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A Study on the Evaluation of Construction Supervisory Competence in Applying Engineering and Technology-Related Fundamental Concepts - Sri Lankan Perspective

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Abstract: In the construction industry, productivity growth is linked to competitiveness, profitability and sustainability. However, studies show that ineffective supervision techniques and a lack of training opportunities are the main contributors to productivity decline. Accordingly, this research intends to examine construction supervisory abilities in executing the fundamental notions of engineering and technology for enhancing the effectiveness of construction operational flows through a case study. A total of 59 construction supervisory workers were trained and evaluated in accordance with six competency elements and the pertinent domains of learning as part of an advanced supervisory training program that was meticulously constructed utilising sequential approaches. Through literature reviews and expert interviews, an assessment guide with several levels of descriptions and criteria was well-developed. The study findings highlight a new generalised guideline that defines the levels of supervisory abilities/qualities that can be theoretically and practically considered in construction processes. The reliability of the results, as well as the generalisation of the applications and outcomes of this research, were assured using applicable statistical assessments and expert reviews. The overall study findings present new principles and standards for site supervisory procedures that have the potential in elevating construction supervisory attributes to the position of the primary force behind the productivity and sustainability of site operations. To fill the academic gap in establishing the protocols and implementation approaches connected to skill enhancement/upgrading, this paper goes into further depth about the study's general implications and prospective future applications. Even if the study's findings/conclusions are directly applicable to the Sri Lankan construction industry, their application will substantially impact the current and future practices in other developing countries and developing industries.

Keywords: Construction supervision, Engineering application, Performance evaluation, Productivity enhancement, Technology advancement, Training

1. Introduction

By generating a range of investment options, the construction sector substantially contributes to a nation's socioeconomic objectives [1]. Notably, productivity growth in the industry sector has considerable impacts on a country's gross domestic product [2]. According to recent studies, the construction industry employs the most people over a long period of time than any other industry, making it labour-intensive [3-5]. As a result, the effectiveness of labour operations considerably impacts the outcomes of construction processes in terms of safety, quality, and productivity [4]. Because of low levels of outcomes in these variables, the construction sector in many developing nations has encountered several challenges regarding capital flows and competition [1, 3]. This results in problems for construction companies with time and cost overruns and low-quality job operations [1, 4, 6].

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Many construction projects have experienced low levels of construction productivity in recent years in several nations, including Australia [7], Iran [8], New Zealand [2], Nigeria [3], Sri Lanka [9], Trinidad and Tobago [10] and Vietnam [1]. Several factors in construction operations have impacts on the effectiveness and quantity of construction operations [1, 3, 4]. Even though the fact that factors such as motivation [3, 10], labour skills [3, 6, 8], poor material and equipment handling practices [1, 11] and other constantly changing challenges related to technological advancement [3, 6, 12] significantly influence the efficiency and productivity of construction labour operations, better supervision approaches can provide efficient solutions and links between these factors to tackle productivity-related challenges towards creating a significant positive impact on work outcomes. The key determining factors in how effectively labour is led to perform are construction supervisors' abilities, and they play a significant role in bridging the gap between labour and organisations [1, 3, 9]. In particular, modern scenarios of emerging nations like Sri Lanka show dominant influence levels of site supervisory approaches on work productivity in construction projects [1, 3, 9]. Studies show that in order to supervise labour operations requiring managing tools, materials, and equipment more skillfully, site supervisors from those nations need to practice sharpening their application-based learning abilities [3, 13].

However, it is important to understand that competence is the result of cognitive, manual and affective/emotional domains, as they have significant impacts on the elements related to the job process, learning demand and responsibilities [13]. Recent studies [1, 3, 6, 14] and interviews with industry experts in the construction sector have shown that the ability of construction supervisors to apply the fundamental concepts and theories of engineering and technology-based practices has a significant impact on enhancing the efficiency and productivity levels of construction activities. This study emphasises the need for modern traits in construction supervisory procedures in light of this significant fact to assure the efficiency, quality, productivity, and safety expectations for the work outputs of construction operations. It is critical to realise that job-based training components must be linked to regular work procedures to improve job readiness, job applications, and employability towards solving challenges related to job responsibilities and specialised vocations of construction supervisory personnel [13].

1.1 Sri Lankan Setting

When Sri Lankan national plans are considered from the perspective of the nation, construction projects are crucial [6]. Following the end of the protracted war, the Sri Lankan construction sector has experienced significant growth, attracting substantial investments from the government and private sectors, leading to a wide range of infrastructure improvement projects presently underway in the country [9, 11]. However, ineffective supervision techniques have been a major factor in the productivity-related challenges that many Sri Lankan construction businesses have been suffering in a number of those infrastructure development projects [5, 6, 11]. According to studies, the main cause of these difficulties in the Sri Lankan setting is structural issues with the nation's vocational training system [6, 11]. The nation's secondary education and vocational training sector deliverables and the industry sector's requirements are vastly out of step [6, 9]. The poor emphasis on job-based apprenticeship procedures in construction practices is a contributing element to this across the country [6, 11, 13].

1.2 Problem Statement

Concerning the aforementioned factors, recent studies [6, 11, 13, 14] and industry expert consultations, training institutions, and skill enhancement authorities revealed that numerous developing countries such as Sri Lanka lack appropriate methods and actions to evaluate the construction supervisory skills in using necessary engineering and technology-based applications in construction operations. The importance of solving this issue lies in its repercussions on the connection of inadequate apprenticeship facilities, gaps in supervisory competence elements, and skill-shortage of workers, which are the main causes influencing the effectiveness of construction operational flows in an emerging nation like Sri Lanka [3, 4, 9, 11, 12]. The current study emphasises how inadequate attention was paid to these issues in past investigations. This study identifies the knowledge gap regarding how apprenticeship designs, competence measurements and performance assessment approaches should be methodically created and handled in site supervision procedures for improving the supervisory attributes related to the domain of applying engineering and technology-based approaches with a specific scope of enhancing the effectiveness, productivity, and safety of construction operational flows.

1.3 Research Aim and Importance

This research intends to examine the abilities of construction supervisory workers in comprehending engineering and technology-related theories as well as in carrying out their applications/functions for the improvement of the efficiency and productiveness of construction activities based on the difficulties and needs mentioned above. The research focuses on a wide range of supervisory practice competencies related to the study's objective. The cognitive gaps in the perspectives of the industry on the formation of covenants and application techniques required to examine the capabilities of site supervisory workers and monitor their performance outcomes in this environment are importantly highlighted in this research. To comprehend and predict what degrees of supervisory competence and capacities can be theoretically taken into account and practically considered in real operations, the research intends to open a portal that allows the industry sector's knowledge attributes to pour in, together with the essential comparison approaches on the pertinent competency factors and their weightage. This could result in more modern methods for scientifically and technically understanding the rules, agreements and adherence to employment constraints in the construction sector.

2. Literature Review

Based on the industry perspectives, large gaps in skills and low levels of work productivity make it difficult for construction firms to compete internationally. This gap was brought on by the early recessions [6]. In recent decades, construction firms have faced a broad range of productivity-related difficulties in numerous countries, including Australia [7], India [4], Nigeria [3], South Africa [12], Sri Lanka [6] and Vietnam [1]. These studies all point to the lack of systematic practices as the primary cause of these difficulties.

2.1 Effective Models to Assess the Site Supervision Practices and the Effectiveness of Labour Activities

A conceptual framework associated with resource planning for the construction practices in emerging countries was created by Uwakweh and Maloney [15], and it accentuates the need to improve job-based training procedures in order to produce a well-qualified group of site supervisors with a broad range of skills. The relevance of cooperative skills in supervisory techniques, as well as the right path to take when performing tasks and employing equipment, was stressed by Uwakweh and Maloney [15]. In the recent decade, Dickinson et al. [16] created a set of digitalised models using 360-degree panoramic and virtual gaming technologies, focusing on encouraging awareness and interaction in the job-based apprenticeship and competency evaluation elements. Furthermore, a construction labour training guiding tool [13], a construction supervisory apprenticeship guide manual [14], and a modern system for measuring the labour performance in construction [17] have been presented in recent studies as useful practical training tools, models and systems that directly focus on improving the efficiency of construction operational flows. The labour training guiding tool comprises a number of labour apprenticeship exercises (LAEXs) that construction supervisors can administer to workers. Manoharan et al. [17] methodically created the necessary labour apprenticeship outcomes (LAOs) according to the characteristics of each LAEX element. Manoharan et al. [17] additionally developed a labour performance measuring system (LPMS) connected with a modern grading scheme (MGS) using comprehensive approaches to measuring the effectiveness of construction activities inside a methodical framework in their thorough analysis of these LAEXs and LAOs. This study emphasises the significance of upgrading the supervision qualities in the application of engineering and technology-related theories and functions for the systematic execution of the necessary activities associated with these LBEXs, LBEOs, LBPS, and LGS.

2.2 Crucial Supervisory Abilities Affecting the Effectiveness and Productiveness of Construction Activities

For increased levels of job motivation as well as better productivity and quality of job processes, robust communication between site supervisors and workers is necessary [3]. The key driving force of job-based apprenticeship elements for construction workers at work sites includes supervision approaches [13, 14]. Construction supervisors who possess strong decision-making, planning and site management skills enable their employees to function at their best [3, 10]. Notably, Jarkas et al. [18] conducted a survey between 84 Qatari construction companies and determined that leadership qualities are the major elements in the project management strategies used by site supervisors. On the other hand, the planning skills of site supervisors have been found as one of the important performance aspects that greatly affect worker efficiency in numerous construction projects in India [4]. Effective project planning improves efficiency, productivity and resource management strategies to control financial constraints and task delays [9]. Combining human, material and equipment resources for construction activities requires effective site management and coordination, especially to maximise resources [2]. As a result, costs decrease, productivity rises and time-saving can be achieved [9]. In addition to these skills, ethical behaviour is another important skill element in site supervision procedures associated with the application of engineering and technology-based approaches, especially integrity, honesty, justice and other moralities are critical elements [8]. Importantly, when supervisory employees behave morally, it can significantly increase employees' satisfaction and commitment to improving work efficiency [19].

A significant influencing element on construction productivity in a variety of building projects in Australia was found to be the construction supervisors' poor cognitive abilities in quality control methods [7]. Project activities can be made safer, and costly mistakes can be avoided by improving quality control systems [7]. The insufficient cognitive domains of site supervisors' comprehension of health and occupational safety aspects represent another important obstacle to contractors improving the efficiency of building project operations in Australia [7]. Numerous construction projects in Nigeria were also found to be hindered by similar concerns with construction supervision [3]. In addition, Adi and Ni'am [20] recommended that Indonesian construction supervisors improve their cognitive abilities when doing technology-focused research and surveys. A growing body of studies emphasises the importance of improving the research abilities of construction supervisors to enable prompt identification of issues at job sites [9-10].

Taking on the Sri Lankan industrial environment for construction, a few investigations have only attempted to advance construction oversight techniques. It is necessary to enhance the cognitive domains of supervisory resources related to health and occupational safety guidelines and their capacity for testing labour competencies [11]. Significantly, it is good to pay attention to the research findings of Manoharan et al. [9], which identified the problems associated with supervisory procedures that affect the productivity of work activities in the construction industry of Sri Lanka. These problems mainly include the supervisors' poor cognitive and manual skills/abilities in site coordination and resource management, construction technology and procedures, material and tool handling, waste management procedures, architectural features, environmental sustainability, health and safety aspects, quality assurance and control, modern technologies in construction, estimation and measurements, basic concepts of structures, handling with electrical sources, etc. Additionally, 20 essential behaviours for construction supervision were identified by Manoharan et al. [9] and need to be considered in designing new training curricula for site supervisors. These resulted in the creation of 20 program outcomes (POs), giving a reinforcing layer to the development of more efficient construction supervisory apprenticeships (See Table 2). The stated POs represent a cross-view of the industry's expectations from the role of site supervisors across a range of project tasks, such as building construction, road, highway and bridge construction, irrigation, water supply and dredging work.

2.3 Overview of the Limitations and Shortcomings Revealed by the Research Findings

Overall, only a few studies have provided a limited number of tools and models to enhance competence development processes and examine construction productiveness at project sites, even though the present study's literature review identifies a variety of site supervisory skills that affect work productivity. However, the current study has shown that using such tools/models following industrial requirements and characteristics has considerable limitations. The biggest shortcomings of such tools and models are their lack of specific competency features and performance evaluation procedures, despite the fact that they hardly address the issue of productivity enhancement.

The current study highlights the main reasons for this constraint at this moment as being the incapacity of many construction enterprises in poor nations to adapt to the use of such cutting-edge technologies and their restricted fund availability. Dickinson et al. [16] offered digitalised models that are primarily used in the industrialised countries' construction sector. The fact that these models and tools ignore methods for enhancing the effectiveness and safety of construction operations is another serious weakness in their design.

The literature review part of this research also states that significant knowledge gaps still exist, which must be filled to increase the effectiveness and productivity of construction operations through the performance assessment of construction supervision practices. Because there is a cognitive gap in the creation of application methods, covenants and protocols needed to examine the capabilities of site supervisory workers and measure their performance, the industrial sector has difficulty in determining the levels of competence that can be practically and conceptually used in supervisory attributes and characteristics.

2.4 The Importance of the Adaptability and Applicability of the Apprenticeship Manual of Manoharan et al. [14], as per the Current Study's Aim

In more detail, Manoharan et al. [14] have offered a guiding tool for creating advanced construction supervisory training curricula that methodically address the difficulties facing the sector as they change. The apprenticeship manual of Manoharan et al. [14] notably comprises twelve competency units (CUs) and sixty-four elements of competencies (ECs) for enhancing the effectiveness of construction project operations, with one of those competency units emphasising the application of engineering and technology-related methods. Within the scope of implementation of effective engineering and technology-related approaches for increasing the productivity of construction activities, six of the 64 ECs addressed the required supervision features. Manoharan et al. [14] also provide the distributed weights of such ECs in relation to the learning domains of Bloom's taxonomy, as seen in Table 1. Importantly, this weighting system provides a way to create competency evaluation methods, as per the required characteristics of the ECs. It should be notable that a group of subject matter experts examined the above-highlighted six ECs. Three academic specialists and three industrial experts made up the panel, and all of them had extensive knowledge and experience in the application of engineering and technology related methods, construction project management aspects and productivity enhancement approaches. This revealed that those six ECs cover a wide range of key attributes and implications connected with the applicability of basic engineering and technological concepts to improve the efficacy of construction operational flows through supervisory features. Hence, the experts' review of the ECs found that no more ECs need to be considered as the units of analysis of the case connected with the execution of the fundamental notions of engineering and technology for enhancing the effectiveness of construction operational flows through supervision characteristics. However, the current study applications, findings and outcomes are limited to work characteristics, operational flows and implications connected with those six ECs.

The following descriptions were used to illustrate the mapping levels between such six ECs of Manoharan et al. [14] and the POs of Manoharan et al. [9], as described in Table 2.

- Introduced (I): The learning components give an overview of the intended outcome.
- Emphasised (E): The learning components emphasise the desired result/outcome.
- Reinforced (R): The learning components strengthen the outcomes in the direction of the desired result.
- Advanced (A): The learning components represent an advanced level of interaction with the resources in order to achieve the desired results.

The supervisors' capacities, the expectations of the industry and practical considerations were all carefully taken into account during the processes of mapping. Given the mapping levels that arose between the POs and ECs, the mapping results of the entire competency unit under the POs were established in line with the statements, mentioned below.

- The mapping level implies that CU prominently (P) / considerably (C) / moderately (M) / slightly (S) fulfills the required characteristics of the PO.

Table 1 – Mapping and Distributed Weights of Relevant Elements of Competencies (ECs) among the Learning Domains, Presented in the Training Guiding Tool of Manoharan et al. [14]

Elements of Competencies (ECs) / Competency Unit (CU)	Weight (%)	Levels of Learning Domains															
		Cognitive (C)				Psychomotor (P)							Affective (A)				
		C1	C2	C3	C4	P1	P2	P3	P4	P5	P6	P7	A1	A2	A3	A4	A5
EC1: Performing simple analysis in solving structural-related problems	25	5	9	6		3	2										
EC2: Working with fluid and soil properties and their applications in relevant construction operations	15	6	2	2		3	2										
EC3: Applying surveying techniques/methods for setting out constructions	25	3	3	2		6	2	2	5				2				
EC4: Applying fundamental concepts of architectural aspects in construction activities	10	2	2			2	1						3				
EC5: Working with electrical equipment and sources related to construction operations	10	2	2			5	1										
EC6: Preparing apprenticeship plans and materials for enhancing labour skills in the basic-level comprehension of fundamental structural concepts, flow measurements, soil investigations, surveying methods, architectural concepts, use of electrical sources and safety aspects	15	2	2			1	2	3					5				
Competency Unit (CU)	**100**	**20**	**20**	**10**	**0**	**20**	**10**	**5**	**5**	**0**	**0**	**0**	**10**	**0**	**0**	**0**	**0**

C1 - Remembering and understanding; C2 - Applying; C3 - Analyzing 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 - Organization; A5 – Characterization

Table 2 – Mapping Levels between the Elements of Competencies (ECs) of Manoharan et al. [14] and the Program Outcomes (POs) of Manoharan et al. [9]

Elements of Competencies (ECs) / Competency Unit (CU)	Program Outcomes (POs)																			
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
EC1			I				E							R	I	I				
EC2			I				E							E	E	I				
EC3			E				E							E	E	E		E		
EC4			I				E							E		I	I	E		
EC5			I		E		E									I		I		I
EC6			I			I	I		I	I	I							I	I	I
Competency Unit (CU)			**S**		**M**	**S**	**C**		**S**	**S**	**S**			**C**	**M**	**S**	**S**	**M**	**S**	**S**

POs of Manoharan et al. [9]: Monitoring the storage, delivery and usage of construction materials and tools in project operations (PO1), Planning the resources at project sites efficiently (PO2), Applying productive-based supervision approaches on the construction labour operations (PO3), Assisting in estimating and budgeting for the construction operational flows effectively (PO4), Following the site regulations associated with overcoming health, safety and environmental related problems during the project tasks (PO5), Implementing the constructive practices on enhancing labour performance in project operations (PO6), Applying self-learning approaches to learn modern concepts, advanced technologies and theories associated with construction works (PO7), Applying brainstorming approaches/techniques to enhance the labour skills in construction (PO8), Applying competency-based apprenticeship approaches to enhance the labour skills in construction (PO9), Instruct fundamental concepts, principles and applications to enhance the labour skills in construction (PO10), Providing experimental training exercises to the construction labourers for their skill enhancement (PO11), Assessing the labour performance at construction project sites (PO12), Implementing labour rewarding mechanisms at construction project sites (PO13), Applying suitable mathematical principles and theories to solve real problems at construction project sites (PO14), Conducting field surveys, investigations and tests associated with feasibility studies on construction project works (PO15), Maintaining the records o fthe project activities and assisting to prepare the relevant reports (PO16), Applying green concepts and sustainable development practices on construction project tasks (PO17), Performing tasks as a very good team player and communicator among construction workers (PO18), Performing tasks with positive thinking to effectively address the evolving challenges (PO19), Performing as a good guider for construction labourers in project sites (PO20)

3. Research Methodology

The design of the research approach to accomplish the study objectives is depicted in Figure 1. With a focus on the necessary actions in construction site management practices to face the challenges and conveniences of the industry in next-normal situations, several discussions, consultative interviews, workshops, and review sessions were held among academic experts and industry specialists (comprising project directors, civil engineers, project managers, and senior technical officers) throughout the process. Throughout all stages of the study methodology, problem-oriented communication techniques were used, especially for identifying the difficulties, sharing knowledge, sparking innovations, and developing solution mechanisms. Importantly, the construction supervisor apprenticeship manual of Manoharan et al. [14] was used which provides the basis for the methodology of this research. Expert talks, evaluations and reviews assured the applicability of the implementation of this apprenticeship manual while taking the current research objectives and other significant elements into consideration.

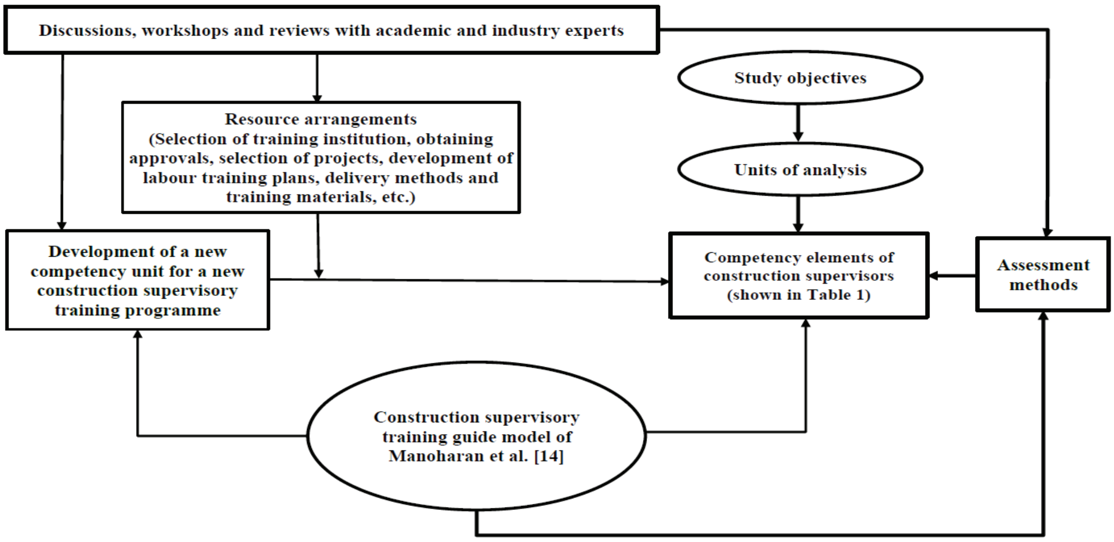

Figure 1 – Illustration of Research Methodology through a Flow Diagram

3.1 Development of a New Competency Unit for a Training Program of Construction Supervisors

A new vocational-specific and occupation-based training program was methodically developed for construction supervisors to achieve the diploma qualification stage of the Sri Lankan National Vocational Qualification (NVQ) framework according to the competency elements produced in the apprenticeship manual of Manoharan et al. [14]. The NVQ framework is nationally uniform and preserves the permissibility of certificates, diplomas and degrees conferred in Sri Lanka according to the international norms benchmarked [21]. NVQ framework is authorised by the Sri Lankan Tertiary and Vocational Education Commission [21].

During the training and development practices, sequential procedures were followed, considering novel characteristics in the industry's next normal conditions. Following expert deliberations with the use of the SWOT (Strength, Weakness, Opportunity and Threats) analysis, the training provider/institution was selected for the execution of the developed apprenticeship. For the commencement of the proposed apprenticeship delivery, the required approvals were attained through a series of meetings and discussions with the relevant academic boards and administrative committees in the selected institution that are related to academic planning, curriculum design, finance, ethics and scholarships. The nomination of teaching staff, Board of Study members, and other crucial resources were established in order to ensure the methodical delivery of training elements at the institution, considering the long-term run and sustainability of the program. Notably, the proposed training featured a particular course unit that consisted of a variety of job-integrated academic strategies to apply better approaches to supervision competence based on the main objectives of the present research. Notably, the pertinent course unit covered each of the elements listed in Table 1 and Table 2.

A panel of experts comprising three academic specialists and three industry experts assessed the detailed curriculum of the pertinent course unit. These assessors were selected as per their degree of industry expertise and ongoing involvement in apprenticeship development methodologies. They were all found to be having a minimum of 10 years of expertise in their particular fields. During the review process, the necessary documentation, observations, and discussions were held, specifically focusing on the title of the course unit, academic credit weight, time breakdown, course objectives, learning outcomes, learning contents, methods for teaching, learning, and assessments, weights of assessment components and the requirement of the resources, within a specific consideration on the applicability and practicality of those components and the aspects shown in Table 1 and Table 2.

3.2 Delivery of the Academic Components of the Competency Unit

The snowball sampling technique was executed to find out the potential site supervisors. Notably, this technique is suitable when it is difficult to obtain the relevant samples with the necessary features. To find additional supervisors who would be interested in applying to the designed training program, the sample was initially enlarged through a small group of well-known supervisors. In total, 59 supervisors were finally chosen following their qualifications and how they performed in the selection interview evaluations, as per the specifications laid out in the program's drafted by-laws. Seven academic specialists with backgrounds in construction engineering made up the interviewing panel. The interviewers came up with an evaluation system, which is divided into two categories (A and B), with Category A evaluating the qualifications of the applicants concerning the eligibility regulations and Category B evaluating their subject interest, knowledge, communication abilities, job experience, attitude, self-discipline and capacity to apply contemporary practices. The majority of the selected supervisory resources were engaged in building-related projects (41%), while a sizable portion of the supervisors was working on road/highway (37%) and water supply (17%) projects, respectively. Notably, the majority (30%) of them had between six and ten years' worth of experience, with every single one of them having at least one year's worth of job experience in the construction field. The chosen supervisors were well-represented from all the provinces of Sri Lanka. According to the instructions presented in the guiding model created by Manoharan et al. [14], all the selected supervisors received the training components.

A thorough marking guide was developed after consulting academic specialists to examine the six ECs highlighted in Table 1. Notably, the created marking tool assures that the distributed weights of ECs with respect to the learning domains of Bloom's taxonomy indicated in Table 1 are satisfied. The mapping of those ECs with the POs of Manoharan et al. [9] was also taken into consideration when creating the marking guide. In this competency unit, 50% of the apprenticeship was focused on enhancing the cognitive abilities (knowledge) of supervisors, particularly in connection with examining how they delineate concepts and approach problems, and 40% of the training materials were intended to evaluate the supervisors' abilities with an insistence on the relevance of readiness to convert taught reactions for action. The final 10% of the apprenticeship focused on the attitudes of supervisory resources associated with their emotions to encourage active participation in relevant tasks. The ratio of the knowledge, skills and emotion levels of the site supervisory resources who were the subject of the study was 5:4:1. Each construction supervisory worker was assessed for each EC under each category in accordance with the degree of descriptions and criteria, and was given a score within the range illustrated in Table 3. The weightage of the ECs throughout the domains was then used to generate the final performance scores (as indicated in Table 1). The descriptions and standard levels of ECs with the score ranges were developed based on discussions among the panel of assessors, as illustrated in Table 3.

Table 3 – The Score Ranges and the Description/Standard Levels of the Supervisory Competencies

Standards/ Descriptions	Standard Levels	Range of Scores
Superior / Exemplary (E)	E1: Slightly above	95 - 100
	E2: Same level	90 - 94
	E3: Slightly below	85 - 89
Proficient / Accomplished (A)	A1: Slightly above	80 - 84
	A2: Same level	75 - 79
	A3: Slightly below	70 - 74
Fair / Developing (D)	D1: Slightly above	65 - 69
	D2: Same level	60 - 64
	D3: Slightly below	55 - 59
Attempted / Beginning (B)	B1: Slightly above	50 - 54
	B2: Same level	45 - 49
	B3: Slightly below	40 - 44
Inadequate (I)	I1: Weak	30 - 39
	I2: Very Weak	20 - 29
	I3: Unacceptable	0 - 19

3.3 Validation of the Research Tools

An expert panel, comprising three academicians and four industry professionals, undertook a number of evaluation processes involving observations, written documents, interviews, workshops and discussions with an emphasis on the study's plans and tools employed, in consonance with the aforementioned sections. Noticeably, all the academicians who participated in this process had doctorate qualifications, and the industry professionals had chartered engineering qualifications in the field of civil engineering. Each member of the panel had above 10 years of job experience in a particular profession.

4. Results and Discussion

Figure 2 displays the percentage of site supervisors at numerous degrees of standards and descriptions for each element of competency while also taking into account the full competency unit when providing the academic components.

Half of the supervisors demonstrated their expertise when it came to performing simple analysis for structural-related problems (EC1), and the remaining half was still in the developing stage. Noticeably, 10% of them were found to be exemplary/superior in EC1. None were found to be at exemplary/superior level when it came to their working capabilities with the fundamental knowledge of soil and fluid properties and its applications (EC2), while 35% of them were at accomplished/proficient level, 50% were at the developing stage, and the remaining 15% were at the attempted/beginning stage. Taking on their abilities in applying surveying techniques for setting out a construction (EC3), the patterns of the variations among the categories look similar to EC1 with small differences. When it considers the supervisors' abilities in applying simple architectural concepts in the construction works, 35% of the superiors showed their proficiency, where 55% of the supervisors had fair level competencies, and 10% were still at attempted/beginning level. There was a significant difference when it compared the supervisors' abilities in working with electrical sources in construction (EC5) with other ECs. The performance levels were significantly lower in EC5 compared to other ECs. In EC5, half of the supervisors' abilities were noticeably at the beginning level, where 40% of them were at the developing stage, and only 10% of them were at the accomplished level. Taking on the last EC (EC6: preparing apprenticeship plans and materials for enhancing labour skills in the basic-level comprehension of fundamental structural concepts, flow measurements, soil investigations, surveying methods, architectural concepts, use of electrical sources and safety aspects), around 70% of the supervisors were found to be at accomplished or above that stage. Noticeably, 10% of them were superior. Among the remaining 30%, 25% were at a fair level, and only 5% were at the beginning stage. This highlights that the supervisors performed better as per the characteristics of EC6 than the other five ECs.

The mean scores of construction supervisors' performance obtained for each EC are listed in Table 4, and Figure 3 shows the curves of frequency distributions of their performance ratings for each EC. Overall, EC6 reported the highest mean score of 73.6, which is nearly at the proficient level, while EC5 had the lowest average score of 47, which indicates the attempted level of competency standards. The mean score for supervisors in the overall CU was 65.2, and no obvious disparities were found between the average score values of the competency unit for the different project types. This ensures that the suggested training materials are extremely adaptable and transferable to the supervisory techniques used in all different kinds of construction project work.

When it considers the detailed cross-section on the disparities between the average score values of each EC for the different project types, the supervisors involved in road construction work showed lower levels of performance than the supervisors involved with other types of project works in ECs related to performing simple analysis in solving structural-related problems (EC1), applying fundamental concepts of architectural aspects in construction activities (EC4), working with electrical sources in construction (EC5) and preparing training plans/materials for improving the relevant labour skills (EC6). On the other hand, they showed better performance than the other supervisors in applying surveying techniques for setting out constructions (EC3). Additionally, it was reported that the supervisors employed in water supply work had noticeably lower levels of performance scores than the other supervisors in EC3. But, they obtained higher scores than other supervisors in applying fluid and soil properties to relevant construction operations (EC2), whereas the scores of the supervisors involved in building project work were lower than the others in EC2. These disparities can be justifiable since the different characteristics of work processes and project scopes are obvious influencing factors on the performance and competencies of supervision practices.

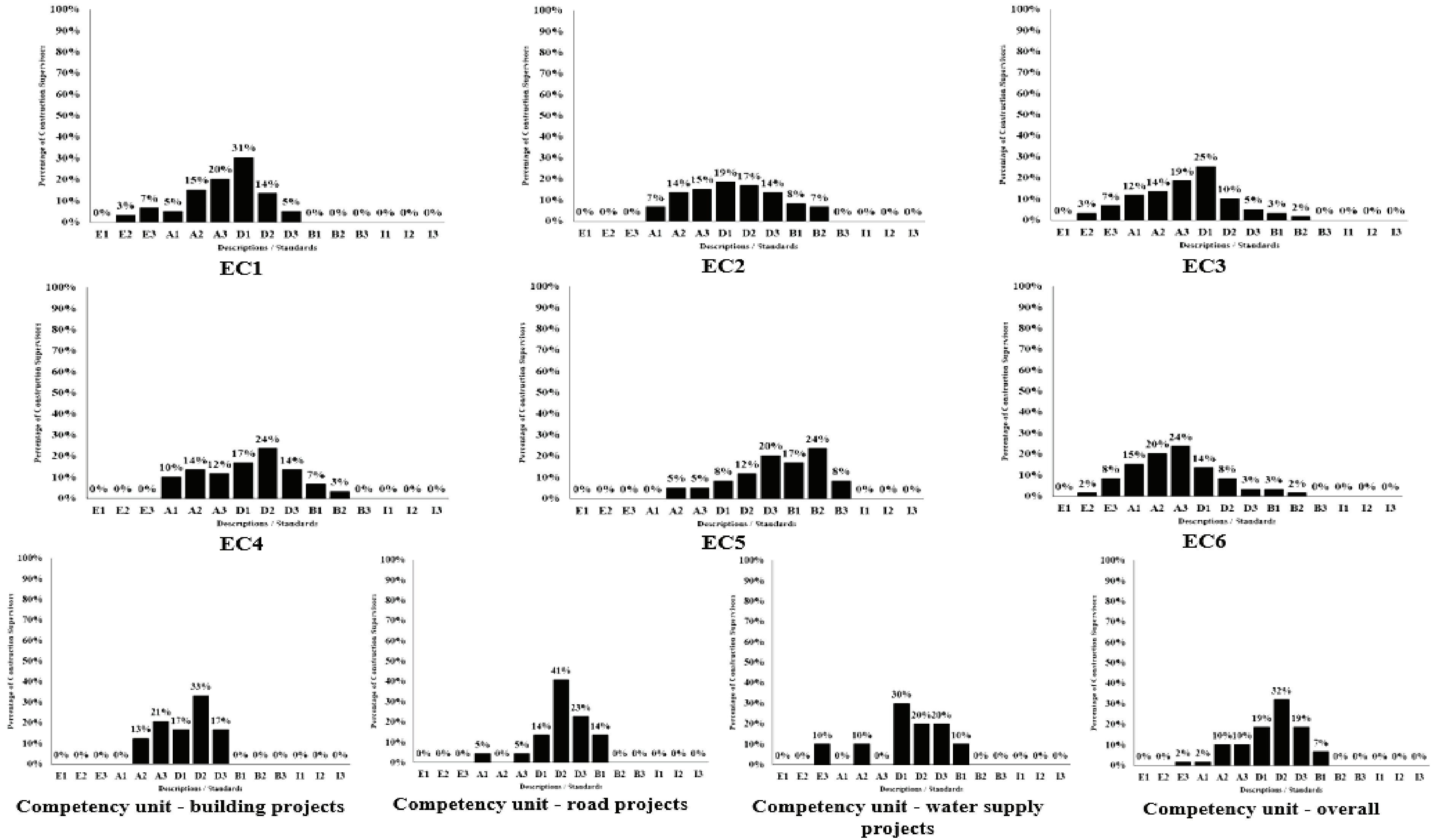

Figure 2 – Clusters of Supervisors at Various Degrees of Standards and Descriptions

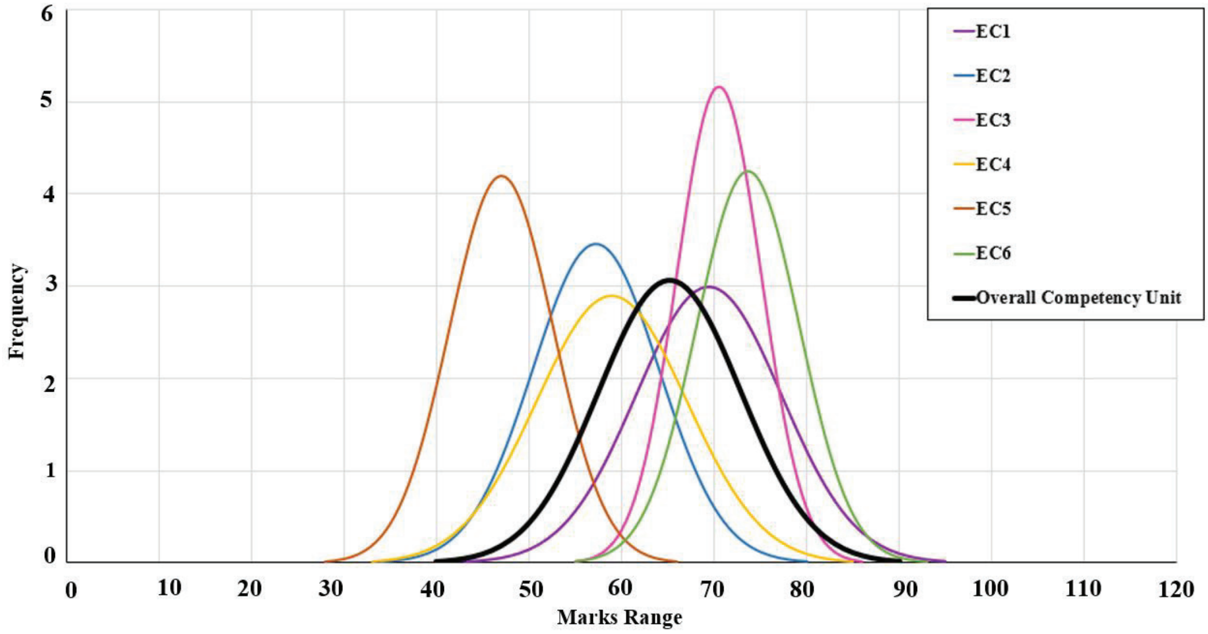

Figure 3 – Frequency Variation of the Supervisors' Performance Scores

Table 4 – Scores of Supervisors under Each Competency Element

Elements of Competencies (ECs) / Competency Unit (CU)	Building Works			Road Works			Water Supply Works			Overall		
	M	SD	CV	M	SD	CV	M	SD	CV	M	SD	CV
EC1	74.51	4.25	0.06	64.64	7.45	0.12	70.44	8.37	0.12	69.41	7.88	0.11
EC2	53.32	6.74	0.13	58.11	6.85	0.12	66.78	7.56	0.11	57.18	6.82	0.12
EC3	68.11	6.88	0.10	71.65	6.75	0.09	61.58	7.37	0.12	70.54	4.56	0.06
EC4	63.08	5.95	0.09	51.75	7.82	0.15	61.88	6.57	0.11	58.92	8.12	0.14
EC5	51.21	6.32	0.12	40.08	5.88	0.15	51.65	6.84	0.13	47.04	5.61	0.12
EC6	74.18	8.24	0.11	68.84	7.64	0.11	77.96	7.56	0.10	73.62	5.54	0.08
Overall CU	**66.21**	**6.28**	**0.10**	**62.30**	**6.80**	**0.11**	**66.07**	**9.82**	**0.15**	**65.20**	**7.67**	**0.12**

M - Mean, SD - Standard deviation, CV - Coefficient of variation

The value of the coefficient of variation (CV) of the supervisors' performance score was apparently under 15% in each EC category. This ensures that the results are consistent between raters in accordance with the allowable CV value ranges prescribed by Statistics Canada [22]. This makes it even more certain that the offered training components can be used broadly for the sustainable applications of the sector. Along with the data mentioned above, the observations of a group of experts were also displayed. Intriguingly, the expert group comprised academic authorities from the training-providing institution and other universities in addition to industry specialists. Overall, the panel was pleased with the results under all competency categories and emphasised the importance of advancing these programs in underdeveloped nations like Sri Lanka.

The above-illustrated findings will be used to generate a modern generalisable manual that can be used in forecasting and comprehending what degrees of abilities and qualities can be considered in supervisory attributes, which is an essential consequence of this study (See Table 5). Concerning enhancement in technical competence, business, apprenticeships, work outputs and employment constraints, this might considerably contribute to upgrading the engineering management and planning processes associated with construction flows sustainably.

Table 5 – The Generalised Guideline Showing the Cross-section on the Levels of Supervisory Attributes

ECs / CU	Building Works	Road Works	Water Supply Works	Overall
EC1	A3	D2	A3	D1
EC2	B1	D3	D1	D3
EC3	D1	A3	D2	A3
EC4	D2	B1	D2	D3
EC5	B1	B3	B1	B2
EC6	A3	D1	A2	A3
Overall CU	**D1**	**D2**	**D1**	**D1**

The aforementioned findings indicate that this research has addressed the issues about performance evaluation aspects raised by earlier investigations [1, 3, 6, 9, 11] to a certain extent. The industry's approaches in emerging countries like Sri Lanka may adequately achieve the anticipated apprenticeship results in site supervisory procedures supplied by Manoharan et al. [9] and the components of anticipated outcomes in workforce operations recommended by Manoharan et al. [17]. The research findings may further bolster the use of the digital tools that Dickinson et al. [16] have suggested for enhancing on-the-job training and competency evaluation techniques. The methods for the delivery of training elements and assessments described in this study can be improved slightly with the help of those digital technologies, in line with the recommendations made by Dickinson et al. [16] on using videography and photography techniques for job-based training tasks. The description/standard levels supplied in Table 4 and Table 5 serve as a jumping-off point for a thorough investigation of the characteristics of site supervision procedures in diverse settings of developing countries and emerging industries.

As a consequence of the enhanced abilities/qualities of construction supervisory workers in developing apprenticeship plans and materials for enhancing relevant labour skills (EC6), the majority of the labour resources worked under their supervision gained the competence required to do their duties with little responsibility and autonomy. Importantly, they enhanced a wide range of practical, operational and conceptual competence that allowed them to do activities related to their employment, and also to express their own impressions on work sites. Noticeably, the difference between the work hours and the labour supervision levels has decreased as a result of these changes in the behavioural patterns of work processes. This emphasises how the key to defining the essential components of supervisory approaches is the ability of the labourers to match their knowledge and operational capabilities to the interaction of the job process, demands of learning and obligations. However, the levels of labour productivity in the projects where those supervisors and labourers were employed showed a noticeable improvement. Notably, productivity levels decreased during the start of most initiatives for the majority of the project sites. The primary determinants could be time-related labour and resource scarcity as well as the postponement of some operations because of severe weather. However, during the mid and finishing stages of the work-based training applications in the projects, the absence or reduction of the aforementioned principal causes resulted in a steady increase in productivity levels across all work categories. The work quality and quantity of labour work have significantly improved, according to ongoing observations by the construction project management staff (CPMS) employed in the projects. The CPMS further stated, in consonance with the rules/conditions provided in NVQ Circular No. 02 of 2021 [23], the construction supervisory workers were made up to conduct the recognition for prior learning (RPL) assessments necessary to award those labourers with the relevant NVQ level qualifications. However, the majority of CPMS agreed that they were ready to provide the site supervisory resources with wage increases and new promotions. The results of this research also contribute to enhancing the job description for supervisory staff, also known as 'NVQ assessors' and 'labour training experts'. The interviews were held among the labourers who were trained, and these highlighted their altitudinous satisfaction levels with the effects of adopting the components of EC6 on their life needs, lifestyles, work qualities, financial status and opportunities for career advancement.

The case study's exploratory and descriptive functions associated with the proposed apprenticeship applications can be used to verify the logical aspects of this investigation, in accordance with the guidelines provided by Mohandes et al. [24]. The case study's construct validity was eminently clear. It illustrates the formation of the chain of evidence and the location of each case study component. The results unmistakably show how the units of analysis are causally related, as illustrated in Table 4 and Table 5. The internal validity of the study's results/conclusions has been guaranteed by the depiction of patterns of variance in each EC while taking into account different types of projects. More significantly, the outcomes of the expert conversations and analyses of the data showed that the suggested techniques for assessing the effectiveness and productivity of construction activities were generalisable, valid, and applicable. This ensures both the external validity and the quality of the outputs of the specified mechanisms. It proves that any construction project, as well as endeavours in other growing industries, can use the suggested competency enhancement mechanism. Design logics, data collection, and analysis techniques are all immediately visible in the structure of this case study. Importantly, quantitative and qualitative methods were applied for analysing data, depending on the various stages and goals. Meta-evaluations linked to customary institutional and industrial practices were incorporated into the case study applications.

5. Conclusions

This research has demonstrated efficient mechanisms to drive supervisory workers to achieve improved levels of efficiency and quantity in construction operational flows by strengthening the skill enhancement practices in the use of engineering and technology-related application methodologies. The results and discussion section indicate that there have been severe impacts on the job responsibilities of supervisors, quality, safety and quantity of work outputs, work progress and the career enhancement of industry workers. The results of the overall study are significant because they have impacts on how the reskilling approaches are viewed by the industry and how they need to be considered in practice to determine what competency levels must be applied practically and conceptually in supervisory attributes linked to productivity and performance enhancement in industrial flows.

This research provides advanced characteristics of supervision approaches that can be crucial in improving the efficiency of construction work processes towards enhancing the values and job roles/functions of site supervisors. Highlighting the outcomes of EC6, which is one of the important units of analysis of the study mechanism, construction supervisors may discover a realistic route to getting the accredited NVQ assessor title. These upgrades or changes in supervisory outcomes may have further consequences on the characteristics of the job role of construction engineers and managers. The research outcomes may encourage modifications to the existing curricula of various technology education and vocational apprenticeship programs to meet the industry's evolving issues in the next normal conditions. The study findings have further implications because they confirm the connection between labour work and supervision approaches related to the effectiveness of construction workflows, establishing a steady working relationship between organisations and workers towards the long-term survival of the industrial processes. Accordingly, this research adds some significant contributions to the enhancement of work quality standards at project sites and controlling the over-preference for hiring foreign workers by local enterprises.

Although the chosen construction organisations where the research methods were applied had a broad range of management procedures, financial policies, resource availabilities and project operation types, the results indicated only small differences between the different types of projects and substantiated the liableness of the study findings. This makes it certain that a variety of enterprises in the construction sector can benefit from these research applications. The only people who can apply for the study are the bulk of the supervisors in the industry, whose level of competence ranging from the technician stage to the management stage. Even though the scope of this research is limited to the Sri Lankan setting, other developing nations can still use comparable approaches to achieve similar results and outcomes in their industrial operations. In order to strengthen their guiding principles and operational techniques for their human resources, other emerging industrial sectors may apply the study findings to influence their workflow procedures. Future studies should concentrate on analysing the traits and working methods of the various trades from various circumstances. This research also recommends that future investigations perform quantitative measurements to compare the competencies of supervisory workers with the growth of labour productivity levels in construction. Future research could also look at how digital technology might be used to better training development approaches in the construction field.

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