

**HUMAN SKILL FACTORS THAT AFFECT ON
DIGITAL TRANSFORMATION OF THE
CONSTRUCTION INDUSTRY IN SRI LANKA**

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Degree of Master of Science

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Sri Lanka

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This thesis is submitted in partial fulfilment of the requirements for the
degree Master of Science in Construction Project Management

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DECLARATION

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Prof.A.A.D.A.J. Perera

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.....

Date

Abstract

The world is leading to an Industrial revolution by automating and integrating novel construction technologies for efficient decision-making. However, the local Construction industry lacks to adopt state-of-the-art digital transformation techniques due to the lack of awareness, technical know-how, and a higher capital cost of those technologies. Literature reveals numerous research studies in this area have sufficient frameworks worldwide to improve human digital skill factors. However, there is a lack of information on improving human digital skill factors in the Sri Lankan context. Therefore, developing a comprehensive guideline to expedite the construction industry digitalization process in Sri Lanka is essential.

Available competencies and frameworks were identified using a Literature review. Required competency levels were categorized according to the complexity of the task, autonomy, and cognitive domain from Level 0 to Level 4 (No skill to Expert Level). For the ease of the data collection, the workforce was divided into 4 categories: Senior Management, Engineers/Architects, Quantity Surveyors and Storekeepers. /TO. A questionnaire survey was conducted with the help of industry experts for the local Construction Industry regarding digital transformation techniques, training, and consultation programs.

According to the analysis, 94% of respondents believe the construction industry needs to upskill its digital skills. In Sri Lanka, digital technologies such as Augmented Reality, Virtual Reality, Three-Dimensional Printing, Drones, Robotics, and the Internet of Things are relatively less than developed countries. Only 28% of the responders are experienced in Building Information Modelling (BIM) applications, while 53% are involved in productivity and planning apps, Communication and Document management systems and Enterprise Resource Planning. Moreover, it's found that Senior Management and Middle Management need a higher digital skill competency level (Level 3) while the technical officer level needs a comparatively lower level of competency (Level 2). Senior management's active involvement is critical for the successful digital transformation process. This research's findings benefited the public and Private sectors in their construction digitalization process.

Keywords: Human Digital Skills; Construction Digitalization; Digital Transformation; Digital Construction

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S.H.V.D Jayasingha

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LIST OF ABBREVIATIONS

Abbreviation	Description
OECD	Organization for Economic Co-operation and Development
ICT	Information and Communications Technology
DIHK	Association of German Chambers of Commerce and Industry
BIM	Building Information Modelling
DQ	Developmental quotient
3D	Three Dimensional
IoT	Internet of Things
IT	Information Technology
5-D BIM	Five Dimensional BIM
DTM	Digital Transformation Monitor
DIGCOMP	The European Digital Competence Framework
UK	United Kingdom
CITB	Construction Industry Training Board
HR	Human Resources
VR	Virtual Reality
AR	Augment Reality
ERP	Enterprise resources planning
DTM	Digital Transformation Monitor

1 INTRODUCTION

1.1 Background

In digitalization, almost every business process is connected through a digital system at every value chain link, using tools and practices supported by Information and Communication Technology (Roland Berger, 2016). But the Construction industry is still not fully utilized by digitalization, which has significantly affected the industry, especially in developing countries (Aghimien et al., 2018). Several identified factors cause this lag in progress. From them, one of the key reasons is the negligence of the Human factor while technology implementations, IT Projects, and any efforts on digital transformations or digital business projects (Clerck, 2018). According to OECD research, ICT is reshaping organization models. Workforces must improve their interaction, communication with colleagues, clients and problem-solving skills (Rimini & Spiezia, 2016). And every industry should be prepared with new skills or enhancement of skills to succeed in this transformation because that technology is changing the nature of work faster than people's capability of changing their skills (Levy, 2010).

When it is come to the digitalization of the construction industry, while other industries are already implemented and benefiting the entire business process, construction still lags. Only a few players have entered the flow to resolve this problem, but according to a survey by the German Chambers of Commerce and Industry (DIHK), 93 construction companies have agreed that digitalization influences their processes. According to the study, manufacturing companies, retailers and service providers are leading to digitalization compared with construction companies. Building material producers focus on digitalizing production and distribution, while construction companies are primarily concerned about digitalizing the planning, construction, and logistics (BIM-Building Information Modelling and interconnection of construction sites). Since building material traders tend to do their making and sales procedure online, currently Construction Industry understands how important digitalization is, but still, the issue is about implementation (Schober & Hoff, 2016).

Current Sri Lanka has done some initiatives regarding digitalization and digital maturity. Sri Lanka is still in the “Digital Followers” category (De Bustis, et al., 2018).

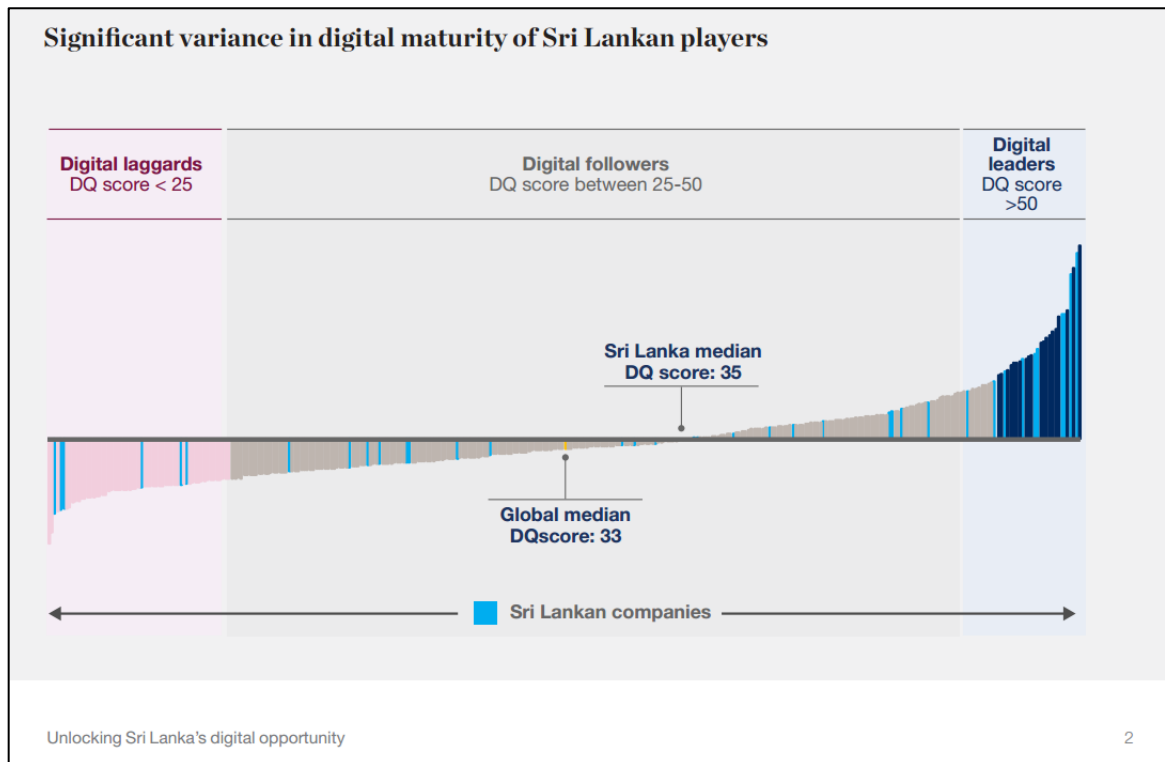


Figure 1-1 Digital Maturity of Sri Lankan players – Source (Blanco, et al., 2018)

The Sri Lankan construction industry needs to put more effort into the digital transformation process to be competitive with the global economy. As for the Construction industry in Sri Lanka, very little literature is available regarding digitalization.

Digital skills are essential for successful transformation. Therefore, more research is needed to identify the required skills for digitalization and address development. (Revealing Reality, 2018)

1.2 Problem statement

Sri Lanka is a digital follower, and the Construction industry needs to focus on digitalization to face global competitiveness. The purpose of this research is to

identify Human factors that affect the successful digital transformation of the industry.

1.3 Objectives

The main objective of this study is to identify the digital skills and competencies required for construction industry digitalization in Sri Lanka. Here are the Sub objectives.

1. To identify globally available digital skill frameworks
2. To Identify Digital Skills/Competencies and levels required for Construction Industry in Sri Lanka
3. To identify current emerging Digital technologies' status from the point of view of users and people involved in the Construction digitalization process

1.4 Research Methodology

This report consists of a qualitative study's results with the practitioners involved in Construction Industry Digitalization. For the study following steps were followed.

- Literature Survey for investigating existing identified skills, competencies framework
- Develop a Questionnaire for identifying attributes
- Conduct a Pilot survey
- Data Collection and analyze the results

1.5 Limitation of Study

In Sri Lanka, Digital Construction is its initial stage and the areas applied are limited to a few popular technologies. Therefore, the population is limited because the sample frame is people involved in digital construction through implementation, consultation, training in new technologies etc.

1.6 Guide to the Thesis

In this thesis, chapter 1 gives the introduction for the study with background, problem statement, Objectives, brief on the methodology followed and limitations of the study.

Chapter 2 represents the results of the literature review under subtopics What is digital transformation, Digital transformation in the construction industry, factors affecting transformation, the importance of digital skills, Identification of Digital skills, available skill frameworks, and finally, what other countries have utilized describing research gap.

Chapter 3 describes the research methodology. Firstly describe previous research methodologies followed and then describe the methodology selected for this study. Then it discusses questionnaire preparation and the sample of the study.

Chapter 4 deals with the analysis and the discussion of the findings of this research. It starts with data collection, analysis of data, processing, and discussion. At the end of the chapter, it has validated the research findings.

Chapter 5 discusses the research's conclusion against each of the research objectives. And applications and future recommendations of the research.

2 LITERATURE REVIEW

This chapter describes digitalization, the success factors, Why Human skills are important, how to identify and acquire Digital skills, Available frameworks, what other countries have already done in Construction digitalization, and future recommendations from earlier research and research gap.

2.1 Digital transformation

“Digital transformation is the cultural, organizational and operational change of an organization using digital technologies” (I-Scoop, 2022).

According to (C.Verhoef, et al., 2021), there are three primary needs for digital transformation, Increasing the number of technologies used by the economy and the need to transform according to them (Digital technology), Increasing the competitiveness of the economy(Digital Competition), and Customer responses and behavior which demanding digital transformation (Digital Customer behavior).

Currently, this is developing and discussed in eight dimensions “Digital Economy, Digital Technologies, Digital Strategy, Digital Adoption, Digital Transformation, Digital Investment, and Impact.” (Probst, et al., 2018) And mainly focuses on technologies like “big data and Data Analysis, Cyber Security Solutions, Social Media, Robotics and Machinery,3D printing, Mobile Services, Cloud Technologies, the Internet of Things, Artificial Intelligence.” (Probst, et al., 2018).

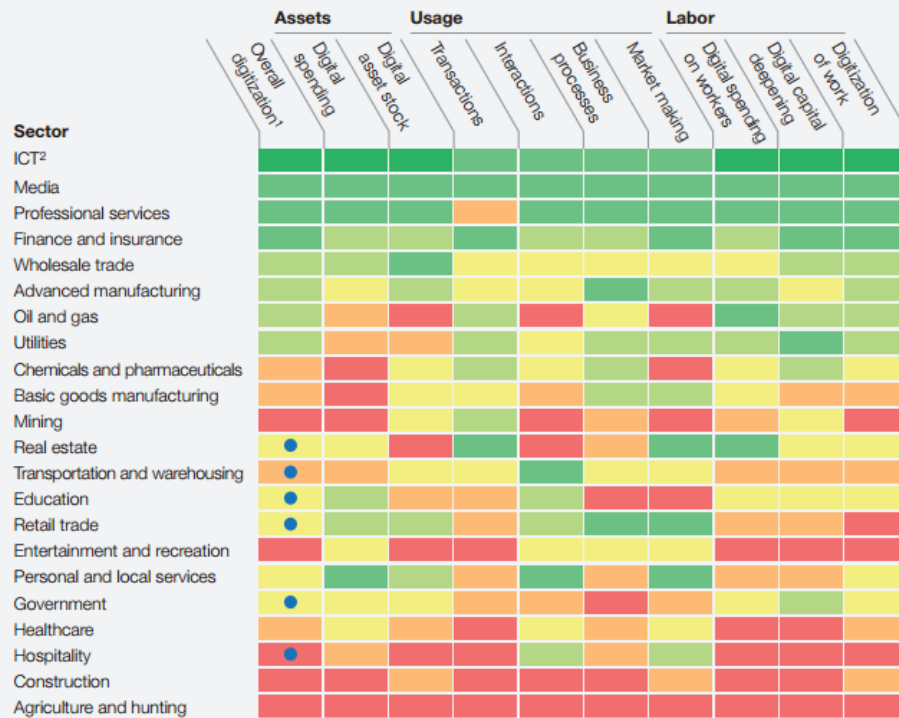
2.2 Digital transformation of the construction industry

According to (Agarwal, et al., 2016), Construction Industry is among the least digitalized sectors.

Exhibit 3 The construction industry is among the least digitized.

McKinsey Global Institute industry digitization index;
2015 or latest available data

Relatively low digitization  Relatively high digitization
● Digital leaders within relatively undigitized sectors



¹Based on a set of metrics to assess digitization of assets (8 metrics), usage (11 metrics), and labor (8 metrics).

²Information and communications technology.

Source: AppBrain; Bluewolf; Computer Economics; eMarketer; Gartner; IDC Research; LiveChat; US Bureau of Economic Analysis; US Bureau of Labor Statistics; US Census Bureau; McKinsey Global Institute analysis

Figure 2-1 McKinsey Global Institute industry digitalization Index

Popularly, Digital construction is often assumed to be Building Information Modelling (BIM), but it is broader than BIM. Persuading the industry for the transformation is a great challenge for the specialist because lack of faith and less knowledge of how technology could be used to solve a problem. Most digital technologies are generally limited to trials or small pilots because more significant investments are riskier.

“Leaders required skills in implementing Digital change and the ability to build the appropriate structures. Both managers and employees require greater digital savvy and problem-solving abilities. It is about facilitating both top-down and bottom-up

change; therefore, not everyone needs to be on equal ground (Revealing Reality, 2018).

There are 5 major dimensions in which the construction industry needs to evolve with digital technologies. They are higher-definition surveying, geolocation-Rapid digital mapping, estimating, 5-D BIM, Digital collaboration, mobility, IoT (The Internet of Things), analytics, and future-proof design and construction (Agarwal, et al., 2016).

While other industries are already implemented and benefiting the entire business process, construction still lags. Only a few players have entered the flow to resolve this problem, but according to a survey by the German Chambers of Commerce and Industry (DIHK), 93 construction companies have agreed that digitalization influences their processes. According to the study, manufacturing companies, retailers and service providers are leading to digitalization compared with construction companies. Building material producers focus on digitalizing production and distribution, while construction companies are primarily concerned about digitalizing the planning, construction, and logistics (BIM-Building Information Modelling and interconnection of construction sites). Since building material traders tend to do their making and sales procedure online, the Construction Industry is currently aware of digitalization's importance. Still, the problem is with the implementation (Schober & Hoff, 2016).

“The industry has suffered significantly due to this failure to capitalize on the inherent benefits of digitalization, particularly in developing nations” (Aghimien, et al., 2018). “The neglect of the essential human component is one of the primary causes of unsuccessful technology implementations, digital transformation efforts, IT projects, customer service or experience optimization plans, and digital business projects.” (Clerck, 2018). According to studies, there are four major areas of digital transformation.

- “Digital Data - collection and analysis of electronic data
- Automation - Use of the latest technologies to create autonomous systems
- Connectivity - Connection and synchronization

- Digital access ” (Schober & Hoff, 2016).

Current World trends in Construction Industry

- “Electronic tendering
- Digital procurement systems to save time and money
- Drones and robots
- Building material suppliers are going to digitize their process
- Digital sales
- BIM (Building Information Modelling) Future standard for everyone on the building site” (Schober & Hoff, 2016)

2.3 Factors affecting digital transformation

According to researchers, several success factors enable successful digital transformation. It requires a culture created by the leadership that promotes innovation, is ready to take risks, delegates to work at all hierarchy levels, and empowers them (world economic forum with Accenture, 2016).

According to mapping, the following major factors in the literature review research conducted by Swen Nadkarni and Reinhard Prügl. They have categorized them as Technology factors and Actors (Nadkarni, 2020).

Technology factors

- “Pace of Change and Time to Market (Right Timing)
- Technology Capability and Integration
- Consumer & other Stakeholder Interface
- Distributed Value Creation & Capture
- Market Environment & Rules of Competition” (Nadkarni, 2020).

Actors

- “Transformative Leadership
- Managerial & Organizational Capabilities
- Company Culture with an adaptive skill set

- Work Environment” (Nadkarni, 2020).

As a part of the Digital Transformation Monitor (DTM) by the European Union, (Probst, et al., 2018) have identified 5 major digital transformation enablers.

- “Digital Infrastructures
- Investment and Access to Finance
- Supply and Demand of digital skills
- Entrepreneurial Culture
- E-Leadership” (Probst, et al., 2018).

Sousa and Rocha had concluded the following impacts expected from new technologies from the data collection. (Sousa & Rocha, 2019)

- Reduction of the Labour costs
- Decreases in delivery time and more flexibility
- Growth of the Productivity
- Higher quality of products and services
- New challenges in education, training and working methodologies
- Culture addresses new tasks like big data analysis, Machine Learning, real-time monitoring, etc.

The results of the survey indicate

- “Low positive correlation between opportunities for new, disruptive businesses and perceived challenges
- The negative correlation between organizations' perceived challenges and emerging skill trends
- Strong positive correlation between new skill trends and opportunities for disruptive businesses” (Sousa & Rocha, 2019).

Therefore, according to (Sousa & Rocha, 2019), to overcome these negative insights, organizations need to adapt and develop new trends in skills, and it helps to better utilization of opportunities and resources and sustain the industry.

2.4 Digital skills

Changing the business model, Product or organization structure using digital technologies is a massive management challenge for the coming decades. It is not a task of technology alone but a combination of People and technology (Nadkarni, 2020).

Developing Skills for digital transformation needs a new beginning. There should be a clear understanding of the skills people already have and the skills required. This requirement goes beyond “how to use tech” but to concern with behaviors and attitudes and focuses on developing ‘softer’ skills (Revealing Reality, 2018).

People have to up-skill or reskill to go with rapid technological transformation in the economy. Digital technologies are opening new opportunities, and to seize them, individuals must reskill or up-skill the correct skill set (Rimini & Spiezia, 2016).

Digitalization is already started, and transforming enterprises into digital enterprises has become a leading goal of most Industries worldwide. Only investing in new emerging technologies would not make a digital enterprise. Companies need to re-engineer their business models, revamp the process of attracting and encouraging digital talents, and measure the business's success. (world economic forum, 2016) Organizations need to rethink the competencies needed for the changing industry and how to manage those competencies (Wahlund & Wahlberg, 2018) Because it is a characteristic of “Technology can change the nature of work in labour markets faster than people can change their skills” (Levy 2010).

“At the heart of digitalization is a need for a digitally skilled workforce. Construction businesses need to be able to use technology and make the most of it. The right skills are a key catalyst for digital growth. The industry is growing interested in becoming digital, but it doesn’t always know how to go. The sector’s vision of how to implement, recruit and fill the digital skill gap is unclear” (Revealing Reality, 2018).

From the facts mentioned above in the literature, Identifying and attracting required digital talents for the enterprise is a crucial task because companies cannot achieve digitalization without the support of workforce skills.

When defining digital competency, it needs to include both higher-level competence components that apply to various settings and practical components that apply to the requirements of various occupations. The Normal skills we referred to earlier related to ethics and attitudes also remain. When the world's practices change, including competencies relating to practical tasks and knowledge due to digital tools, change thanks to technological developments, and regular revisions are required (Ala-Mutka 2011).

2.5 Identifying and acquiring the skills required for the transformation

In Digital scoreboard, (Probst, et al., 2018) have described identifying required skills. The industry needs to identify whether future jobs will appear and whether current jobs will disappear. Then need to evaluate what are the skills required for future jobs and define future skills required for existing jobs.

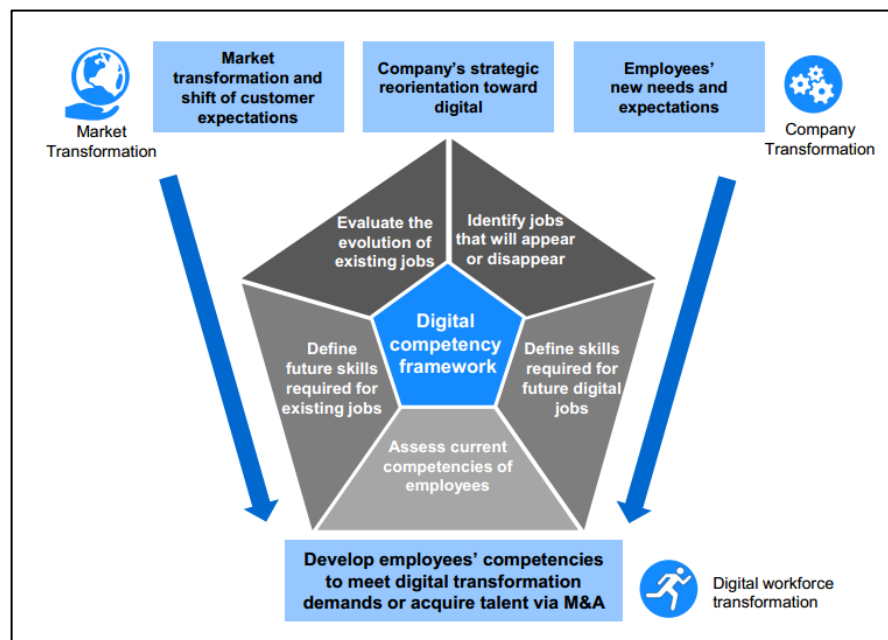


Figure 2-2 How to identify required skills for the digital transformation, Source - (Probst, et al., 2018)

To successfully digital transformation, Organizations need to develop and attract new skills. They can develop required skills within their workforce by training or mining the workforce to assess their hidden skills. For this continuous skill, companies need an assessment process.

Bring new skills to the organization by recruiting and employee exchange programs from digitalized sectors. Importantly, if the current leadership is not enthusiastic about digitalization, they need to bring leadership skills that can work in collaboration with millennials because digitalization needs to happen at every industry level.

“Leaders need to hire people with digital mindsets, and less resistance to change the status quo” (world economic forum with Accenture, 2016). Organizations should collaborate with universities, institutes, colleges, and schools to produce the workforce with the required digital skills. Ordination between the private and public sectors is crucial for bridging the long-term skills gap. An organization should develop critical skills to return the optimum output from the workforce with the right digital skills. (world economic forum, 2016) According to McKinsey’s Digital Academy, organizations can achieve 2.5 times an increase in the success rate from investing in talents. (Blanco, et al., 2018) And it is advised to explore talents in digital native or already digitally transformed companies and industries, even though employees from outside of the industry can be paired with the right leaders and achieve the required level of digitalization (Blanco, et al., 2018).

2.6 Available frameworks and skills/competencies

There is a difference between competencies and skills. Kööhler and Söderqvist state the difference as follows. “Competence is an individual capacity consisting of skills, knowledge, and behavioral competencies. Skills represent the ability to perform something specific. To utilize skills, a person requires certain knowledge”. (Jsoderqvist & Koohler, 2016) “Knowledge represents cognition or theoretical comprehension of a subject. Behavioural competence characterizes inner attributes of a person to behave in different ways depending on context”. (Jsoderqvist & Koohler,

2016) Therefore, for people to acquire competency, they need skills and behavior, while knowledge leads to acquiring the skills.

1). The following figure includes the framework developed by the European Commission (DigComp 2.1) for categorizing and measuring competencies. As an initial approach, the DIGCOMP can be used as an umbrella framework to select the competencies which need to assess according to the target group (Kluzer & Priego, 2018).

1 Competence areas	2 Competences	3 Proficiency levels			
		Levels	Complexity of tasks	Autonomy	Cognitive domain
1. Information and data literacy	1.1. Browsing, searching and filtering data, information and digital content 1.2. Evaluating data, information and digital content 1.3. Managing data, information and digital content	1	Simple tasks	With guidance	Remembering
		2	Simple tasks	Autonomy and with guidance where needed	Remembering
2. Communication and collaboration	2.1. Interaction through digital technologies 2.2. Sharing through digital technologies 2.3. Engaging in citizenship through digital technologies 2.4. Collaborating through digital technologies 2.5. Netiquette 2.6. Managing digital identity	3	Well-defined and routine tasks and straightforward problems	On my own	Understanding
		4	Tasks, and well-defined and non-routine problems	Independent and according to my needs	Understanding
3. Digital content creation	3.1. Developing digital content 3.2. Integrating and re-elaborating digital content 3.3. Copyright and licenses 3.4. Programming	5	Different tasks and problems	Guiding others	Applying
		6	Most appropriate tasks	Able to adapt to others in a complex context	Evaluating
4. Safety	4.1. Protecting devices 4.2. Protecting personal data and privacy 4.3. Protecting health and well-being 4.4. Protecting the environment	7	Resolve complex problems with limited solutions	Integrate to contribute to the professional practice and to guide to others	Creating
		8	Resolve complex problems with many interacting factors	Propose new ideas and processes to the field	Creating
5. Problem solving	5.1. Solving technical problems 5.2. Identifying needs and technological responses 5.3. Creatively using digital technologies 5.4. Identifying digital competence gap				

Figure 2-3 DigComp Framework adopted for assessment of construction project managers' skills (Acar & Dogan, 2018)

2). Literature research done by (Laar, et al., 2017), They have listed the following skills as new digital skills “Technical Skills, Information Management, Communication, Collaboration, Creativity, Critical Thinking, Problem Solving” (Laar, et al., 2017).

3). Construction Industry Development Board in the UK (CTIB) has approached construction Industry digitalization with two main driving forces: Understanding

tools and data and a flexible mindset. It shows that only Knowledge and Skill can't do the work without the involvement of positive attitudes. Here are the skills mentioned in their publication.

- a. Look creatively about issues and solutions, be able to pinpoint what is the issue that needs to be fixed and think outside the apparent solutions
- b. Know about using digital technology: have a basic understanding of the various digital platforms and devices accessible
- c. Determine which instruments to employ in situations: When the correct tool isn't available, be able to evaluate a variety of choices to come up with a solution.
- b. Organize the data that travels into and out of these applications: understanding different forms of data, what data can be collected, and how to distribute it (Revealing Reality, 2018)

4). Rimini and Spiezia have identified three main skills: Skills to develop and manage using new technologies, Basic Skills to use developed programs and

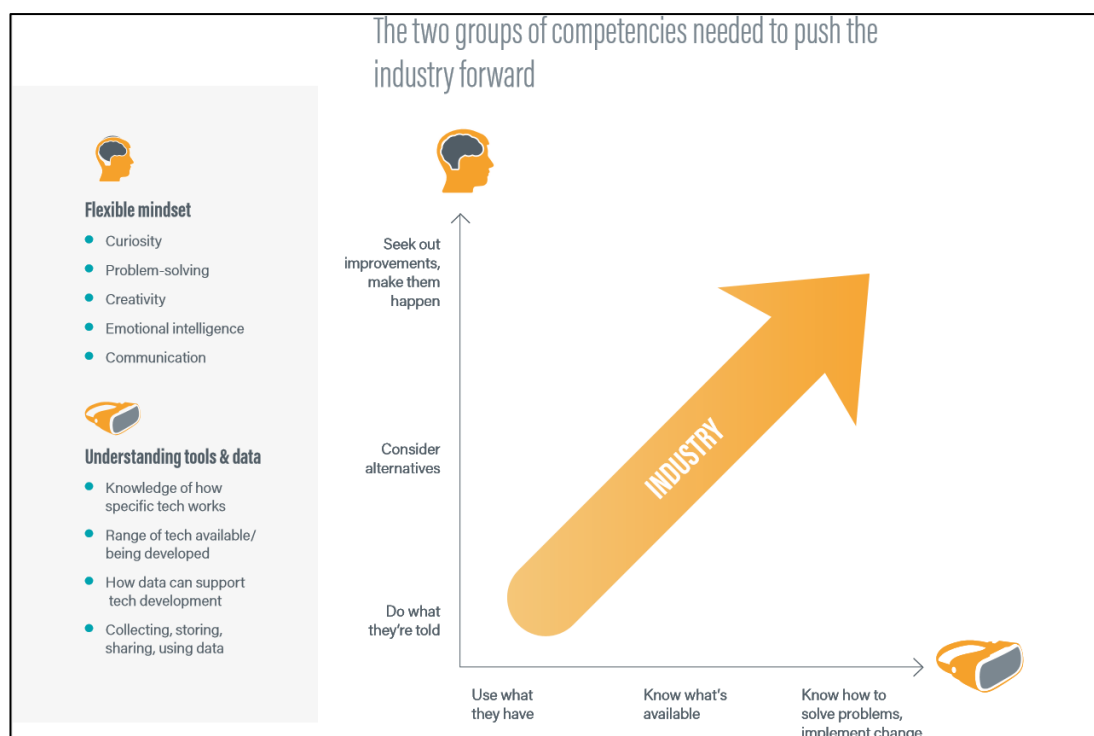


Figure 2-4 Driving forces for Construction industry digitalization from CITB, UK (Revealing Reality, 2018)

technologies, and perform new tasks using developed new programs. And as skills, they have identified communication foundation level, problem-solving, Self-Direction, Process information and Social and Emotional Skills. All employees don't need to use technology effectively but need skills to carry out work in a technology-rich environment (Rimini & Spiezia, 2016).

Skills required for the future are difficult to identify because of the fast technological changes. The next challenge is the keep a matching skills development system sufficiently fast to match new skills demands (Rimini & Spiezia, 2016).

2.7 What other countries have done

According to the latest research by (Blanco, et al., 2018), the construction industry now focuses on digitalization, and most technologies engage in emerging status. They have built a categorization considering two factors.

- Number of companies with transactions in the past five years
- Number of transactions

They have identified technologies used in 7 phases as follows. And also, they have identified and categorized the business processes related to the phases.

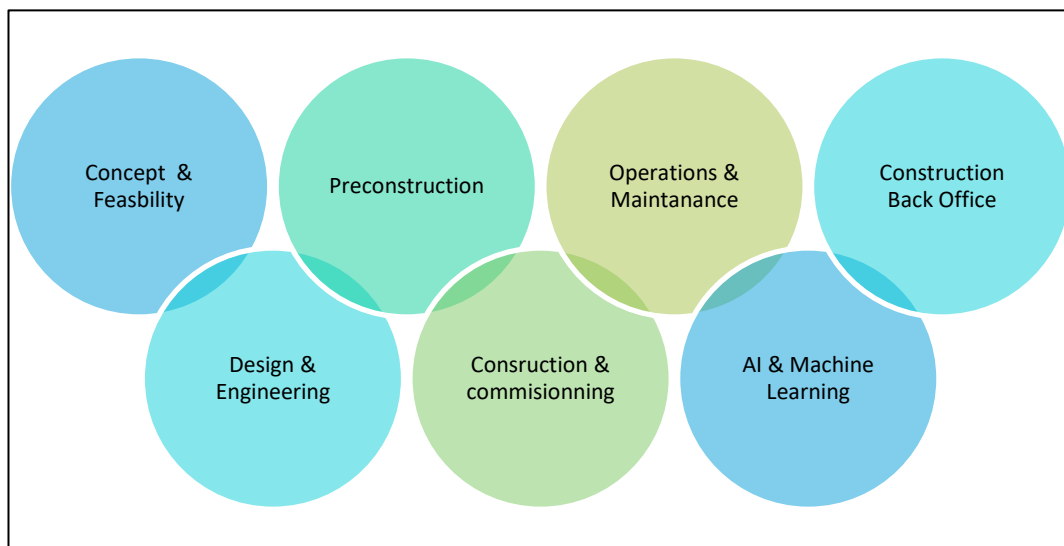


Figure 2-5 Phases in Construction in which technologies are engaged

After considering the Number of new Companies found using the new technology area and the number of transactions, it has been divided into 4 stages. Established, Maturing, Emerging and Talent Acquisition. Check the figure below.

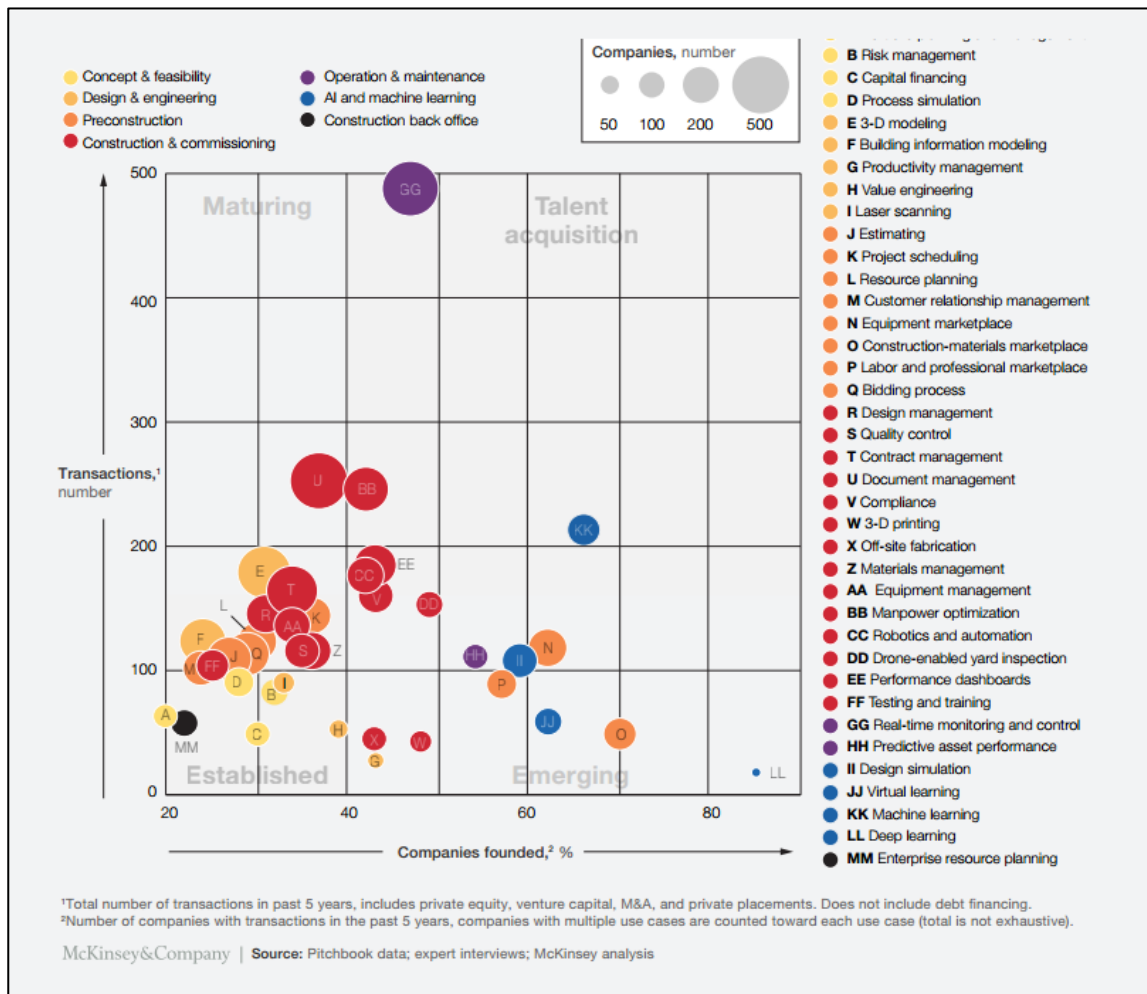


Figure 2-6 Status of Technologies and phases in construction Industry Today (Blanco, et al., 2018)

According to their survey, most of the technologies are in the “Established level” (Lower left Quadrant), which means those technology markets are either already saturated because less user case % within the past 5 years (2013-2018) or some are showing a lesser user case with fewer transactions. Few technologies are in the Emerging phase like Design Simulation, Virtual Learning, Machine Learning, predictive asset performance etc. And it means there are higher numbers of new user cases but fewer transactions. If, eventually, the usage of those technologies increases,

they will enter the talent acquisition phase, which means skill demand for those technologies increases (Blanco, et al., 2018).

2.8 Recommendations from previous researchers

There is a need to measure actual skill levels within the workforce, and future researchers can use performance tests as an appropriate measurement tool to get a realistic view. Doing smaller, more in-depth qualitative research is recommended before gathering large-scale quantitative data (Laar et al., 2017). and it is concluded that the requirement of developing a broader conceptual framework that embraces digital abilities for the twenty-first century. The vision of digital skills in the twenty-first century is that they need to engage a knowledge worker and empower people to manage their learning. The “definition for 21st-century digital skills must be exact, as well as the existing and expected needs quantified” (Laar, et al., 2017).

If Companies need to consider digital skills for future employability, then there should be a method to assess the actual skills levels of employees. For future research, Performance tests would be an appropriate measurement tool to achieve more realistic data. But still, 21st-century digital skills haven’t been established; it is better to conduct smaller qualitative in-depth studies before going for larger-scale quantitative data gathering (Laar et al., 2017). and they have concluded that it is necessary to have a framework for Digital skills, and the first step is “quantifying current and expected skills” (Laar, et al., 2017).

2.9 Summary

According to the literature survey, the world is aiming for industry 4.0 and already considered skills a critical factor. For construction also, it’s identified skills as an important driving force but hasn’t identified the specific skills precisely. BIM is not the only technology emerging in Digital construction. As per the Sri Lankan context, a skill framework has still not been developed and hasn’t measured employees' current digital skill levels.

3 RESEARCH METHODOLOGY

This chapter describes the methodologies which have been adopted for previous research. After considering those, it is decided to proceed with a questionnaire survey for the data collection. And also it is described developing the questionnaire and the study's sample.

3.1 Previous research

- Wahlund & Wahlberg from Gothenburg has researched “digitalization and competence management within the telecommunications industry” and used semi-structured interviews as the primary method for data gathering. And they have conducted an in-depth literature survey, interviews, and case study interviews (Wahlund & Wahlberg, 2018).
- Another research has done by Acar & Dogan on the topic “Assessment of the Digital Competence of Construction Project Managers” For that, the framework has adopted the DigComp2.1 framework published by the European Commission to measure digital competence. They have designed their questionnaire survey considering 5 proficiency levels, rather than the 8 levels mentioned in DigComp 2.1, for simplicity and ease of application. On a 1-to-5 Likert scale, they asked construction managers to select proficiency levels that best reflected their competencies. It included 5 levels as follows.

(i) “I’m capable of doing the given [tasks/jobs] on my own with guidance where needed.”

(ii) “I’m capable of doing the given well-defined, straightforward tasks/problems on my own”

(iii) I’m capable of doing the given tasks on my own to resolve well-defined and non-routine problems.”

(iv) I’m capable of doing the given tasks at a complex level to guide others when they encounter complex situations.”

(v) “I’m capable of doing the given tasks at a level of expertise to guide others to resolve problems in professional life and propose new methods and innovations to the industry” (Acar & Dogan, 2018).

- (Acar & Dogan, 2018) have conducted a pilot study and then distributed the questionnaire through the industry.
- Sousa & Rocha 2019 have researched digital learning: Developing skills for the digital transformation of organizations” (Sousa & Rocha, 2019). For that, they used a questionnaire survey that was prepared based on Three hypotheses .they are

H1. “There is a significant difference between perceived challenges faced by organizations and opportunities for new disruptive Business”

H2. “There is a significant difference between perceived challenges faced by organizations and the new trend of skills.”

H3. “There is a significant difference between opportunities for new disruptive business and the new trend of skills.”

- The Organization for Economic Co-operation and Development, France (OECD) Skills Strategy has valuable insights to approach Opportunities and challenges regarding digital skills development. It has three main steps. Firstly Identify the skills required more accurately by referring to valid frameworks and evaluating available databases cross-country. Secondly, evaluate how these changes can adopt into teacher training and professionals. Finally, Use ICT facilities to improve quality educational opportunities. Ex-, online courses, new facilities, tolls for schools to improve identified skills (Rimini & Spiezia, 2016)

3.2 Adopted methodology for this study

It is decided to proceed with a literature review and a questionnaire survey with structured interview sessions when required. After considering the above previous research conducted in the same perspective, and methodologies they have followed.

Here is the brief procedure followed for the research study.

- Literature Survey for investigating existing identified skills/competencies
- Develop a Questionnaire for identifying attributes
- Conduct a Pilot survey
- Data Collection and analyze the results

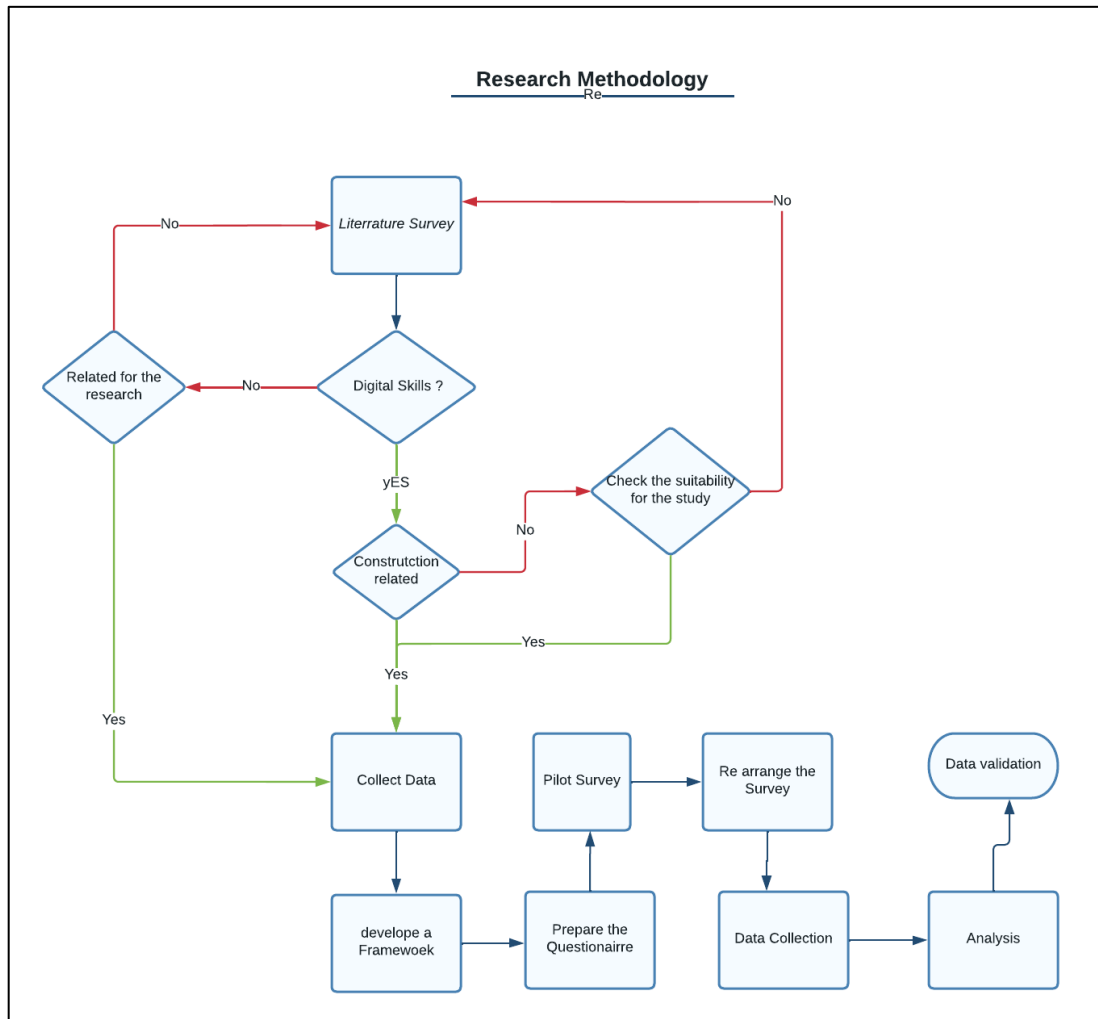


Figure 3-1 Research Methodology

A literature survey was conducted using keywords, digital skills and digitalization, Construction skills, digital transformation, digital competencies, 21st-century skills, Digital Construction and Construction Digitalization. 80 references were reviewed, and 33 were referred to in this thesis.

After considering selected frameworks from literature, DigComp 2.1 framework, developed by the European Commission and adopted by the European Union, is adopted for this research study because it is a comprehensive framework developed after studying more than 47 countries from Asia, the European Union. High-income countries outside the European Union, Latin America, Middle East and North Africa, and Sub-Saharan Africa (Law, et al., 2018) And is a comprehensive framework which has included almost all the skills found in the literature survey. “DigComp is known to have been developed with the participation of a large number of experts and to be endorsed at the European level” (European Commission -Joint Research Centre, 2018). DigComp has been widely used to develop policies/strategies and support education, training purposes, professional skills/activities and certification in different countries (Acar & Dogan, 2018).

3.3 Preparing the questionnaire

Based on selected skills and competencies from the literature, the questionnaire survey was built after doing a matrix analysis to obtain optimum results from a minimum number of questions. Seven major competency areas were identified, and the questionnaire is built to aim to identify the level of competency required for the major 4 groups. Rather than asking one by one occupations’ required skill levels, they were grouped as senior Management, Engineers/Architectures, Quantity surveyors and Technical Officers /Storekeepers/Admin Officers and used matrix type question format to reduce the complexity of the questionnaire and save space.

Table 3-1 Matrix analysis for questionnaire

Attribute	Number of Questions	Objective
Job Role / Organization Type	2	
Experience	1	3
Opinion on current skill level	1	3
Current usage of technologies	1	3
Competencies	7	2
Other Opinions /The Current condition of the digitalization of Construction	1	3

Skill/Competency levels were identified from the literature as follows (European Commission -Joint Research Centre, 2018). Although DigComp 2.1 suggest 8 proficiency levels, and to maintain the simplicity of the questionnaire, 5 levels were used. And this is also a summarized version mentioned in DigComp 2.1.

T.4 Main keywords that feature the proficiency levels								
4 OVERALL LEVELS	Foundation		Intermediate		Advanced		Highly specialised	
8 GRANULAR LEVELS	1	2	3	4	5	6	7	8
COMPLEXITY OF TASKS	Simple task	Simple task	Well-defined and routine tasks, and straightforward problems	Tasks, and well-defined and non-routine problems	Different tasks and problems	Most appropriate tasks	Resolve complex problems with limited solutions	Resolve complex problems with many interacting factors
AUTONOMY	With guidance	Autonomy and with guidance when needed	On my own	Independent and according to my needs	Guiding others	Able to adapt to others in a complex context	Integrate to contribute to the professional practice and to guide others	Propose new ideas and processes to the field
COGNITIVE DOMAIN	Remembering	Remembering	Understanding	Understanding	Applying	Evaluating	Creating	Creating

Figure 3-2 DigComp Proficiency levels (European Commission -Joint Research Centre, 2018)

Table 3-2 Competency Levels used for this study

Level	Description
0	No need for knowledge at all
1	Should Have conceptual knowledge with the ability to continue work with the support of another
2	Should be able to complete the work independently for the same or Different tasks
3	Should be able to complete work independently and teach someone else
4	Expert level - Can teach and create new applications as well. Use technology to solve the problems

The questionnaire structure was arranged to give less confusion and a better flow between questions. Also, questions were arranged in matrix form to save space. After that, a pilot survey was conducted, identifying the questionnaire's drawbacks and altering it accordingly.

3.4 Sample of the study

According to the literature review, 7 major Competency areas were identified as testing objectives.

For the survey, the target group was selected as people with experience in digital technology implementation, training, and consultancy in the construction industry in Sri Lanka. Because questions asked in the questionnaire are more subject-specific and required to obtain the best results, all possible questionnaires were collected while taking interviews with the respondents to avoid any misunderstandings due to the framework's complexity and wording.

Data were collected from organizations like digital technology service providers, construction companies, design firms etc. But due to the specific requirement of the target group, the available sample size was limited, and I managed to gather 32 samples from various organizations until the data saturation level approached.

4 ANALYSIS AND DISCUSSION OF RESULTS

In this chapter, I'm describing the Data collection methods used, the results and findings of analyzed data, a Discussion of findings and validation of the results using previous research findings.

4.1 Data collection

The questionnaire is developed aiming at the people involved in the construction digitalization through training, consultation, implementation etc. For finding the survey participants, Non-random sampling methods were used, like LinkedIn profile searching, direct contact company management and snowball sampling method. (Saunders, et al., 2012). 32 responses were collected, and responses reached the data saturation level.

4.2 Analysis of Data

Here are some data collected from the questionnaire survey. The following tables describe respondents from what kind of organizations and their experience in digital construction.

Table 4-1 Composition of survey participants according to organization type

Organization	Percentage (%)
Digital solution Service Provider	25.00
Contractor Organization	47.22
Government Body	2.78
Consultancy Firm	11.11
Design Firm	11.11
Construction material Supplier	0.00
Other	2.78

Table 4-2 Composition of survey participants according to experience in digital construction

Age Group	Percentage (%)
Less than 1 year (A1)	15.62
Between 1 to 2 years (A2)	6.25
Between 2 to 3 years (A3)	15.62
More than 3 years (A4)	62.50

Respondents are working in various occupations related to construction or digitalization like Project Managers, system development managers, Senior Design Engineer - Civil & Structural, Jt. BIM Manager - Engineering & QS, Senior Quantity Surveyor, BIM Team Leader - QS, BIM Manager, Lead Co-Ordinator, Joint BIM Manager, ERP System Administrator, Implementation and Monitoring All Cost related activities, Quantity Surveyors, ERP Manager, Planning Engineers, Researcher, Site engineers, Managing Director, Trainee, Consultant - technology in Data Science and Analytics, Quantity Surveyor & ERP Project Co-ordinator Business Development, Civil Engineer/ERP Specialist, Software Engineers, Team Lead, Business Development, 5D BIM Quantity Surveyor, Civil Engineers, Project Manager Implementation.

4.3 Processing of Data

According to the survey, respondents had worked in these areas.

Table 4-3 Areas in which respondents worked with digital technology

Technology	Count	Percentage (%)
BIM (Building Information Modelling) (SQ002)	9	28.12
ERP (Enterprise Resource Planning) (SQ003)	17	53.12
HR (Human Resources Management) (SQ004)	12	37.50
Communication and Document Management (SQ005)	20	62.50
Drones/UMV (Unmanned Vehicle) (SQ006)	0	0.00
Artificial Intelligence (AI) (SQ007)	2	6.25
AR (Augmented reality) (SQ008)	0	0.00

VR (virtual reality) (SQ009)	0	0.00
Robots/Automation (SQ010)	1	3.12
Structural Design Software (SQ011)	5	15.62
Project Planning /Productivity Apps (SQ012)	17	53.12
3D Printing (SQ013)	0	0.00
Estimating and Budgeting (SQ014)	14	43.75
Taking Off Quantities Apps (SQ015)	5	15.62

From them, 94 % of respondents believe construction people need to up-skill their digital skills.

According to the survey, the following figure depicts the required competency levels for each category in a summarised way for main competencies. See appendix B for detailed findings.

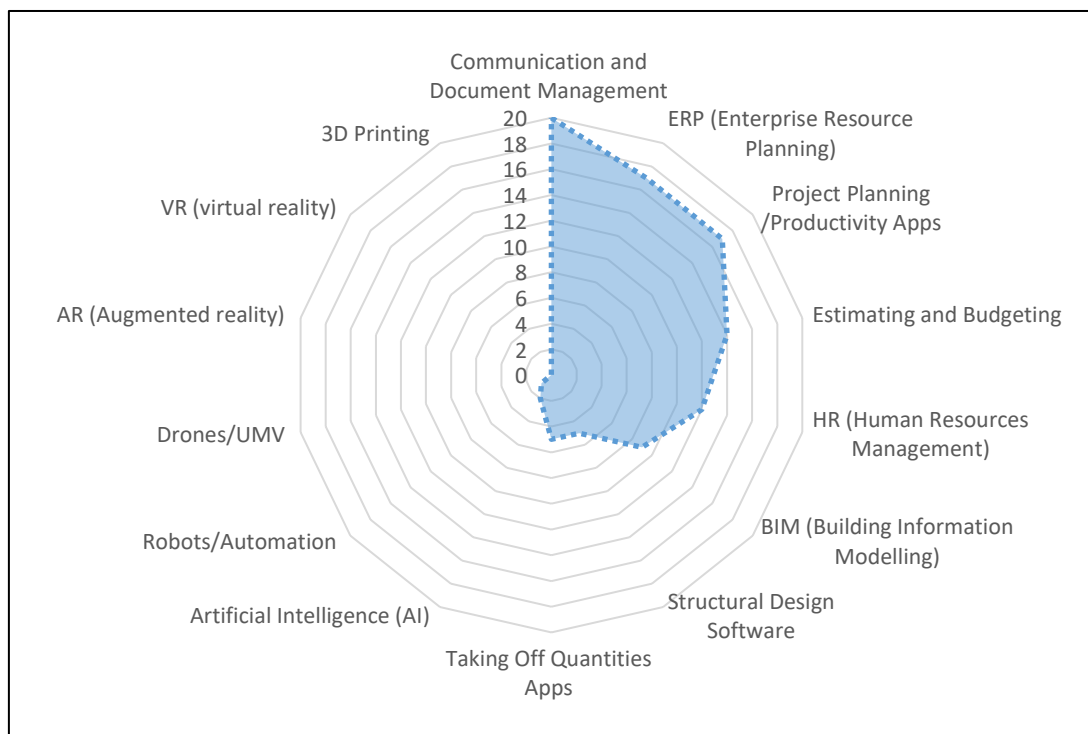


Figure 4-1 Areas in which respondents had worked

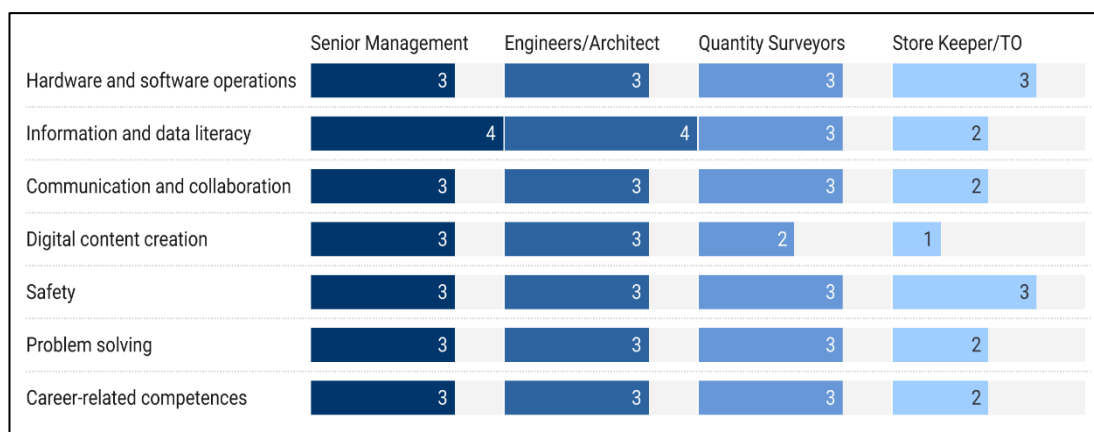


Figure 4-2 Required competency levels for each competency category

The Results can be summarized without considering the Skill category as follows. As an average, this table shows what proficiency levels are required.

Table 4-4 Summarized Proficiency levels required according to research findings

	Senior Management	Engineers/ Architect	Quantity Surveyors	Storekeeper/TO
Required Proficiency Level	3	3	3	2

Other than mentioned competencies in the questionnaire, here are summarized table of other mentioned facts/comments on the research area.

Table 4-5 Summarized Additional comments facts and their frequency

Comments	Frequency Mentioned
Senior Management Support	8
Ability to Change	4
Separate personnel/department responsible for digitalization	4
Attitude Change	3
Basic IT Literacy	3
Trust in New Technology	3
Leader's Motivation and Understanding	2
Specific software competency	2
Digital Communication	2
Correct Requirement gathering before selecting technology	1
The majority needed only well-trained usability (Level 1)	1
All levels of digitalization, including the Authorization level	1
Use of equipment with safety	1
Method to Evaluate skills	1
Correct decision-making competency for senior Management	1
Basic Construction Knowledge	1
Lack of English Knowledge	1
Correct effective Training	1
Understanding/Interpret software outputs	1
Empower End Users	1
Identify processes which can be automated	1
Improve Industry people skills	1

4.4 Discussion Summary

According to the survey results, 94% of participants state that Srilankan Construction Industry needs to upskill its Digital Competency levels to achieve its digitalization goal. 62 % of participants had over three years of experience in the construction digitalization industry, which indicates the digitalization effort has more than three years of history now in Sri Lanka.

The majority of participants (~60%) have experienced Project Planning /Productivity Apps, ERP (Enterprise Resource Planning) and Communication and Document Management, while around only 30% of participants have experienced HR (Human Resources Management), Estimating and Budgeting and BIM (Building Information

Modelling) software. Participants showed lower experience in areas like Drones/UMV, Artificial Intelligence (AI), AR (Augmented reality), VR (virtual reality), Robots/Automation, 3D Printing, and Taking Off Quantities Apps. That shows the industry needs to try more with new technologies and expand its use. This study is based on data collected within the 2020-2021 time in Sri Lanka and compared to the publication done in 2018 by (Blanco, et al., 2018) about world digital construction, Sri Lanka lags. According to the survey, emerging technologies mentioned in (Blanco, et al., 2018) are not much famous among construction professionals.

As per the survey results, senior Management, Engineers /Architectures and Quantity surveyors need level 3-4 competency in all areas except Programming. It describes that they need to learn how to use technologies independently and should be able to teach their subordinates and co-workers. For Programming, it is enough to have level 1-2 competency, which means it's enough if they can perform a task with support.

Storekeepers /Admin officers and technical officers need level 3 competency in Basic hardware knowledge, Safety and Browsing, and Searching filtering data. For example, if they are given a new computer different from the previous one, they should be able to turn it on/off, log in, Lock it etc. And search and browse safely using a different browser than the usual one. According to findings, they need Level 0 competency in programming, which means it is okay not to have programming knowledge for that category. For all other competencies, they need to have a minimum level 2, which means they should be able to conduct a routine task independently.

Besides those results, the comments section gave valuable input to this research. Most of them have mentioned that senior management involvement, support and knowledge of digitalization are crucial. And some of them proposed that having Separate personnel/departments responsible for digitalization is needed since all staff have the required competency level is yet to be achieved by the industry.

4.5 Validation from previous research studies

The CITB report mentioned levels of desired skills for each level of employees from construction (Proficiency levels). After scrutinizing the model, I could find more similarities with the competency levels described in the DigComp framework. DigComp is more descriptive and has gone for 8 levels, while this research adopted the simple categorization for more accessible references in data collection.



Figure 4-3 Competency levels published by CITB for the construction industry

After comparing the frameworks and research framework (See Anne C), CITB and this research scale were compared as follows.

Table 4-6 Comparison of the scales used in this research and CITB Publication

CITB	0	1	2	3	4	5
This Research	0	1	2	3		4

According to CITB, it is adequate to possess competency levels 0-2 for site operatives, while site managers, senior managers, and higher management need

competency levels above 3. (Revealing Reality, 2018) According to this research study's findings, all the cases showed the required level of competency as 3 for Project managers, engineers, architects, and senior management.

Table 4-7 Comparison of Findings

Job Category	CITB (Revealing Reality, 2018)	Job Category	This Research Study
Site Operatives	0-2	Storekeepers/Technical Officers	2
Site Managers	3	Quantity Surveyors	3
		Engineers/ Architect	3
Directors /Leaders	4-5	Senior Management	3

The comparing result provided good validation for the research findings.

5 CONCLUSION

There are 4 main skills /frameworks identified in the literature. Dig Comp 2.1 is a comprehensive umbrella framework developed after analyzing available literature and framework worldwide. It was decided to carry out this research study using DigComp 2.1 as a guiding framework.

The study has identified the required skills with proficiency levels for each category of construction staff. All Employees don't need the same competency levels after comparing results with the previous research publication by CITB (UK). Findings were validated.

For all Categories from Technical Officers/Storekeepers to Senior Management, level 3 competency is required for both competencies, basic hardware and software Operation and Safety. Senior and middle managers need to have level 3 competencies for Communication and collaboration, Problem-solving and Career-related competencies, while Technical Officers/Storekeepers need to have level 2 competencies. The Highest competency (Level 4) is only needed for the information and data literacy competency and only for the senior management, engineers, and architects.

It has found the digital technologies currently used in Sri Lankan Construction Industry. Sri Lanka is lagging compared to the world's current trends, and the digitalization effort has more than three years of history now in Sri Lanka.

The construction industry needs to improve the skills of employees. And most of the respondents commented on the requirement of senior management support for the implementations. Therefore, the industry needs to check the digital competency level of Senior managers when recruiting them or should consider to up-skill them.

This research study was particularly interesting for industrial management professionals since they encounter many difficulties while handling the site staff and senior management with the new technology implementation. Changing attitudes over digital construction is required, and another frequently mentioned factor is the

requirement of Separate personnel/departments responsible for digitalization. It may be crucial, and they also mentioned employees' need for skill improvement. Therefore, the construction industry should add a separate category for system administrators and digital transformation task leaders.

5.1 Applications and Recommendations

These findings can be used as a basis for further research and guideline as an educational institute for educating students and preparing the learning objectives. Recruiters can consider these framework and proficiency levels when recruiting new employees and also when deciding on Continuous professional development (CPD) activities to up-skills the existing employees

Industry task force institutes should focus more on developing identified skills/competencies for their students. Organizations themselves should develop their employees' skills in recognized areas.

As a recommendation for future research, it is necessary to develop a comprehensive digital competency level measurement method for the Construction industry and need to measure the current digital skill levels of the industry.

REFERENCES

- Parthasarathy, S. & Chandrakumar, T., 2015. Efficiency analysis of ERP projects—software quality perspective. *International journal of project management*, pp. 961-970.
- Acar, E. & Dogan, Y., 2018. *Assessment of the Digital Competence of Construction Project Managers*. North Cyprus, ResearchGate, pp. 458-466.
- Agarwal, R., Chandrasekaran, S. & Sridha, M., 2016. *Imagining construction's digital future-Capital Projects and Infrastructure*, Singapore: McKinsey Productivity Sciences Center.
- Aghimien, D., Oke, A. & Koloko, N., 2018. *Digitalization In Construction Industry: Construction Professionals Perspective*. Brisbane, s.n.
- Blanco, J. L. et al., 2018. *Seizing opportunity in today's construction technology ecosystem*, s.l.: McKinsey & Company.
- C.Verhoef, P. et al., 2021. Digital transformation: A multidisciplinary reflection and research agenda. *Journal of Business Research*, pp. 889-901.
- Clerck, J.-P. D., 2018. *I-SCOOP, digitalization and the human element in digital change*. [Online]
Available at: <https://www.i-scoop.eu/digitalization-human-element-technological-change/>
[Accessed 17 March 2019].
- Clerck, J.-P. D., 2018. *I-SCOOP, digitalization and the human element in digital change*. [Online]
Available at: <https://www.i-scoop.eu/digitalization-human-element-technological-change/>
[Accessed 17 March 2019].
- Damodaran, L., 2001. Human factors in the digital world enhancing lifestyle - The challenge for emerging technologies. *International Journal of Human-Computer Studies*, October, 55(4), pp. 377-403.

- De Bustis, A., Ganesan, V. & Herath, G., 2018. *Unlocking Sri Lanka's digital opportunity*, s.l.: McKinsey & Company.
- Eli hustad, D. H., 2013. Critical Issues across the ERP life cycle in Small -and - Medium -Sized Enterprises: Experiences from a Multiple Case Study. *Procedia Technology* 9, pp. 179-188.
- European Commission -Joint Research Centre, 2018. *DigComp into Action - Get inspired, make it happen*, s.l.: European Commission Publication Office.
- Forbes Insights, 2017. *The New Culture Of Work: Don't Get Left Behind*. [Online] Available at: <https://www.forbes.com/forbes-insights/our-work/new-culture-of-work/>
- Grabot, bernard, 2002. *The dark side of the moon: some lessons from difficult implementations of ERP systems*, Barcelona: Elsevier IFAC publications.
- Item, E. & Laryea, S., 2014. Survey of digital technologies in the procurement of construction projects. *Automation in Construction*, Volume 46, pp. 11-21.
- I-Scoop, 2022. *What is digital business transformation? The essential guide to DX*. [Online] Available at: <https://www.i-scoop.eu/digital-transformation/> [Accessed 31 May 2022].
- Jsoderqvist, O. & Koohler, O., 2016. *Competence Management Systems-Implications for operative resource allocation*, Göteborg, Sweden: Chalmers Repro service.
- Kluzer, S. & Priego, L. P., 2018. *A user guide to the European Digital Competence Framework*, s.l.: Joint Reserch Centre European Commision.
- Laar, E. V. et al., 2017. The relation between 21st-century skills and digital skills or literacy A systematic literature review. *Elsevier*, pp. 577-588.
- Law, N., Woo, D., Torre, J. d. l. & Wong, G., 2018. *A Global Framework of Reference on Digital Literacy Skills for Indicator 4.4.2*, Quebec: UNESCO Institute for Statistics.

Leviäkangas, P. & Paik, S., 2017. Keeping up with the pace of digitization: The case of the Australian construction industry. *Technology in Society*, Volume 50, pp. 33-43.

Levy, F., 2010. How Technology Changes Demands Human Skills. *OECD Education Working Papers*, No. 45,

Nadkarni, S. :. P., 2020. Digital transformation: a review, synthesis and opportunities for future research. *Management Review Quarterly*, 18 April. pp. 234-341.

Probst, L. et al., 2018. *Digital Transformation Scoreboard 2018-EU businesses go digital: Opportunities, outcomes and uptake*, Luxembourg: Publications Office of the European Union.

Revealing Reality, 2018. *UNLOCKING CONSTRUCTION'S DIGITAL FUTURE: A skills plan for the industry*, s.l.: Construction Industry Training Board (CITB).

Rimini, M. & Spiezia, V., 2016. *Skills For A Digital World*, s.l.: OECD publishing.

Roland Berger, 2016. THINK ACT. *Digitalization in Construction Industry*, June.

Saunders, M., Lewis, P. & Thornhill, A., 2012. *Research Methods for Business Students*. Harlow: Pearson Education Limited.

Schober, K. & Hoff, P., 2016. *Digitalization in the Construction Industry-Building Europe's road to construction 4.0*, s.l.: Roland Berger.

Sousa, M., & Rocha, Á., 2019. Digital learning: Developing skills for the digital transformation of organizations. *Future Generation Computer Systems*, p. 327–334.

Van Deursen, A. H. E. & E. R., 2014. *Measuring Digital skills From Digital Skills to Tangible Outcomes project report*, s.l.: oxford internet institute.

Wahlund, F. & Wahlberg, V., 2018. *A study of digitalization and competence management within the telecommunications industry*, Gothenburg: Department of Technology Management and Economics.

Warner, K. & Wäger, M., 2018. Building dynamic capabilities for digital transformation: An ongoing process of strategic renewal. *Long Range Planning*.

World economic forum with Accenture, 2016. *World Economic Forum White Paper Digital Transformation of Industries: In collaboration with Accenture-Digital Enterprise*, s.l.: s.n.

World economic forum, 2016. *World Economic Forum White Paper Digital Transformation of Industries: In collaboration with Accenture-Digital Enterprise*, s.l.: s.n.

APPENDIX A - DETAILED COMMENTS FROM RESPONDENTS

1. They need to improve their Attitudes regarding changing their working habits and digitalization.
2. Senior management need to support and guide the decision they take regarding digitalization
3. and I should say, something big needs to be done to improve our Industry people skills and take them out of this darkness
4. It is decent if we can formalize the crucial human factor required. Also, there should be a proper and accurate evaluation method to deduce those human factors when recruiting employees to organizations
5. At least basic IT literacy is a must.
6. Modern tools like google sheets, jam boards, cloud storing of data, etc. can be considered as basic technical knowledge that a construction professional should understand to move into a paperless environment
7. It should include the ability to change
8. It can update all people in the construction field on new technologies and new machinery and equipment and how to use them on-site properly and safely.
9. Digital Transformation should happen at the Authority level. Authorities who approve the design, construction method, environmental issues, etc. Every aspect of the construction field should be digitalized as it will help to save time, quality, and cost.
10. There should be a competent IT person / Software Engineer with total responsibility
11. Most users only need well-trained usability

12. Computer literacy is highly required, and literacy in a specific software (Ex-AutoCAD, MS Office, etc..) is highly required.
13. Alone skills will not be enough. We need to change our attitude toward new technologies. Management needs to trust them and collaborate
14. Digital communication, Interpreting the software outputs
15. Not having trust in software is a real challenge. They are trying to do both processes at the same time, thus making them do double work
16. Senior Management involvement is critical. They should be the leaders and should be able to see the big picture of the digitized future
17. One additional skill would be the ability to identify areas that could be automated. Digitalization is a continuous process; leaders need to spot other areas where automation can be applied within the organization. This skill also entails the ability to understand the benefit of digitalizing a particular task.
18. This is important because many organizations have leaders who are not motivated to initiate or continuously improve digitalization. Lack of leadership motivation results from having traditional leaders with less understanding of the benefits of automation and digitalization.
19. Need to be a good understanding of BOQ
20. I need to be a good understanding of how to work with software products.
21. I think the survey was comprehensive
22. Maybe, as per the current condition in Srilankan Construction Industry, it is not easy to find senior management with higher Digital competency. So, the most important thing is having separate personnel for those technical areas with higher digital competency and knowledge of construction processes

23. One of the largest elements that prevent successful digital transformation is the inability of contractors and staff to be onboarded with the proper training to get the most out of their technology. Often, contractors end up going back to pencil & paper because it's easier for them and the path of least resistance, but one must empower the end-users to be decision-makers and feel like they have control over the technology versus it controlling them.
24. The lack of English knowledge is a great issue when adopting new technologies. The gap between the technologies used in Sri Lanka is shallow compared to other countries. Also, our construction practitioners must explore the new technologies other countries have been using. Communication skill is another mandatory skill construction professional could have. Thinking out of frame, the ability to take risks and being keen on learning new things are important for successful digital transformation. The majority of construction professionals think they do not have adequate knowledge regarding IT for digital transformation. But if you have a general idea regarding a computer's basic function, you can quickly learn the software and ease your work—best of luck with your research.
25. A flexible Mindset is a must. Positive attitudes toward transformation from management are required
26. These might be there, in other words, in your survey. But I prefer the following terms to be included. Senior Management and IT, Requirement Gathering, It Task management (KanBan Board), Acceptance of IT infrastructure, IT infrastructure evaluation and valuation (Buy outsource decision making)
27. Please note that these are not IT literacy-related competencies but decision-making and management competencies.

28. For the Digitalization process, having a separate administrator or co-ordinator is critical. Here should have considered their skills also. Other than that, all skills are mentioned here.
29. The company needs to have a technology champion whose skills are in an expert area. Because in Sri Lanka, especially in construction companies, the senior manager category has the slightest knowledge and interest in new things. We are facing difficulties in training. having their person is better
30. according to my experience, applying digital technology appropriately to solve a problem is critical. Here it belongs to problem-solving. And also, faith in digital technology is essential. Rather than practicing both conventional and new systems. Of course, in early implementation time, it's required, but after that, people should adapt to the new environment.

APPENDIX B - REQUIRED LEVEL OF COMPETENCY FOR EACH JOB CATEGORY IN DETAILED

Areas	Competencies	Senior Management	Engineers/Architect	Quantity Surveyors	Store Keeper/TO
Hardware and software operations	Basic knowledge such as turning on/off, ch locking, charging devices	3	3	3	3
	User account, log in, password management, privacy settings, etc	4	4	3	3
Information and data literacy	Browsing, searching, and filtering data, information and digital content	3	4	4	3
	Evaluating data, information, and digital content	4	4	3	2
	Managing data, information, and digital content	3	3	3	2
Communication and Collaboration	Interacting through digital technologies-understanding suitable digital communication means/media for a given context	4	3	3	2
	Sharing through digital technologies-To share data, information and digital content with other parties through appropriate digital technologies, to act as an intermediary, to know about referencing and	4	4	3	2

	attribution practices				
	Collaborating through digital technologies- To utilize digital tools and technologies to collaborate.	4	4	3	2
	Netiquette-online ethics regarding the acceptable use of online resources	3	3	3	2
	Managing digital identity - To be able to create and administer one or more digital identities, as well as to safeguard one's reputation	3	3	3	2
Digital content creation	Developing digital content - To generate and edit digital content, as well as to communicate thoughts via digital media	3	3	3	2
	Integrating and re-elaborating digital content - To develop unique, original, relevant content and knowledge by modifying, improving, and integrating information and content.	3	3	3	2
	Copyright and licenses - To understand how copyright and licenses work on data, information and digital content	3	3	3	2
	Programming	2	2	1	0
Safety	Protecting devices -To Understand the possible risks involved in a digital environment	3	3	3	3

	and protect devices /digital content by taking safety and security measures				
	Protecting personal data and privacy - To ensure the privacy and security of personal information in a digital context. To learn how to use and share recognized data while still having the option to protect oneself and others from danger. to realize that advanced administrations make use of a "Privacy policy" to explain how personal data is used	4	3	3	3
	Protecting health and well-being - Choose how to avoid health risks and threats. Having the ability to protect oneself and others from possible threats in digital contexts (for ex - cyberbullying).	4	3	3	3
	Protecting the environment - To be aware of the influence of digital technologies on the environment.	3	3	3	3
Problem-solving	Solving technical problems - To identify technical issues that happen when using devices and to have a solution in place for them (Ex, basic steps like troubleshooting to solving more	3	3	3	2

	complex scenarios)				
	Identifying needs and technological responses - Conduct a survey of needs and identify, analyze, choose, and implement digital tools and technologies to address them. To adapt and transform the digital environment to meet specific needs (e.g., accessibility)	3	3	3	2
	Using digital technologies - To develop knowledge and innovate processes and products using digital tools and technologies. To interact in cognitive thinking, individually and as a team, to comprehend and address conceptual difficulties and challenging situations in digital environments.	3	3	3	2
	Identifying digital competence gaps -. Recognize areas in one's skills that need to be enhanced or improved. To be able to assist others in developing their digital skills. To look for chances for self-improvement and to stay current with the digital transformation.	3	3	3	2

Career-related competences	Operate specialized hardware and software for a specific industry, such as engineering design software and physical tools.	2	3	3	2
	Interpreting and manipulating data, information and digital content for a particular field - To understand, analyze and evaluate specialized data, information and digital content for a particular field within a digital environment	3	3	3	2

APPENDIX C - COMPARISON AMONG THE FRAMEWORKS AND RESEARCH FRAMEWORK

DigComp categorization (Descriptive)		This research study adopted categorization (Summarized DigComp version)		CITB Categorization	
		No Skill	0	No experience Never used tech	0
Simple task With guidance Remembering	1	Foundation Conducting simple tasks on my own or with help /Remembering	1	Default users Trained to use a specific tech Not highly skilled/competent or confident	1
Simple task Autonomy and guidance when needed/Remembering	2				
Well-defined and routine tasks and straightforward problems On my own Understanding	3	Intermediate Well-defined routine tasks /on my own /with understanding	2	Competent users Competent and confident in using specific tech for tasks Could handle some problems if they arose	2
Tasks and well-defined and non- routine problems Independent and according to my needs Understanding	4				

Different tasks and problems Guiding others/Applying	5	Advanced Different tasks Guide Others	3	Mindful operators Actively consider how tech could be used better on existing or similar tasks Could handle problems or would know whom to ask for help	3
Most appropriate tasks Able to adapt to others in a complex context/Evaluating	6			Selective generalists Chooses the most appropriate technology for the task Actively considers how problems could be solved using tech Could handle/delegate problems effectively	4
Resolve complex problems with limited solutions Integrate to contribute to the professional practice and guide others/Creating	7	Highly specialized Complex tasks Guide others Creating	4	Skilled innovators Considers/tries inventing own tech solutions Identifies problems/goals that tech could help to solve Implements change and make it happen	5
Resolve complex Problems with many interacting factors/Propose new ideas and processes to the field Creating	8				

APPENDIX D – QUESTIONNAIRE

Digital Skill Factors That Effect on Digital Transformation of The Construction Industry in Sri Lanka

I am a Postgraduate student of the Faculty of Engineering, University of Moratuwa, reading for research as partial fulfilment of the Masters Degree in Construction Project Management.

This research aims to "**Identify Digital Skills/Competencies required for the Construction Industry in Sri Lanka**" regarding Digital Transformation. This questionnaire is a part of the research study.

This questionnaire will remain confidential and be used solely for academic purposes. I would appreciate it if you could spend a few minutes of your precious time filling out the questionnaire.

This will take around 15 min to complete.

There are 13 questions in this survey

General

[01] Please select the type of your organization *

Please choose **all** that apply:

- ☐ Digital solution Service Provider
- ☐ Contractor Organization
- ☐ Government Body
- ☐ Consultancy Firm
- ☐ Design Firm
- ☐ Construction material Supplier
- ☐ Other:

[02] What is your Job Role within your Organization

Please write your answer here:

[03] What are the areas you have/had to deal with within your organization?

Please choose **all** that apply:

- ☐ BIM (Building Information Modelling)
- ☐ ERP (Enterprise Resource Planning)
- ☐ HR (Human Resources Management)
- ☐ Communication and Document Management
- ☐ Drones/UMV
- ☐ Artificial Intelligence (AI)
- ☐ AR (Augmented reality)
- ☐ VR (virtual reality)
- ☐ Robots/Automation
- ☐ Structural Design Software
- ☐ Project Planning /Productivity Apps
- ☐ 3D Printing
- ☐ Estimating and Budgeting
- ☐ Taking Off Quantities Apps
- ☐ Other:

[04] Please select your Experience in the Digitalization area

Please choose **only one** of the following:

- ☐ Less than 1 year
- ☐ Between 1 to 2
years
- ☐ Between 2 to 3
years
- ☐ More than 3 years

[05] Do you think Construction Industry need to upgrade its Human Skills/Competencies?

Please choose **only one** of the following:

- ☐ Yes
- ☐ No
- ☐ No Idea

Competency Areas

This section is to check **what are the competencies necessary for the people in the construction Industry to Digital Transformation to be successful**. According to the relevance of the selected competency to the Construction, You have to give marks from 0 to 4.

For example:

If you think programming skill is not needed for Store Keeper, you can mark it as 0

If you think Senior Management highly need to be experts in using digital technology creatively, Mark it as 4

Here is the matrix You should refer to before giving marks.

0- No need for knowledge at all

1- Should Have conceptual knowledge and should be able to continue work with the support of another

2- Should be able to complete the work independently.

3- Should be able to complete work independently and teach someone else

4- Expert. Can teach and create new applications as well. New problems can be solved with technology

[06] Do you think the following competency areas are required for people in the construction Industry for Digitalization?

Competency - Fundamental Knowledge of hardware and software

	Senior Management	Engineers /Architect	Quantity Surveyors	Store Keeper/TO
Basic knowledge of hardware such as turning on/off and charging, locking devices	☐	☐	☐	☐
User account and password management, login, and how to do privacy settings, etc.	☐	☐	☐	☐

[07] Do you think the following competency areas are required for people in the construction Industry for Digital Transformation?

Competency - Information and data literacy

	Senior Management	Engineers /Architect	Quantity Surveyors	Store Keeper/TO
Browsing, searching, and filtering data, information and digital content	☐	☐	☐	☐
Evaluating data, information, and digital content	☐	☐	☐	☐
Managing data, information, and digital content	☐	☐	☐	☐

[08] Do you think the following competency areas are required for people in the construction Industry for Digitalization?

Communication and Collaboration

	Senior Management	Engineers /Architect	Quantity Surveyors	Store Keeper/TO
Interacting through digital technologies – to understand appropriate digital communication means for a given context	☐	☐	☐	☐
Sharing through digital technologies -To share data, information, and digital content with others through appropriate digital technologies. To act as an intermediary, to know about referencing and attribution practices	☐	☐	☐	☐
Collaborating through digital technologies -To use digital tools and technologies for collaborative processes and co-construction and co-creation of resources and knowledge	☐	☐	☐	☐

Netiquette -online ethics focuses on the acceptable use of online resources	☐	☐	☐	☐
Managing digital identity -To create and manage one or multiple digital identities to be able to protect one's reputation, to deal with the data that one produces through several digital tools, environments, and services	☐	☐	☐	☐

[09] Do you think the following competency areas are required for people in the construction Industry for Digitalization?

Competency Area - Digital content creation

	Senior Management	Engineers /Architect	Quantity Surveyors	Store Keeper/TO
Developing digital content - To create and edit digital content in different formats, to express oneself through digital means	☐	☐	☐	☐
Integrating and re-elaborating digital content – To modify, refine, improve and integrate information and content into an existing body of knowledge to create new, original and relevant content and knowledge	☐	☐	☐	☐
Copyright and licenses - To understand how Copyright and licenses apply to data, information and digital content	☐	☐	☐	☐
Programming	☐	☐	☐	☐

[10] Do you think the following competency areas are required for people in the construction Industry for Digitalization?

Competency Area - Safety

	Senior Management	Engineers /Architect	Quantity Surveyors	Store Keeper/TO
Protecting devices -To protect devices and digital content and to understand risks and threats in digital environments. To know about safety and security measures and to have due regard for reliability and privacy	☐	☐	☐	☐
Protecting personal data and privacy - To protect personal data and privacy in digital environments. To understand how to use and share personally identifiable information while being able to protect oneself and others from damage. To understand that digital services use a “Privacy policy” to inform how personal data is used	☐	☐	☐	☐
Protecting health and well-being - To avoid health risks and threats to physical and psychological well-being while using digital technologies. Protect oneself and others from possible dangers in digital environments (e.g. cyberbullying). To be aware of digital technologies for social well-being and social inclusion	☐	☐	☐	☐
Protecting the environment - To be aware of the environmental impact of digital technologies and their use	☐	☐	☐	☐

[1 1] Do you think the following competency areas are required for people in the construction Industry for Digitalization?

Competency Area - Problem Solving

	Senior Management	Engineers /Architect	Quantity Surveyors	Store Keeper/TO
Solving technical problems - To identify technical problems when operating devices to use digital environments and to solve them (from troubleshooting to solving more complex problems)	☐	☐	☐	☐
Identifying needs and technological responses – To assess needs and to identify, evaluate, select, and use digital tools and possible technological responses to solve them. To adjust and customize digital environments to personal needs (e.g., accessibility)	☐	☐	☐	☐
Creatively using digital technologies - To use digital tools and technologies to create knowledge and to innovate processes and products. To engage individually and collectively in cognitive processing to understand and resolve conceptual problems and problem situations in digital environments.	☐	☐	☐	☐
Identifying digital competence gaps - To understand where one's digital competence needs to be improved or updated. To be able to support others with their digital competence development. To seek opportunities for self-development and to keep up to date with the digital evolution.	☐	☐	☐	☐

[12] Do you think the following competency areas are required for people in the construction Industry for Digitalization?

Competency Area - Career-Related Competencies

	Senior Management	Engineers /Architect	Quantity Surveyors	Store Keeper/TO
Operate specialized hardware/software for a particular fields, such as engineering design software and hardware tools	☐	☐	☐	☐
Interpreting and manipulating data, information and digital content for a particular field - To understand, analyze and evaluate specialized data, information and digital content for a particular field within a digital environment	☐	☐	☐	☐

Additional Contribution

This section is to collect your valuable opinions regarding this data collection

[13] Please mention any other skill or competency construction people require for success! Digital transformation to happen

Please write your answer here:

[illegible]

Thank you, and I Highly Appreciate your time spent on the survey!

Submit your survey.
Thank you for completing this survey

