall mean score values for the various project types did not differ from one another. This assures that the proposed training components are vastly adaptable and consignable to the supervision practices used in different types of construction project works.

When the detailed cross-section on the differences between mean score values of each CE for the various project categories is taken into account, the supervisory staff involved with road construction project works showed significantly lower levels of performance than the supervisory staff employed in other types of project work in the CEs associated with generating drawings and designs using manual techniques and computer-aided tools (CE-ii) and using ICT application tools in construction activities (CE-iv). Besides, their performance levels were substantially higher than the other supervisors in taking measurements in construction works (CE-i) and preparing training plans and training materials for improving the knowledge, skills and abilities of labourers on estimation, measurements, simple ICT applications and understanding drawings (CE-v). On the other hand, the supervisors involved with building project activities had significantly lower performance scores than the other supervisors in CE-v. However, their performance was much greater than other supervisors in CE-ii and CE-iii, whereas the supervisors employed in water supply projects had considerably lower performance score values than the others in CE-iii. These notable

Table 4.
Mean score values of construction site supervisors under the required competency characteristics relevant to proficiency in applying science and technology related fundamental concepts in work operations

Competency elements (CEs) /	Road projects			Building projects			Water supply projects			Overall		
Competency unit (CU)	AVS	SDV	CV	AVS	SDV	CV	AVS	SDV	CV	AVS	SDV	CV
CE-i	74.65	6.32	0.08	68.86	5.11	0.07	65.93	9.59	0.15	70.83	6.55	0.09
CE-ii	58.32	5.47	0.09	77.46	6.84	0.09	70.94	8.18	0.12	68.24	8.61	0.13
CE-iii	63.01	8.26	0.13	70.54	8.85	0.13	57.62	6.83	0.12	65.18	6.22	0.10
CE-iv	49.32	7.14	0.14	56.02	5.87	0.10	57.48	8.77	0.15	53.43	7.45	0.14
CE-v	83.71	6.27	0.07	62.85	8.66	0.14	73.42	7.61	0.10	73.22	6.23	0.09
CU: Proficiency in applying science and technology related fundamental concepts in work operations	*67.08*	*7.37*	*0.11*	*67.79*	*7.90*	*0.12*	*65.50*	*8.98*	*0.14*	*67.05*	*8.11*	*0.12*

Notes: AVS = average score; SDV = standard deviation; CV = coefficient of variation
Source: Authors' own work



Source: Authors' own work

Figure 3.
Curves showing frequency distributions of construction supervisors' scores under the required competency characteristics

differences can be justifiable by the fact that the various work processes and project scopes have clear effects on the effectiveness and proficiencies of supervision procedures.

In all CE categories, the coefficient of variation (CV) values of the supervisors' performance scores appeared to be not more than 15%. This guarantees that the outcomes are comparable between raters and conform to the range of CV values outlined by Statistics Canada (2020). This increases the reliability that the given training components can be applied widely for the industry's long-term applications. Together with the previously given facts, a panel of experts' observations were also shown. It is noteworthy that academic experts from the training-providing institution and other universities were included in the panel, in addition to construction experts. The panel expressed satisfaction with all of the competency aspect categories overall and emphasised the importance of expanding the proposed training applications in developing countries like Sri Lanka.

4.3 Generalising the supervisory attribute levels in applying science and technology-related fundamental concepts in work operations

An important outcome of this study is that the data will be used to develop a new generalised guideline that can be useful in forecasting and understanding what degrees of traits can be taken into consideration in supervisory attributes (see Table 5). This could significantly help to improve the planning processes connected to construction flows in a sustainable way depending on advances in technical competence, business, training, scientific documentation, adherence to employment limitations and work outputs.

4.4 Discussion with past studies

According to the results described above, the current study has addressed the concerns about performance evaluation features brought up by past investigations to a certain extent (Tertiary and Vocational Education Commission, 2017; Onyekachi, 2018; Silva *et al.*, 2018; Dinh and Nguyen, 2019; Manoharan *et al.*, 2020). The required apprenticeship outcomes on construction supervision procedures and the workforce operations highlighted by

Manoharan *et al.* (2022b) would soon be sufficiently attained by industry practices in developing countries like Sri Lanka. On the other hand, the findings discussed above will support the conceptual foundations of the digitalised training environment/models of Pham *et al.* (2018) for boosting work-based training and skill evaluation methodologies. With the aid of those digital technologies, the methods for training delivery and assessment described in the present study could be improved in the near future, in line with the suggestions made by Pham *et al.* (2018) regarding the use of photography and videography techniques for work-based training delivery and skill assessments. A thorough analysis of the peculiarities of construction supervision procedures in various contexts of developing nations and industries serves as a jumping-off point for the levels of standards/descriptions provided in Table 4 and 5.

5. Implications of the findings

5.1 Connection between theoretical, practical and social implications of the study

The study deliverables highlight notable theoretical, practical and social implications and new values, connecting with the industrial and institutional practices in present and future circumstances. In terms of the protocols that are necessary and how they should be put into practice to understand, this study displays what competency levels can be applied both theoretically and practically in supervision characteristics related to science and technology-based applications linked to improving performance and productivity in construction operational flows. This leads to laying a fundamental base to reshape the job role of construction supervision and opens a window to re-organise the supervisory attributes under the categories of work process, learning demand and responsibilities. This theoretical implication connected to some practical implications adds new values to the construction management and planning practices, especially in preparing the organisations to determine key performance indicators and potential action plan frameworks towards achieving their goals and sustaining them in the next normal circumstances.

5.2 Theoretical implications of the study

Some theoretical conclusions/implications can be derived based on the generalisation aspects shown in Table 5. The supervisory abilities can be limited up to the proficient level in taking accurate measurements in construction works, generating drawings and designs using manual techniques and computer-aided tools, preparing BOQs for the construction works and preparing training plans/materials for improving the skills of labourers on

Table 5. The developed new guideline generalising the results associated with the construction supervisory attribute levels in applying science and technology related fundamental concepts in work operations

Competency elements (CEs) / Competency Unit (CU)	Road projects	Building projects	Water supply projects	Overall
CE-i	A	B	B	B
CE-ii	C	A	B	B
CE-iii	B	B	C	B
CE-iv	C	C	C	C
CE-v	A	B	B	B
CU: Proficiency in applying science and technology related fundamental concepts in work operations	B	B	B	B

Source: Authors' own work

estimation, measurements and understanding drawings. The types of projects that the supervisors employ also notably influence this theoretical conclusion slightly. Furthermore, the supervisory abilities can be limited up to an average/satisfactory level for the use of information and communication technology (ICT) application tools in construction activities. These theoretical implications will lead to an upgrade of the existing theoretical structures of some vocational-technical competence frameworks, especially adding more technical or scholastic skills to offer a considerable choice of procedures requiring prioritisation to achieve optimum outcomes in a variety of familiar and unfamiliar contexts for the enhancement of work processes. This will have further influences on the supervisory learning demands associated with incorporating some theoretical concepts, analytical interpretation of information, informed judgment and a range of innovative responses to concrete but often unfamiliar problems. These implications may result in significant changes in the responsibility levels of the supervisory role related to the quality and productivity of the work outputs.

5.3 Practical and social implications of the study

Taking on practical and social implications of this study, most of the labour resources employed under their supervision/management have developed the abilities necessary to perform their jobs somewhat independently because construction supervisory workers have become more proficient in developing training plans and training materials for improving labour skills on estimation, measurements, basic ICT applications and understanding drawings (CE-v). Crucially, they gained a variety of theoretical and practical knowledge and abilities that allowed them to do duties associated with their employment, as well as to come up with their own ideas and mentor less-experienced workers on construction sites. These modifications in the behavioural patterns of work processes have reduced the disparity between the working hours and degrees of supervision of labourers. This emphasises how the ability of the workers to fit their cognitive and operational capacities to the interaction of the work process, learning demands and obligations is the key to establishing the important components of supervisory techniques. Construction management teams (CMTs) in the selected projects have been witnessing a steady improvement in the quantity and quality of work performed in labour operations. The CMTs additionally noted that the construction supervisors were prepared to perform the evaluations required to award those labourers with the NVQ qualifications in accordance with the guidelines/conditions of the recognition for prior learning mechanism specified in NVQ Circular 02/2021. The majority of CMTs concurred that they were prepared to offer future pay raises and job prospects to the construction supervisors. The results of the study also contribute to the understanding of what construction supervisors often referred to as “labour training mentors” and “NVQ assessors”.

The above-described implications associated with the characteristics of CE-v assure the requirements highlighted by Manoharan *et al.* (2021b) for the better achievement of the labourers in their lifestyles, needs, standards of employment, financial status and chances for professional progression. Furthermore, the study offers new features to methods of construction supervision that can be significant in raising the efficiency of construction work processes to improve the values and job roles/functions of construction supervisors in the construction industry. Construction supervisors may find a feasible path to becoming authorised NVQ assessors by emphasising the results of CE-v, which is one of the key analytical units of the study mechanism.

The above-stated improvements or changes in supervision outcomes may have additional implications on the job characteristics of engineers and project managers, which is why it is important to ensure the sustainability of project participants' workflows and job outputs. The study findings may lead to prompt changes in training curricula in higher education institutions and the sector of vocational training to address the industry's changing needs and problems in the new normal scenarios. The study has additional ramifications because the outcomes associated with CE-v characteristics support the relationship between labour operations and supervision techniques related to the efficiency of construction workflows, establishing a solid working relationship between employees and employers in support of the long-term survival of the construction industry. As a result, processes will behave differently, and the gaps will be filled between organisational policies and site operations.

5.4 Implications connected to the theories and concepts of worker motivational factors

The above-stated implications are well-connected to the theories/concepts of worker motivational factors. In light of the two-factor hypothesis proposed by Herzberg, the current study outcomes push the organisations to take the required steps to improve the job satisfaction of site workers by lowering or controlling unhygienic factors linked to working conditions, employee relations, organisational policies, quality regulations and wage policies, as well as by raising motivating factors associated with achievement, recognition, responsibility, advancement and personal growth. By developing an action plan with the aim of motivating and guiding a person or group, site workers can assert improved performance outcomes by embracing the goal-setting theory's concept regarding clarity, obstacles, commitment, feedback and complexity. This will help not only the organisations to understand what motivates their site workers to reach their full potential but also the site workers to stay motivated to make improvements to the organisations. As a result, organisations can understand, evaluate and identify the key factors driving each site worker's conduct. This will support the effective creation of fresh strategies to preserve the drive of site supervisory and labour resources. Moreover, it is expected that the skilled workforce will grow rapidly and that more individuals will transition from temporary to permanent employment in the construction industry. Therefore, this study helps to raise the bar for job quality at construction sites and lower local firms' excessive predilection for using foreign employees.

6. Conclusion

The overall study findings contribute to polishing the industrial views on reskilling and upskilling practices connected to industrial processes. The research has demonstrated useful strategies for polishing the construction supervisory attributes to achieve greater performance and productivity in their work by promoting lifelong learning and skill development in the application of science and technology-related procedures. The above-described results and discussion and implications sections make it abundantly evident that the current study findings have been a major influence on the work attributes of construction supervisors connected with the quality, safety and productivity of construction operations, the advancement of work and the long-term professional development of industry practitioners.

Considering the implications and values that the current study findings make on theoretical, practical and social aspects, it is significant to highlight the following notable contributions that this study makes. This will lead to the implementation of sustainable ways to restructure and revalue the present roles related to urbanization, sustainability and society:

- The findings of this study show what competency levels can be applied both theoretically and practically in supervision characteristics related to science and technology-based applications linked to improving performance and productivity in construction operational flows, as well as the protocols that are required and how they should be put into practice. This lays a solid foundation for restructuring the job function of construction supervision and constructs new ways to reorganise supervisory attributes for reinforcing construction management and planning practices.
- The findings generate some conceptualised projections that conclude that the supervisor's capabilities are limited to taking precise construction measurements, creating drawings and designs with the aid of computers and manual labour, preparing BOQs and developing labour apprenticeship plans/materials in estimation, measurement and drawing comprehension become more proficient. However, this theoretical conclusion is also somewhat influenced by the kinds of project work in which the supervisors are involved. Further, the supervisory abilities can be limited up to a moderate level for the use of ICT application tools in construction tasks. These theoretical implications will lead to an upgrade of the existing theoretical structures of some vocational–technical competence frameworks to offer a considerable choice of procedures requiring prioritisation to achieve optimum outcomes in a variety of familiar and unfamiliar contexts for the enhancement of work processes.
- The study findings not only result in valuing supervisory job functions with new roles but also creating sustainable practices to standardise the work patterns of labourers from the close supervision stage to the general supervision stage by redefining the existing boundaries of their work process, learning demand and responsibilities, as well as to emphasise the need for adding new advanced attributes in the job characteristics of engineers and project managers for making productive systems and assuring their sustainable run in practice.
- The findings further show new shapes of the application of the concepts of worker motivational factors, which strengthens the driving force to lower the excessive preference of local businesses for using foreign workers by raising the bar for skilled workers and job qualities at construction sites.

Considering the limitations of the current study's applications, the majority of supervisory personnel in construction firms, whose competency levels range from technician level to management level, are the only individuals who are eligible to apply for the study as the supervisory resource samples. Overall results with the reliability assurance offered by the statistical tests and professional assessments showed only slight differences between the various project types, despite the fact that the selected construction firms where the study applications were processed had widely differing organisational policies, financial capacities, resource availability and project operation types. This guarantees that a variety of construction-related firms will find value in these research applications.

Noticeably, the problems stated in this study mostly exist not only in numerous developing nations similar to the Sri Lankan context but also in some developed countries. While the study's focus is only on the Sri Lankan setting, other developing and developed countries can also employ similar strategies to obtain equivalent results and outcomes in their industrial operations. Several other emerging industrial sectors may also test the current study's results and mechanisms to impact their workflow processes to strengthen their guiding principles and operational methods for their human resources. Accordingly, this study recommends that future studies focus on examining the characteristics and operational procedures of the various job categories in the various trades under varied conditions.

Future studies may further potentially examine how digital technology might be used to improve training procedures in the construction industry. Accordingly, modern mobile application tools can be developed to deliver work-based apprenticeships and measure performance within the base of the proposed mechanism. This may lead to opening new networks associated with tracking performance and rewarding workers. Besides, future studies may also use quantitative metrics to compare the skills of construction supervisors with the increases in workforce efficiency and productivity levels. This may lead to developing new norms, frameworks and benchmarking systems that can contribute to resulting in sustainable policies in construction management and planning practices and smart ways for the enhancement of efficiency and productivity.

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