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Developing a Constructive Mobile Application Tool for the Systematic Delivery of Work-based Training Components Associated with the Enhancement of Labour Performance and Productivity in Construction

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Abstract: Various sources highlight that the ineffective work-based training methods in construction site procedures have been the primary cause for the construction firms experiencing labour skill shortages in many developing countries like Sri Lanka. This study attempts to investigate developing mobile application tools for systematically applying work-based training practices, performance evaluation methods and grading mechanisms in the practices on construction sites for labourers. With the aid of problem-focused and action-oriented communication techniques, a comprehensive study methodology was adopted through a sequential procedure, including literature studies, expert discussions/reviews and mobile application development practices. The study approach specifically lays a mechanism linking with efficacious/valuable models and systems offered in recent studies. The study findings display the sketches of user interface visual designs and data flow procedures for integrating the labour training components through mobile application tools within a constructive mechanism. Importantly, labour performance, labour grading/classification and labour productivity levels have been emphasised as the major units of analysis in the application of the proposed mechanism and tools. The validity and reliability of the proposed mechanism and tools were ensured using comprehensive approaches. The study opens a new window to implement constructive approaches, innovative practices and operational systems linking with organisational vision and mission elements within the direct scope of productivity and performance improvement in the direction of expanding the industrial and institutional linkages nationally and internationally towards the economic recovery, social development and sustainability of a nation. Though the study findings directly contribute to the construction sector of developing countries like Sri Lanka, the study outcomes may create considerable impacts in other developing industry sectors within a similar scope.

Keywords: Construction industry, Mobile application, Performance improvement, Productivity growth, Work-based training

1. Introduction

Construction is one of the key industries that has a significant impact on the economic growth of a country [1-2]. It connects various related other sectors and boosts employment by generating a large number of investment opportunities [3-4]. The construction industry encompasses numerous unique businesses operating inside a multi-disciplinary corporation, as noted by Pathirage et al. [5]. In many nations, the construction sector accounts for a sizeable share of the gross domestic product (GDP), particularly in Japan and the United Kingdom, where it accounts for more than 6% of GDP [4]. Notably, the spending in the construction sector was estimated to be over 9.5 trillion US dollars in 2014, and it is anticipated to rise by 50% over the next 10 years [4].

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Despite the enormous scale and prominence of the construction sector in the economies of most nations, it has a significant impact on organisational efficiencies due in large to its productivity [3, 6]. Completing projects on time with the expected quality and within budget is an indicator of efficiency, but the construction process is affected by a variety of elements that have their origins across many areas [7-11]. Any firm focused on making a profit should be concerned about productivity improvement because it relates to the quality of input, output and the process for achieving organisational goals [12-13]. Productivity improvement represents the effective and efficient conversion of resources into marketable commodities [13-14]. According to Patel et al. [15], keeping a consistent workflow is essential for boosting productivity. On the other hand, performance is the primary determinant of productivity, which includes both the economic and operational characteristics of the industry [16]. The performance and productivity of work processes are highlighted in studies as the most important variables influencing the physical development of any construction project [1, 13, 17]. The performance and productivity of work operations are directly correlated to an organisation's profitability, competitiveness and ability to implement essential stakeholder suggestions for the long-term growth and sustainability of the industry sector in any nation [14]. Moreover, the business is expanding quickly due to technological advancements [18]. The major obstacles to productivity improvements and technical advancement in the construction sector of many developing nations have been the lack of skills, work methods and ethics among labourers [1, 17, 19-20]. These have been the main causes of cost overruns, time overruns, and quality-related issues for construction firms [21-23].

In its different stages, the construction industry uses a wide range of resources, including labour, capital, supplies, machinery and technology. Given that it integrates all other resources in construction operations, labour is the most important one [24]. A laborious endeavour is one that necessitates both physical and mental effort [25]. The majority of construction labourers in most developing nations work seasonally and according to the particular needs of the projects [21, 26]. The performance levels of various labourers are impacted by a variety of factors [13, 26]. Construction labourers are classified as either skilled or unskilled in many nations, and their pay reflects this classification [27]. However, recent studies show that many countries lack adequate methods for this classification among construction enterprises instead of paying enough attention to their training credentials and certifications [26, 28-30]. This has been a substantial barrier to improving labour skill levels, which has caused labour resources to perform below par [30]. Utilising labour resources based on performance is essential to the expansion of the industry's practices ensuring productivity and profitability. Labour costs typically account for between 30% and 50% of the total cost of a construction project, and they are considered a reliable measure of the project's economic performance [31]. In industrialised countries, typically up to 40% of the direct capital cost accounts for site workers in large construction projects [21].

Recent studies emphasise the need for systematic work-based training practices linked to the competencies, performance, productivity and work ethic of construction labourers considering the above-highlighted significant issues and challenges [13, 18, 32-36]. Consequently, the construction sector of many developing countries must be concerned with changing industry practices by specifically addressing the above-highlighted changing difficulties and opportunities in the near future [2, 18, 35-36].

1.1 Sri Lankan Context

In the Sri Lankan context, the socio-economic development of the nation and other national plans place high importance on construction projects [1, 3, 18-19, 24, 26, 35]. According to statistics, the construction industry has expanded significantly since the end of the protracted war, which has brought up both significant opportunities and challenges for the nation [1, 18, 24, 26, 30, 35]. Despite this, the Covid 19 pandemic-related problems and the recent economic crisis in the nation have caused many Sri Lankan construction enterprises to face a variety of obstacles, including financial difficulties and project stoppages. On the other hand, recent studies indicate that numerous construction firms in Sri Lanka have failed as a result of challenges or difficulties related to workforce operations with low performance and productivity levels of labour over a long period of time. Meanwhile, the country's local community has been experiencing an increase in unemployment, which has a significant impact on the economy of the nation [1, 3, 18-19, 24, 26, 35].

The construction labourers working in the Sri Lankan construction industry typically originate from low-income and low-education backgrounds, and their skill levels vary due to various economic, social, physical and psychological variables [19]. Recent studies highlight that the major issue facing the Sri Lankan construction industry has been the labour skill shortage [1, 11, 19, 24]. According to Tertiary and Vocational Education Commission [30], the consultations between the experts from the Construction Skill Sector Council (CSSC) of Sri Lanka have confirmed that labourers engaged in various trades of the construction industry lacked cognitive, soft and job-specific technical skills [30]. The main cause for this is the absence of effective work-based training methods in construction site procedures [30, 35-36]. One of the top five ranking elements contributing to the low performance of labour in Sri Lankan construction projects was found to be a poor performance appraisal of labour abilities [26]. No systematic mechanisms or tools are used by the Sri Lankan construction firms to assess the labour performance and the productivity levels of labour operations [30, 35]. Moreover, other recent studies have also drawn attention to comparable issues and requirements when it comes to the current state of the construction sector in numerous other developing countries [2, 6, 17, 20, 29].

1.2 Study Aim and its Significance

Taking into consideration of the above-highlighted aspects, this study intends to investigate developing mobile application tools for the systematic application of work-based training practices, performance evaluation methods and grading mechanisms in the practices on construction sites for labourers. This may offer proactive and sustainable solutions to successfully integrate skill development practices and systems in construction projects towards boosting productivity and performance of labour operations in construction with a direct focus on the nation's economic recovery and social development.

2. Literature Review

Numerous countries, including Egypt [17], India [2], Nigeria [29], Vietnam [20] and Sri Lanka [1], have found that a variety of labour skills influences the productivity and performance of construction activities. Labourers working on numerous construction projects have been discovered to lack knowledge of health and safety procedures and cognitive construction skills, which have been identified as notable factors affecting work productivity in a large number of construction projects in Egypt [17] and India [2]. Besides, the labourers' self-management skills, particularly their dedication, participation and punctuality, are crucial for the firms to maintain the proper flow of communication between the various construction activities as well as for the labourers to establish a reputation as dependable and consistent workers [37]. To increase the effectiveness of Sri Lankan construction enterprises, Manoharan et al. [24] explicitly note the necessity of improving the problem-solving skills of construction labourers. Contrarily, over the course of several years, a range of construction work operations has been significantly impacted by Sri Lankan employees' poor cognitive abilities in measuring, estimating, and handling materials, equipment and modern technologies [35, 38].

According to recent studies, effective labour supervision practices help the labourers to reach higher levels of motivation, which in turn improves the quality and productivity of their outputs [17, 20, 29]. In light of this, effective supervision techniques can be essential for the efficient use of skill development procedures at construction sites [20]. Notably, a training guide model presented by Manoharan et al. [18] is significant because it specifies a set of supervisory competencies for the effective delivery of work-based training components for construction workers with the evaluation of labour skills, performance and productivity levels in all types of construction projects. The training model of Manoharan et al. [18] also offers thorough guidelines for developing programmes for construction supervisory training that are both occupationally and vocationally specialised and include productive ways for work-integrated learning.

Ojha et al. [34] highlight the need to increase awareness on the use of work-based training practices among construction organisations and training providers since many of them have adapted to the use of traditional methods, which are lecture-based sessions and toolbox talks. Previous studies highlight various

benefits of work-based training methods [32-33]. According to Siregar [32], the methods of training delivery and skill assessments need to take into account how trainees take notes on the instructor's explanations, summarise the learning materials, ask questions, interact with others in group tasks, share ideas, respond to others' opinions and display confidence. This is based on the results of a work-based training programme conducted among 30 construction workers in Medan City, Indonesia [32]. On the other hand, past studies emphasise the use of 360-degree panorama and virtual reality gaming technologies to construct digital environments for fostering the workers' interaction and situational awareness in training tasks and skill assessments [39-41]. The use of photography and videography techniques to provide realistic surrounding views for training assessment purposes is also stressed by Jeelani et al. [42]. However, Ojha et al. [34] have assessed the suitability of these digital technologies for training activities and found that the construction training sectors in many developing countries are hesitant to employ them due to the demands of technological innovation and high expenses.

Although the methods/practices mentioned above can be used to deliver work-based training components, more guiding tools are needed for construction organisations to execute labour training components in a systematic manner. The literature review of this study emphasises the importance of the construction labour training guide model presented by Manoharan et al. [35] as well as the labour performance score and grading systems of Manoharan et al. [36] in order to meet this criterion.

In contrast, a set of well-developed labour training exercises (LBEXs) with relative weights were included in the labour training guide model of Manoharan et al. [35]. Based on the aims of the LBEXs, a set of labour training elements of outcomes (LBEOs) with the relative weights were then comprehensively designed by Manoharan et al. [36] to direct the training delivery and assessment components connecting with work operations, as shown in Table 1. It is significant to note that all of these LBEXs and LBEOs cover the common elements that might be used in all types of construction processes. Additionally, Manoharan et al. [36] presented a labour performance score (LBPS) system and a labour grading scheme (LGS), which offer a systematic framework for performance assessments and performance-based classifications of construction labourers as part of their extended investigation into these LBEXs and LBEOs. By using these systems/schemes, construction practices may change behaviourally towards the improvement of organisational effectiveness associated with work outputs.

Table 1 – Labour Training Elements of Outcomes

Code Numbers and Aims/Objectives of Labour Training Exercises [Relative Weights] [35]	Labour Training Elements of Outcomes (LBEOs) [Relative Weights] [36]	
LBEX1: Improving the soft skills of labourers required in the construction works [0.23]	LBEO1.1:	Labourers perform activities with the required work-related transferable skills at construction sites (Learning; Reading, writing and listening; Leadership; Teamwork; Communication; Memorisation; Innovative thinking; Analytical skills and abilities) [0.4]
	LBEO1.2:	Labourers perform activities with the required work-related self-management at construction sites (Adapting to changes in new environments; Critical reasoning; Problem-solving; Decision making; Psychology; Reduction of alcohol and drugs usage; Commitment; Self-motivation; Punctuality) [0.6]
LBEX2: Improving the performance of labourers on understanding and application of basic science and technology related practices [0.10]	LBEO2.1:	Labourers assist with the tasks related to measurements and estimation in the construction [0.6]
	LBEO2.2:	Labourers carry out labour works with a proper understanding of construction drawings [0.3]
	LBEO2.3:	Labourers use appropriate ICT applications for easy work operations [0.1]
LBEX3: Improving the performance of labourers on an understanding of simple engineering and technology related practices [0.10]	LBEO3.1:	Labourers carry out labour works with the proper understanding of simple structural and architectural concepts [0.3]
	LBEO3.2:	Labourers assist with the tasks related to flow measurements, soil testing and surveying procedures [0.4]
	LBEO3.3:	Labourers use electrical sources following safety regulations [0.3]
LBEX4: Improving the performance of labourers on understanding and application of technologies used and methods followed in construction works [0.18]	LBEO4.1:	Labourers follow health and safety guidelines in all types of labour works at the construction site [0.3]
	LBEO4.2:	Labourers carry out labour operations with the proper cognitive and manual skills in technologies used [0.5]
	LBEO4.3:	Labourers handle the equipment properly in machinery operations [0.2]
LBEX5: Improving the material handling abilities of labourers [0.24]	LBEO5.1:	Labourers use construction materials in labour work with a basic understanding of the properties and behaviour of materials [0.4]
	LBEO5.2:	Labourers handle tools to properly follow the procedures in material testing activities [0.6]
LBEX6: Improving the performance of labourers on applying green practices in construction [0.10]	LBEO6.1:	Labourers follow green practices in labour works (e.g. water supply, waste disposal, material usage, etc.) with the understanding of the importance of environmental sustainability [0.6]
	LBEO6.2:	Labourers explain the importance of the application of energy conservation methods and other green practices to co-workers [0.4]
LBEX7: Improving the management related skills/abilities of labourers required in construction works [0.06]	LBEO7.1:	Labourers follow the guidelines/procedures related to quality assurance and control practices in labour operations [0.6]
	LBEO7.2:	Labourers manage themselves to strengthen their financial background for personal life aspects [0.3]
	LBEO7.3:	Labourers follow the aspects of labour laws for career benefits [0.1]

3. Research Methodology

To achieve the study aims, a mechanism was laid for how the application of the labour training components needs to be functioning, as shown in Figure 1. By focusing on the systematic function of this mechanism, a study methodology was adopted to design the new mobile application tool, as shown in Figure 2.

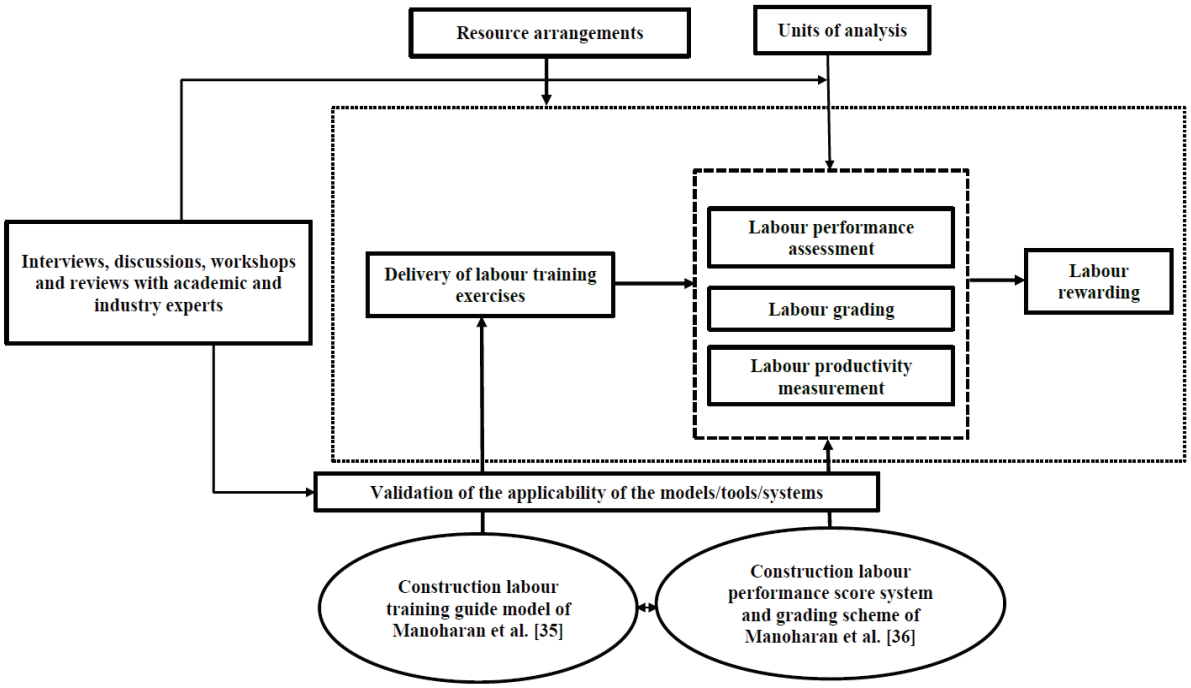


Figure 1 – The Mechanism for how the Delivery of the Labour Training Components Functioning

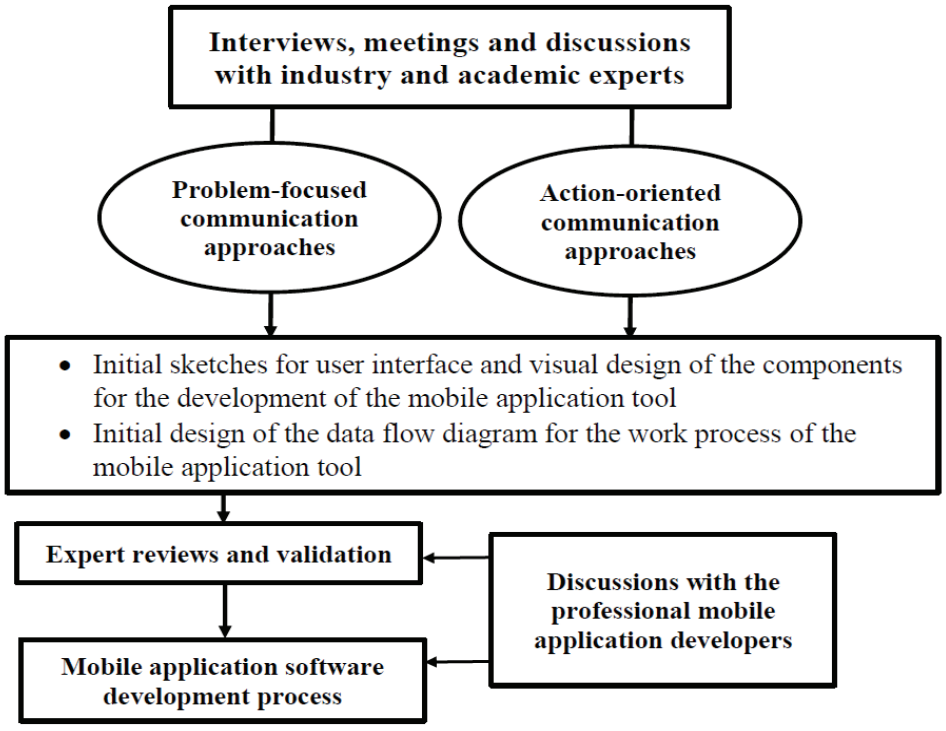


Figure 2 – Study Methodology to Design the New Mobile Application Tool

In particular, the importance of the applicability of the construction labour training guide model of Manoharan et al. [35] and the construction labour performance score system and grading scheme of Manoharan et al. [36] was validated through the expert interviews and discussions in the sequential processes for achieving the study aims, as shown in Figure 1. The labour training materials can be created based on the LBEOs and LBEXs, indicated in Table 1 for the delivery of the labour training exercises. Brief manuals and video clips outlining the fundamental ideas, directions, steps and application techniques to accomplish the corresponding LBEOs for each LBEX component can be created in the mother tongue of the labourers. The labourers working on the projects can receive the necessary demonstrations, brainstorming sessions, field exercises and interactive discussions using the training materials. It is crucial to encourage labourers to study on their own by disseminating produced manuals and video content.

The study emphasises that the labour performance assessments, labour grading/classification and labour productivity levels need to be considered as the major units of analysis in the function of the mechanism shown in Figure 1. Taking on the labour performance assessments, the levels of descriptors under the categories of process [P], learning demand [L] and responsibilities [R] mentioned in the National Vocational Qualification (NVQ) framework of Sri Lanka [43] (See Table 2) can be considered.

Table 2 – Qualification Level Descriptors of NVQ Framework of Sri Lanka for the Labour Competency Assessments [43]

Level	Process (P)	Learning Demand (L)	Responsibilities (R)
1	Carry out processes that **(P1)**: - are limited in range - are repetitive and familiar - are employed within closely defined contexts - are single processes	Employing **(L1)**: - recall - a narrow range of knowledge and cognitive skills - no development of new ideas	Applied **(R1)**: - in directed activity - under close supervision - with no responsibility for the work or learning of others
2	Carry out processes that **(P2)**: - are moderate in range - are established and familiar - offer a clear choice of routine responses - involve some prioritising of tasks from known solutions	Employing **(L2)**: - basic operational knowledge and skill - readily available information - known solutions to familiar problems - little generation of new ideas	Applied **(R2)**: - in directed activity with some autonomy - under general supervision and quality control - with some responsibility for quantity and quality - with possible responsibility for guiding others
3	Carry out processes that **(P3)**: - require a range of well-developed skills - offer a significant choice of procedures requiring prioritisation - are employed within a range of familiar contexts	Employing **(L3)**: - some relevant theoretical knowledge - interpretation of available information - discretion and judgement - a range of known responses to familiar problems	Applied **(R3)**: - in directed activity with some autonomy - under general supervision and quality checking - with significant responsibility for the quantity and quality of output - with possible responsibility for the output of others
4	Carry out processes that **(P4)**: - require a wide range of technical or scholastic skills - offer a considerable choice of procedures requiring prioritisation to achieve optimum outcomes - are employed in a variety of familiar and unfamiliar contexts	Employing **(L4)**: - a broad knowledge base incorporating some theoretical concepts - analytical interpretation of information - informed judgment - a range of innovative responses to concrete but often unfamiliar problems	Applied **(R4)**: - in self-directed activity - under broad guidance and evaluation - with complete responsibility for quantity and quality of output - with possible responsibility for the quantity and quality of the output of others

The level of LBEOs under each category for every labourer can be indicated through continuous observations on his/her involvement in assigned tasks every month. The steps listed below can be used to determine the labour grade and labour performance score (LBPS) values for each labourer each month in accordance with the recommendation of Manoharan et al. [36].

- Assign the following scores for each level of descriptor under each category. Through consultations with the NVQ assessors and officials from the Tertiary and Vocational Education Commission (TVEC) of Sri Lanka, these scores were validated by Manoharan et al. [36] for the level descriptors under each category shown in Table 2 to fill the procedures of measuring the LBPS values.
  - Process (P) - P1: 25; P2: 50; P3: 75; P4: 100
  - Learning Demand (L) - L1: 25; L2: 50; L3: 75; L4: 100
  - Responsibilities (R) - R1: 25; R2: 50; R3: 75; R4: 100
- Assume equal weights for each category (P, L and R) and calculate the average score for each labourer under each LBEO based on the scores mentioned above.
- Calculate the performance score of each labourer for each LBEX using the following formulas.
  LBEX1 = 0.4 * LBEO1.1 + 0.6 * LBEO1.2
  LBEX2 = 0.6 * LBEO2.1 + 0.3 * LBEO2.2 + 0.1 * LBEO2.3
  LBEX3 = 0.3 * LBEO3.1 + 0.4 * LBEO3.2 + 0.3 * LBEO3.3
  LBEX4 = 0.3 * LBEO4.1 + 0.5 * LBEO4.2 + 0.2 * LBEO4.3
  LBEX5 = 0.4 * LBEO5.1 + 0.6 * LBEO5.2
  LBEX6 = 0.6 * LBEO6.1 + 0.4 * LBEO6.2
  LBEX7 = 0.6 * LBEO7.1 + 0.3 * LBEO7.2 + 0.1 * LBEO7.3
- Use the following formula to calculate the labour performance score (LBPS) value for each labourer.
  LBPS = 0.23 * LBEX1 + 0.10 * LBEX2 + 0.10 * LBEX3 + 0.18 * LBEX4 + 0.24 * LBEX5 + 0.10 * LBEX6 + 0.06 * LBEX7
- Consider the following criteria to determine the grade of each labourer based on his/her LBPS value.
  - LBPS value range: 75–100; Grade: A; Color code: Green
  - LBPS value range: 50–74; Grade: B; Color code: Yellow
  - LBPS value range: 25–49; Grade: C; Color code: Orange
  - LBPS value range: 0–24; Grade: D; Color code: Red

For tasks where trained labourers are primarily used, the productivity levels of labour work can be measured. It should be taken into account that they might collaborate on some jobs with other workers (who are not part of the labour training circle). However, the majority should be the labourers who adhered to the labour training, and they should be the primary contributors to the tasks that are recorded.

In order to perform the above-described tasks within the proposed mechanism, the construction supervisory workers can be trained with a specific focus on developing their competencies under the following categories.

- Describing the significance of a training needs assessment for construction labourers
- Outlining the processes necessary to design the implementation of training for construction labourers
- Summarising how to conduct a training needs assessment for construction labourers
- Developing training plans, course materials and assessments for construction labourers
- Demonstrating a variety of advanced brainstorming approaches to construction labourers
- Demonstrating competency-based training approaches to the construction labourers
- Demonstrating basic theories and applications of construction-related works to construction labourers
- Providing experiential learning exercises to construction labourers
- Maintaining proper records of the labour training exercises
- Assessing the performance of construction labourers in construction works
- Implementing the possible labour rewarding mechanisms for construction labourers

In order to make sure that the training is carried out in the intended direction, regular observations are largely required on evaluating the training goals and objectives, training materials, training delivery strategies, labourer participation, supervisor performance, organisational management policies and other follow-up activities. On the other hand, the labour rewarding mechanisms can be implemented in the projects using the

Recognition for Prior Learning (RPL) method. Notably, the RPL method provides quick procedures that assess how well the person has attained the necessary competencies in accordance with the national skill standards of the NVQ framework [36]. Each labourer can be recommended for a suitable NVQ level at the conclusion of the training period based on his or her LBPS value and labour grade. As per the recommendation of Manoharan et al. [36], the NVQ levels ranging from 1 to 4 can be compared with the labour grades D to A, respectively. In order to implement RPL, the essential procedures need to be taken, and the overall variations in the monthly labour performance score values and productivity measurements can be reported for the observations of the construction management teams and career development units in the projects.

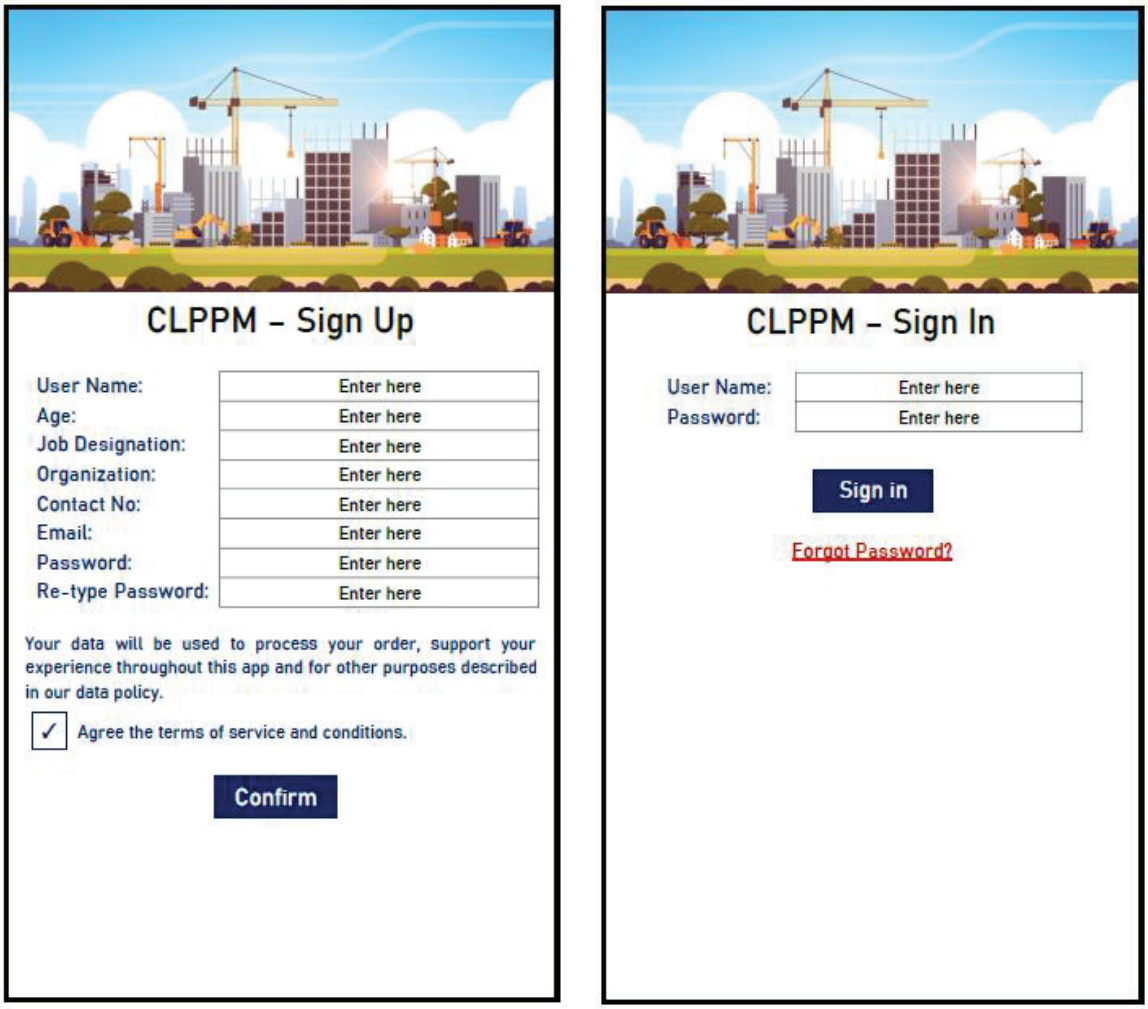
With regard to the sequential processes of the development of the mobile application tool shown in Figure 2, a series of interviews, meetings and discussions were held among industry and academic experts with a focus on the aforementioned areas. Problem-focused and action-oriented communication approaches were employed in the interviews, meetings and discussions as the primary means of comprehending the problems, exchanging information and developing solutions in sketching user interface and visual design of the components for the development of the mobile application tool as well as in designing of the initial data flow diagram for the work process of the mobile application tool. The validity of the initial sketches on the user interface, visual design and data flow of the mobile application tools was then assessed through the discussions and reviews conducted among the construction industry experts and professional mobile application developers. Conclusively, the mobile application software development process was initiated.

4. Results and Discussion

4.1 Detailed Cross Section of the Developed Mobile Application Tool and its Functions

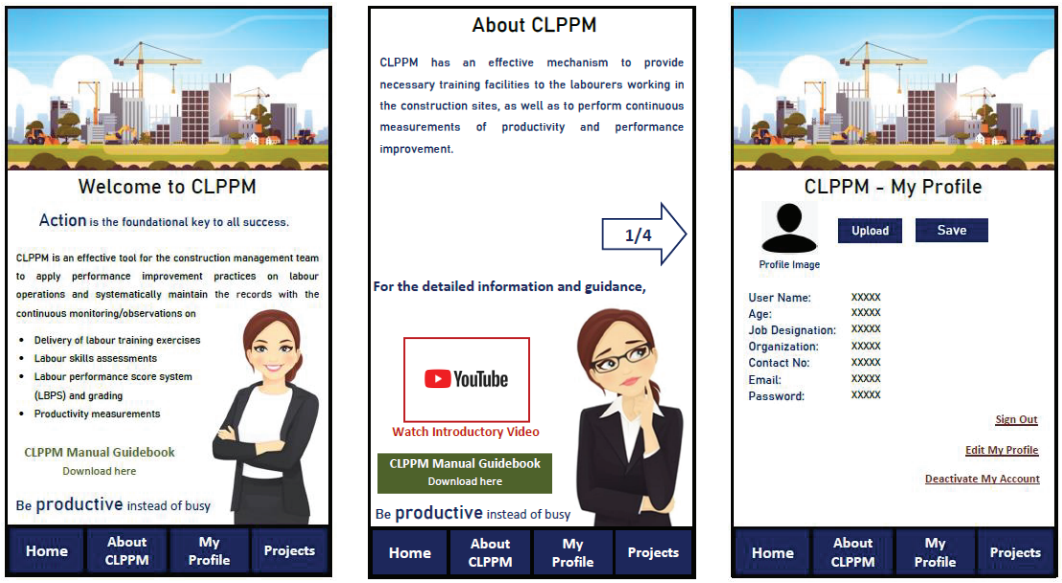
The new mobile application tool was initially named 'CLPPM', which refers to 'Construction Labour Productivity and Performance Management'. The main users of this mobile application will be the labour trainers (construction supervisory workers). The user interface and visual design were sketched as the essential components of the CLPPM mobile application tool, as shown in Figure 3 – Figure 11.

The interface for signing up and signing in includes the attributes, such as user name, age, job designation, organisation, contact details, email addresses and passwords with the agreement statement for the terms of service and conditions, as shown in Figure 3. The main interface of this mobile application has four main categories, which are 'Home', 'About CLPPM', 'My Profile' and 'Projects'. The interface for the 'Home' window mainly includes the welcome information about the usage of this mobile application, as shown in Figure 4. Further information about this mobile application and the mechanism shown in Figure 1 are included in the 'About CLPPM' window with the facilities to watch introductory videos and download manuals/guidebooks. The data provided during the signing up process will be autosaved in the 'My Profile' window, which has further functions for uploading profile images, editing profile information, signing out and deactivating the account, as shown in Figure 4.



(a) (b)

Figure 3 – User Interface Visual Design of the Mobile Application for Signing up and Signing in



(a) (b) (c)

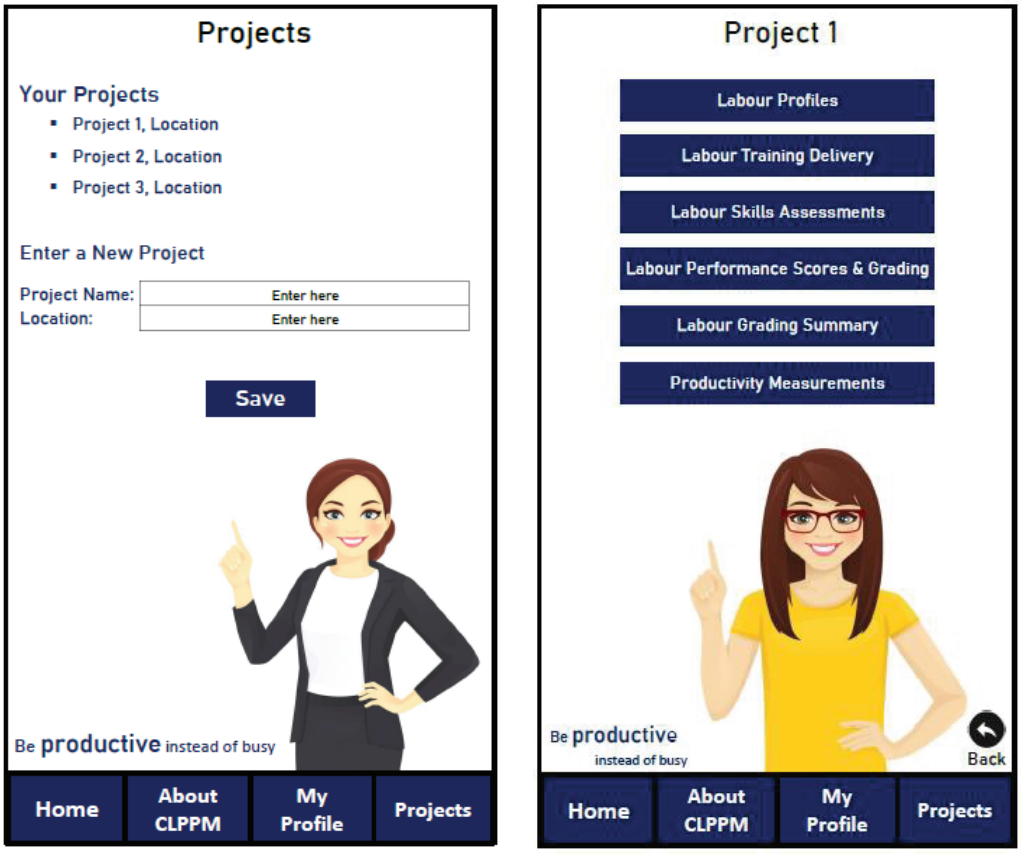
Figure 4 – User Interface Visual Design of the Mobile Application for the 'Home', 'About CLPPM' and 'My Profile' Windows

The 'Projects' window is the key component for this mobile application, which may have a list of projects with the function to enter a new project. Each project window will be having sections for labour profiles, labour training delivery, labour skill assessments, labour performance scores, labour grading summary and productivity measurements, as shown in Figure 5.

The window of 'Labour Profiles' will include the list of labourers with the function for creating new labour profiles, where each labour profile may include the name, age, profile image and contact details of the labourer with remarks, as shown in Figure 6. The window of 'Labour Training Delivery' will facilitate the maintenance of the labour training delivery records, including learning contents, methods of delivery and dates of delivery, as shown in Figure 7. On the other hand, the window of 'Labour Skill Assessments' will facilitate marking the levels of labourers under process, learning demand and responsibility (based on the level descriptors illustrated in Table 2) for the LBEOs of each LBEX, as shown in Figure 8.

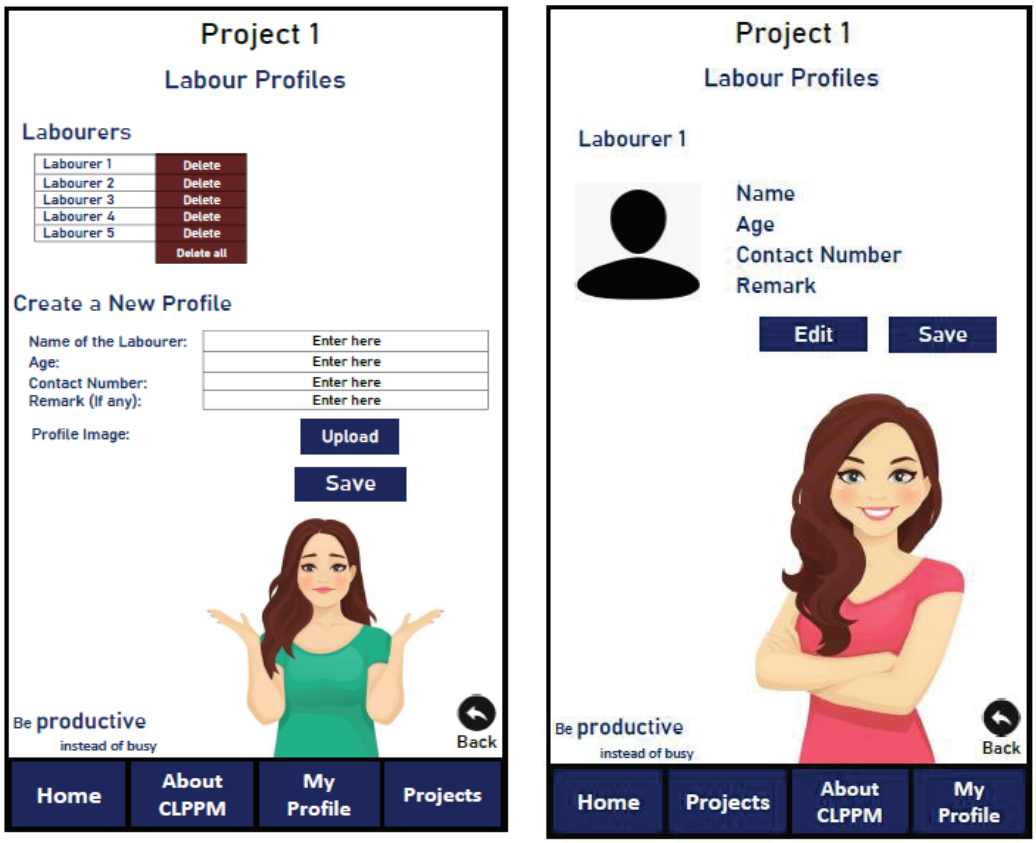
The window of 'Labour Performance Scores and Grading' will be displaying the results of labour performance scores and grades with the necessary graphs for each labourer, as shown in Figure 9. The window of 'Labour Grading Summary' will be showing the number of labourers in each grade with the average labour performance score values for each month at the particular project, as shown in Figure 10. The window may also display the graphs which illustrate the variations in the average labour performance score values and the labour grades between the months.

The window of 'Productivity Measurements' will be providing a way to maintain the productivity measurement records for each type of labour work, as shown in Figure 11. The window may also display graphs which illustrate the variations in the productivity levels of each type of work between the months.



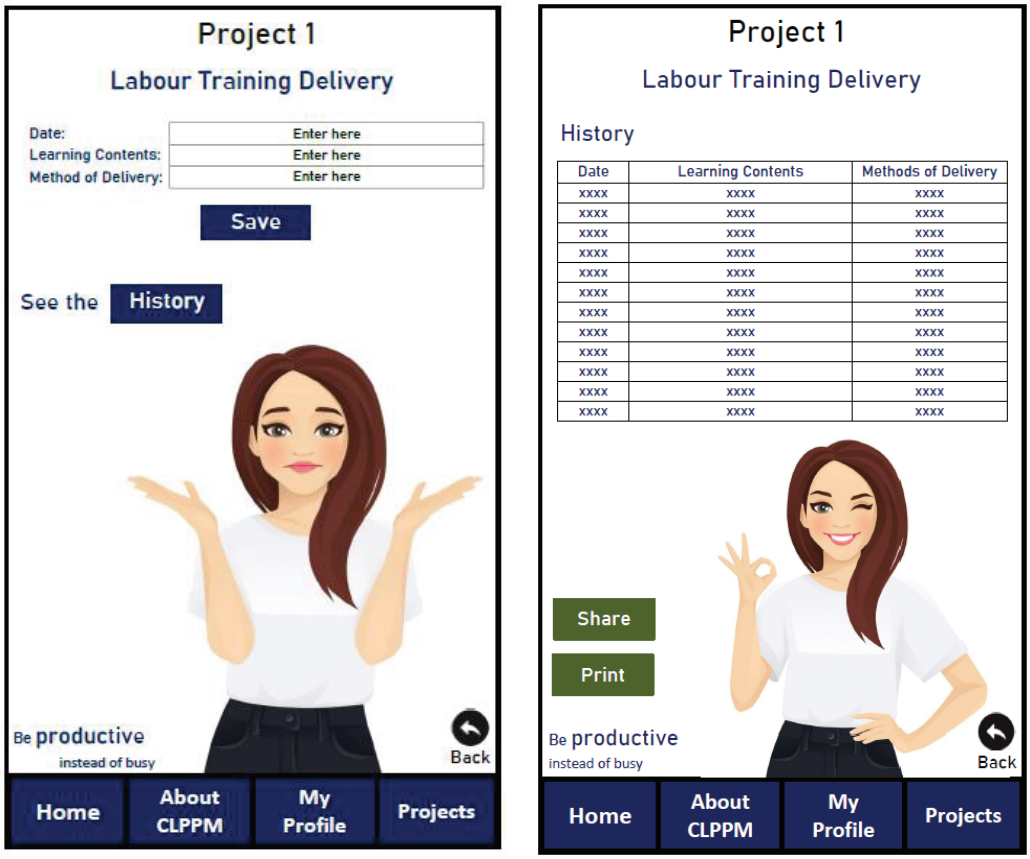
(a) (b)

Figure 5 – User Interface Visual Design of the Mobile Application for the 'Projects' Windows



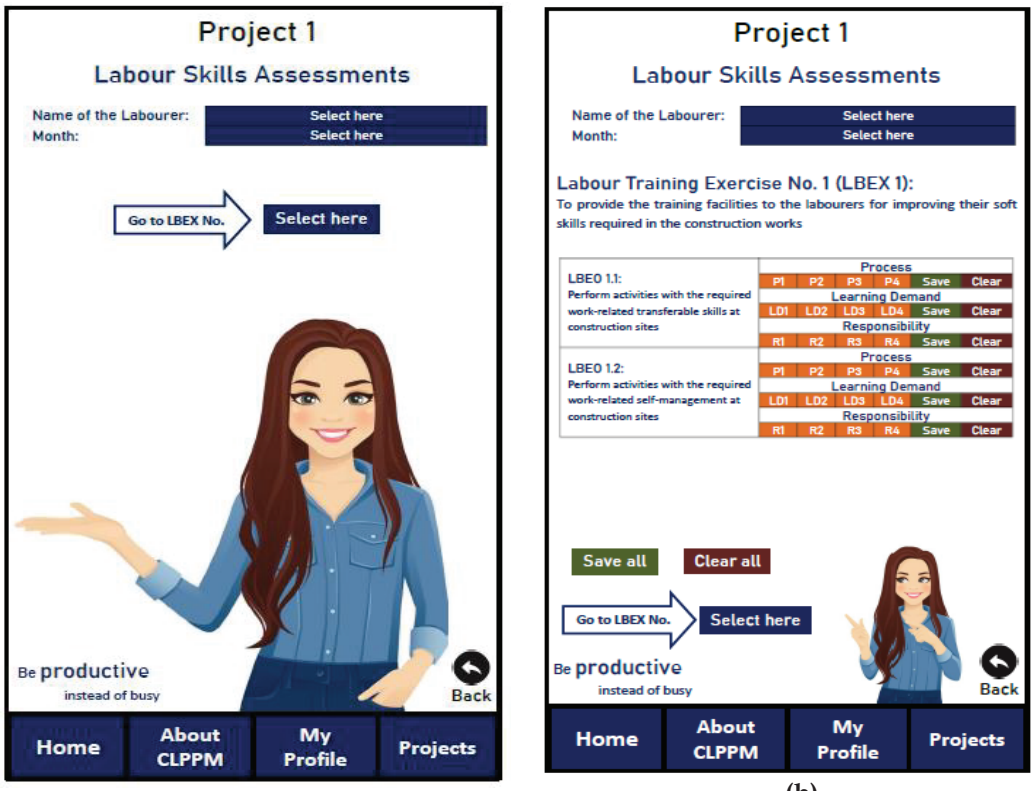
(a) (b)

Figure 6 – User Interface Visual Design of the Mobile Application for the 'Labour Profile' Windows



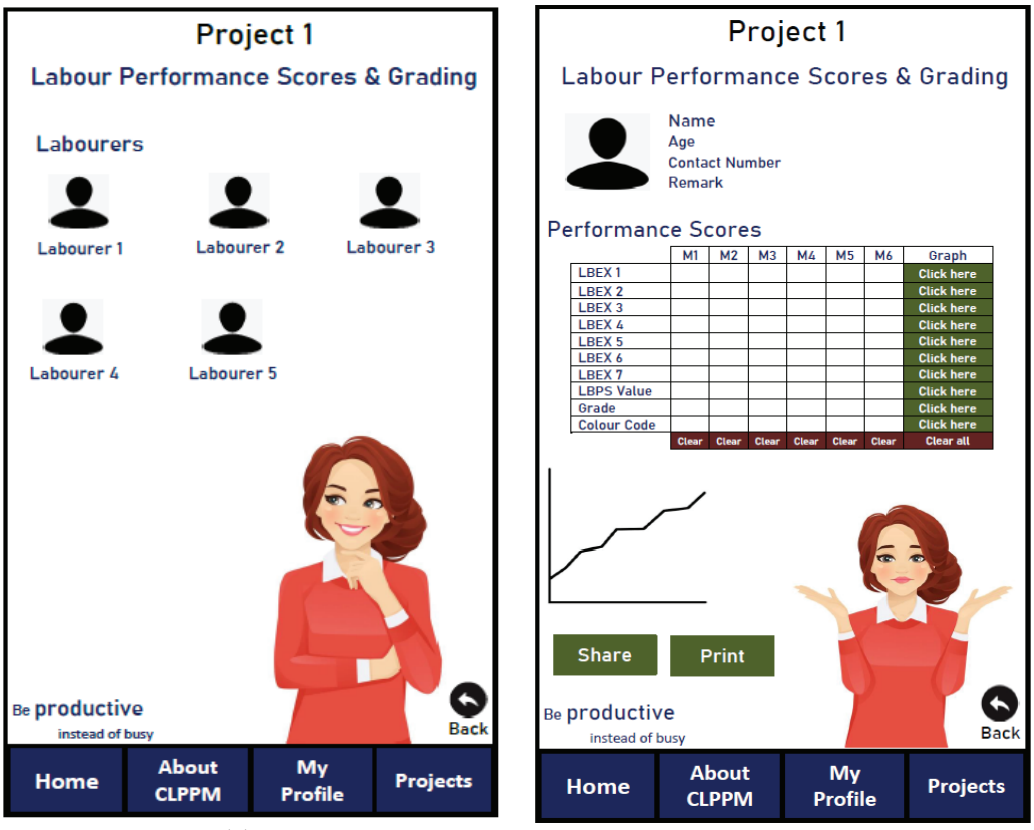
(a) (b)

Figure 7 – User Interface Visual Design of the Mobile Application for the 'Labour Training Delivery' Windows



(a) (b)

Figure 8 – User Interface Visual Design of the Mobile Application for the 'Labour Skills Assessments' Windows



(a) (b)

Figure 9 – User Interface Visual Design of the Mobile Application for the 'Labour Performance Scores and Grading' Windows

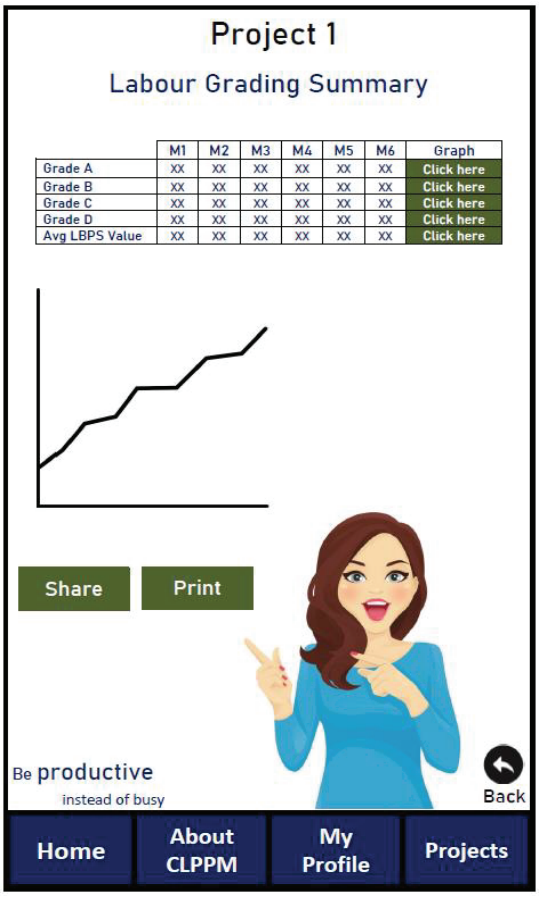
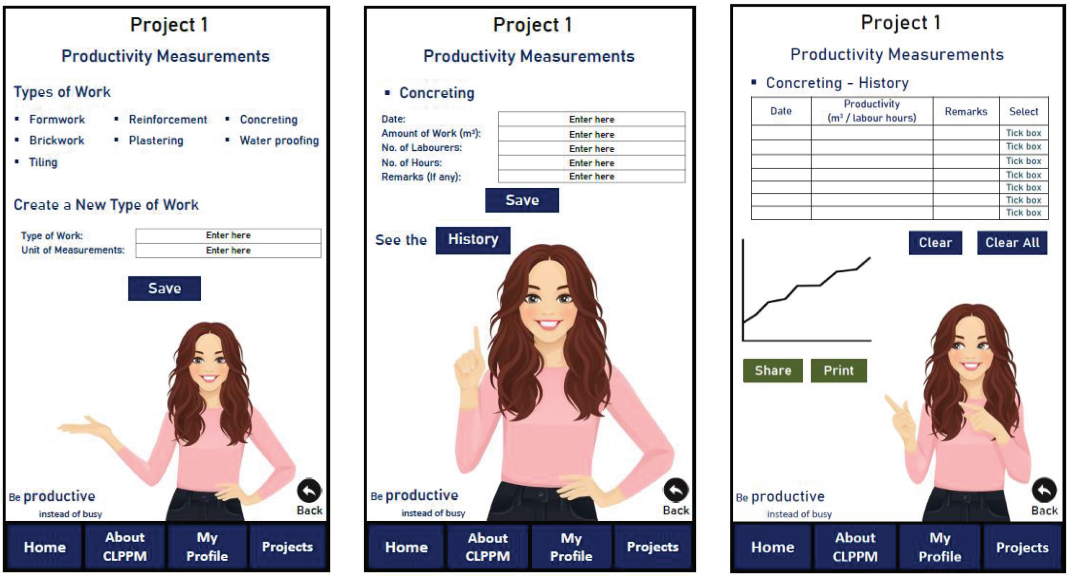


Figure 10 – User Interface Visual Design of the Mobile Application for the 'Labour Grading Summary' Window



(a) **(b)** **(c)**

Figure 11 – User Interface Visual Design of the Mobile Application for the 'Productivity Measurement' Windows

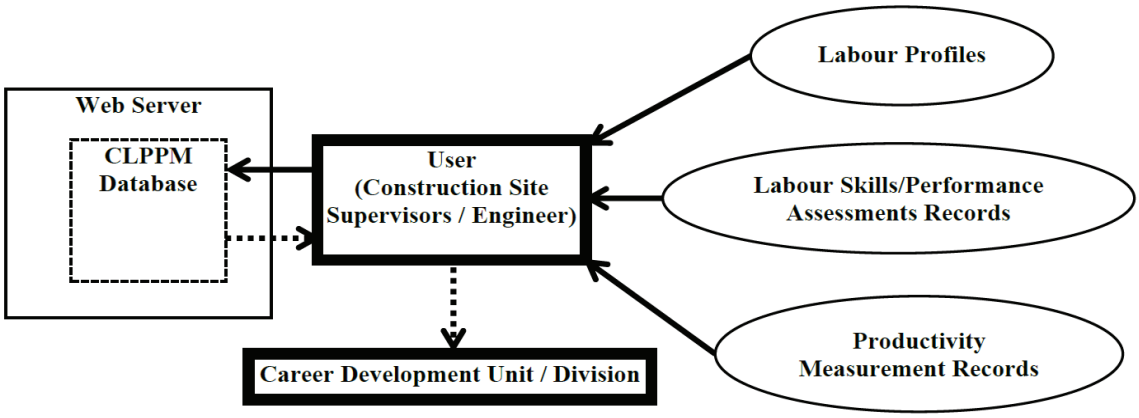


Figure 12 – Data Flow Diagram for the Work Process through the Mobile Application Tool

The data flow diagram is shown in Figure 12. The overall process shows that the records of labour profiles, labour skills assessments, performance score values, labour grades and productivity measurements will be stored in the CLPPM database of the web server through the user (construction supervisory worker / engineer). The necessary records can be transferred to the career development unit / relevant division of the firm through the user from the CLPPM database, as shown in the data flow diagram.

Overall, the proposed user interface visual sketches of the mobile application tool lead to laying the proposed mechanism of labour training project practices (shown in Figure 1) among the construction firms in local and foreign contexts within the simplified process flow. The records of labour training delivery, labour skills assessment, productivity measurements, LBPS calculations, labour profiles and labour grading can be systematically maintained through a well-developed mobile application tool with the functions of comparison analysis and reporting systems.

4.2 Expert Reviews, Validity and Reliability

Overall, the expert reviews ensured the validity and reliability of the proposed designs of mobile application tools for upgrading the current practices of the construction industry with the systematic application of the work-based training and performance evaluation elements associated with the enhancement of performance and productivity of labour operations in construction. In particular, the expert reviews revealed that the proposed mobile application tool has an ideal mechanism that includes innovative practices and operative systems to meet the timely needs/expectations of the industry towards successfully facing the evolving challenges and opportunities in the new normal situations. The expert reviews also stated that the visual designs of the mobile application tool provide easy ways and ensure user-friendliness for the long-term based sustainability of the functioning of the proposed mechanism. Noticeably, this review process was carried out among 10 construction experts through observations, documentary evidence, interviews and discussions with a specific focus on the eight statements listed below. All of these experts had more than five years of work experience, accomplished with chartered engineering and other academic/professional qualifications and were expertise in planning, designing, construction and operational stages in the construction field.

The proposed mobile application tool makes a significant contribution to:

- creating a systematic environment associated with apprenticeship practices for fulfilling the timely needs of the industry sector in the next normal (Statement 1).
- promoting advances in the quality standards, performance, effectiveness and transparency of industry-based activities within a framework (Statement 2).
- changing the characteristics of workforce practices in varied contexts (Statement 3).
- delivering innovative ways to boost industrial work productivity (Statement 4).
- assuring user-friendliness for the long-term based sustainability of the operational flows (Statement 5).

- enhancing self-sustainable approaches towards impacting the commercialisation aspects of the industry sector (Statement 6).
- constructing a platform for developing relationships with stakeholders from the business, industry, society and other sectors of the outside world in an efficient manner to better align the national and international linkages (Statement 7).
- determining new concepts and data needed to forecast for planning or carrying out future research (Statement 8).

The satisfaction levels of the experts on the proposed mobile application tool based on the above-highlighted eight statement categories are shown in Table 3. Overall, the results indicate that all the experts expressed high levels of satisfaction with the functions of the proposed tool under each statement category.

Table 3 – Satisfaction Levels of the Experts on the Functions of the Proposed Mobile Application Tool

Statement Category/ Number	Percentage of Experts				
	Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree
1	-	-	-	-	100%
2	-	-	-	10%	90%
3	-	-	-	40%	60%
4	-	-	-	20%	80%
5	-	-	-	30%	70%
6	-	-	-	20%	80%
7	-	-	-	10%	90%
8	-	-	-	-	100%

Furthermore, the proposed mechanism (shown in Figure 1) was manually applied to train more than 250 labourers working on 22 construction projects (including buildings, roads/highways and water supply project works) through 60-70 construction supervisory workers. It has reported positive results, especially a significant improvement in labour performance, working patterns and productivity levels. Figures 13 and Figure 14 depict the monthly LBPS values that were attained in the chosen projects. Figure 14 shows the fluctuations in monthly average LBPS values based on the project categories, whereas Figure 13 shows how much labour performance scores varied for each LBEX between the months. Overall, the findings show that for all LBEXs across all project categories, labour performance has improved to specific levels. The outcomes support the substantial improvement in labour performance for all LBEX categories across all project types, as shown in Figure 13 - Figure 14. The bulk of the labourers had a limited set of competencies to complete their responsibilities in all LBEX categories at the beginning of the training. The majority of the trained labourers have developed the operational knowledge and abilities necessary to perform the duties associated with all the LBEXs according to the LBPS values acquired at the end of the training.

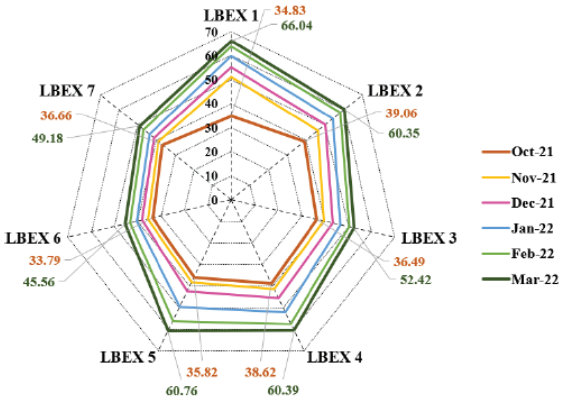


Figure 13 – Variations in Monthly Labour Performance Scores among LBEXs

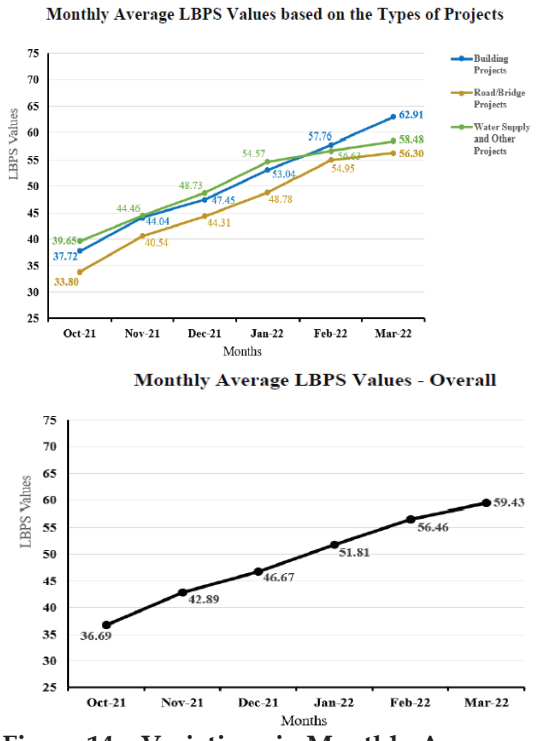


Figure 14 – Variations in Monthly Average LBPS Values

Figure 14 indicates that the monthly average LBPS values for the building, road/bridge and water supply project categories at the start of the labour training were 37.72, 33.80 and 39.65, respectively. At the conclusion of the training, it

was 62.91, 56.30 and 58.48 for each of those project categories respectively. When looking at the entire category, the monthly average LBPS values steadily increased over the six-month period of apprenticeship, rising from 36.69 to 59.43. The findings show a consistent trend in the modest marginal variances of LBPS values across the various project types. This affirms the generalisability of the developed work-based training components among a wide range of construction projects. Taking on the labour grades as per the LBPS values, the approximate ratio between the labourers in grades A, B, and C was 1:4:1.5 at the end of the training.

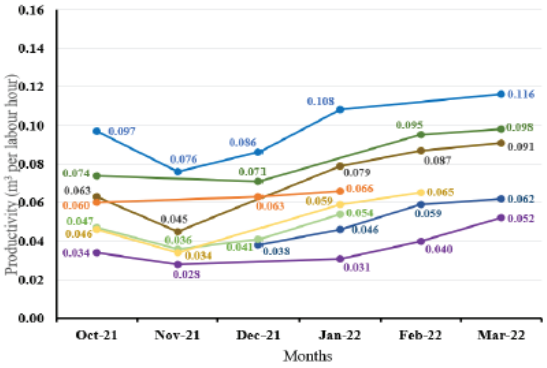


Figure 15 – Variations in Monthly Average Productivity Levels (Sample: Concrete Site Mixing and Placement for Slab and Beams)

Figure 15 illustrates the variations in the monthly average productivity levels among the projects for a sample task (Concrete site mixing and placement for slab and beams). The study finds that during the period of labour training, the productivity levels of the labourers in the chosen projects significantly increased. According to the findings, most projects experienced a noticeable decline in productivity during the early stages. Due to a variety of factors, the majority of the projects had a labour shortage during this time. Additionally, some projects had to stop working throughout the period due to the terrible weather. These could be the main causes of productivity declines in projects during the initial stages of the work training cycle. However, the productivity levels steadily and significantly increased in the vast majority of the chosen projects during the middle and end of the labour training.

Interviews, awareness sessions, open discussions and survey polls were conducted among the construction supervisory workers and the construction management teams of those projects on the visual designs of the mobile application tool and its application practices. These also ensured the reliability and user-friendliness of the proposed designs and practices. These further highlighted that the proposed mobile application tool will provide productive ways to simplify the processes included in their own mechanism, reducing the time constraints and additional material wastage.

4.3 Discussions with Past Studies

Past studies highlighted the need for addressing the ineffective practices associated with work-based training and skill evaluation methods for improving the competencies of construction labourers working in numerous nations throughout the recent decade [2, 8-9, 17, 19-20, 24, 29, 37]. The current study outlines a methodical approach that uses elements of work-based training to generate considerable improvement in a variety of competencies of labourers. The proposed mechanism and its practices emphasise the significant advantages of work-based training techniques over conventional methods that are in line with the findings of Siregar [32], Gao et al. [33] and Ojha et al. [34]. According to the recommendations of the recent studies to incorporate photography and videography methods into work-based training components [40-42, 44], the approaches and application practices of the current study findings can be further upgraded with those digital technologies in the near future.

5. Conclusions

The study has shown how training and performance evaluation procedures can be systematically processed using mobile application tools to improve the performance and productivity levels of labour operations in construction. The proposed designs of mobile application tools have their own mechanism that accentuates the labour performance assessments, labour grading/classification and labour productivity levels as the major units of analysis. The applicability of this mechanism can be suitable among construction firms, in spite of the wide variations in financial capabilities, resource availability and organisational policies among the firms.

The study emphasises that the variety of work processes, learning needs and responsibilities can be used to analyse the shape of labour performance, and this concept offers a baseline for enhancing the ability of construction supervisory workers (labour trainers) to observe labour outputs in order to conduct performance evaluations methodically. As a result, the study introduces novel aspects of construction supervision techniques that could have a significant impact on raising the performance and productivity of labour operations. In addition to giving them efficient means to become trained NVQ assessors within a framework, this may reinforce the values of the supervisory job roles in the construction industry. This will also lead to additional effects on the job characteristics of engineers and project managers in improving the implementation of the components of work-based training. Consequently, the study's findings may encourage the upgrading of training curricula presently offered by universities and technical institutes in order to better meet the demands and problems of the industry.

The labour training components used in the proposed mobile application tool designs may have a substantial impact on changing labourers' working habits to fit the new typical circumstances. The proposed tool can be the key to making a bulk of construction labourers strongly develop the transferable and self-management abilities that enable them to perform their job duties. The mobile application tool may also be a functional element that leads the construction labourers to become to be familiar with how basic engineering, scientific and technology principles must be applied in their daily work activities. The proposed work-based training components may be crucial to enhancing the capacity of construction labourers to carry out processes with some autonomy, especially when it comes to adhering to health and safety regulations, making measurements and estimates, operating machinery, handling materials and carrying out other tasks with the appropriate cognitive and manual skills for the technologies being used. The study findings will also help construction workers become more capable of coming up with novel suggestions for environmentally friendly construction methods and adjusting to the practices of quality control and assurance. In particular, the study findings lead to strengthening the value of encouraging workers to learn for themselves on a lifelong basis, so they can meet the demands of the new normal situations.

The study findings present systematic ways to display the cross-section of labourers that allow the identification of their strengths and shortcomings based on their performance score levels under various categories of labour training and competency factors. The study findings may also lead to strengthening the resource leveling and utilisation procedures in site management and planning by adding some efficient ways of preparing crew mixes among the project tasks as well as in upgrading the productivity benchmark levels of various construction tasks.

The study outcomes reinforce the chain linkages connected between training components, competencies, performance and productivity levels, enabling construction enterprises to achieve organisational objectives and endure in the new normal. The study outcomes will lead to effective communication flows between various job categories in construction sites, which will strengthen ties between employees and employers and contribute to the long-term viability of the firms. The outcomes demonstrate the behavioural shifts in the labourers' work habits and the supervision techniques that lead to a narrowing of the gap between management policies and labour operations. This may lead to a rapid rise in the number of skilled workers in the industry within a short period of time, as well as a rise in the number of labourers switching from casual to permanent employment in construction firms, improving the standard of living for workers and providing them with benefits like job security, pay raises, opportunities for advancement and other benefits for career development. This may further improve worker motivation and the standard of work operations at construction sites, so removing potential obstacles to increasing the local labour supply and reining in the excessive local business tendency toward foreign labour.

The overall study results offer a link between institutional and industry practices, promoting the improvement of the entire quality of labour capacity involving professional, technical and vocational competence in the sector. The study findings are anticipated to have a significant impact on the business practices of other developing nations, despite the fact that their application is restricted to the Sri Lankan

setting. The study gives up new opportunities for upgrading the current practices of construction education and training with new mobile application tools to broaden the suggested methods for attracting more users globally and strengthening the generalisation of the suggested practices. The findings of the study may also encourage other emerging industrial sectors to take into account comparable techniques and policies to raise the bar for performance, quality and productivity in the workplace. Accordingly, the study suggests that future studies concentrate on creating new training models and evaluating training outcomes, taking into account the traits of various trades or business sectors in various circumstances. The proposed designs of the mobile application tool are still in the development phase. Therefore, the study recommends that future studies focus on the crucial elements of the creation, testing and upkeep of this mobile application tool.

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