

**ADAPTABILITY OF DIGITAL TECHNOLOGIES
IN CONSTRUCTION PRACTICES IN SRI LANKA**

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Degree of Master of Science in Project Management

Department of Building Economics

University of Moratuwa
Sri Lanka

November 2018

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Dissertation submitted in partial fulfilment of the requirements for the
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DECLARATION

I declare that this is my own piece of work and it does not incorporate without acknowledgement any material previously submitted for a Degree or Diploma in any other University or institute of higher learning. Moreover, to the best of my knowledge and belief, it does not contain any material previously published or written by another person except where the acknowledgement is made in the text.

Further, I acknowledge the intellectual contribution of my research supervisor Ch.QS, Prof.(Mrs) Kanchana Perera for the successful completion of this research dissertation. I affirm that I will not make any publication from this research without the name of my research supervisor as contributing author unless otherwise, I have obtained written consent from my supervisor.

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I hereby acknowledge that Widana Hewage Terans Gunawardhana has followed the dissertation process for the Masters Dissertation set by the Department of Building Economics under my supervision.

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Ch.QS. Prof. (Mrs.) Kanchana Perera

Dissertation Supervisor

.....

Date

ABSTRACT

Enormous literature sources suggest that with the development of digital technologies many industries tend to change their business models, strategies and applications. Accordingly, some scholars argue that the construction industries are facing significant challenges as more processes are digitised and automated. Therefore, this study aimed at studying how developing technologies affect the future of construction industry.

In this study, the objectives were formulated as, identify the current level of application of modern technologies in Sri Lankan construction industry, identify the possible developments in modern technologies in Sri Lankan construction industry, and explore the possible issues of modern technologies in Sri Lankan construction industry and solutions for them. The qualitative approach was adapted to attain the aim and objectives of the research. A manual content analysis was done to analyse the responses received from semi-structured interviews and validated.

One of significant findings of the research indicate that lack of awareness about the advantages of adopting technologies in construction industry activities has become a severe problem, in this case, actions should be taken to increase the awareness of the entire industry. There were some identified limitations throughout the whole research process. Mainly, time was recognised as a crucial boundary for the research, especially for the data collection process. However, these study results suggest to carry out some research in the future to assess effect through economic, social and environmental aspects of technologies used in the construction industry and to develop a framework to understand the future role of each expert in Sri Lankan construction industry due to changes in technologies.

Keywords: *Digital Technologies, Level of Application, Construction Industry*

DEDICATION

I dedicate this research to my beloved parents & my brothers, Wife & her family for the immense love, care, support and encouragement conveyed to me at all times

ACKNOWLEDGEMENT

First and foremost, I wish to pay my gratitude to Ch.QS. Prof. (Mrs.) Kanchana Perera, Department of Building Economics for being Supervisor to me, giving her expert guidance and greater supervision extended throughout for the success of this research.

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I owe you all, thank you so much!

Terans Gunawardhana

November 08, 2018

LIST OF ABBREVIATIONS

ABBREVIATION	DESCRIPTION
CEA	Central Environmental Authority
CSEB	Cement Stabilized Earth Blocks
CIDA	Construction Industry Development Authority
CICA	Confederation of International Contractors' Associations
EPs	Expanded Polystyrenes
EAIA	Environment Aspect Impact Assessment
GBCA	Green Building Council of Australia
ISO	International Organization for Standardization
IoT	Internet of Things
ICTAD	Institute for Construction Training and Development
JIT	Just-in-time
LEED	Leadership in Energy and Environmental Design
OSHAS	Occupational Health and Safety Assessment Series
TR	Technology Readiness
TTF	Task-Technology Fit
TBL	Triple Bottom Line
TQM	Total quality management
UNEP	United Nations Environment Programme

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1.1. Background

Enormous literature sources suggest that with the development of digital technologies and especially smart tools and concepts, many industries tend to change their business models, strategies and applications. In the construction industry, the use of technologies continues to become an integral part of the investment and operational process. The use of technologies to analyse and make sense of large data sets has never been stronger. This is because the quality of data directly impacts the quality of critical decision making, helping to mitigate risk. Accordingly, it is no surprise that construction companies are increasingly using technology to gain a competitive advantage. It argues that such development will significantly affect the future of the construction industry. To survive in the industry, professionals in the construction industry need to be information arbiters, not information gathers (Motta & Endsley, 2003). Because the industry is facing significant challenges as more processes are digitised and automated, and the role of the project manager becomes more of data handling and information processing than of active management. Also, the role of the project manager must change to respond to changing technologies and evolving industry needs. Many countries have started to study the possible implications of Digital Technology and Big Data on the Future of the construction industry.

This research describes the significance of deep understanding of Implications of Digital Technology and Big Data on the Future of the Sri Lankan construction industry. Further, the aim of the research and objectives to achieve the aim have been emphasised with the research methodology concisely.

It has become increasingly important to understand the relationship people have with technology. Many positive effects have arisen from technology use such as social inclusion, increased access to information, assistance with every-day tasks, and healthcare applications (Shaw, A. Ellis, & V. Ziegler, 2018)

The internet and mobile telephony have enabled a boom in technology platforms applied to nearly all areas of our lives – jobs, homes, education, health, leisure, finance, and even romance. This has happened through the facilitation of three different activities: Information provision, Transactions, and Management and control. (University of Oxford Research, 2017) . Accordingly, digital change has radically altered consumer expectations and business models across many industries, such as transport, entertainment, communication, public services, and construction (Bookallil & Birkby, 2017). At the same time, (Maarbani, 2017) stated that the real estate sector professionals need to understand the latest in technological innovation and implement strategies to integrate those advancements into their projects and businesses in order to stay ahead of the pack.

Technology, the innovation economy and their spin-offs, such as the sharing economy, co-working, and the digital economy, are significant disruptors for the real estate and construction industry (Clark & Moonen, 2015). According to (Bookallil & Birkby, 2017) the advancement of construction technology, the quality of physical conditions and investigations is being improved.

Growing data availability enabled more finance-grounded quantitative modelling, and project analysis software and property and portfolio management systems became computer and technology based. Because data already plays a central role in the construction sector and the construction project management, and will only become more critical. Before going into technological developments, we need to understand the role of data, as well as the challenges in gathering it, namely quality, sources and processing (RICS, 2017). Excel became an essential real estate tool (University of Oxford Research, 2017). Driven by the demand for higher efficiencies throughout the sector and enhanced user experiences, new technologies are re-imagining every aspect of how real estate is procured, developed, managed and utilised (Maarbani, 2017). Another topical concept is digital disruptions; there are three primary forces behind disruption: technology, demographics, and globalisation. These forces are not new — they have been around for many years — but they evolve in successive waves, as well as interact with one another. Digital disruption continues to have a tremendous impact on real estate (Roth & Welch, 2016).

Big data definitions have evolved rapidly, which has raised some confusion (Gandomi & Haider, 2015). However, the emergence of new data management technologies and analytics, which enable organisations to leverage data in their business processes, is the innovative aspect. There will be greater use of data to empower the customer further. For example, providing a view of “personal and property risk as soon as possible in the process” to help customers make informed decisions, ideally before investing too much time and money (Bookallil & Birkby, 2017).

On the other hand, advances in wireless Internet and mobile communications devices have driven significant development in the Internet of Things (IoT), bringing a stream of innovative technologies and services (Wanga & Hsieh, 2018). All of these technological advancements will be utilised for the construction profession as well. With such developments, it is also possible to use Mass Appraisal Models and Automated Cost Estimation Models etc. (Hromada, 2016). Finally, the ultimate question is raised: who, in the end, will use this technology, and how will this be done? Currently, this role remains human, but recent progress in artificial intelligence may change this in the future (RICS, 2017).

Like many professions and industries, the construction industry is experiencing a more competitive environment. There is a need to establish where the construction industry and project management is going and, by definition, where it is now, for strategic planning purposes at both the profession and corporate level (Elliott & Warren, 2005). In order to understand how the project management profession should be changed to not only survive, but thrive, in the new century, there is a clear need to understand the main issues and challenges faced by profession (Wilkinson, Halvitigala, & Antoniadis, 2017). For this, the educational system at the university level should encompass programmers who will prepare project managers etc. for providing proper advice affecting crucial investment decisions of construction market participants. They stress the role of international and national organisations in re-shaping the profile of the construction project manager (Żróbek & Grzesik, 2013). However, it is expected that transparency, professionalism, and independence will also increase in importance (RICS, 2017).

Therefore, directing to the sustainable construction practices by all stakeholders is significant for Sri Lanka. In this case, as the stakeholders, the construction organisations and professionals play a significant role in the adaptation of sustainable construction practices. Hence it is essential to identify the sustainable construction practices, issues in adaptation and the remedies to be taken.

1.2. Problem Statement

Literature above suggests that there will be a broader impact of Digital Technology and Big Data on the future construction industry and the role of a project manager. Some scholars argue that the construction industry is facing significant challenges as more processes are digitised and automated, and the role of the project manager becomes more of data handling and information processing than of project analysis. Also, the role of the project manager must change to respond to changing technologies and evolving industry needs. Accordingly, this research focuses on the following research problem that is to be answered in the future.

Also, there is an increasing trend in the world for the adaptation of sustainable construction practices in the construction industry. For example, in recent years the number of green buildings being constructed in Melbourne has steadily grown (CityOfGreaterGeelong, 2017).

Although there are an increasing trend and demand for sustainable buildings in the world, insufficient attention has been paid to the adaptation of sustainable construction practices in Sri Lanka. This implies that there are barriers regarding sustainable construction and contractor organisations are having issues in establishing the viability of sustainable construction practices.

Therefore, it is essential to find out the issues faced by construction organisations in practising sustainable construction in Sri Lanka.

How do developing Technologies affect the future construction industry?

1.3. Aim and Objectives

This research aims to examine the adaptability of Digital Technologies on the future of the Sri Lankan construction industry.

1.3.1. Research Objectives

The research is broken down into the following objectives:

- a) To identify the changes in construction industry with the use of most modern technologies
- b) To identify the current level of application of modern technologies in the Sri Lankan construction industry
- c) To develop a framework to address possible issues arise through technological advancements in the future construction industry.

1.4. Research Methodology

A semi-structured interview is a meeting in which the interviewer does not strictly follow a formalised list of questions, and more open-ended questions are asked, allowing for a discussion with the interviewee. This allows new ideas to be brought up during the interview as a result of what the interviewee says. Also, according to the literature, the semi-structured interview has been identified as a preferable method for qualitative research data collection. Hence data was collected through the semi-structured interviews held with the selected construction organisations and professionals.

Interviews were held as face-to-face interviews based on interview guidelines prepared in order to meet the research objectives. Interview guidelines were prepared separately for the construction organisations and professionals focusing on obtaining answers for the research objectives.

This research is based on both quantitative and qualitative data, and therefore a content analysis was done for obtaining answers for the first two research objectives and a stakeholder analysis was done in order to obtain answers for the second objective of the research.

Table 1.1: The information on data collection and analyzing

Objectives	Data Collection Method	Data Analysis Method
To identify the changes in construction industries with the use of most modern technologies	Secondary data	Review
To identify the current application level of modern technologies in construction project management	Semi-structured interviews	Manual Content Analysis
To develop a framework to address possible issues in the future construction project management practices	Semi-structured interviews	Manual Content Analysis

Source: Compiled by Author, 2018

- **Literature survey and review:** A comprehensive literature survey was carried out with the aid of journals, articles, dissertations, books and the internet to gain existing knowledge on shared workspace concept.
- **Expert Interviews:** Fourteen number of expert interviews were carried out to verify the finding of the literature survey and identify the relevance of factors concerning the shared workspaces in office buildings.

1.4 Scope and Limitation

The data collection from construction organisations is focused on selected leading construction organisations which are currently engaged in sustainable construction in Sri Lanka. Small-scale contractors are not considered here. Also, this research is concentrated on the building construction sector only.

1.5 Chapter Breakdown

This research report consists of five chapters namely, introduction, literature review, case study, data analysis, and conclusions and recommendations. A summary of each chapter is outlined below.

Chapter 1: Introduction

This chapter includes the background of the research. A brief introduction to the research topic, the research problem, aims and objectives of the study, research methodology and scope and limitations are supported in this chapter.

Chapter 2: Literature Review

This section presents a review of relevant literature based on previous researches. The chapter consists of already established knowledge on sustainable construction, the importance of the use of technologies in the construction industry in sustainable development, sustainable construction and eventually stakeholder theory and sustainable construction.

Chapter 3: Research Methodology

This section contains the methods which are used to research data collecting method, data analysing method, research process, etc.

Chapter 4: Data Analysis and Findings

This chapter addresses analysing the data which is collected by preliminary interviews and stakeholder analysis.

Chapter 5: Conclusion and Recommendations

This chapter concludes the research findings, proposes recommendations and avenues for further research.

CHAPTER TWO

2. LITERATURE REVIEW

2.1 Introduction to the Chapter

This chapter provides a review of relevant literature based on previous researches. The chapter comprises several areas of sustainable construction where the knowledge already established. The areas discussed in this chapter are the development of digital technologies, sustainable development, the importance of the construction industry in sustainable development, sustainable construction and eventually stakeholder theory and sustainable construction. Under the sustainable construction, it is interpreted areas on sustainable construction, a review on the advantages and disadvantages of applying digital technologies to sustainable construction, drivers of sustainable construction and barriers of sustainable construction.

2.2 Importance of Construction Industry

The global construction industry is worth close to \$10tn per annum but suffers from severe worker shortages, little use of new technology and weak or zero productivity growth (Bogue, 2018).

As stated by Bourdeau (1999), due to the direct and indirect linkage of the construction industry with economic, social and environmental aspects, it is absolutely an important sector in order to achieve sustainable development.

“There is now a wide recognition that the construction industry has a vital contribution to make towards sustainable development” (Opoku & Fortune, Implementation of Sustainable Practices in UK Construction Organizations: Drivers and Challenges, 2013). And also, the above definitions and attempts of the world mentioned in the previous section, reflect the necessity of applying sustainable practices to the industries as well as day-to-day activities. Emmanuel (2004) has stated that, building industry has become a prime candidate for sustainable development because of the significance of the built environment to the economic development of a country and according to Yates (2003), if there is a balance of social, environmental and economic impacts of the construction industry, it would be able to play a powerful role in achieving sustainable development.

Due to the high fragmentation and impact on the socio-economic aspects of the construction sector, it has a great responsibility for any sustainable development initiative (Majdalani, Ajam, & Mezher, 2006). Further, Shi *et al.* (2012) stated that, the construction industry can be recognized as a major sector involved in achieving sustainability as it has a great impact on environment and society and therefore it is clear that present environmental and socio-economic problems can be offered a first-rate response by sustainable construction (Yunus & Yang, 2011).

According to Emmanuel (2004), the increasing urbanization and industrialization and living standards throughout the world have turned the creation of the built environment into a rising threat to the natural environment. Further, he has stated that the rapid increases in the building industry contribute to resource depletion, waste generation and energy consumption and also Al Hathloul (2004) has described that the construction sector has resulted in an escalation of domestic energy consumption per capita.

As mentioned above there is a massive impact of the construction industry on the environment. Especially the buildings as one of the outputs of the construction industry, largely reflect these impacts during its lifecycle (Zuo & Zhao, Green building research—current status and future agenda: A review, 2014). They consume space and natural resources, and they require cement and other building materials like sand (Majdalani, Ajam, & Mezher, 2006). Further, they have stated that even during the construction, there is a number of pollutants and noise are released, and the workers and nearby residents are exposed to them. After construction, occupants consume water and generate wastewater, and solid waste and buildings also consume energy and release carbon dioxide etc. to the environment. And finally, even if buildings are demolished, rubble and debris are released to the environment. Therefore, it can be understood that the construction industry has an unavoidable impact on the environment which can not be neglected.

The environment is not the only aspect that construction industry effects on. As Mayers (2005) stated, in the construction industry, social equity and cultural issues have also been promoted such as (Zuo & Zhao, Green building research—current status and future agenda: A review, 2014) providing buildings and facilities for the satisfaction of human being's requirements, providing employment opportunities and contributing to the

national economy. Horta *et al.* (2013) further stated that the construction industry has significant influences on society as it is one of the major employers in most countries, accounting for around 7% of total employment worldwide. Even though the environmental impacts such as pollution, and consumption of resources are negative, the above-mentioned social factors provide positive impacts on society.

Apart from the environmental and social aspects, the construction industry affects the economy as well. As Spence & Mulligan (1995) stated, the construction industry affects various aspects of economic development through the creating of physical assets. According to Majdalani *et al.* (2006), for a sustainable economy, more infrastructure and facilities are needed, and therefore the construction industry plays a major role in that aspect.

“Environmental, social, and economic considerations need to be integrated into the business strategies and daily practices of construction enterprises so that contributions can be made to sustainable development” (Tan, Shen, & Yao, 2011).

2.3 Digital Technologies

It has become increasingly important to understand the relationship people have with technology. Many positive effects have arisen from technology use such as social inclusion, increased access to information, assistance with every-day tasks, and healthcare applications (Shaw, A. Ellis, & V. Ziegler, 2018)

The internet and mobile telephony have enabled a boom in technology platforms applied to nearly all areas of our lives – jobs, homes, education, health, leisure, finance and even romance. This has happened through the facilitation of three different activities Information provision, Transactions, and Management and control. (University of Oxford Research, 2017) . Accordingly, digital change has radically altered consumer expectations and business models across many industries, such as transport, entertainment, communication and public services (Bookallil & Birkby, 2017). At the same time, (Maarbani, 2017) stated that the real estate sector professionals need to understand the latest in technological innovation and implement strategies to

integrate those advancements into their projects and businesses in order to stay ahead of the pack.

Technology, the innovation economy and their spin-offs, such as the sharing economy, co-working, and the digital economy, are significant disruptors for the real estate industry (Clark & Moonen, 2015).

Growing data availability enabled more finance-grounded quantitative modelling, and construction, property, and portfolio management systems became computer and technology based.

Before going into technological developments, we need to understand the role of data, as well as the challenges in gathering it, namely quality, sources and processing (RICS, 2017). Excel became an essential real estate tool (University of Oxford Research, 2017). Driven by the demand for higher efficiencies throughout the sector and enhanced user experiences, new technologies are re-imagining every aspect of how real estate is procured, developed, managed and utilised (Maarbani, 2017). Another topical concept is digital disruptions; there are three primary forces behind disruption: technology, demographics, and globalisation. These forces are not new — they have been around for many years — but they evolve in successive waves, as well as interact with one another. Digital disruption continues to have a tremendous impact on real estate (Roth & Welch, 2016).

Big data definitions have evolved rapidly, which has raised some confusion (Gandomi & Haider, 2015). However, the emergence of new data management technologies and analytics, which enable organisations to leverage data in their business processes, is the innovative aspect. There will be greater use of data to empower the customer further. For example, I am providing a view of “personal and property risk as soon as possible in the process” to help customers make informed decisions, ideally before investing too much time and money (Bookallil & Birkby, 2017).

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technological advancements will be utilised for the construction profession as well. With such developments, it is also possible to use Mass Appraisal Models and Automated Models etc. (Hromada, 2016). Finally, the ultimate question is raised: who, in the end, will use this technology, and how will this be done? Currently, this role remains human, but recent progress in artificial intelligence may change this in future (RICS, 2017).

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2.4 New Technologies in Construction Industries

The construction industry is in a moment of enormous change (Forbes, 2018). However, technology is shaping the world with everything from electric cars to hyper loop. But when it comes to the real estate construction industry, it is still underserved by technology. The construction industry contributes over 4% to the U.S. GDP, and it needs to adapt to new technologies in order to automate processes and decrease dependencies on manual labor (Nikhil, 2018).

It's no secret that technology is revolutionizing literally every aspect of modern day life. The construction industry, continually being updated and upgraded with the latest technology (GenieBelt, 2018). The complex nature of the construction environment may influence the technology investment decision. It is observed that the construction

industry is conservative and slow to adopt most new technologies (Peansupap & Walker, 2006). At the same time, construction companies struggle to find skilled workers to staff their projects. To keep up with these increasing pressures, construction companies are embracing new technologies to gain competitive advantage (Forbes, 2018).

Technology in construction comes with devising innovative new ways of constructing and whilst the changing future of construction is largely unknown, there are some construction technology trends that are paving the way for certain futuristic construction technology (GenieBelt, 2018). However, the breakthrough technologies to make construction more efficient that have hit the market within the past five years have primed the industry for disruption (Nikhil, 2018).

Many different classes of robots aimed at a diversity of uses in the construction industry exist or are at an advanced stage of development. While some seek to automate conventional building practices, others such as concrete printing robots underpin novel construction concepts. Their use has the potential to yield significant economic, operational, environmental and other benefits and many technologically advanced companies have recently been established which aim to exploit these opportunities. While the industry has traditionally been slow to adopt new technologies, robots are now exerting a real impact and will inevitably play a vital and growing role in the future (Bogue, 2018).

The competitive pressures are just too great to forego the advantages technology offers. Here are some ways technology is changing the construction industry (Forbes, 2018).

Table 2.1 technology use in construction industries

01	Self-healing concrete
02	Transparent aluminum
03	Aerogel insulation
04	Robotic swarm construction
05	3D printed houses
06	Smart roads

07	Bamboo cities
08	Smart bricks
09	Vertical cities
10	Pollution fighting buildings

2.5 Advantages of use of New Technologies

Construction companies can see a complete picture of the entire project from one place and improve efficiency across the entire project by using a cloud-based platform that can handle work management, enable collaboration between employees, contractors, and clients, automate approvals and alerts, and do all of this in real time (Forbes, 2018).

Further, most major construction projects run over budget, material wastage is rife and accident rates are high. These factors underpin the view that the industry could benefit greatly from more automation, including robotics, and a growing number of new companies are seeking to exploit this opportunity. Some plan to automate existing construction practices such as bricklaying, while others are exploring the role of novel techniques such as 3D printing (Bogue, 2018).

They can also digitize many manual processes such as punch lists, change orders, and safety logs, and keep them in a single central location, so time isn't wasted chasing down the latest information. The time savings can be significant (Forbes, 2018).

No industry is as labor-intensive as construction. Since construction sites are uncontrolled (open) environments, it is most difficult to incorporate robotics, unlike in closed industrial environments. However, construction activities such as bricklaying are so repetitive and labor-intensive that the use of robotics is helpful to not only reduce costs, but also maintain quality and precision (Nikhil, 2018).

2.6 Disadvantages of use of New Technologies

The complex nature of the construction environment may influence the technology investment decision (Peansupap & Walker, 2006). Top-down culture with decision being imposed; only senior management perspectives are gained and also Lack of

understanding of the contexts and viewpoints of other levels of the hierarchy are some of disadvantages of use of New Technologies (Henderson & Ruikar, 2010).

These positive strides have consequently led to a reduction in the prominence of certain strategic based implementation barriers. For example, it was viewed that both the barriers of “a lack of IT leadership” and “a lack of organizational strategic planning” have declined

The first gap is a lack of technology awareness that influences ICT investment decisions. Senior IT managers from all three cases stated that some senior managers were unaware of key potential ICT innovation benefits. Lack of technology awareness may also obscure the ICT investment opportunity (Peansupap & Walker, 2006).

2.7 Barriers for Technology adoptability

ICT implementation and adoption is a management intensive activity (Peansupap & Walker, 2006). The reluctance of management investing in innovation have seen a decrease or relatively little change in their significance. It can therefore be deduced that measures developed to overcome these specific factors are being much more effective and well received (Henderson & Ruikar, 2010). Another barrier that remains relatively important to overcome, with a slight increase in significance, is “the lack of leadership by major client organizations”.

Table 2.2 Barriers for Technology adoptability

01	Fear of change and uncertainty by some project participants
02	Limited IT expenditure on projects
03	Low technology literacy of some project participants
04	Tight project timeframes inhibit training and experimenting with IT
05	Security and privacy issues
06	Lack of IT leadership on projects

In order to improve technology implementation strategies, it was found that progress is needed in addressing these behavioral and emotional concerns. It was also viewed that to have the greatest positive impact on overcoming these issues, a minimization of the initial uncertainty surrounding change needs to be made. This is due to its evident link

with increasing the levels of emotional distress of change participants. To accomplish this, two-way communication, education, training and understanding of the rationale bringing about change should all be improved. This is due to it being observed within this study that these aspects can all be enhanced through focusing on increasing the levels of involvement of all participants in every stage of the process (Henderson & Ruikar, 2010).

2.8 Disruptive Innovations

Disruptive Innovations which transformed the world have two things in common. First, digital technologies are the key trigger for those innovations and Second; disrupted business models are those that had not fundamentally changed for many decades.

According to (Wade, 2016) Digital disruptors create value for customers in at least one of three ways, the three drivers are:

- Cost value – competing by offering the customer a lower cost or other economic gains.
- Experience value – competing by offering the customer a superior experience.
- Platform value – competing by creating network effects that benefit customers.

Further (Wade, 2016) states that *“the strongest digital disruptors - Amazon, Google, Uber and others – do not focus on just one type of value. They employ combinatorial disruption, which is so potent because the three values are mutually reinforcing. For example, Starbucks is not successful because it has better coffee – it is selling a superior experience, beyond the coffee. And now it is trying to provide platform value with its own pre-pay mobile app, which has \$1.4 billion of coffee drinkers’ cash earning interest”*.

According to (Organisation for Economic Co-operation and Development, 2015) report, the following impacts can be identified by the Digital Disruption.

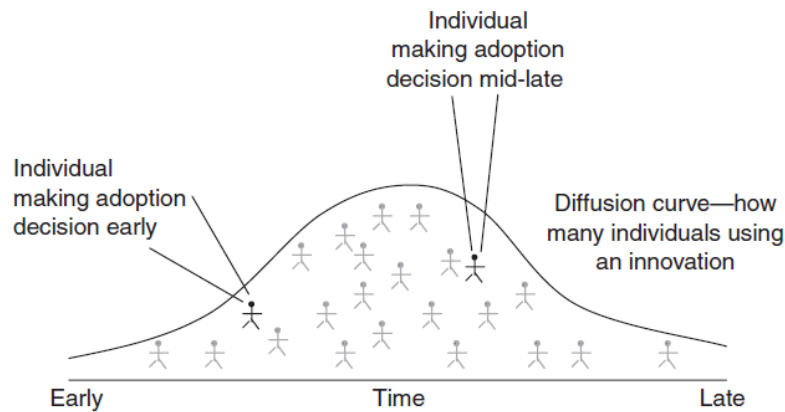
- Disruptors scale up very quickly because their services and products are mainly provided through the Internet or Mobile Technologies.
- Disruptors offer customers new ways to satisfy an unmet (e.g. by introducing a new product) or poorly met (e.g. by introducing a new distribution channel) demand.

- Disruptions generally bring substantial consumer benefit through enhanced competition.
- Disruptions challenge - and sometimes bypass - existing products and business models.
- Disruptions threaten incumbent firms and business models by reducing or destroying their market shares.
- The appearance of disruptive innovations may raise a variety of policy considerations as these phenomena may involve privacy, consumer protection, competition law and policy, taxation and labour issues requiring a multifaceted policy approach to address them.
- Many new/disruptive business models do not fit into existing regulatory frameworks, and this may call for the adoption of new and flexible regulatory frameworks to cover these new forms of competition. Competition agencies can play an essential role in advising regulators in this process and allow pro-competitive reforms across markets and sometimes across borders.

Technologies adaptability is a widely discussed the topic in the recent researches. There are three critical theories related to this: Rogers's innovation diffusion theory, the Concerns-Based Adoption Model, the Technology Acceptance Model, and the United Theory of Acceptance and Use of Technology (Straub, 2009). All in all, technology adaptation is a complex, inherently social, developmental process. Therefore, successful technology adaptation is all about dealing with cognitive, emotional, and contextual concerns of decision makers.

The Concerns-Based Adoption Model examines the individual and the selections an individual makes to accept or reject a particular technology. In some other models, adaptation is not only the choice to accept a specific technology but also the extent to which that technology is integrated into the appropriate context (Straub, 2009). The Adoption theory, then, is a micro perspective on change, focusing not on the whole but rather the pieces that make up the whole. In contrast, diffusion theory describes how an innovation spreads through a population.

Figure 2.1: Individual adoptions compose diffusion

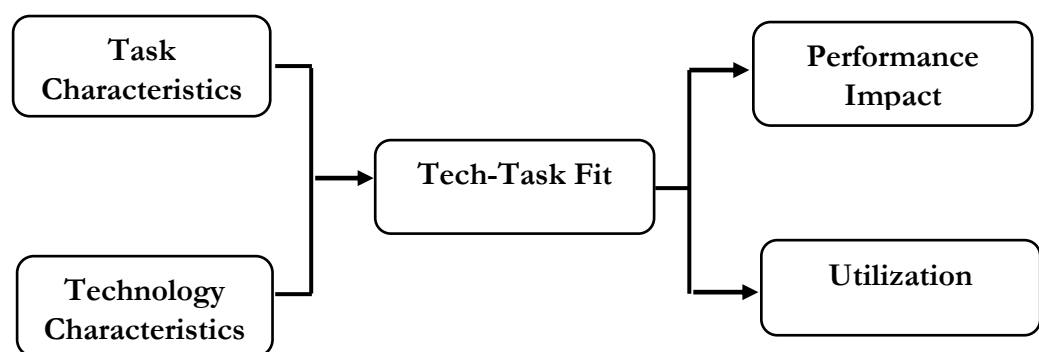


Source: (Straub, 2009)

Another popular theory called, Technology Readiness (TR) refers to people’s tendency to accept and use of new technologies for accomplishing goals in personal life and at work (Lai, 2017). The Diffusion of innovation or Technology willingness is vital for organisation implementation success because it is market-oriented.

In addition to the above, Task-Technology Fit (TTF) stresses individual impact. Individual impact refers to improved efficiency, effectiveness, and higher quality (Lai, 2017). Some researchers argue that the excellent fit between task and technology is to increase the likelihood of utilisation and also to increase the performance impact since the technology meets the task needs and wants of users more closely. Following the model, figure 4.4 is suitable for investigating the actual usage of the technology especially testing of new technology to get feedback. The task-technology fit is suitable for measuring the technology applications already release in the industry (Straub, 2009).

Figure 2.2: Task-technology fit Model



Source: (Lai, 2017)

As per the above discussion, concepts, applications and development of technology adaptation models and theories based on the literature review include different views and interpretations. The literature reviews share the difference in technology adaptation models and theories with different theoretical insights, research problems, variables, and measurements. The development of the new theoretical research framework will depend on several factors. The understanding of technology adaptation models and theories based on the available materials and others. Such knowledge is vital to enable the stakeholders to relate with both the theory and practical aspects of the technology adaptation models and theories. Above discussed theories will support potential applications for technology applications for future researchers to conceptualise, distinguish and comprehend the underlying technology models and theories that may affect the previous, current and future application of technology adoption (Lai, 2017). However, the rate of adaptation includes perceived attributes of innovation, the type of innovation-decision, communication channels, and the nature of the social system and change agents' promotion efforts.

Most of the materials, practices and technologies employed in the construction sector have remained largely unchanged for decades and have led to an industry characterised by flat productivity, a poor safety record, spiralling costs, high material wastage and a shortage of labour. To overcome these limitations, technological innovation is vital and robotics is expected to play a central role (Bogue, 2018).

The extent to which successful technology implementation can be achieved, ultimately depends on the degree to which changes are planned, managed and evaluated. Therefore, technology implementation within construction organisations is not so much a technological problem as it is a human behavioural one (Henderson & Ruikar, 2010).

Overall, this technology is being rapidly adopted by the construction industry and the companies who do not quickly adapt will find themselves less competitive in the market (Nikhil, 2018).

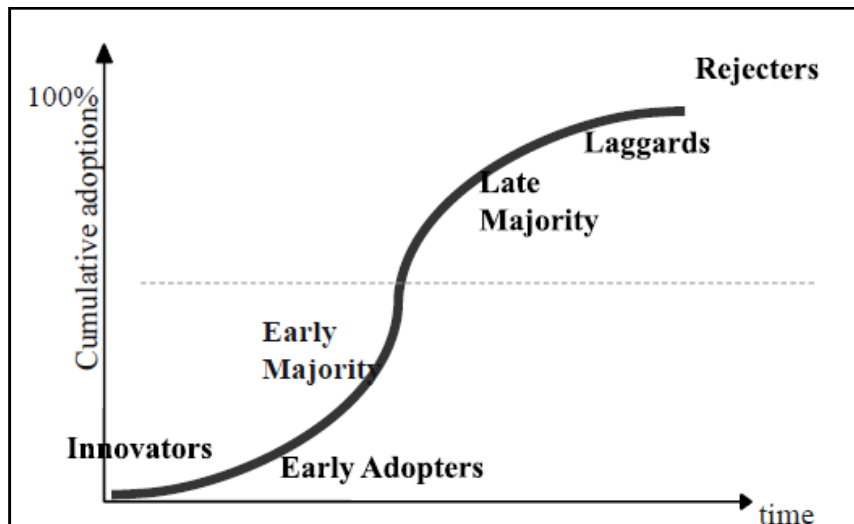
Table 2.3 Common technology adoption theories

		Theories				
		Diffusion Theories	User Acceptance Theories	Decision Making Theories	Personality Theories	Organisation Structure Theories
Focus	Focus on technology, on the environment and on the using organisation	Focus on the rational employee interest	Focus on the rational organisational /management interest	Focus on the individual cognitive interest	Focus on the strategic organisational interest	

Source: (U., 2009)

Innovations are diffused over time in a pattern that resembles an S-shaped curve. Innovation starts with a slow, gradual growth before experiencing a period of relatively dramatic and rapid growth. This will then gradually stabilise and eventually decline (U., 2009).

Figure 2.3: S-shape curve of technology diffusion.



Source: (U., 2009)

Summary

The complex nature of the construction environment may influence the technology investment decision. It is observed that the construction industry is conservative and slow to adopt most new technologies. There is a significant impact of the construction

industry on the environment, society and economy which implies the need for sustainable construction practices to the construction industry. Accordingly, the issues in the adaptation of sustainable construction practices by construction organizations are compliance with sustainability legislation, design, and procurement, education and training, organizational structure and process and Technology and innovation. Further, the technology adaptability depends on the Task Characteristics, Performance Impact, and Technology Characteristic and Utilization. It is therefore expected, through a multi-dimensional approach requiring the effective leadership of the process, people and culture, that a greater adaptability and acceptance of change can be created. This is due to the reduction of emotional distress throughout the change process.

CHAPTER 03

3. RESEARCH METHODOLOGY

3.1 Introduction

This chapter focuses on the systematic approach adopted in order to fulfil the aim and objectives of the study. Fellows and Liu (2008) state that the research methodology comprises the entire process ranging from theoretical underpinning to data collection and analysis. A detailed account of the research approach, research design, data collection methods, populations, sampling method and data analysis methods is discussed. A comprehensive review of the literature, expert interviews, were conducted so as to achieve the objectives of the research. Finally, the chapter concludes with the research process and the summary.

3.2 Research Design

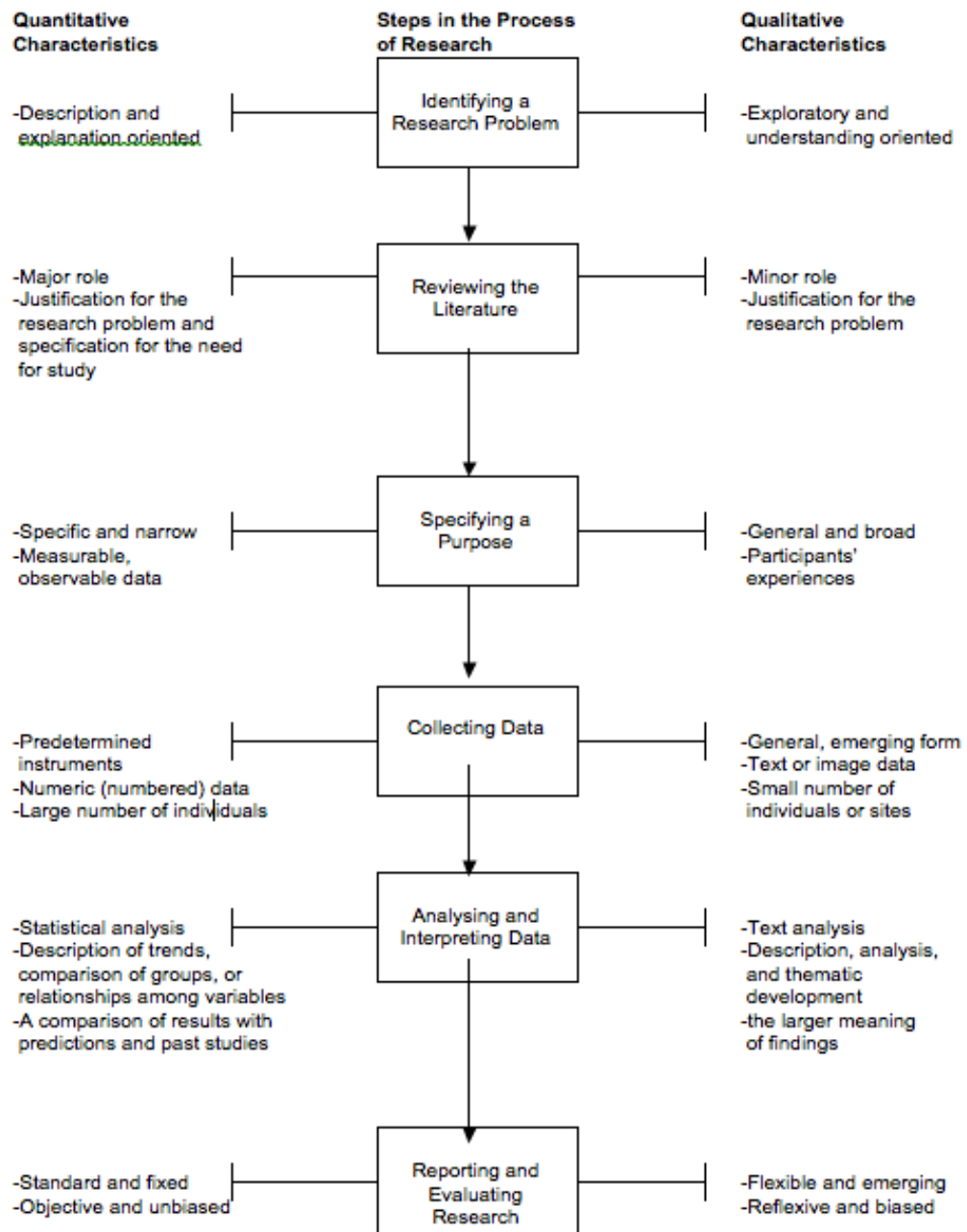
The research design is an essential subdivision of research methodology in order to develop a conceptual plan, which may highly influence the outcome of a research study. According to the Yin (1994) explanation, research design can be introduced as an action plan from the primary stage of the research to the final conclusions. Further, Punch (2005) explained that research design links the research problem and data of particular research. Further, Lu and Sexton (2004) explained that research design, research approach and research techniques are also interconnected in order to attain the aim and objectives of the research.

3.3 Research Approach

The term research approach derives how a researcher undertakes the research activity, such as the methods the researcher anticipates to use and to explain why a researcher is researching a specific way (Johnston, 2014). Creswell (2003), stated that there are three methods that contribute to a research approach those tend to be quantitative, qualitative, or mixed. In any study, the researcher must identify the type of data that the researcher needs to respond to the research question. Based on the type of data assessment the research approach can be selected (Williams, 2007).

Every approach has its characteristics. Based on the type of requirement to study the method of approach selection will vary. Table 3.1 represents the characteristics of each approach.

Figure 3.1 Quantitative and Qualitative Approaches



(Source: Creswell, 2008)

Table 3.1: Types of Research Approaches

Research Approach	Characteristics of the Approach
Quantitative Approach	<ul style="list-style-type: none"> • Quantitative or numeric description of trends, attitudes, or opinions of a population by studying a sample of that population (Fowler, 2009). • Leedy and Ormrod (2001) alleged that quantitative research is specific in its surveying and experimentation, as it builds upon existing theories. • Experimental designs and non-experimental designs such as surveys can be identified as the main alternative research designs(Criswell,2012) • Complex relationships among variables found in techniques of structural equation modelling, hierarchical linear modelling, and logistic regression (Criswell,2013)
Qualitative Approach	<ul style="list-style-type: none"> • Subjective assessment of opinions, attitudes and behaviour (Kothari, 2004) • As per Leedy and Ormrod (2001), this approach is less structured in the description because it formulates and builds new theories. Case studies, grounded theory, ethnography, content analysis, and phenomenological. • Data, procedures and the conceptualising and reducing data to elaborate are the main three components (Strauss & Corbin, 1990).
Mixed Approach	<ul style="list-style-type: none"> • Denzin (1973) as "the combination of methodologies in the study of the same phenomenon." • Class of research where the researcher mixes or combines quantitative and qualitative research techniques, methods, approaches, concepts or language into a single study • Johnson and Turner (2003) call the fundamental principle of mixed research where researcher collect multiple data using different strategies, approaches, and methods in such a way that the resulting mixture or combination is likely to result in complementary strengths and non-overlapping weaknesses

3.4 Selected Research Approach for this Study

The concept of adopting technologies in the construction industry is novel and topical to the Sri Lankan context, hence the studies related to technology adaptability in construction industry quite diminutive. Therefore when selecting an approach, it must ensure that the selecting approach will result for a better output. According to Leedy and Ormrod, (2001), while conducting quantitative research, the researcher's seeks

explanations and predictions that will generalize to other persons and places. The result is to establish, confirm, or validate relationships and to develop generalisations that contribute to theory. However, for this study experts opinions need to be taken into consideration through a series of interviews. Since technologies, adaptability in the construction industry is not popular in Sri Lanka, and the available details are limited to carry out this research. The quantitative approach may not be the best approach because of the difficulty in specific data collection, to analysis and to give a specific output. Therefore to continue with the research most series of interviews, case studies, physical observations document reviews need to be done. The quantitative approach may not be the best option to be selective. Hence the qualitative approach is selected for this study.

3.5 Research Methods Used for this Research

Research methods basically identified as data collection techniques and data analyzing techniques (Amarathunga, Heigh & Thurairajah, 2007). This research is mainly focused on conducting expert interviews.

The research methodology is defined by Leedy & Ormrod (2001) as “the general approach the researcher takes in carrying out the research project”. Specific research methods that involve the forms of data collection, analysis, and interpretation that researchers propose their studies (Crewell, 2013). There are different methods that can be observed in the literature. Out of these methods, a majorly primary data collection method is expert interviews which are used to research to achieve the optimum results due to the constraints in availability details and construction industry expertise in Sri Lanka.

3.7 Data Analysis Techniques

Schutt, (2012) mention that data analysis is the next important step after completing the data analysis. The content analysis technique was used in this research to analyse data which were recognized by preliminary interviews

3.7.1 Content Analysis

Content analysis was used to analyse the qualitative data which is to be identified through preliminary interviews. In the stakeholder analysis, the semi-structured

interviews are used to collect data from the participants. That leads to the use of content analysis method to this study.

3.5.1 Expert Interviews

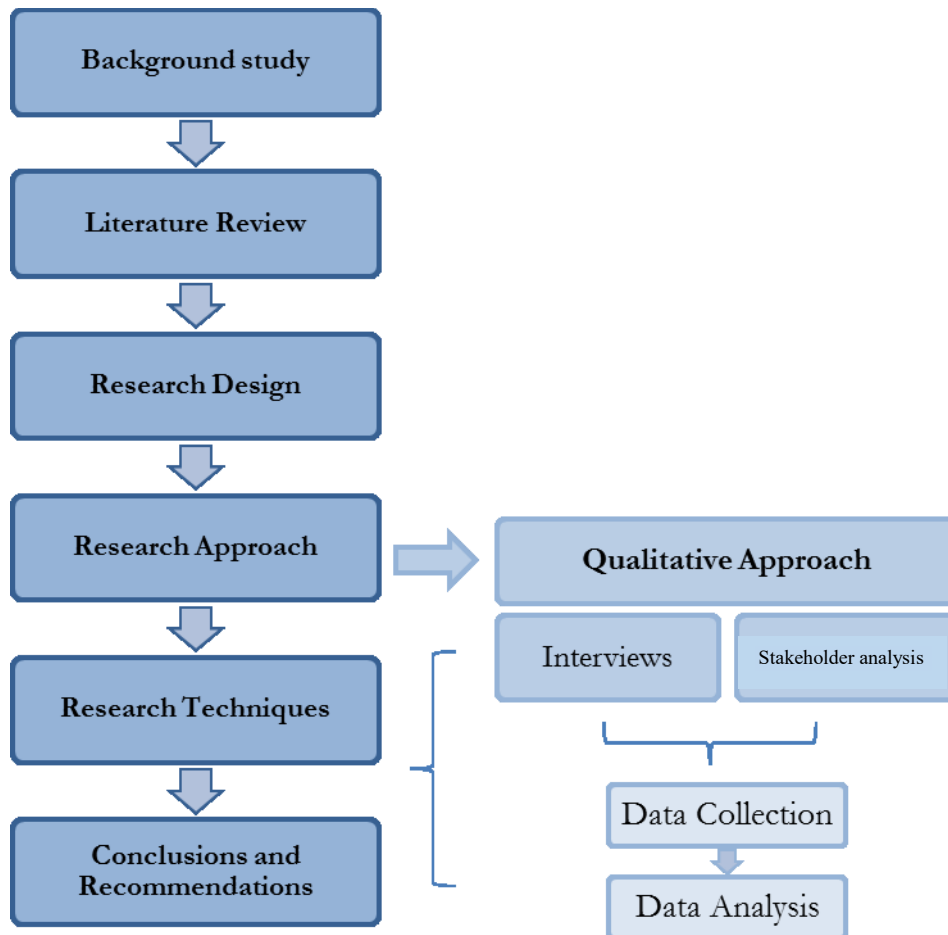
Expert interviews are an attractive data collection method because they allow researchers to link the gap between case studies and the comparison of a large number of countries based on more general and publicly available data (Dorussen, Lenz, & Blavoukos, 2005). Interview in which the individual is allowed to talk freely about a study, largely without the use of specific questions on of the way to collect data (Creswell, 2013). Interviewing an expert is more efficient when compared to participatory observation or systematic quantitative survey (Bogner, Littig & Menz, 2009). For this study fifteen (15) construction industry experts were interviewed for the purpose of in-depth data collection.

Macdonald & Headlem (2009) has identified three types of interviews as structured, semi-structured and unstructured. To proceed with this research study expert interviews, observations, semi-structured interviews and secondary data sources were used as data collection techniques. Then the snowball sampling method was used to reach expert interviewees. A semi-structured interview is a verbal communication was one the interviewer attempts to produce information from another person by asking questions (Longhurst, 2003). This is not open-ended questions which are time-consuming. Barribal and While (1994) support this argument by indicating that semi-structured interviews enable more clarification answers than structured interviews. With these interviews, thorough knowledge can be gain from the study concerning the Sri Lankan context.

3.6 Research Process

As illustrates in Figure 3.2 research process for this study streams on several levels. The process will carry out from the background study up to developing a framework.

Figure: 3.2 Research Process



Source: Compiled by author, 2018

Within this process, the objectives that are covered and will be covered are stated. The data collection and analysis methods for the steps for the process are further mentioned in this graph. Background and the current research problem was identified in the beginning. A detail literature review was carried out afterwards to support the study. To fill the gap of literature, the data collection has been done and the research method used was identified prior. The objectives of the study are achieved by receiving the required data on several levels; the objectives of the study are stated below.

The research is broken down into the following measurable objectives:

- a) To identify the changes in construction industries with the use of most

modern technologies

- b) To identify the current application level of modern technologies in construction project management
- c) To develop a framework to address possible issues in the future construction project management practices with technologies

The way which each of the objectives was achieved were stated in Figure 3.2. Objective one was achieved through a depth literature survey and knowledge gain through expert interviews. The second objective was also completed as the previous objective. The experts' validations and ideas were highly desired to achieve the objective more over the outcome were validated using the stakeholder analysis. Third and fourth Objective was purely achieved through data collection; this includes findings of experts 'interviews and findings from stakeholder analysis.

The data analysis took place to get the expected outcome from the study and finally the framework has been developed by achieving the final objective.

3.8 Summary

This Chapter consists of how to solve the research problem. Research approach, methods, data collecting and analysing techniques were discussed along with the research process. Accordingly, a qualitative research approach is used to proceed with the study. The experts' interviews were conducted to collect the data. The process identified the objective one and two can be covered through the literature survey, and objective two and three can be covered through data collection. The final objective is covered at the end of the recommendation by preparing the guideline for the study. This chapter enhances the systematic approach that can be adapted to proceed with the study

CHAPTER 04

4. ANALYSIS AND RESEARCH FINDINGS

4.1 Introduction

The previous chapter discussed the research methodology. This chapter presents the analysis and findings of the research. The results from data collection relating to each objective are derived using previously discussed analytical techniques. In this chapter, the analysis part has four sections as sustainability, construction industry and Sri Lanka, digital technology adaptability in sustainable construction practices in Sri Lanka, issues in the adaptation of technology adaptability sustainable construction practices and stakeholder analysis. The data collection was carried out in two stages as expert interviews and case studies with interviews and physical observations within them.

The purpose of conducting expert interviews was to assess the applicability of the literature review findings to the Sri Lankan context while determining the best path to proceed to achieve the research aim. Then to validate expert interview findings, two case studies were carried out to verify the adaptability of digital technologies to attain sustainable construction practices. After that, a thorough investigation was carried out to analyse the collected data. The expected outcome of this chapter is to assess the adaptability of digital technologies in sustainable construction practices in Sri Lanka.

4.2 Analysis of Expert Interviews and Findings

The study on the adaptability of digital technologies in sustainable construction practices in Sri Lanka had in-depth expert interviews as this is a new area for Sri Lanka. The expert interview was carried out targeting different professionals who have more than five years of industry experience. The interviewees were asked only subject related questions through the expert interviews; therefore, fifteen number of expertise been interviewed to gain maximum possible outcomes. The findings of the discussions mentioned above were analysed broadly using the content analysis. The data collected from the interviews was categories as background information, exposure to digital technologies, the importance of digital technologies in sustainable construction practices, barriers and enablers of adapting digital technologies in sustainable

construction practices. The findings of expert interviews are directly using for the semi-structured interviews in stakeholder analysis.

4.2.1 Objective of Expert Interviews

The ultimate objectives of the conclusions of expert interviews are to confirm the results of the literature review which was targeting the global platform and their applicability to the Sri Lankan context. The second objective is to gain the expertise ideas and facts to proceed with a successful study with the fruitful stakeholder analysis. The interview addresses five objectives of the study, and it is useful to get the views and ideas of the experts in the industry to check the adaptability of the novel concept.

4.2.2 Respondent Profiles of Interviewees

The semi-structured interviews for expert interviews are consist of a different set of questions; some of the experts only answered the questions that they are knowledgeable. The experts of the selected interviews can be categorised as the people who are active in the building construction industry, and construction industry related personals who deal with building construction projects.

Table: 4.1 Details of Interviewees of Expert Interview

Interviewee No	Professional Category	Designation	Industry experience
Interviewee A	Architecture	Chartered Architect	Twelve years
Interviewee B	Architecture	Owner/Managing Director	Sixteen years
Interviewee C	Facilities Management	Facility Executive	Six years
Interviewee D	Facilities Management	Facility Executive	Six years
Interviewee E	Civil Engineering	Operations and Maintenance Engineer	Eight years
Interviewee F	Civil Engineering	Civil Engineer	Twenty years
Interviewee G	Civil Engineering	Operations Manager	Twenty Five years
Interviewee H	Project Management	Premises Project Manager	Fifteen years
Interviewee I	Project Management	Project Manager	Six years
Interviewee J	Quantity Surveying	Project Consultant	Seven years
Interviewee K	Quantity Surveying	Quantity Surveyor	Seven years
Interviewee L	Land Surveying	Land Surveyor	Ten years

Interviewee M	Land Surveying	Land Surveyor	Eight years
Interviewee N	Real Estate Valuer	Owner/Managing Director	Twenty years
Interviewee O	Real Estate Valuer	Owner/Managing Director	Thirty years

The expert interview phases consist of four main categories of questions which were broadly addressed in the literature review of this research. The first category collects general information about the interviewees. The second category addresses their exposure to the construction industry concepts. The third category is focused on the adaptability of digital technologies in sustainable construction practices. The fourth category is based on the barriers and the enablers for adaptability of digital technologies in sustainable construction practices in the Sri Lankan context.

4.2.3. The concept of Disruptive Innovations

Disruptive Innovations which transformed the world have two things in common. First, digital technologies are the primary trigger for those innovations and Second; disrupted business models are those that hadn't fundamentally changed for many decades. For example, Traditional Brick and Mortar Retailers were hurt by Online Shopping; Crowd Funding democratised traditional Financial Services, Ride Sharing and Home Sharing threatened traditional Taxi Services had disturbed the commercial Hospitality Industry.

According to (Wade, 2016) Digital disruptors create value for customers in at least one of three ways, the three drivers are:

- Cost value – competing by offering the customer a lower cost or other economic gains.
- Experience value – competing by providing the customer with a superior experience.
- Platform value – competing by creating network effects that benefit customers.

4.2.3.1 Existing level of application of modern technologies towards Sustainable practices in Sri Lankan construction industry

As per the opinions of the fifteen interviewees, it could be concluded that the modern technology should be driven by the requirements of the industry stakeholders, the core business processes and by the employees of the company. Most commonly used techniques (known as Lean tools) by the organisations where interviewees work for are given in the table below.

Table: 4.2 Misconception of using modern technologies

Techniques in use	Interviewee Code														
	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
ERP system	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓			
5S		✓	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Total Quality Management (TQM)	✓	✓	✓	✓		✓		✓	✓	✓		✓		✓	✓
Total Productive Maintenance (TPM)	✓	✓	✓	✓		✓		✓	✓	✓			✓		
OSHAS		✓	✓	✓				✓	✓	✓	✓			✓	✓
Six Sigma tools		✓	✓					✓	✓	✓	✓		✓	✓	✓
Just in Time		✓			✓			✓	✓	✓	✓	✓	✓		

As per the respondents' opinions, 5S is the most common and well-known tool which is applied in the construction industry as well. Moreover, the ERP system, total quality management, total productive maintenance and Occupational Health and Safety Assessment Series (OSHAS) were mentioned as Lean tools. All most all the respondents highlighted that there is no proper guidance to implement and monitor these techniques and during the interviews, it was reviewed.

As per the above response, very few respondents revealed the auditing procedures of their practising techniques and tools as respondent F and G mentioned the “*OSHAS audit, TQM audit and JIT-monitoring as the existing procedures of their organisation currently*”. Moreover, K, N and O mentioned that “*there is a misconception that application of, 5S and ERP are the use of technologies*”.

In addition to these opinions, there were few views that organisations who were planning to apply those new technologies like Drones and accept the importance of those new technologies. Respondents A and E mentioned that “*industry awareness level on the use of technologies is low and we are not that much developed regarding tech-based sustainable construction*”. Further, the respondents belong to this category highlighted that they do not have proper guidance to adopt technologies and there should be risk takers to guide them until they get into the correct path. Through the response given by some interviews, it could be proved that they have the day to day practice of carrying out construction projects. As per response from the interviewee F, “*in technical terms, though we can prove that we design a building with our experience and available technologies, honestly, we do not have any clear idea on the use of Drones for site investigation and measurement. However, we wish to learn them*”.

Hence some organisations and individuals are seeking to adopt new technologies for their practices.

As the final result of this evaluation, it was found that most of the organisations and individuals have a misconception of the use of modern technologies. Those organisations are satisfied with the current recordkeeping and analysing procedures, and some respondents argued that they could survive in the industry without applying continuous technological advancements. However, in order to satisfy the end-users and to ensure industry sustainability, there should be movements towards the use of technologies which reduces time, cost and waste.

Table 4.3: Existing level of modern technologies used in the construction industry

Level of technologies use	Interviewee Code														
	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
High						✓			✓			✓			
Average	✓	✓	✓											✓	✓
Low				✓	✓		✓	✓		✓	✓		✓		

In Sri Lanka, the use of modern technology is not at a satisfactory level in almost all the industries. As per the responses of the interviewees, as listed above table 4.3, the existing level of modern technologies used in the construction industry is very low or an average level. Seven respondents believe that the current usage of modern technology is very low while five supposed it is at an average level. According to interviewee D, E, J, K and M, the lack of awareness, cost and the lack of technical competencies have led to this situation. It is proved by the indications of respondents F, I, and L as *“Most people have not yet understood the advantage. Sometimes even the ones who adapted technologies”*. Therefore, it is emphasised that most of the time this concept is adopted by those who have the affordability to do such things for marketing which adapts this concept limited to a certain sector, most probably large-scale construction organisations and clients. As stated by respondent N and O, *“companies in the construction industry have to accept a certain level of risk and adjust to the modern world. If not, the traditional venture will have to exit the market. Therefore, the entire private sector has to pay attention to this without limiting to one particular section like the construction industry.”*

4.2.3.1 Emerging Technologies to be adapted in Building Construction Industry

The experts emphasised their views regarding the Key trending Technologies which can be adapted in Building Construction Industry. Fifteen number of experts gave their opinions on this Key Technologies as displayed in table 4.4

Table: 4.4 Key Technologies of which Construction industry must be aware

Technology	Sources	Validation
Mobile – everything must be mobile compatible.	Literature & experts	A,B,C, G,H,I
Video – vital for remote learning	Literature	A,B ,D,E, L,M,N,O
Apps – face falling behind.	Literature	F, ,J,K,
Internet of People/Internet of Things	Literature	A,B,C, G,H
3D printing	Literature & experts	A,B ,D,E, L,M
Robotics and AI	Literature	B,C, G,H
Drones	Literature & experts	A,B,C,
Regulation	Experts	A,B ,D,E, L,M,N,O
Blockchain –revolutionary in financial services,	Experts	A,B ,D,E, L,M,N,O

As per Table 4.4, the critical technologies identified by literature was further confirmed by the experts. Moreover, there were new ideas that were mentioned by the experts in their view. B, C, and F believed that *“all organisations in the building construction industry should have a chief digital officer for business transformation.”* According to most of the interviewees, the main emerging technology for this trend is the use of mobile phones and devices. G insisted, *“The construction industry is large and well established, but it has not embraced transformation and innovation like others, and it must not assume that it will not be affected.”* Further C, D and E mentioned that *“Technological change has brought tremendous opportunity for innovative organisations, but it is also driving to destruction companies that fail to adapt.”*

Most of the expert opinion was that in general, all possible technologies could be used to face dynamic changes in the world. Another main suggestion was that the formulation and application of a sound set of rules and Regulation with the view of minimising the possible disadvantages of technology use.

4.3. Sustainability of modern technologies in Construction Industry

One of the themes emerged from the collected data from interviews is “Sustainability, Construction Industry and Sri Lanka”. When analysing all the interviews done with professionals and construction industries, it is evident that everyone accepts the fact

that the concept of sustainability is important in the construction industry. Sustainability is important to the construction industry because of the increase of energy usage and depleting of resources and as stated by respondent A, F, I, and J, *“we are in a raw material shortage and also the restrictions for those materials are increasing. As Sri Lanka is a small country, resources are also limited. Therefore, to manage resources effectively, sustainability is a must”*.

The other important factor that comes along with the depletion of resources is the impact on the environment. For instance, As well explained by interviewees A, E, M and O *“flood issues due to sand mining, pollution of stone quarries can be pointed out. Possibly, it is imperative unless there will be health effects, energy problems as buildings consume huge energy, and will impact on the economy of the country as well.”*

On the other hand, because of the limited land area of the country, the density of construction is increasing. Hence, when the frequency is increasing as doing many developments in a restricted space, if the attention is not paid for the environment and economy, people will be adversely affected by health hazards, dust.

Since the construction industry has an excellent liaison with the above factors, it is evident that sustainability is significant in the construction industry.

Interviewee C and I, explains that *“the sustainability is maintaining resources while maintaining the comfort level of living and that pushes to get maximum luxurious level using a lower level of energy which implies that this concept should not be over-utilised.”* Hence it should be focused on 3 Ps; people, planet and profit, maximising comfort level, reducing resource usage and also the cost of resources.

There are three pillars of sustainability as environment, economic and social sustainability. That means, if every construction has to be sustainable, it has to cover the mentioned three pillars. Interviewee E, F and I emphasised that *“there is economic and social sustainability in every construction. Otherwise, there is no survival or existence.it means that if there is no economic sustainability, projects can neither be done nor acquirable as contractors will not do the constructions because they are profit*

oriented.” On the other hand, Interviewee A, G and H confirmed that “if it is not socially sustainable, people will not allow the construction to be done. It implies that environmental sustainability is the part that is not touched in the construction industry.”

However, as stated by respondent B and D, *“when considering the environment, sometimes its cost may be higher”*. As we are a developing country, due to the cost of these practices, people may not compel to adopt sustainable construction practices. For example, a solar panel installation has a higher cost and not very popular. However, as construction is always a disturbance to the natural environment, those practices have to be adapted as much as possible.” However, respondent F mentioned that *“for example, if there is a common criterion on sustainability, that manufacturing industry can fulfil 90% and construction industry can fulfil only 15%, it has to be adopted that 15%, as it is better than neglecting 100%.”*

In Sri Lanka, sustainability is not soundly used in the construction industry. However, there are some measures taken to go for sustainability by construction organisations which shows that there is a trend, but it has limited to a particular society. It is proved by an indication of respondents E, F, L, N, and O as *“Most people have not yet understood the advantage. Sometimes even the ones who adapt, their intention is marketing or prestige”*. Therefore, it is emphasised that most of the time this concept is adopted by those who have the affordability to do such things for marketing which adapts this concept limited to a certain sector, most probably large-scale construction organisations and clients. As stated by respondent N and M, *“government consider this concept when constructing government buildings, but when it takes the ratio, the private buildings are higher. Therefore, the entire private sector has to pay attention to this without limiting to one particular section.”*

Further, respondent N and M are with the view that *“Sustainability is essential. Construction Industry contributes to 8% - 10% of the GDP with over 800,000 people directly and indirectly employed in the sector. Therefore, its contribution to sustainability will have a significant impact in Sri Lanka”*.

4.4 Applicability of Technologies in Sri Lankan Construction Practices

Almost every respondent agreed with the fact that sustainable construction is hundred per cent applicable to Sri Lanka. According to interviewees A, B, D, and J *“From our point of view, our country has used sustainable practices since very past. For example, people lived in houses made of mud and thatched the roof. That is the best example of sustainable construction. However, gradually we used cement, concrete and steel and in some points, we have missed that concept”*.

The interviewees offer reasonable explanations that this concept is not a new idea to Sri Lanka as it has been used in Sri Lanka since the past. For instance, respondent H and I demonstrates, *“It is applicable. Because Sri Lanka has used this concept since the past, for example, we can take Sigiriya.”* Also, the other countries have got ideas from us, but today, we have given up those practices and adopt the whole different practices from other countries. Therefore, even though this is widely applicable, the problem is that people have no better impression on how to apply this concept and it implies that the mindset of people should be changed to adapt this concept. As stated by C and K, *“It applies to Sri Lanka as well. However, sadly, the importance of it is not recognised or appreciated. The benefits are not known to the majority of the population”*.

The matter of not having a good impression on sustainability arises because people do not feel it and hence there is no motivation. For instance, respondent E, H, and N indicated *“Among the carbon emitted countries, we are in a below level. Moreover, in the present, we do not have the problem of water; for construction, there is no stress on water. Therefore, people do not feel it. That is why people do not compel to go for that concept”*. However, it is significant to align with that concept before it gets critical.

At some point, it is believed that as we are a small country, less applicability sufficient. Hence, the level of applicability has become a matter. However, as overall, it should be applied, and the level of applicability should be increased because the amount of impact effect on the entire world as a whole whether it is a small country or large country. It proves the statement of respondent B, K and O, *“Sri Lanka is a country that certified the application of millennium development goals that had been established following the Millennium Summit of the United Nations in 2000 and ensuring environmental*

sustainability one of that goals. So, we are responsible for applying as we are a member of the United Nations". Therefore, it should be increased the application of this concept. It is not a big task to increase the level of application in Sri Lanka. The respondent C and E, pointed out *"we do not have to do many things. In the construction industry, there are standards of CIDA (Construction Industry Development Authority, former ICTAD (Institute for Construction Training and Development)), building regulations and if they are accurately practised it is easy to apply sustainable practices with low cost"*. For an instant, the environmental management of a construction site is in the regulations and CIDA standards, and it is also pointed out in the sustainable concept. Hence, if those standards are covered, the sustainability concept will also be included. However, the construction companies in construction industry consider the assigning staff for site cleaning is a cost and don't see the benefit/profit of it such as the reduction of wastage and hazards, increasing of efficiency and safety due to the clean and clear site.

Another instance is, when considering the population, the elderly population is increasing. Therefore, when doing construction, those things also can be regarded as from the design stage to the end user, so that it would be usable for everyone. That is also a step to sustainability. *"It is 100% applicable. This is the time that we need it. Without that, there is no future"*. (Interviewee A and F)

4.4.2. Technologies, Processes and Innovations for Construction

The main advantage of adopting technologies in construction industry relies on awareness on the 3R concept (Reduce, Reuse, and Recycle). As per that interviewee G and K, *"We reduce, delay, re-use and recycle construction waste, but we do not think much about how to utilise technologies to implement 3R concepts in different stages construction projects or activates"*.

The interviewee L, has a strong argument on the sustainable processes and technologies like rainwater harvesting, re-using, MIVAN technology, and using rammed earth walls for construction houses in rural areas also can be seen in the construction industry. *"Material selection is also important in this case. Materials have to be decided for the designed building or while designing; it should be designed according to the relevant/selected material."* Here the materials with the least environmental impact are

selected by the construction organisations. Moreover, there is a review stage in some organisations where it is reviewed the usage of materials.

Using lightweight material is another significant factor in sustainable processes. As noted by the interviewees K and L *“We use for high rise buildings a type of blocks; its density is 800 kg/m³ which is floating on water, bricks are heavier. Here the soil usage is lower. It saves natural resources. On the other hand, due to the reduction of weight, the usage of steel, concrete, the thickness for other structural components also reduced”*.

It can be identified as two main processes regarding lightweight material usage by reviewing the collected data;

- EPS panels (expanded polystyrene)

EPS panels are used instead of bricks and blocks to minimise the impact on the environment. These panels are energy saving as the heat transfer is very low, and therefore energy usage for air conditioning is also low. As noted by the interviewee C and G, *“We have used this for a building, and the temperature difference between inside and outside is 5⁰C that means if the outside temperature is 30⁰C, inside temperature is 25⁰C”*.

- CSEB (cement stabilised earth blocks)

It can be used for load bearing walls. The heat transfer is lower of the walls made by these CSEBs, and therefore AC usage is also lower.

Using alternatives or substitutes for materials which are depleting is a sustainable process that has also adopted in Sri Lanka which is currently becoming popular. Under that, the primary material can be identified as M sand (Manufactured Sand) which is made using the dust of stone quarry as an alternative for river sand. Previously it was not allowed by designers to use it, but gradually it was used like 30% M sand and 70% river sand, and now there is even 100% M sand usage. As stated by interviewee G, *“Sand is rare, and sand mining impacts the environment, so it is not sustainable. So, we use an alternative, M sand. It is a good sustainable practice. We have an M sand manufacturing plant. Sometimes we use 100% M sand for construction”*.

When the project is executing, construction organisations follow processes in a way that environmental impact is lessened. For instance, as stated by interviewee G, *“There are regulations, we comply with them and assess whether they are complying. When*

the project is executing, we put controls to minimise impact. We also monitor environmental parameters. There, first, we measure the parameters in the area before starting the project — for example, the PH value of a water body near the site. Moreover, when the project is executing, we measure them. Then if there is a deviation, we can take actions, and if someone complains, we can check whether he or she is right or wrong.”

“Waste disposal is also a critical process in executing the project. Construction organizations adopt sustainable practices in this case such as taking precautions to prevent illegal discharge of waste into groundwater, solid waste separation and disposing into dumping yards, timber off-cuts reusing as firewood by workers” (interviewee F), measuring the amount of garbage taken out of the site, minimizing wastage by using resources economically and safeguarding materials from environmental impacts. (Interviewee H) Handles waste through a waste management plan in which plan they identify the activities and the waste generated from each. As stated by the interviewee F, *“Sometimes we have to get approval to dispose of hazardous waste. There are registered people/approved agents in CEA to manage waste. We give our waste to them. Sometimes we pay and dispose of e-waste. That is mainly due to cooperate citizen responsibility”*.

Also, he mentioned that *“Organizations that have obtained ISO 14001 certificate, have certain procedures for environmental management such as waste segregation, waste minimisation, Environment Aspect Impact Assessment (EAIM)”*. This is further confirmed by interviewee H, *“According to EAIM, we first identify and list up all the activities and their possible harms respectively. Then we give marks according to the criteria. Moreover, we identify the possible risks and set controls to those risks. Here we use Pareto Theory. We are doing periodical audits to check whether that requirement is compiled”*.

4.4.3 Issues in Adaptation of technologies for Construction Practices

Through the going-over of interview responses, four major issues in the adaptation of technologies for sustainable construction practices have emerged, namely,

- Awareness, attitude, training and education
- Legal framework and enforcement

- Availability of tools, techniques and suppliers
- Research and Development on the use of technologies for sustainable construction practices
-

Awareness, attitude, training and education

The most significant issue in the adaptation of technologies for sustainable construction practices can be identified as a lack of knowledge. In this case, it is not only a lack of knowledge about tools, techniques but the lack of understanding of importance or advantages of them. As stated by respondents of F and K, *“Awareness of technologies is an issue, therefore higher-level staff, management has to be aware of existing and trending technologies. They have to understand the value”*. For instance, if we consider material selection, as stated by interview B, *“the current practice is, normally it is used common materials that used in building construction. However, if we have update knowledge on trending and developed materials, it is possible to use materials that reduce life cycle impact, but the knowledge is a lesson that even”*.

When the awareness of staff is lower, they consider how to minimise the cost using traditional methods and don't use new technologies and not aware of how to be sustainable in construction. In this case, labour awareness is vital as labours are the highest number of workers in a site. Therefore, no matter how good the plans are, there may be issues in execution.

Sustainability is based on practices. In that case, the awareness is necessary but not only the consciousness of workers. If a company need to go for this concept, and if the top management has poor awareness, then the project will be failed. It can be formed as a rule or a guide and impose on workers, but not for management level. Therefore, awareness is essential from the management level. Also, the lack of clients who are aware of the sustainability concept is an issue as they have the dominant role in this case. Therefore, contractors should be able to inspire clients with the benefits of sustainable construction. For example, as stated by A, B and G, *“EPS panels, there is material saving, better wat to construct houses in rural areas, heat transfer is lower, and comfortability is higher, the cost is lower, but people do not accept because knowledge is lower”*.

The attitude of people is vital in adopting sustainability through technologies in any field. Even in the past, we used sustainable practices. However, now we have given them up and adapting them from other countries as our mind is set to depend. Having the wrong concepts about sustainability is also a critical point. As stated by B, *“Sometimes when we talk to a supplier, they might say that they are not using sustainable materials or percentage even though they use. They think it is not a good thing”*.

Lack of training and education is also a barrier. Even though there are training programmes in leading construction organisations, it is rare in small-scale organisations. The knowledge on the use of technologies for sustainability concept is also a barrier as it has not yet become a core subject in schools, universities or technical institutes.

4.4.4. Framework for Enforcement of the use of Technologies

The legal framework currently used is Blue Green Sri Lanka (Neela Haritha), Green Building guidelines for Sri Lanka. However, none of these discussions on the use of technologies for sustainable construction. The main issue regarding this is this is designed for new construction and not for already constructed buildings. Even though this can be used, it would be difficult as the entire building has to end up with a massive change. Therefore, separate guidelines for old buildings to convert to this concept is needed.

Even though there is a guideline that applies to Sri Lanka, as per the opinions of professional, implementation is questionable, as noted by interviewee M and N, *“Legal framework for the private sector is sufficient, but the enforcement is the thing that matters”*.

Further, they emphasised that *“Waste disposal has become a significant issue in construction and there is no proper procedure to dispose of some type of waste especially hazardous waste like glass wool. Moreover, also lack standards to formulate the guidelines for the processes and the materials that are identified as sustainable is another issue”*.

As well as the standards, incentives from the government are also less. As stated by B, *“There must be incentives like tax concession and further even it is said to go for renewable energy; it is not a legal requirement, enforcement is lower”*.

4.4.5. Availability of tools, techniques and suppliers

A construction project has three targets; cost, time, quality. Hence, if it is needed to spend more time and cost to plan the project, find materials, and execute the project, it would not be sustainable. Therefore, the lack of sustainable material in Sri Lanka has become one of the most significant barriers. As stated by E and G, *“It is difficult to find FSC certified timber in Sri Lanka”*. Besides the lack of materials, there is a monopoly for available materials as there are fewer suppliers in the market. Furthermore, the required quantity cannot be supplied by them. *If it is possible to use mobile applications for placing material orders and supplies, this issue can be minimised”*.

When the suppliers are limited, the materials have to be imported, and it costs more due to the taxation which does not fulfil the economic sustainability. As stated by interviewee M, *“we bought material about 25 million and the tax was 40 million. Even though we bought them because we wanted to establish EPS technology here, normally contractors do not compel to do so”*.

4.4.6. Research and Development on the use of technologies for construction practices

As agreed by all the interviewees, research and development is a missing part of the sustainable construction. Especially their attention was on the use of modern technologies to minimise cost and time. As there are not sufficient innovations to improve sustainable construction, the adaptation has become lower. As per the construction organisations are considered, only one organisation has a separate Research & Development unit. However, the organisations that have no separate Research & Development division, practise several innovative processes, as noted by interviewee B and O, *“in most of the construction companies, no separate unit for Research & Development, but we give innovative proposals to clients. Also, there are projects, plants, internally there are innovations”*.

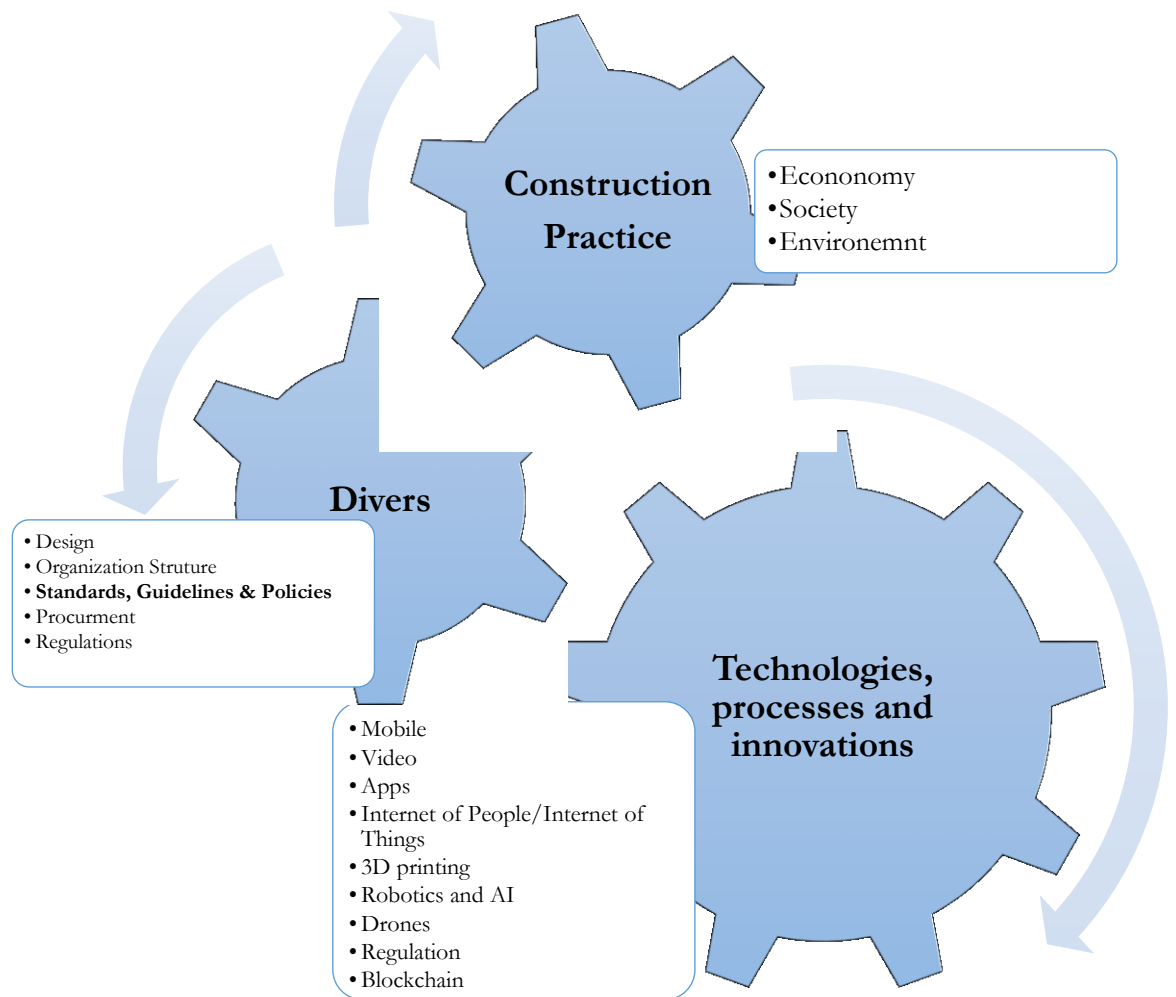
To go for sustainability Research & Development is significant but it is less in Sri Lanka which has become a critical issue. As stated by interviewee B, “*Sri Lanka is a country that applied the sustainable concept since very ancient time. However, there is no Research & Development even to find what sustainable practices were used in the past*”. Even though some researches are undertaking in the present for example by sustainable energy authority, but the problem is they are not coming out in a way that can be used by professionals or construction industry.

Table 4:5 Validation of issues in Adaptation of technologies

Adaptation of technologies for Construction																
No.	Factors – Identified from literature	Interviewee Validation														
		A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
01	Awareness, attitude, training and education	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
02	Legal framework and enforcement			✓		✓		✓	✓		✓	✓	✓			
03	Availability of tools, techniques and suppliers	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓	
04	Research and Development on the use of technologies for sustainable construction practices	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓

According to the above table, out of four identified factors that effect on the adaptation of technologies for sustainable construction practices, Awareness, attitude, training and education is the critical factor while Research and Development on use of technologies for sustainable construction practices are also salient. Further, the availability of tools, techniques and suppliers to adopt emerging technologies is also a salient problem.

Figure: 4.1 Framework of Technology adaptability in Construction Industry



4.5. Stakeholder Analysis

Stakeholder analysis as suggested by Benjamin & Levinson (1993) is done as the fourth part of the review to meet the objectives. As this research is intended to analyse issues that affect the adaptation of technologies for sustainable construction practices by Sri Lankan construction organisations, only two construction organisations are considered in this analysis. The stakeholder analysis method is shown in the figure.

Step 1. Identify a vision or objective.

Step 2. Describe some future states regarding goals understandable by the stakeholder group.

Step 3. Break the goals down into the process, technology, and organisation and culture

steps necessary to balance the organisational equilibrium.

Step 4. Identify the stakeholder groups whose commitment is necessary to achieve each goal.

Step 5. For each type of stakeholder, describe the needed changes, perceived benefits, moreover, expected kinds of resistance.

Step 6. Analyse the effort required to gain the necessary commitment from the stakeholder group.

Step 7. Develop action plans for those stakeholder groups that are not committed enough.

Table 4.0:3: Stakeholder Analysis

Source: (Benjamin & Levinson, 1993)

Step 1: Identify a vision or objective

The issue of non-sustainable practices that distract the sustainable development has become a growing concern. As the construction organisations are mainly focussed on competitiveness and profit, it is significant to focus on sustainability when setting up their goals. Accordingly, the objective is to inspire the construction organisations to make sustainable development through the use of technologies one of the goals and a part of the organisation.

Step 2: Describe some future states regarding goals understandable by the stakeholder group (- two construction organisations)

1. Doing constructions to ensure healthy lives and promote well-being.
2. Utilising affordable, reliable, sustainable and modern technology and energy for construction and entire life cycle of the building.
3. Developing ways to integrate socio-economic issues such as unemployment or lack of skills into sustainable construction.
4. Promoting sustainable construction to the clients through inspiring them with the benefits.
5. Increasing the knowledge and training on services for sustainable buildings.

Step 3: Break the goals down into the process, technology, and organisation and culture steps necessary to balance the organisational equilibrium

1. Doing constructions to ensure healthy lives and promote well-being

- Process** : Improved lighting, better air quality and greenery.
- Technology** : Using LED bulbs, Double glazed window systems EPS panels, CSEB.
- Organisation** : Reducing emissions to reduce pollution and improve air quality, benefiting the health of dwellers.
- Culture** : Constructing buildings not only good for the environment but also support healthier, happier and more productive lives.

2. Utilising affordable, reliable, sustainable and modern technology and energy for construction and entire life cycle of the building

- Process** : Using renewable energy.
- Technology** : Using solar energy, biomass.
- Organisation** : Energy efficiency coupled with local renewable sources.
- Culture** : Limiting the impact on the planet by producing no carbon emissions.

3. Developing ways to integrate socio-economic issues such as unemployment or lack of skills into sustainable construction

- Process** : Understand the talent value chain.
- Technology** : Leverage ICT.
- Organisation** : Understanding the full talent value chain and the impact to be achieved.
- Culture** : Creating incentives for people to engage with sustainable practices as employees.

4. Promoting sustainable construction to the clients by inspiring them with the benefits

- Process** : Proving that sustainable does not cost prohibitive.
- Technology** : Using the World Wide Web for promotions.

Organisation : Showing the clients, a broader view of what sustainability can mean and additional ways they could achieve the types of environmental goals that the clients had sought.

Culture : Designing in a way that ensures they are resilient and adaptable without forcing.

5. Increasing the knowledge and training on services for sustainable buildings

Process : Support consistent training and qualifications across the industry that can be recognised by all employers and employees.

Technology : Sustainability and Life Cycle Assessments.

Organisation : Support training providers in improving training courses and qualifications to encourage the construction industry to build sustainably, aiding the transition to an energy efficient and low carbon-built environment.

Culture : Providing services by the culture. For example, when adapting sustainable practices for condominiums, providing building services according to sustainable technologies as well as condominium culture.

Step 4: Identify the stakeholder groups whose commitment is necessary to achieve each goal

In this research, the stakeholder analysis is done only for the construction organisations, and therefore only construction organisations are considered here.

Step 5: For each type of stakeholder (- here, construction organisations only), describe the needed changes, perceived benefits, and expected kinds of resistance

Modifications required for construction organisations

The perspective and the attitude of the construction organisations are necessary in order to be changed to fulfil the successful adaptation of sustainable construction. Not only the benefit but also the real value behind this sustainable concept are essential to be understood by construction organisations.

Perceived benefits for construction organisations

Adaptation of sustainable construction practices can be beneficial to the construction organisations in many ways such as long-term cost saving, increasing the goodwill and reputation and can be recognised as an organisation that funnelling the benefits to the society at large.

Expected kinds of resistance for construction organisations

Construction organisations have to maintain the balance between cost and benefit of adopting sustainable construction practices to resist in the construction industry with other competitors.

Step 6: Analyse the effort required to gain the necessary commitment from the stakeholder group (- construction organisations)

To obtain the essential commitment form construction organisations for the adaptation of sustainable construction practices, the main action to be taken is that, those who practice green concept and sustainable construction must be recognised and rewarded for others to get attracted. They can be provided with incentives like tax concessions etc. Moreover, also, to increase the involvement of small-scale construction organisations to this concept, it can be added adapting sustainable construction practices as an eligibility criterion to level up in the registration grading.

Step 7: Develop action plans for those stakeholder groups (-here construction organisations) that are not committed enough

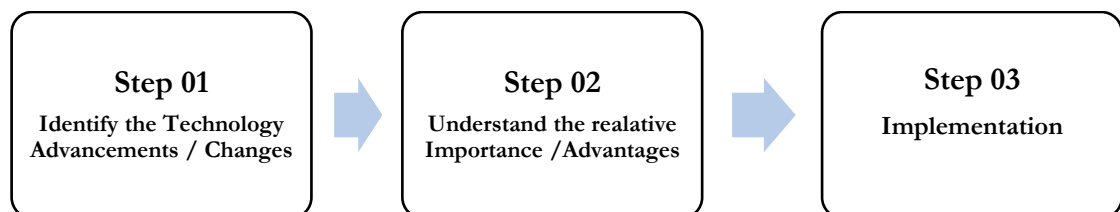
Action Plan for Construction Organizations for the adaption of sustainable construction practices

Stakeholder	Influence	Interest
Construction Organizations	High	High
Strategies to be taken		
<ul style="list-style-type: none"> • Increase the training and awareness programs to make the staff sustainable rich with knowledge and practice on sustainable construction adapting possible technologies. • Set controls to minimise waste generation and waste reusing. • Consultation of environmental consultants. 		

- Having separate Research and Development for sustainable construction.
- Harmonisation with academic and technical institutions for innovating sustainable materials and practices.
- Checking the knowledge on sustainable construction when hiring tech-labours as a qualification and offering salary incensement for tech-labours with an awareness of sustainability.
- Sustainable project benchmarking.
- Setting organisation vision and mission by the sustainable concept.

Based on all the above discussions and stakeholder analysis, the following three steps can be identified for the adaptability technologies in sustainable construction practices. Firstly, the identification of the Technology Advancements / Changes is essential. This is one of the primary responsibilities with top management so as they can make policy decisions. The second is, recognise the relative Importance /Advantages of adapting technologies. Finally, implementation and regular monitoring are needed for the sustainability of the industry.

Figure 4.2: Three Steps of the adaptability of technologies



Source: Compiled by the author, 2018

5. CONCLUSION AND RECOMMENDATION

5.1 Introduction

Conclusions of this research and recommendations which were derived from research findings and analysis in the preceding chapter are discussed in this chapter. To develop a framework to address possible issues arise through technological advancements in the future construction industry. Further, this chapter elaborates the summary of research process describing the way of achieving the objectives of the research to the outcome. In this study, the objectives were formulate, first, to identify the current level of application of modern technologies towards sustainable practices in Sri Lankan construction industry, secondly, to identify the possible developments in modern technologies towards sustainable practices in Sri Lankan construction industry, thirdly, to explore the possible issues of modern technologies Sustainable practices in Sri Lankan construction industry. The qualitative approach was adapted to attain the aim and objectives of the research and stakeholder analysis was done to verify the responses received from semi-structured interviews. In addition to conclusions and recommendations, limitations to research and further research were as well addressed in this chapter.

5.2 Conclusions

Different objectives were established to achieve the prime aim of the research. As per that, conclusions are declared as per objectives together with research findings.

Objective 1 - To identify the changes in construction industries with the use of most modern technologies

The literature synthesis attained the knowledge on the existing situation and possible changes in construction industries due to technological advancements (Refer to Chapter 2) and semi-structured interviews (Refer to Chapter 4). Firstly, literature synthesis was done to accomplish the objective 1 and the findings of literature synthesis assisted to understand the background of possible changes in construction industries due to technological advancements Subsequently, a stakeholder analysis was carried out to understand whether there is a significant impact of the use of technologies to

construction industry on environment, society and economy which implies the need of sustainable construction practices to the construction industry.

Objective 2- To identify the current level of application of modern technologies towards Sustainable practices in Sri Lankan construction industry

The literature synthesis and semi-structured interviews accomplished objective 2 of the research study.

As per the thoughts of the interviewees, it is clear that modern technology should be driven by the requirements of the industry stakeholders, the core business processes and by the employees of the company.

5S is the most common and well-known tool which is applied in the construction industry as well. Moreover, the ERP system, total quality management, total productive maintenance and Occupational Health and Safety Assessment Series (OSHAS) were mentioned as Lean tools. All most all the respondents highlighted that there is no proper guidance to implement and monitor these techniques and during the interviews, it was reviewed.

As the final result of this evaluation, it was found that most of the organisations and individuals have a misconception of the use of modern technologies. Those organisations are satisfied with the current recordkeeping and analysing procedures, and some respondents argued that they could survive in the industry without applying continuous technological advancements. However, in order to satisfy the end-users and to ensure industry sustainability, there should be movements towards the use of technologies which reduces time, cost and waste.

The construction industries are large and well-established industry type in many countries, but it has not embraced transformation and innovation like others, and it must not assume that it will not be affected. Technological change has brought tremendous opportunity for innovative organisations, but it is also driving to destruction companies that fail to adapt. According to most of the interviewees, the emerging technology for this trend is the use of mobile phones and devices. Some views traced from the experts through interviews suggest that all organisations in the building construction industry should have a chief digital officer for business transformation.

Most of the expert opinion was that in general, all possible technologies could be used to face dynamic changes in the world.

The semi-structured interviews gave a sufficient amount of facts and views about the possible issues of modern technologies for sustainable practices in the Sri Lankan construction industry, which was established as objective 4 of the research study. Almost every respondent agreed with the fact that sustainable construction is hundred per cent applicable to Sri Lanka. According to interviewees, the Sri Lankan construction industry has to adopt sustainable practices very without further delay.

Expert interview results suggested that to provide a sustainable construction in Sri Lanka through contractor organisations, structured long-term strategic visionary leadership that can be supported by the proposed framework as is needed. Another main suggestion was that the formulation and application of a sound set of rules and Regulation with the view of minimising the possible disadvantages of technology use. Through the going-over of interview responses, four major issues in the adaptation of technologies for sustainable construction practices have emerged, namely,

- Awareness, attitude, training and education
- Legal framework and enforcement
- Availability of tools, techniques and suppliers
- Research and Development on the use of technologies for sustainable construction practices

Objective 3 -To develop a framework to address possible issues arise through technological advancements in the future construction industry.

Semi-structured interviews and the stakeholder analysis accomplished objective 5 of the research study. The developed framework to address possible issues arises through technological advancements in the future construction industry address the previously discussed issues. Out of four identified factors that effect on the adaptation of technologies for sustainable construction practices, Awareness, attitude, training and education is the critical factor while Research and Development on use of technologies for sustainable construction practices are also salient. Further, the availability of tools,

techniques and suppliers to adopt emerging technologies is embedded in the framework.

Awareness of sustainable technologies, harmonisation of academic and technical institutions and searching for cost-effective methods, sustainable construction evaluation criteria during the project activities are the most significant aspect to be considered.

Based on all the discussions and case studies, the following three steps can be identified for the adaptability technologies in sustainable construction practices. Firstly, the identification of the Technology Advancements / Changes is essential. This is one of the primary responsibilities with top management so that they can make policy decisions. The second is, recognise the relative Importance /Advantages of adapting technologies. Finally, implementation and regular monitoring are needed for the sustainability of the industry.

5.3 Recommendations

By taken the findings of the study into account, the following recommendations can be given.

As the lack of awareness about the advantages of adopting technologies in construction industry activities has become a severe problem, in this case, actions should be taken to increase the awareness of the entire industry. As stated by experts in the industry, “We need to follow a top-down approach to educate people on sustainability and adapting technologies to make it easy”. From the construction organisations’ view; they should increase the training and awareness programs and also the importance and benefits of sustainable construction must be driven into the minds of the clients.

As suggested by the professionals, the governing body of sustainable construction must be a non-profit and non-government organisation. Moreover, also, the findings suggest that the government should take actions to provide incentives for the organisations that adopt technologies in order to achieve sustainable construction practices. Furthermore,

there is some evidence to suggest that there must be programs for encouraging small-scale organisations to align with this concept.

Limitations to Research

Several limitations were identified throughout the whole research process. Mainly, time was recognised as a crucial boundary for the research, especially for the data collection process. Further, some respondents could not be interviewed due to the complexity and depth of the interviews. Additionally, lack of sound awareness on the use of technologies to the construction industry was identified as a limitation to the research. Due to these limitations, fifteen (15) respondents were interviewed from the target of twenty (20).

Further Researches

The research suggests that there is an enormous requirement to address in the following areas as further researches;

- Analysis of effect regarding economic, social and environmental aspects of technologies used in the construction industry
- Develop a framework to understand the future role of each expert in Sri Lankan construction industry due to changes in technologies.

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APPENDIX A: QUESTIONNAIRE

COVERING LETTER FOR THE QUESTIONNAIRE

Dissertation- M.Sc. Degree in Project Management

Dear Sir/Madam,

I am Terans Gunawardhana, a postgraduate student undertaking Degree of Masters of Science in Project Management at Department of Building Economics University of Moratuwa. As a part of my degree curriculum, I am required to undertake a research which is incorporated in the dissertation to be prepared and submitted at the end of the course of study.

The topic of my dissertation is “**Adaptability of Digital Technologies to Sustainable Construction Practices in Sri Lanka**” with the main focus on developing a frameworks for adaptability Digital Technologies to Construction Industry in Sri Lanka in order to achieve sustainable construction practices.

I have identified you/your organization as a potential participant who could provide valuable information for my research. I would be very much grateful, if you could complete the attached questionnaire despite your busy work schedule. The information disclosed here will only be used to complete my research and all information shall be treated strictly confidential. Your early responses will be highly appreciated as I have to undergo a very tight time schedule.

Thank you.

Yours faithfully,

Terans Gunawardhana,
Postgraduate Student,
Department of Building Economics,
University of Moratuwa.
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Ch.Qs.Prof. (Mrs.) Kanchana Perera,
Professor,
Department of Building Economics
University of Moratuwa.

QUESTIONNAIRE

Research Topic:

Adaptability of Digital Technologies to Sustainable Construction Practices in Sri Lanka

Aim and Objectives

This research aims to explore the adaptability of Digital Technologies to Sustainable Construction Practices in Sri Lanka.

Research Objectives

The research is broken down into the following measurable objectives:

A critical review of the literature related to:

To identify the changes in construction industries with the use of most modern technologies

Conduct semi-structured interviews,

To identify the current level of application of modern technologies towards Sustainable practices in Sri Lankan construction industry

To identify the possible developments in modern technologies towards Sustainable practices in Sri Lankan construction industry

To explore the possible issues of modern technologies Sustainable practices in Sri Lankan construction industry

To develop a framework to address possible issues in the future construction project management practices

To test and validate the framework by conducting case studies and in-depth interviews

Respondents' Details

Respondent Number.....

Profession.....

Designation:

Experience (Years): 5-10 10-15 15-20 above 25

Type of the Organization: Construction Others

1. What are the changes in construction industries with the use of most modern technologies?

.....
.....
.....

2. How about the current level of application of modern technologies towards Sustainable practices in Sri Lankan construction industry?

.....
.....
.....

3. What are the possible developments in modern technologies towards Sustainable practices in Sri Lankan construction industry?

.....
.....
.....

4. What are the possible issues of modern technologies Sustainable practices in Sri Lankan construction industry?

.....
.....
.....

5. What are the factor that need to be considered to develop a framework to address possible issues arise through technological advancements in the future construction industry. ?

.....

APPENDIX B: MEETING RECORDS WITH THE SUPERVISOR