APPLICABILITY OF ARTIFICIAL INTELLIGENCE TECHNIQUES FOR EFFECTIVE COMMUNICATION IN GREEN CONSTRUCTION

Kadirappulige Isuri Ridmika

(208082R)

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Department of Building Economics
Faculty of Architecture

University of Moratuwa
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DECLARATION

I affirm that this is my effort, and this dissertation does not contain any material previously published or written by another person except where the acknowledgement is made in the text to the best of my knowledge and belief.

Further, I here admit the intellectual assistance of my research supervisor Dr. Menaha Thayaparan for the successful fulfilment of this MSc by Research thesis. I affirm that I will not make any publication from this research without the name(s) of my research supervisor(s) as contributing author(s) unless otherwise, I have obtained written consent from my research supervisor(s).

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…….. 23/08/2022

Dr. Menaha Thayaparan Date

Dissertation Supervisor

ABSTRACT

Applicability of Artificial Intelligence Techniques for Effective Communication in Green Construction

Green construction is the flagship in the construction industry as a guide to tackle environmental tragedy. With the rapid development, Sri Lanka also has concentrated on applying green concept in construction industry. Nevertheless, poor communication impedes adoption and corporative environment for implementing green construction. Understanding and then overcoming the barriers to effective communication is decisive for a successful construction project delivery. While prevailing environmental tragedy lead the concentration of green concept, there is a remarkable awareness of AI application in construction industry. Therefore, this study aims at to investigate the application of Artificial Intelligent (AI) techniques in addressing the barriers related to effective communication to successfully deliver green construction in Sri Lanka.

This research adopts a pragmatism philosophy and pace through mixed research approach to draft an abductive conclusion. Under survey strategy, key informant interview (KII) and questionnaire survey were utilised as the data collection techniques. The qualitative findings from KII were analysed through manual content analysis and quantitative findings from questionnaire survey were analysed through analytical hierarchical process (AHP).

Framework to enhance the effectiveness of communication using AI techniques for successful delivery of green construction in Sri Lanka is developed based on the combination of both inductive and deductive interpretation of findings from KII and questionnaire survey. The developed framework has been validated through a questionnaire survey. The framework embedded with eighteen communication barriers and fourteen applicable AI techniques. Each communication barriers are assigned with the applicable AI to overcome for effective communication in green construction with the rank and performance score gained through AHP. Accordingly, this study gives a guidance for identifying communication barriers in green construction, applicable AI techniques in Sri Lankan construction industry and possible AI techniques to overcome communication barriers in green construction project.

Keywords: Artificial Intelligence Techniques, Communication, Green construction

DEDICATION

To my beloved parents, brother and Haritha

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

EQUATIONS

ABBREVIATIONS

ABC	- Artificial Bee Colony
ACO	- Ant Colony Optimization
AHP	- Analytical Hierarchical Process
AI	- Artificial Intelligence
AIT	- Artificial Intelligence Techniques
AR	- Augmented Reality
BI	- Business Intelligence
CI	- Consistency Index
CR	- Consistency Ratio
CRI	- Copenhagen Resource Institute
DE	- Differential Evolution
FA	- Firefly Algorithm
GA	- Genetic Algorithm
PSO	- Particle Swarm Optimisation
RI	- Random Consistency Index
SA	- Simulated Annealing
SFLA	- Shuffled Frog-Leaping Algorithm
VR	- Virtual Reality

CHAPTER ONE

1 INTRODUCTION

1.1 Background

Even though the world is leading towards great achievements all the time in terms of physical development and facilitating the quality of life, it is questionable whether all kinds of living creatures are protected in this state of environment (Hossain & Ng, 2019). The depletion of Ozon layer, ascending of global warming day by day, deforestation and adverse climatic changes have become huge environmental tragedies (Hussin et al., 2013). Most of the human activities directly or indirectly cause to these adverse effects (Enshassi et al., 2014). Hence, there should be a way to convert these activities to become more environmentally friendly (Waghmode et al., 2018). Construction industry performs a vital role in the global economy that contributes to the global GDP by 13% (Hossain & Ng, 2019). Hence, it is becoming increasingly difficult to ignore the output of such a wide-spread industry throughout the world. Typically, it satisfies the need of building and infrastructure development to facilitate the necessities of human beings (Enshassi et al., 2014). Unfortunately, construction industry does not only play an important role in the global economy, but it also generates adverse consequences towards social and environmental aspects (Hussin et.al, 2013). Typically, the construction activities influence the environment substantially across a wide range of off-site, on-site and operational activities (Shen & Tam, 2002). Mining and exposition of materials and components, the transport of materials and components, the accession of land and the designing of projects can be identified under off-site operations (Udomsap & Hallinger, 2020). On-site construction operations result in air pollution, water pollution, and building waste generation (Copenhagen Resource Institute [CRI], 2014). Construction activities negatively influence on environmental through the mining of environmental resources such as fossil fuels and minerals; the growth in the use of generic resources such as soil, water, air and energy; the production of waste requiring land use for disposal; and contamination of the natural ecosystem with noise, odours, dust, vibrations, chemical and particulate pollutants, and solids (Shen & Tam, 2002). In global scale, the

construction industry is responsible for 40 per cent of energy consumption, 30 per cent of CO2 emissions and 40 per cent of total solid production waste (CRI, 2014).

Within construction industry, it was subjected to discuss this issue and have suggested the solutions to overcome (Hussin et.al, 2013). Rather than focusing on cost, time, and quality that were described under the paradigms of traditional design and construction, the aim should be focused on the human satisfaction, minimum negative environmental influence and minimal consumption of energy and material within the built environment (Vanegas et al., 1995). The concept of Green has been directly addressed that environmental unfriendliness of the construction industry (Glavinich, 2008). A Green building can be identified as a building that in its design, construction, operation, maintenance, renovation and demolition minimize or eliminates adverse impacts, and can form and maximize positive impacts, on the climate and natural environment (Zuo & Zhao, 2014). Green buildings use resources in more efficient way compared to conventional buildings and it makes healthy and productive environment for occupants as ultimate output (Waidyasekara & Fernando, 2013). The spreading of green building is changing the way construction professionals design and execute a project (Ahn & Pearce, 2007).

According to Schwab (2017), the Industrial Revolution occurred almost four times in the world. Those revolutions can be identified as Industrial Revolution 1.0 on a steam-based industry, the Industrial Revolution 2.0 on an electrical-based industry, the Industrial Revolution 3.0 on an information technology-based industry and the Industrial Revolution 4.0 on a digital-based industry. the Industrial Revolution 4.0 can be seen mainly in the physical, digital and biological domains. (Mahmud et al., 2018). A rapid enhancement of digital technology and the development of big data can be seen in recent decades in the old construction industry (Pan & Zhang, 2021). The awareness towards Artificial Intelligence (AI) has gained significant concentration, which focuses to equip machines with human-like intelligent behaviour and reasoning (Chen et al., 2008). AI is a branch of science that deals with allowing machines to find solutions for complicated situations in a more human-like fashion (Xiang et al., 2021). AI generally involves borrowing characteristics from human intelligence and applying them as algorithms in a computer friendly way (Chen et al., 2008). AI techniques have

successfully intervened in construction management in terms of more trustworthy, automated, self-modifying, time-saving, and cost-effective processes throughout the life cycle of the projects. AI exceptionally perform in dealing with intricate and vigorous situation and come up with more accurate and tactical solutions unlike traditional computational methods and expert decisions (Pan & Zhang, 2021). AI displays huge possibilities in managing various construction projects, with automated and accelerated processes of understanding, reasoning, and perceiving from extensive data. Hence, diversified AI-based solutions can be utilised for each construction project based on the prevailing characteristics of the particular construction project. Therefore, those AI based systems analyses the complex and dynamic environment in a construction project without human intervention and then propose strategies which are felicitous for that particular project (Abubakar et al., 2019). Though there is extensive data to be analysed, AI has profound insights to effectively perform such through four basic steps including data acquisition, pre-processing, data mining and erudition revelation and analysis (Vinuesa, et al., 2020). Besides, this kind of tactical decision making can possibly be acclimated to the mutable conditions to optimise the project operation perpetually for distributing more perspicacious construction management throughout the full project lifecycle (Pan & Zhang, 2021). Accordingly, there is immense interest in implementing a variety of AI methods in the construction industry to seize the valuable opportunity of digital evolution for better performance and profitability (Pan & Zhang, 2021).

Even the green concept precisely addresses the environmental unfriendliness in the construction industry, still its adaptation has barriers and issues. A construction is not an outcome of a sole person but is executed by a number of different stakeholders (Jingxiao et al. 2019; Sarkis et al. 2012). Different success factors of each stakeholder are to be often incorporated to ensure a successful green construction (Jingxiao et al. 2019). Since the green concept is a new effort in construction industry, embracing and managing it in conventional construction is almost relied upon greater communication (Hwang & Tan, 2012). Greater communication among project participants, particularly through multiple communication means contribute to success in the delivery of green buildings. Poor communication does have negative effects on green

practice in each stage of a green project (Ying et al., 2012). Even as in conventional construction project, poor communication negatively influences to the cost, time and quality goals in green construction projects (Hammond et al., 2019). The new conversion towards green development in construction industry is only fed through the collaboration of each stakeholder and each process (Azeem et al., 2017). A greater communication is the key for such collaboration (Glavinich, 2008). Hence, poor communication has been identified as the barrier which fences not only the achievement of green goals but also the initiation of them particularly in green construction projects (Darko & Chan, 2017; Hasan & Zhang, 2016). Errors in green design, higher waste generation, poor green process monitoring and late responses to the events in green construction project management are few of effect factors from poor communication in green construction project (Gamil & Rahman, 2017;Darko & Chan, 2017).

The application of AI has been discussed in terms of the collaborative working environments and knowledge representation and reasoning (Pan and Zhang 2021). According to Vinuesa et al. (2020), AI can be used to preserve the environment through its possibility of analysing large scale interconnected database to develop cooperate actions. AI creates exciting opportunities in the construction industry with different techniques. Voice assistants, virtual robots, and robotic process automation do collaboratively work with humans to facilitate both communications and operations in construction projects (Oesterreich & Teuteberg 2016). Few studies have explored the value of sub area of AI on the provisions such as green building management and green architecture (Elshafei and Negm 2017). Hence, this study will investigate whether or to what extent the AI techniques can be incorporated for an effective communication to execute successful green projects.

1.2 Problem Statement

The constant high rate of resource consumption in terms of usage of outrageous energy, water and forest and raw materials has given pitch to grow the concept of green construction in the construction industry (Hammond et al., 2019a). Green building stresses the physical development that encompasses sustainable construction. Under

the concept of green building, the construction projects are built with the inputs which are generated through resource-efficient ways starting from the exploitation of raw materials to the demolition and disposal of their residues (Mohamad Bohari et al., 2016). However, the delivery of a green construction project is a complex and unique process (Verma et al., 2021). Compared to the carrying out of conventional buildings, green buildings require more process requisites such as extra site precautions, energy efficiency modelling, designing iterations and sophisticated simulations to achieve green objectives (Mohamad Bohari et al., 2016). Therefore, there are barriers and issues in executing a green construction even the initiation of the project (Hasan & Zhang, 2016). Among other prevailing barriers, poor communication in green construction projects prominently prevents the achievement of green goals throughout the project lifecycle (Darko & Chan, 2017; Hasan & Zhang, 2016). Poor communication barriers initiation to the green projects, green designs, green project monitoring, achievement of green goals and collaboration among project stakeholders and processes (Hammond et al., 2019; Ying et al., 2012).

While prevailing environmental tragedy leads to the concentration of the green concept, there is tremendous attention to AI applications in the construction industry (Pan & Zhang, 2021). Few studies have explored the value of the sub-area of AI on the provisions such as green building management and green architecture (Elshafei & Negm, 2017). Accordingly, these studies only delivered a narrowed stance rather than a general sentiment of AI implementation for effective communication within green construction. Hence, this study will investigate whether or to what extent the AI can be incorporated to have greater communication within a green project. Although the construction industry is well placed to leverage these technologies for competitive and operational advantage, the diffusion of the technologies in the industry follows a steep curve (Vinuesa, et al., 2020). Accordingly, this study will inspire the adaptation of AI techniques in construction industry (Pan & Zhang, 2021). There is a significant necessity to facilitate the adoption of the green concept for the construction industry in Sri Lanka, considering the remarkable growth in the construction industry. (Waidyasekara & Fernando, 2012). Thalpage & Karunasena (2016) explicitly recognised that poor communication as a barrier to a successful ogreen construction in

Sri Lanka. Accordingly, this study is narrowed down to review the applicability of AI techniques for an effective communication in the green construction in Sri Lanka. Particularly, there is no significant research carried out on application of AI techniques for green construction in Sri Lanka. Hence, this study will be significant milestone as there is a dearth in literature referring AI application in green construction industry in Sri Lanka.

1.3 Aim and Objectives

This study aims to investigate the application of Artificial Intelligent (AI) techniques in addressing the barriers related to effective communication to successfully deliver green construction in Sri Lanka.

1. To critically review the concept of green construction in a global context and in the context of Sri Lanka
2. To investigate barriers related to effective communication among project stakeholders in successfully delivering green construction in Sri Lanka
3. To critically review Artificial Intelligence (AI) techniques that can be used in construction industry in Sri Lanka
4. To evaluate the application of AI techniques to address the barriers related to effective communication within green construction in Sri Lanka
5. To develop a framework to enhance the effectiveness of communication using AI techniques for successful delivery of green construction in Sri Lanka

1.4 Scope of the Research

The Artificial Intelligence have a board scope, usually addressing in the global context. The scope of this study is to narrow down the focus of these concepts to Sri Lanka and to adapt AI in the communication within green construction in Sri Lankan context.

1.5 Limitations to the Study

It had to carry out the process of fulfilling the objectives of this research under several limitations namely limited time duration, less awareness of green concept in industry, unfamiliarity with the AI techniques in industry, less availability of professionals with both experience and profound knowledge in concept of green construction in Sri

Lankan construction industry. Further this research has only focused on Sri Lankan construction industry.

1.6 Methodology Outline

A research design will identify the suitable philosophy, approach, methodological choice, strategies and techniques to present a clear image on research area. Research philosophy means the view for a study, based on which data about a phenomenon should be collected, analysed and used. Positivism, interpretivism and pragmatism are the three focal research stances. At extremes, it believes that society shapes the individual and use quantitative methods in positivism whereas it believes individuals shape society and use qualitative methods in interpretivism (Rahi, 2017). Pragmatism is a paradigm that encourages the use of mixed methods in research to undertake different ways to interpret the phenomena since there may be multiple realties (Creswell, 2018). This research adopts a pragmatism philosophy as it allows to align with the best methodology for the study (Creswell, 2013). Inductive, deductive and abductive reasoning can be used as the approaches to theory development in research. According to Rahi (2017) inductive reasoning intends to develop a theory while deductive reasoning intends to test an existing theory. Abductive reasoning typically commences with an incomplete set of observation and proceeds to the possible explication for the set (Kaushik & Walsh, 2019). Abductive conclusion is to be drafted in this research to adapt the best approach to work with the research problem. In terms of methodological choice, qualitative, quantitative and mixed methods (Saunders et al., 2019) are the key choices. Mixed approach is an amalgamation of qualitative and the quantitative approaches within a single study (Creswell, 2018). According to Tashakkori and Teddlie (2018) the mixed approach addresses a research problem overcoming the biases adhered to one method. As such, this study paces through mixed method approach to draft the abductive conclusions. Survey has been adopted as the most suitable research strategy as this study was done in a broader term as exploratory research. The survey is a research strategy that permits the collecting of data from a comparatively higher number of participants (Pheng & Hou, 2019). Within this strategy several data collection and analysis techniques were used.

First, comprehensive literature synthesis was carried out when pacing through objectives 1, 2 and 3. The objectives 1, 2 and 3 were further primarily investigated using qualitative data collected through Key Informant Interviews (KII). KII are undertaken to achieve in depth information from the people who have been identified as knowledgeable in particular research area (Elmendorf & Luloff, 2006). Therefore, purposive sampling was used to select the participants for the interviews and for the questionnaire survey as Etikan (2016) stated it enables to select participants depending on their knowledge, experience, availability, and willingness to provide information. The key informants who were selected for the KII, consist of experts/professionals who are knowledgeable and have experience in green construction together with the knowledge of applying innovative and emerging technologies to the construction industry. In addition, AI experts who have hands-on experience for more than 10 years in the Sri Lankan IT industry were also selected. KII were conducted as semi-structured interviews. Once the applicable AI techniques for an effective communication in green construction in Sri Lanka using literature review and KII were gathered, a structured questionnaire survey was carried out to prioritise the AI techniques in overcoming barriers in communication in green construction. Finally, a validation questionnaire was carried out to validate the final framework.

The KII was conducted to achieve the partially completed second and third objectives through the literature review and a part of fourth objective. The third objective was achieved by finding further applicable AI techniques in construction industry through KIIs. None of the existing studies was found which particularly illustrated the barriers related to effective communication among project stakeholders in successfully delivering green construction project in Sri Lanka. Therefore, the achievement of third would be completed purely by using the primary data obtained through KII. This objective was to identify and validate the new barriers related to communication among stakeholders in the context of green construction in Sri Lanka. The initiation for fourth objective was taken by analysing the application of AI techniques to address the barriers related to effective communication within green construction in Sri Lanka.

Content analysis is frequently selected as the data analysis methods in qualitative research approaches (Wahayuni, 2012). As such, the findings from KII were analysed using manual content analysis. Analytical hierarchical process (AHP) which allows ranking different alternatives (Vaidya & Kumar, 2006) was employed as the data analysis technique for the quantitative data collected through structured questionnaire survey. As this research focused on evaluating and prioritising the application of each AI technique to overcome the barriers in communication in green construction project in Sri Lanka, the AHP has been selected as the most appropriate technique for data analysis. The fourth and fifth objectives were achieved through by AHP. The developed framework was finally validated, where the findings of validation questionnaire survey were statistically analysed.

1.7 Chapter Breakdown

The research writing is completed in Chapters, which evidently feature the steps followed throughout the research. There are five Chapters which are appropriately presented in Sections to effectively comprehend the study.

- Chapter One- Introduction

Chapter 01 demonstrates the background of the study which subsequently leads to the research problem understudy. The aim of the study and the objectives to achieve the aim to answer the research problem and the methodology followed to accomplish the objectives are briefly elaborated in Chapter 01.

- Chapter 02- Literature Review

The literature review provided the context for research. This chapter will include the barriers and issues in green construction, green delivery strategies and AI techniques.

- Chapter 03- Research Methodology

This chapter contains the methodological design that is used to carry out the study, inclusive of the research philosophy, research choice, data collection and data analysis techniques.

- Chapter 04- Data Collection, Analysis and Discussion

Chapter 04 includes the data collection process conducted through expert interviews and questionnaire survey. The collected data is analysed through content analysis and descriptive statistical analysis. The key outcomes are outlined, and the discussion is conducted on the research findings by revisiting the literature at the end of this Chapter.

- Chapter 05- Conclusions and Recommendations

The conclusions from the findings and recommendations will be presented in this chapter. Proposed recommendations for further studies will be also included.

1.8 Chapter Summary

The background study, problem statement, aim and objectives, scope and limitations were described under this chapter. Furthermore, the research methodology, which was followed to acquire the aim and objectives of the study, was discussed in brief. Finally, the breakdown of the chapters of the research was presented giving the contribution of each chapter to accomplish the aim and objectives of the research.

CHAPTER TWO

2 LITERATURE SYNTHESIS

2.1 Introduction

Chapter one presented the background, stated the research problem with the aim and objectives, and outlined the methodology and chapter breakdown. This chapter focuses on first, second and third objectives of the research study. First, the green concept in global and in Sri Lankan construction industry has been defined. Then, the significance of communication for successful green construction is justified followed by the exploration commutation barriers in green construction project. Thereafter, the possible application of AI techniques in construction industry are reviewed. Finally, a conceptual framework has been developed based on the literature synthesis undertaken.

2.2 The Concept of Green Construction

Green construction assists in tackling environmental tragedy, achieving social equity and acquiring the accompanying economic rewards in the construction industry (Ahn et al., 2017). The concept of Green within the business world emerged in the literature in 1980s and 1990s, having same background as the concepts that were adopted in businesses such as sustainability (Trandafilovic et al., 2017). Being green balances one base of sustainability as environmental health or economic vitality while sustainability focuses on three legs of its tripod as economic vitality, environmental health and social equity (Ernest, Levine, & Lancaster, 2009). But being green has become a flagship of sustainable development because its accomplishment provides long term economic, environmental and social well-being (Ali & Nsairat, 2009). Green is a concept which amalgamates best environmental and business performances within an organisation, as to be more sustainable, responsive to the society's environmental concerns, effective, competitive and attentive to the customers (Miller & Szekely, 1995).

The continuous and worst impact on natural environment can be vividly identified in construction industry (Waghmode et al., 2018). Hence, the construction is an ideal

sector to adopt the concepts of environmental responsiveness to address the global tragedy of natural environment (Orra, et al., 2019). Poveda and Young (2015) stated that the implementation of "green" within the construction industry is energised by the successive expansion of the green revolution in the markets. The concept of green has penetrated into the construction industry mainly as the term of green building, to overcome the effects of its huge participation in total energy consumption and greenhouse gas emission (Guanwardana, Maheepala, & Jayasinghe, 2017).

Green building can be defined as a structure that is designed, executed and/or operated as to minimise the environmental impacts, at least including reduced energy and water usage, minimised toxic materials and increased recycled material usage (New York City Economic Development Corporation [NYCEDC], 2007). Green buildings use resources in more efficient way compared to conventional buildings and it makes healthy and productive environment for occupants as ultimate output (Waidyasekara & Fernando, 2013). Several stakeholders should collaborate to achieve successfully sustainable design and construction of a project.

2.2.1 Adoption of Green Construction in Global Context

Green construction encompasses the resource-efficient and environmentally accountable processes throughout the life cycle of a construction project (Zhao et al., 2020). Other than the environmental soundness, there are various positive impacts of green construction (Onubi & Hassan, 2020). Therefore, the worldwide construction industry warmly welcomes this concept (Ofek et al., 2018). Unique construction components that guarantee the efficient use of resources are encompassed in green construction (Darabpour et al., 2018). Therefore, even green construction required an expanded budget than their non-green elements, the low maintenance and functioning cost can be expected throughout the building's life cycle (Olubunmi et al., 2016). Green construction tries to accommodate renewable energy rather than non-renewable energy (Dai et al., 2016). Furthermore, indoor environment quality is enhanced through green construction (Banerjee et al., 2021). As green construction encompasses different approaches for using safe material, eco-friendly approaches and ensuring occupants' health, better health conditions can be expected (Wei et al., 2015). Green building uses

material efficiently in the physical process without compromising the quality of the outcome (Olubunmi et al., 2016). Due to those positive impacts, the green concept is typically embraced by the construction industry (Ahn & Pearce, 2007). In the global context, a green rating system has been introduced to promote this invaluable concept to conserve the environment without compromising need of having built environment (Dwaikat & Ali, 2018).

World Green Building Council (WGBC) has been established to regulate green construction (Ali & Nsairat, 2009). Under WGBC, there are several green rating tools registered to ensure that the development and implementation of green construction is robust, transparent and to a good standard (Doan, et al., 2017). Building Research Establishment Environmental Assessment Method (BREEAM), Leadership in Energy and Environmental Design (LEED) and Green Star are some of such tools initiated in different countries as international rating systems (Shan & Hwang, 2018).

Though there are efforts in adopting green construction, there are still barriers and issues in implementing green construction all over the world (Darko & Chan, 2017). Higher initial construction capital compared to the capital needed for non-green construction is one of the main barriers in implementing green construction (Shen et al., 2018). Hasan and Zhang (2016) identified that the lack of expressed interest among the stakeholders and less acquaintance and knowledge for strategies and technologies in green concept are other peculiar barriers in green construction. Low levels of innovation among construction professionals also impede the growth of green design and construction (Hammond et al., 2019b). Further, the attitude to not to change is a prominent barrier in implementing green concept in conventional construction industry (Hoffman & Rebecca, 2008). Lesser interest, regional ambiguities, unawareness, narrow supply and higher prices of sustainable materials and products within the industry, concerns on warranties and risks for non-standard sustainable materials and methods, lack of codes and regulations, dearth of an integrated work setting among project stakeholders, the elongation of project schedules, lack of government incentives/support, lack of communication are further barriers that can be seen in implementing green construction (Ahn & Pearce, 2007; Azeem et al., 2017; Darko & Chan, 2017).

2.2.2 Adoption of Green Construction in Sri Lankan Context

With the rapid development, Sri Lanka also has concentrated on applying green concept in construction industry. International Finance Corporation (IFC) in 2017 has stated in the Green Building Market Intelligence Sri Lanka Profile, that government projects funded by IFC should be followed green standards since 2017. The analysis that was issued by the IFC as Climate Investment Opportunities in South Asia also expressed that 8.4 billion dollars will be invested in green buildings in Sri Lanka within the time period of 2018-2030 (IFC, 2017). It proves the awareness in green construction practices within Sri Lankan construction industry. Green Building Council of Sri Lanka (GBCSL) provides the main platform to encourage green construction in Sri Lanka. Green buildings are a direction that is gradually seizing in Sri Lanka, with some LEED-certified buildings constructed in the last decade (Pandithawatta, Zainudeen, & Perera, 2019). Although the number of these buildings are countable, there are significant efforts made in green construction in the Sri Lanka (Thalpage & Karunasena, 2016). Being a developing country and slow pace of technological advancement, the Sri Lankan construction industry encounters the barriers in embracing green construction (Pandithawatta et al., 2019).

As the collaboration of stakeholders in green construction is an extensive success factor (Ahn et al., 2017), the communication in green contruction is also an very important success factor much more than in conventional contruction process (Darko & Chan, 2017). Hence tha lack of communication barrirs the sucessful delivery of a green contruction project (Li et al., 2011). Since the green construction is a novel approach to Sri Lankan construction industry, extensive communication is needed among the stakeholders to understand, adopt and implement the process (Pandithawatta et al., 2019; Thalpage & Karunasena, 2016).

2.3 Communication in Green Construction

2.3.1 Communication

Communication exchanges information to convey a message. Effectual communication entails being able to disseminate the message in such a manner that the intended recipients receive and comprehend it (Guzman & Lewis, 2020).

Communication may transmit verbal and/or non-verbal messages. There is a sender, a receiver and a mean in the communication process (Luthra & Dahiya, 2015). Communication creates a bridge to pass the information from the sender and understand it by the sender (Ali et al., 2021). The sender encodes the message, and the receiver decodes it. Then, the feedback can be transmitted by the receiver. This information is transmitted through different types of communication channels. Adopting appropriate communication channel is essential for an effective communication (Radovic & Salamzadeh, 2018). The communication can be vague and complex since the encoding and decoding defends upon the person (Rosengren, 1999). Effective communication allows a structured flow of information from responsible sender and an understanding of captured data by the receiver (Luthra & Dahiya, 2015). It is considered as the base of the success of any implementation, organisation and project (Ali et al., 2021). Communication lays the foundation for the decision-making process (Fischer et al., 2016).

2.3.2 Need of having Greater Communication for a Successful Green Construction

Any construction project's success relies greatly on effective communication (Gunkel, 2012). Teamwork and project collaboration will also benefit from good communication (Zerfass et al., 2020). Misunderstandings, delays, and problems can arise due to poor communication (Affare, 2012). Owing to the greater focus on meeting green standards, ineffective and less communication among the stakeholders prevents achieving the goals of a green construction (Hwang et al., 2013). The ability of project team members to execute tasks together is critical to the achievement of high performance and productivity of the green construction project. For a successful green construction, communication between stakeholders regarding the four cornerstone factors such as cost, time, quality and scope should be effective (Guzman & Lewis, 2020). Hence, communication is a strategic consideration in green construction projects (Li et al., 2011). Further, as green building construction requires a more detailed design due to its complex technological characteristics, greater efforts in communication and collaboration between project parties are essential (Hwang et al., 2013). Success of any construction project relies greatly on effective communication

(Olanrewaju et al. 2017). Teamwork and project collaboration will also benefit from good communication (Li et al., 2011).

Integrated processes and approaches are encompassed in planning, designing and constructing for a successful green construction (Elforgani et al. 2006). There are many different stakeholders, including architects, engineers, contractors, construction managers, owners, building occupants, building operators, and government agents in green construction (Hammond et al. 2019a). All of the stakeholders are required to fully commit towards ensuring integrated design and construction processes for a successful green construction (Jingxiao et al. 2019). Developing an innovative and effective green building solutions through a greater communication is a prominent factor in successful green construction throughout the process (Elforgani et al. 2006; Kibert 2016). According to Robichaud and Anantatmula (2011), there are four stages in green construction namely feasibility, design, implementation and close out as shown in Table 2.1.

Table 2.1 – Stages in Green Construction Process

Project Process	**Approach**	**Required Details**
Phase 1 – Feasibility		
Project need assessment	Need a definition for the project (Ogunmakinde et al. 2017)	Project requirements, market conditions, environmental goal and green certification Level, possible capital investment
Project manager selection	Hire a competent consultant/project manager for green construction (Ogunmakinde et al. 2017; Robichaud and Anantatmula 2011)	Competent person's familiarity with the construction type, market and profound experience in all phases of sustainable construction
Preliminary site analysis and plan	Finalize economic and ecological goals, consider site characteristics and weigh building needs against ecological issues (Ogunmakinde et al. 2017; Robichaud and Anantatmula 2011) A Green Certification checklist and documenting system is developed for the remaining	Economic and ecological data for analysis Geological records, community needs and ecological concerns of the Site Resource allocation for Project's goals Project priorities Details of green certification system

Project Process	Approach	Required Details
	portion of the feasibility stage (Agyekum et al. 2019)	
Design charrette	Collaborative meeting with all key external stakeholders, including surrounding property owners and other community representatives which considers the functions namely design, architecture, building contractor, environmental engineer, real estate consultant, etc. (Valdes-Vasquez et al. 2014)	Details of all key external stakeholders Scope of the project Assessments and conclusion achieved through the meeting with all key stakeholders and considering project team functions
Final site selection	Select site based on stakeholder involvement including community input (Korchagina et al. 2013)	Details regarding the reuse and restoration of existing buildings and sites Details of natural and agricultural resources Details of biodiversity and hydrology Details of construction waste and disposal Details of expected light pollution Details of heat island effect
Phase 2 – Design		
Initial budget and schedule	Complete preconstruction estimates (Tsai et al. 2014) Estimate costs associated with specialized areas like green-building products (Tsai et al. 2014) An emphasis on life cycle costing, shifting focus from short-term return on investment to long-term gains from operational savings (Robichaud and Anantatmula 2011)	Input from the contractor, structural engineer, project manager, quantity surveyor, architect, and real estate consultant Design cost, construction cost, Energy cost, water cost, sewerage cost, Building maintenance cost and building deconstruction cost (Dwaikat & Ali, 2018)
Zoning approval	Site will be planned by following feedback from design charrette and the from local government planners and other regulatory (Robichaud and Anantatmula 2011)	Feedback from the Charette

Project Process	Approach	Required Details
Design team selection	Usually, the core design team has already been selected by this time.	Experience and capabilities of the core team members
Construction document development	Because the integrated team has participated in the planning and design process, construction documents can be developed more efficiently and with little design modifications	Conclusions and decisions made so far.
Government permitting review	Construction owners and the consultants must obtain accurate cost information for bid selection (Tsai et al. 2014)	Details of applicable government stakeholders and their decisions
Project bidding	Complete preconstruction estimates (Tsai et al. 2014) Estimate costs associated with specialized areas like green-building products (Tsai et al. 2014) An emphasis on life cycle costing, shifting focus from short-term return on investment to long-term gains from operational savings (Robichaud and Anantatmula 2011)	Experience and capabilities of the subcontractors
Phase 3 - Implementation		
Contracting	Integrated development requires a different kind of client/ architect and client/contractor contract (Jingxiao et al. 2019)	Performance agreements, incentives, and bonuses referring implementing green construction Specific provisions for marks attainable through green certification, requirements in Energy Star, the use of recyclable materials, on-site recycling requirements, and agreements to return residual materials to vendors
Construction	Implement sustainable construction practices (Hwang et al. 2013) Periodic education and training sessions on green building (Hasan and Zhang 2016; Wimala et al. 2016)	Details for learning and training sessions on green construction

Project Process	Approach	Required Details
	Sustainable requirements are reviewed with each subcontractor prior to commencing work (Ahn et al. 2017)	Requirements in Sustainable building
Inspections	Necessary inspections and tests for attaining green goals by supervision team (Raouf & Al-Ghamdi, 2020)	Specifications Log Notes at site
Green certification	Following up and documentation of achievements of sustainability benchmarks prescribed in Green Certification (Agyekum et al. 2019)	
Phase 4 – Close Out		
Occupancy and operations	Building commissioning to ensure functioning of the building systems as intended	Commissioning check list Owner's project requirements

In feasibility stage, a greater communication is required among the stakeholders to analyse the viability of the green construction project as depicted in Table 2.1. The design charrette creates and supports for a feasible action plan in green construction with the involvement of all key participants. Incorporating a charrette at the beginning of a construction project is a solution to improve communication and exchanging ideas among a project's stakeholder group (Robichaud & Anantatmula 2011). Further, to select a competent project manager, the construction owners have to consider the experience and capabilities in executing green project (Jingxiao et al. 2019). Construction owners must collect accurate cost information to support bidding judgments in green construction as there are specified cost items such as carbon dioxide emission tax, green building materials, renewable energy sources etc. (Tsai et al. 2014). For a successful green project delivery, it is required to collect, store, analyse and interpret availble past data, real time data, relevant information from stakeholders and hindden data in construction site during tha designing, implementation and also close out phases of green construction (Robichaud and Anantatmula 2011). Accordingly, the green project may require particular and a more detailed communications analysis to keep stakeholders informed throughout the project.

2.4 Barriers in Communication in Green Construction

Quality of relationships and collaboration among construction project stakeholders which direct to an outstanding project performance is relied upon an effective communication (Affare, 2012). Effective communication ensures the achievements of goal in construction projects. It improves knowledge sharing and integration of all stakeholders in a construction project. Dainty et al. (2006) defines effective communication as the process whereby feedback is received for information that is conveyed. Hence, effective communication will ensure successful project performance and makes advancements in the construction industry. Therefore, understanding the barriers to effective communication is vital to improve the communication in construction projects and ultimately achieve the successful project delivery. Table 2.2 presents the barriers to effective communication in the context of construction projects and in green construction. The codes used to identify each barrier will later be used in the primary data analysis.

Table 2.2 – Barriers to effective communication in the construction industry

CODE	Communication Barriers	Identified for any Construction Project						Particularly identified for Green Construction		
		(Ejohwomu et al., 2017)	(Affare, 2012)	(Olanrewaju et al., 2017)	(Meng & Boyd, 2017)	(Thevendran &	(Gamil & Rahaman,	(Zulch, 2014)	(Hasan & Zhang, 2016)	(Wimala et al., 2016)
B1	Political/community interference	√	√	√				√		
B2	Poor listeners	√	√		√	√	√			
B3	Poor leadership	√	√			√	√			
B4	Unclear objectives	√	√			√	√	√		
B5	Conflicting cultural values	√	√			√	√			
B6	Unclear channels of communication	√	√	√	√	√	√	√	√	√
B7	Ineffective reporting system	√	√	√	√	√	√	√	√	√

CODE	Communication Barriers	Identified for any Construction Project						Particularly identified for Green Construction		
		(Ejohwomu et al., 2017)	(Affare, 2012)	(Olanrewaju et al., 2017)	(Meng & Boyd, 2017)	(Thevendran &	(Gamil & Rahaman,	(Zulch, 2014)	(Hasan & Zhang, 2016)	(Wimala et al., 2016)
B8	Information filtering	√	√	√	√	√	√	√	√	√
B9	Conflicting business/industry ethics	√	√						√	
B10	Lack of necessary skills	√	√					√		
B11	Lack of trust	√	√							√
B12	Lack of Concern	√	√							
B13	Limited Resources	√	√							
B14	Stereotyping	√	√							
B15	Religious issues	√	√							
B16	Language difficulties	√	√							
B17	Age Differences	√	√							

Communication is particularly crucial for the green project to transmit the sustainable practices envisioned by the project stakeholders (Affare, 2012). Hereunder, the barriers for effective communication in construction projects are discussed. Each communication barrier has been assigned with a code ranging from B1 to B17 to be used for further analysis.

2.4.1 B1 – Political/ Community Interference

Political and community context for a construction project tends to inform and consult local communities about the impacts on the society from a particular construction project in general. Typically, a green construction project is undertaken in a low supportive atmosphere (Wimala et al., 2016). Therefore, political and community interference obviously affects the project management of green construction projects (Zulch, 2014; Tabish & Jha, 2011). The communication which is a branch of a project

management process will be barriered by this political and community interference (Olanrewaju et al., 2017). The political and community interference causes in selective perceptions among project stakeholders (Affare, 2012). These different selective perceptions interpret the information in a way that is compatible with existing political and community context of a construction project over real context (Ejohwomu et al., 2017).

2.4.2 B2 – Poor listeners

Poor listeners among the project stakeholders is another barrier to the effective communication in construction project (Ejohwomu et al., 2017). Listening is not just an act of perceiving a sound from ears, but it is required a conscious to understand the things told by someone (Affare, 2012). Poor listening permits individual's assumptions and misunderstandings. It makes errors, counterproductive decisions, and/or costly missteps (Olanrewaju et al., 2017). For a successful construction project delivery, the understating and concerning on guidance, decisions and instructions given by a stakeholder is important part in project communication. The poor listening is a personal condition. Therefore, the poor listening barriers the effective communication irrespective of the project type where the human beings are engaged.

2.4.3 B3 – Poor Leadership

A poor leadership has the potential to harm teams, businesses, workplace dynamics, and the processes (Ejohwomu et al., 2017). Leadership takes charge, directs, encourages and stimulates others. Leaders should have an attitude to convince others and to make them follow the defined goals for project (Luthra & Dahiya, 2015). Accordingly, disputes, time overruns, cost overruns in construction projects are caused by poor communication by the leadership of the project (Thevendran & Mawdesley, 2004). A leader cannot become an effective leader without an excellent communication capability (Neill, 2018). In the context of communication, poor leadership shows unprofessional language, poor listening skills, problems in giving and receiving the feedbacks and informing the decisions (Wimala et al., 2016). Therefore, poor leadership skills deteriorate the effective communication in a construction project.

2.4.4 B4 – Unclear objectives

Unclear objectives create problem in communication that continues to plague many projects (Affare, 2012). Vague direction for a construction project causes indistinct activities and process in a construction project (Meng & Boyd, 2017). Therefore, unclear objectives fuel the communication issues in a construction project as well as almost all the project implementations (Mitkus & Mitkus, 2014). Due to unclear objectives of a project, information flow, type of information and responsibilities will not be defined in the context of the project communication (Tipili et al., 2014). Further, those foggy goals and objectives form politics among project stakeholders as doubtfulness and poor directives emphasise in the pace of project implementation (Wimala et al., 2016). Accordingly, the effective communication in construction project is deteriorated through unclear objectives.

2.4.5 B5 – Conflicting Cultural Values

Cultural values are the core principles upon which culture exists and rely upon for existence and cooperative relationship (Gamil & Rahaman, 2017). These cultural values exert an emphatic influence on the objects, events, and concepts to which people follow (Liu et al., 2001). People from diverse cultures prefer different groups, messages, and means to affect the transmission (Wimala et al., 2016). Several researchers conducted studies on the impact of cultural values on communication in construction project (Loosemore & Muslmani, 1999). Depending upon the shared cultural value among a set of stakeholders, information might not be achieved by the peculiar stakeholder at the precise time in a construction project. Accordingly, the effective communication in construction project is weakened through conflicting cultural values.

2.4.6 B6 – Unclear Channels of Communication

In construction industry, there are established communication channels to disseminate the information among the project stakeholders. Hence, each stakeholder is responsible of transmitting the related information through assigned channel of communication (Hasan & Zhang, 2016). Because of the dynamic and complex nature in construction industry, numerous communication problems befall (Ozmen et al.,

2016). Hence, pre-established communication channelling is implemented to manage and control this communication process. However, Affare (2012) stated that unclear channels of communications result in project delay as disseminating the required information is not properly taken place. Hence, it is very important to regulate the channels of communication in construction industry to maintain a structured and fast communication process (Ejohwomu et al., 2017). Accordingly, Lee and Bernold (2008) reported that absence of data channels and unplanned data channels extremely hamper the effective communication in construction project.

2.4.7 B7 – Ineffective Reporting System

Maintaining an effective reporting system is one of the main determinants to successful project completion. The project reporting demand coordinated information and integration from all project stages and construction activities (Ozmen et al., 2016). Due to the existence of a vast amount of data and inherent complexity, an ineffective reporting system can be grasped in a construction project (Ejohwomu et al., 2017). Accordingly, effective communication in a construction project is deteriorated through ineffective reporting system.

2.4.8 B8 – Information Filtering

Information filtering happens where the sender manipulates information (Ozmen et al., 2016). The number of levels in an organisation's structure causes information filtering, to a greater degree. The more vertical levels in the organisation's hierarchy allow for more opportunities for filtering. Filtering prevents stakeholders in a construction project from getting the complete picture of a situation (Ejohwomu et al., 2017). Accordingly, information filtering severely affects the effective communication in a construction project.

2.4.9 B9 – Conflicting Business/Industry Ethics

Business/ industry ethics ensure that a certain primary level of trust exists between consumers and various market participants in businesses/ industry (Ozmen et al., 2016). Each organisation has an underlying business ethic programme. Besides, each organisation adapts different perceptions of ethics in the industry. The construction

project is a collaboration of different stakeholders from different organisations. Therefore, these stakeholders do have not identical perceptions or admiration for the business/ industry ethics (Affare, 2012). Consequently, conflicts over business and industry ethics can emerge among the stakeholders. These conflicts may lead to ineffective communication among the stakeholders in the construction industry (Ejohwomu et al., 2017).

2.4.10 B10 – Lack of Necessary Skills

Having strong communication skills aids in transferring information (Ejohwomu et al., 2017). From a construction project standpoint, communication among the stakeholders plays a vital role as it is essential where different and the number of stakeholders involved, dynamic and complex in its inherent nature (Affare, 2012). Effective communication happens when the communicated information is clear, concise, concrete, correct, coherent, complete and courteous (Ozmen et al., 2016). To encompass those in communication, the sender and receiver of information have to incorporate different skills in verbal, written and non-verbal communication (Ejohwomu et al., 2017). The absence and lack of such skills deteriorate effective communication in a construction project.

2.4.11 B11 – Lack of Trust

It is extremely difficult to communicate anything when there is a lack of trust (Zulch, 2014). Lack of trust indicates the transparency issues in communication among different stakeholder (Fischer et al., 2016). For an instance, if the subordinates believe the employer is not trusting them, they are inclined to be concerned, some will speculate, and as a result, it will be more difficult for them to process any attempt that employer makes to communicate with them (Ozmen et al., 2016). Therefore, the required information will not be transmitted to responsible stakeholders properly (Fischer et al., 2016). Accordingly, lack of trust acts as a key barrier in effective communication in a construction project.

2.4.12 B12 – Lack of Concern

When a person's consciousness is distracted or preoccupied with other matters, the person cannot form a particular message, grasp what others communicate, interpret the message as required and give relevant feedback (Ozmen et al., 2016). Then communication will face problems and becomes ineffective. Lack of concern will ruin effective communication in the construction project as it is dynamic and complex with multiple stakeholders involved (Ejohwomu et al., 2017).

2.4.13 B13 – Limited Resources

To attain a successful communication between parties, there should be certain physical and logical devices at each and intermediate level in the information dissemination (Cheng et al., 2001). Therefore, it is obvious that absence of such required resources in the communication system diminish the effectiveness and efficiency of communication (Gamil & Rahaman, 2017). Accordingly, limited resources for the communication purposes will undeniably deteriorate the effective communication in construction project where ton of information are to be disseminated.

2.4.14 B14 – Stereotyping

The factors such as nationality, gender, age, ethnicity, race, religion, and other socio-economic factors lead to pre assumptions about others, in individuals' mindsets. Then and there the stereotyping among the people is emerged (Ejohwomu et al., 2017). When a stakeholder stereotypes, that stakeholder draw conclusions about another set of stakeholders based on common assumptions. For an instance, employees may sense discomfiting in communicating frankly with those who they perceive as aggressive or uncooperative based on stereotypes (Loosemore & Tan, 2000). Accordingly, effective communication in a construction project deteriorates through stereotyping among the groups of stakeholders.

2.4.15 B15 – Religious Issues

Religious beliefs shape each individual perceptions and behaviours. These religious beliefs apply a strong impact on the objects, events, and ideas to which people attend (Liu et al., 2001). People from diverse religious background prefer different groups,

messages, and means to affect the transmission. Several researchers conducted studies on the impact of religious issues on communication in construction project (Loosemore & Muslmani, 1999). Depending upon the shared religious beliefs among a set of stakeholders, information might not be achieved by the peculiar stakeholder at the precise time in a construction project (Ejohwomu et al., 2017). Accordingly, the effective communication in construction project will be affected through religious issues.

2.4.16 B16 – Language Difficulties

If a stakeholder wants to converse with someone who does not speak the same language, reaching a shared understanding is nearly impossible with the other stakeholder (Azhar & Abeln, 2014). Therefore, language difficulty is a prominent barrier to communication. These language difficulties are not only encountered just because of the different dialects but due to jargon too (Ejohwomu et al., 2017). Human resource plays a vital role in the construction industry. As different stakeholders are equipped with different skills, come from different regional contexts and geographical areas, the language barriers are typical in a construction project (Olanrewaju et al., 2017). As such language difficulties has been identified as a key barrier for effective communication in a construction project.

2.4.17 B17 – Age Differences

With typical ageing, communication skills vary subtly at least in part due to differences in physical health, depression, and cognitive decline (Ejohwomu et al., 2017). Ageing is responsible for physiologic changes in hearing, voice, and speech processing. Furthermore, the language skills persist intact, whereas others tend to weaken (Zulch, 2014). Other than that, the generation gap that arises through age difference also influences communication (Olanrewaju et al., 2017). Accordingly, effective communication in a construction project deteriorates through age differences.

Due to the barriers in communication discussed above, it is visible that the effectiveness in communication is affected by several barriers which might hinder the enhancement of green construction. To make the communication effective in the process of green construction, it is vital to device a mechanism that would address the

gaps in the traditional communication routes. Accordingly, this research intends to explore how the techniques used in AI can be a potential media to enahance communication in green construction. As such the following section focuses on the application of AI techniques in the construction industry.

2.5 Application of Artificial Intelligence in Construction Industry

The construction industry rapidly welcomes digital technology and big data in recent decades (Wang et al., 2022). The adoption of Artificial Intelligence (AI) has particularly gained vital attention in the construction industry. AI-based systems attempt to equip appliances with human-like intelligence for better construction management (Manzoor et al., 2021). AI is not a classical computational model or else expert judgment. It effectively deals with the dynamic, complex and uncertain environments which are definite characteristics of construction projects. AI gives accurate and convincing results through the analysis of extensive data (Waziri et al., 2017). AI techniques have created massive value in transfiguring more reliable, automated, self-modifying, time-saving, and cost-effective processes in management in the construction industry (Lu et al., 2012). AI shows the tremendous possibility to address various engineering projects according to their characteristics since AI's capability in automating and accelerating the procedure of learning, reasoning and perceiving from large data (Pan & Zhang, 2021). Diversified AI-based solutions are utilised for each construction project based on the unique characteristics of the particular construction project (Eber, 2019). Accordingly, AI-based solutions suggest the most preferable strategic decision for a construction project under complicated and dynamic settings without human participation (Pan & Zhang, 2021).

2.5.1 Artificial Intelligence Techniques in Construction Industry

Different AI-related techniques can eventually accomplish operations that are advantageous to construction management through automation, risk mitigation, high efficiency, digitalisation, and computer vision (Pan & Zhang, 2021). AI techniques assist in product quality controlling processes and design stages in a construction project (Manzoor et al., 2021). Hereunder, thirteen artificial intelligent techniques (AIT) that can be applied in construction industry for better performances are

discussed. Each artificial intelligent technique has been assigned with a code of from AIT1 – AIT13.

2.5.1.1 AIT1 – Knowledge Representation and Reasoning

Knowledge representation and reasoning is a field of AI that designs computer model to capture real-world information that can be used for complex problem-solving (Levesque & Brachman, 2003). Instead of complex algorithms or statistics, a knowledge-based system is applied in this AI technique (Lakemeyer & Nebel, 1994). The computer can logically recognise available knowledge, facts, and beliefs from the real world, and then utilise them to draw valid determinations. It facilitates logic inference transparently and efficiently (Levesque & Brachman, 2003).

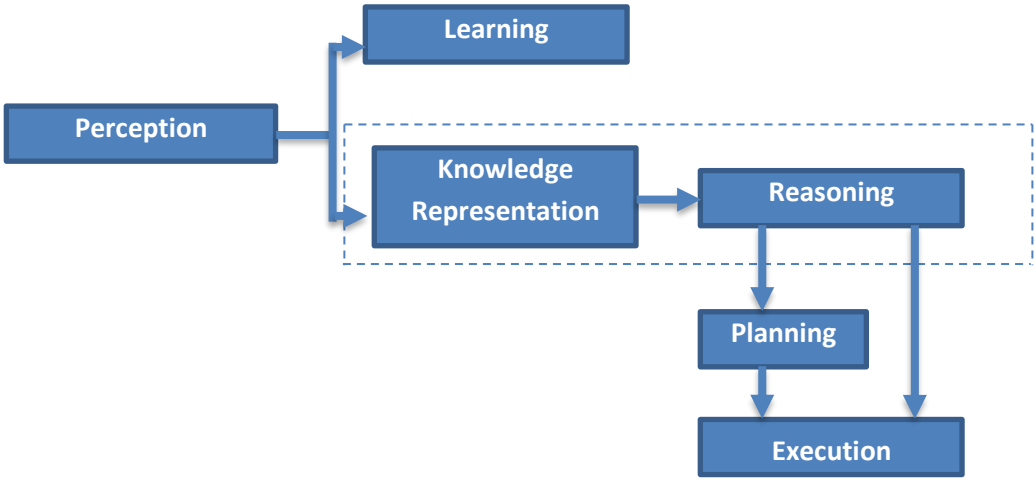


Figure 2-1 - Illustration for Knowledge Representation and Reasoning

Source: Regenerated from https://www.edureka.co/blog/knowledge-representation-in-ai/

Figure 2.1 demonstrates an example of how the knowledge representation and reasoning technique is working. Perception component grasps the knowledge from the environment (Lakemeyer & Nebel, 1994). Learning component learns from these captured data. Then the knowledge representation and reasoning component tries to understand or build intelligent behaviour from the top-down and concentrate on what an agent ought to understand to behave intelligently (Levesque & Brachman, 2003). It has been found that there are possible applications of this AI technique in construction industry. This AI technique effectively models, analyses and forecasts different construction project uncertainties. Some of those can be identified as uncertainties

related to operation quality, cost, scheduling, contract, structural performances and complex construction atmosphere. Likewise, AIT1 allows to recognise the critical factors and to propose more appropriate strategies to minimise failure probability (Pan & Zhang, 2021).

2.5.1.2 AIT2 – Information Fusion

Information fusion is a combined process of collecting information from the source of the same object or scene to acquire more complicated, steadfast and precise information (Nakamura et al., 2007). In construciton projects, the construction sites can be installed with deifferent types of sensors for data acquisition. Due to this type of gathered data possesses extensive hidden knowledge, information fusion integrates the data from multiple sources for better detection, deduction, and portrayal. Overall evaluation of such information ensure the efficiency, reliability, and sustainability of the project (Pan & Zhang, 2021).

2.5.1.3 AIT3 – Intelligent Optimisation

Intelligent optimisation derives the optimal solution among different alternatives. Intelligent optimisation can be applied mainly in two contexts. One context is single objective optimisation to identify a single optimal alternative; while the other context is multi-objective optimisation to identify more than one objective functions and then yield a viable set of conclusions (Pham & Karaboga, 2005). The selection of the most optimal solution in the construction industry is particularly practised under high complicatedness and dynamic nature could be unwieldy and time-consuming (Bilal, et al., 2016). To ease such a process, various types of optimisation techniques have been developed in the construction industry. It reduces the required time for determining the optimal solution for a problem. Genetic algorithm (GA), simulated annealing (SA), particle swarm optimization (PSO), shuffled frog-leaping algorithm (SFLA), firefly algorithm (FA), differential evolution (DE), artificial bee colony (ABC), ant colony optimisation (ACO), have been extensively used in construction management in civil engineering projects (Pan & Zhang, 2021).

2.5.1.4 AIT4 – Smart Robotics

Smart robotics has been playing a vital role in broader scope in terms of semi or fully automating the construction industry (Pan & Zhang, 2021). As an example, the application of robots in repeatable tasks is welcomed and frequently used in the construction industry. Further construction robots are designed based on human requirements in the construction industry (Prasad & Agrawal, 2019).

2.5.1.5 AIT5 – Computer Vision

Computer vision in construction projects has attracted significant interest over the last few years (Fang et al., 2018). In computer vision, image data is captured through different equipment, like cameras, unmanned aerial vehicles, light detection and ranging, and others (Martinez et al., 2019). Then, these captured image data are converted into actional information in a reliable, fast, and cost-effective manner (Paneru & Jeelani, 2021). Therefore, computer vision offers non-contact and remote solutions for project monitoring (Chian et al., 2021). Computer vision ensures automatic vision-based inspection over site activities that tend to be wrong, time-consuming, laborious and dangerous in manual observation (Kazemian et al., 2019).

2.5.1.6 AIT6 – Process Mining

Process mining is a young technology that offers actual operations rather than the ideal processes (Ahn et al., 2015). It analyses a large amount of data that cannot be managed in a manual interpretation (Caron et al., 2013). Therefore, it allows accessing actual context rather than assumptions-based context. It depicts the contemporary situation of actual processes by investigating real-time data and event logs to determine blockages, reduce unneeded steps, and present solid insights (Zerbino et al., 2021). Consequently, process mining proposes the key components of the process and notify decisions to accelerate and get assisted the process (Pan & Zhang, 2021). Furthermore, process mining assists in risk management in construction projects as it considers the real scenarios (Caron et al., 2013).

2.5.1.7 AIT7 – Cloud Virtual and Augmented Reality (Cloud VR/AR)

Virtual reality (VR) creates an artificial, simulated environment that provides an immersive understanding whereas Augmented reality (AR) enhances the real physical world with digital elements (Bello, et al., 2021). The speed and effectiveness of the application of VR/AR are maximised in the cloud concept (Elghaish, et al., 2020). Hence, cloud VR/AR solutions enhance users' experience in typical VR/ AR applications. VR and AR applications visualise available information to realise more connections between physical and cyber properties (Jiao et al., 2013). VR/AR is applied to simulate the risky phenomena in construction projects. It creates an immersive environment to analyse the available information (Noghabaei et al.,2020). It helps managers to identify underlying risks and issues efficiently and effortlessly in the working environment and then to draft reasonable objectives and measures to overcome them (Pan & Zhang, 2021).

2.5.1.8 AIT8 – Natural Language Processing (NLP)

There are different behavioural or psychological change theories or models contain different elements that determine a change of motivational factors are one such element that can influence the desired behaviour or psychological (Kotera & Van Gordon, 2019). NLP identifies how excellent consequences are executed in each of the personal development and psychotherapy disciplines. Then, these insights to enable continuous advancements in human functioning (Craft, 2001). Hence, the implementation of NLP for business excellency has been researched in many industries (Singh & Abraham, 2008; Kotera & Van Gordon, 2019). Therefore, overcoming the behavioural economy hindrance for adopting green construction through NLP will be effective as NLP directly addresses the individuals' perceptions, attitudes, and behaviours to overcome individual level barriers (Craft, 2001). Further, NLP guides computers to process, analyse, and decrypt text and words through a human-like natural language cognition (Olsson & Rexmyr, 2017). The conventional manual mode of investigating the free-text data tends to leave some of the valuable facts unexplored. NLP can retrieve and interpret influential information from the safety

reports. Therefore, it can be seen a growing interest in NLP in construction management to improve construction safety (Pan & Zhang, 2021).

2.5.1.9 AIT9 – Artificial Intelligence of Things (AIoT)

IoT can be identified as a network of interconnected physical devices such as drones, sensors, radio frequency identification devices3D laser scanners, wearable and mobile devices etc. which is affixed to the construction resources. This network gathers real-time data about the operational status of the project through those devices (Pan & Zhang, 2021). In AIoT domain, this network will equip with AI applications. It enhances human-machine integration and enhances data management and analytics. AI can be used to convert IoT data into valuable information for detailed and reasoned decision making (Ng et al., 2021).

2.5.1.10 AIT10 – Digital twin

A digital twin is a digital representation of a physical entity (El Jazzar et al., 2020). Intelligent multidimensional digital models in digital twin integrate a building's system, sensor, and utility meter data (Kaewunruen & Xu, 2018). A digital twin owns the functional and behavioural awareness required to simulate, foresee, and inform judgments based on real-world conditions (Boje et al., 2020). In the digital twin, the smart elements and devices affixed to the physical asset allow collecting real-time data of respective physical assets and comparing them with historical information. Then, the AI can update the digital twin according to the transformation in physical assets (El Jazzar et al., 2020). A digital twin can supply a regularly updated source of information to the entire project team in each stage of a construction project. The data flow between office and site is stored and easily accessible from one location (Pan & Zhang, 2021).

2.5.1.11 AIT11 – 4D Printing

Three-dimensional printing takes a digital blueprint and pivots it into a physical asset using computer-aided design (Tibbits, 2014). The four-dimensional (4D) printing integrates the fourth dimension from time into 3D printing, allowing the entities to adjust their shape and behaviour over time concerning external factors such as

humidity, heat, light, wind, temperature, and others (Momeni et al., 2017). Notably, 4D printing possesses all worth from 3D printing (Mitchell et al., 2018). 4D printing allows the utilisation of advanced and sustainable materials, making building more efficient while producing less waste (Pan & Zhang, 2021).

2.5.1.12 AIT12 – Blockchain

Blockchain is a shared infrastructure that allows recording information as a digital ledger (Perera et al., 2020). There are verified chains with blocks of information, and each block contains data related to processes (Belle, 2017). It is duplicated and distributed across a network of computer systems. Since the blockchain builds a distributed ledger, all stakeholders who have access to the network can concurrently get in touch with the stored digital information (Li et al., 2019). The information in blockchain can change and hack hardly or not at all (Shojaei, 2019). Therefore, the security of recorded information can be assured through this technology (Scott et al., 2021). Blockchain technology can be efficiently used in the area of building information modelling, contract administration, electronic document management, property management, procurement management and finance management in construction project (Pan & Zhang, 2021).

2.5.1.13 AIT13 – Machine Learning

Machine learning technique learns automatically through statistical algorithms without the intervention of human. It is required ample information or knowledge to implement machine learning (Chen et al., 2008). It is foreseen future results through machine learning without the presence of a human. Instead of programming, machine learning uses statistical algorithms in analysing the available information. In the construction industry, machine learning assists in project management as it can foresee the risk and issues involved. Therefore, enhanced design and planning of construction projects can be attained through machine learning (Pan & Zhang, 2021).

Having reviewed several AI techniques in isolation, the following sections present the application of AI techniques in green construction in general and in communication in particular.

2.5.2 Application of Artificial Intelligence in Green Construction

Gilner, Galuszka and Grychowski (2019) has identified that there is an immense effect on improving, accelerating and rationalizing the decisions making in the early design phase of through applying the AI in sustainable construction. Same authors highlighted that application of AI takes part in the energy efficiency of a green building as it empowers the achievement of regulations and standards. Adding to that, Elshafei and Negm (2017) has found that the applciation of AI is very efficient and effective in environmental problems related to green architecure/ building. AI utilises experiences and historical data when making a decision as human intelligence does. As powerful computing power and advanced algorithms are there, the construction industry can effectively gather, analyse and draft conclusions for the problems in construction projects through AI applications. For an instance, as the historical experience and knowledge are processed the effect of a design selection can be seen not only just for a phase but for the entire life cycle of the building. Accordingly, AI applications bypass the memory gap existing in the construction industry in terms of projects and sharing knowledge from previous experience. Hence, AI creates a great space to analyse the previous experience in designing, constructing and using a particular built structure. Therefore, AI applications optimise future structures with these historical data (Mathern et al., 2019). It adds more and more value to the green construction far more than conventional building, as there are few projects are available. Accordingly, artificial intelligence opens up enormous CO2 saving potential for buildings (Elshafei and Negm, 2017)

2.5.3 Application of Artificial Intelligence in Communication

When it considers even daily life, AI has become a part of the daily communication routine all over the world (Campolo et al., 2017). Amazon's Alexa, Apple's Siri, and other digital assistants are some of the examples of this fact (Pew Research Center, 2017). Individuals are further expecting advanced interactions in communication through AI applications (Rainie and Anderson, 2017). Some media providers use AI-enabled technologies to convey the news to their audience (Marconi et al., 2017). Hence, communication and artificial intelligence (AI) are closely coupled throughout the world. Gunkel (2012) highlighted the introduction of new opportunities by AI

applications for communication studies. AI applications enhance particularly interpersonal conversational interactions (Guzman & Lewis, 2020). AI automate communication systems through an application such as chatbots (Gunkel, 2012). In terms of customer care communication, AI does a greater impact. The application of AI responds the same way to a scenario without the apprehension of emotional or any other impacts (Guzman & Lewis, 2020).

Industry revolution 4.0 increases the digitisation and automation of the manufacturing industry while creating a digital value chain to enhance the communication among products, their environment and business stakeholders (Gunkel, 2012). In the context of AI application, it allows machines and software algorithms to imitate human cognitive abilities for human-based content. This will lead to new way of generating, communicating and consuming data (Guzman and Lewis 2020). Social networking platforms and personalised communication will be more intelligent and sophisticated. In near future, the human emotions which are being conveyed as data by humans will be equally or will be contributed by machines (Jakesch, et al. 2019). Combined with virtual and augmented reality, self-learning systems or intelligent systems will percolate mass communication and personal communication (Guzman and Lewis 2020). Wiesenberg et al. (2017) found that the implementation of big data and automation which are the technologies linked to the AI bring unique opportunities for strategic communication. Furthermore, Zerfass et al. (2020) studied initial insights on the advent of AI in communication management. AI techniques can particularly help construction companies to reduce complexity and uncertainty, to enhance information exchange and communication between project stakeholders and thus to increase productivity and quality (Guzman and Lewis, 2020). As there are numerous project stakeholders involved in each construction project, the use of Augmented Reality (AR) can be used for effective communication in the construction industry. Furthermore, cloud based and BIM-based platforms or social media apps can efficiently enhance the collaboration and communication even across company borders (Oesterreich and Teuteberg, 2016).

2.6 A Conceptual Framework for Application of Artificial Intelligence for Effective Communication in Green Construction

The findings through the comprehensive literature review for the areas mentioned in the objectives for the Artificial Intelligence in communication in green construction, are mapped together using a conceptual framework as presented in Figure 2.2. The framework can be applied to find out the relationship between Artificial Intelligence application and effective communication in green Construction.

The conceptual framework in Figure 2.2 shows how application of Artificial Intelligence assists in effective communication in different stages in the green construction project. Good communication is important in green construction (Mohamad Bohari et al., 2016). Misunderstandings, delays, and problems can arise because of poor communication. Effective communication improves the teamwork and project collaboration which are highly impactive to successful green construction (Gamil & Rahaman, 2017). Apart from the huge investment on time and money in a conventional construction project, meeting green goals needs additional effort in green construction project. Prominently, in feasibility phase of a green construction the viability of the project and particularly attainability of green goals are analysed (Jingxiao et al. 2019). Further, as shown in Figure 2.2 even in design phase of a green construction, attainability of green goals through the available budget and design team should be analysed. Therefore, the goals in green construction should be compared with available project details and past details of such projects. Nevertheless, limited knowledge in green construction is one of the greater barriers in adaptation and implementation of green concept in construction industry (Abubakar et al. 2019). As such, due to the limited knowledge on green construction among project participants at initial stages, the relevant communication can be deteriorated. Therefore, optimising the use of the available knowledge is important in effective communication in these stages in green construction (Gamil & Rahaman, 2017). In the application of AI, knowledge representation and reasoning rationally understand the available knowledge, facts, and beliefs from the real world, and then make use of them to draw valid conclusions and facilitate logic inference in a transparent and efficient manner (Pan and Zhang, 2021). In the process of green certification, communicating the data

from construction site is highly considered as the construction process has the immense negative impact on the environment (Robichaud & Anantatmula, 2011). Computer vision, cloud virtual and augmented reality and Artificial Intelligence of Things (AIoT) allow to capture the real time and hidden data of the construction site (Bello, et al., 2021). Extraction, storing, analysing and interpreting the data from the real world, stakeholders and construction site are needed in effective communication in every stage in green construction (Rawai et al. 2013). Further to that, the application of AI does such data extraction, storing, analysis and interpretation (Pan and Zhang 2021; Perera et al. 2020). Accordingly, this conceptual framework depicts a bridge of AI application in effective communication in green construction as per the literature findings considering the global context. The conceptual framework clearly indicates that application of AI techniques can facilitate an effective communication in green construction.

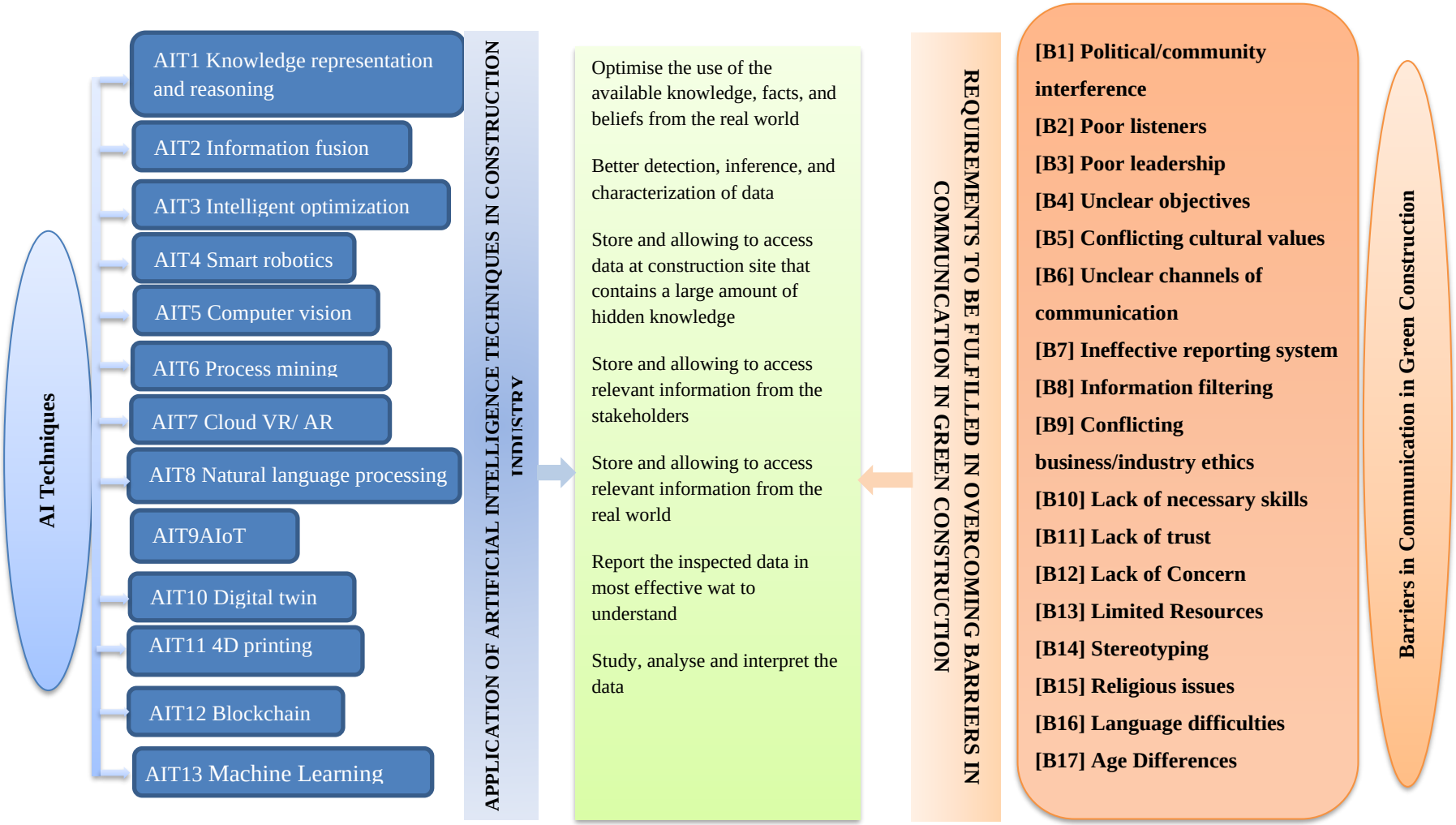


Figure 2-2 - Application of AI techniques for an effective communication in green construction

2.7 Chapter Summary

This Chapter presented the literature findings for the study. Accordingly, first objective of the study which was to critically review the concept of green construction in a global context and in the context of Sri Lanka is achieved. Then the initiation for the second and third objectives which were to investigate barriers related to effective communication among project stakeholders in successfully delivering green construction in Sri Lanka and to critically review Artificial Intelligence (AI) techniques that can be used in construction industry in Sri Lanka were taken through this literature analysis. Hence the chapter two presented about the green construction, artificial intelligence techniques and communication barriers in green construction project. Defining and identifying the green concept adoption in Sri Lankan and global construction industry were done. After that the possible application of AI techniques in construction industry were presented. Then, the commutation barriers in green construction project were explained. Finally, a conceptual framework for possibility of applying AI techniques in overcoming communication barriers in green construction projects was developed.

CHAPTER THREE

3 RESEARCH METHODOLOGY

3.1 Introduction

This chapter explains the scientific and systematic way to answer the research question. Accordingly, the selected research approach and methods for this study are discoursed with justifications. Subsequently, techniques used for collection and analysis of the data for the study are explained. Finally, the research process from research question till analysing, evaluating and finalising the results are depicted.

3.2 Research Methodological Design

A research methodological design for a study can be recognised as a structure which is developed to answer the research question in particular study (Kerlinger, 1986). Further, the research methodology draws the most justifiable, transparent, and clear path the researcher intends to answer the research problem with the idea about commencement, direction of the research, action plan with suitable data collection and analysis techniques (Jonker & Pennink, 2010). The research methodological design encompasses a system of the deems and philosophical views which shape up the stance for answering the research problem (Melnikovas, 2018).

The main framework accessible for research methodology in research in built environment are nested method and research onion (Omotayo & Kulatunga, 2015). Depending on the nature of the research objectives, the researcher can select the most suitable system. Though both the systems incorporating a systematic process towards conducting a research while providing a foundation to draw an infomred decisions, research onion is more comprehensive than nested method due to its detailed structure (Kulatunga, Amaratunga, & Haigh, 2007). The research onion which is developed by Saunders et al. (2016), provides a detailed illustration for the main stages which are to be encompassed to develop a suitable methodology. The research methodology is drawn upon the identifying the research philosophy, selecting approaches, research methods and

strategies, defining time horizon, adapting the techniques, procedures of data collection and finally analysis of the data (Figure 3.1).

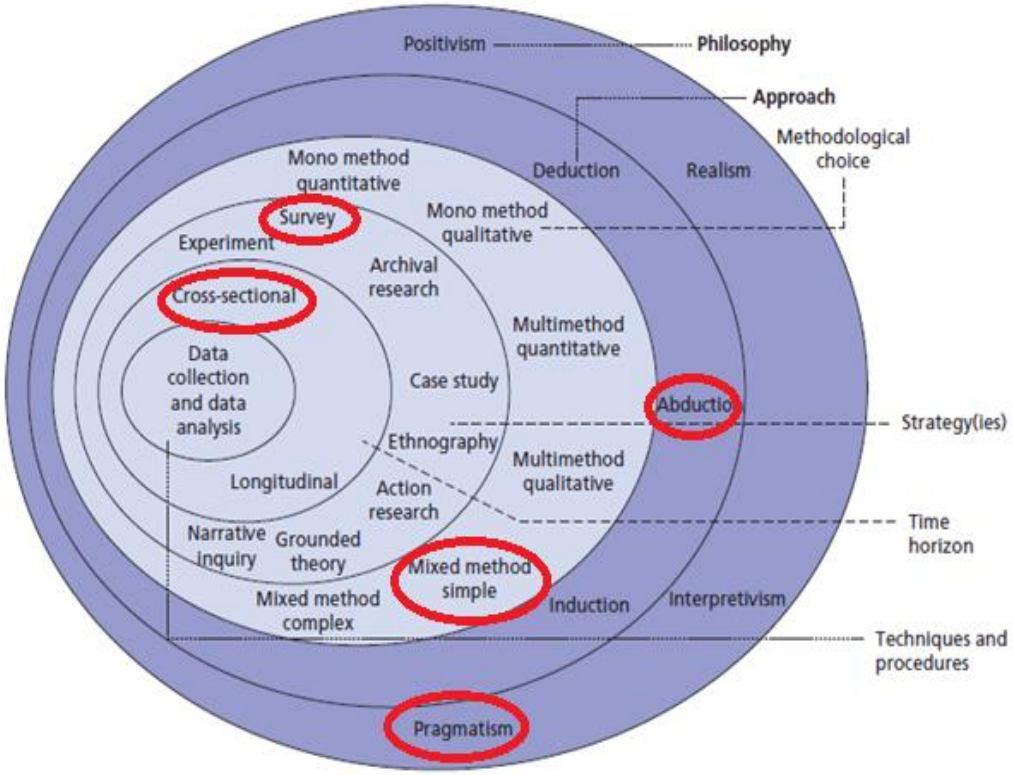


Figure 3-1 – Research Methodological Design

Source: Saunders et al. (2019)

As Figure 3.1 depicted, according to Saunders et al. (2019), data collection and analysis residences in the core of the onion. As its name implied the onion has to be peeled starting from the outside and each layer away until the researcher reaches the core. It signifies the consideration to be taken prior to the data collection and analysis of a study (Al Zefeiti & Mohamad, 2015).

3.3 Research Philosophy

The researcher's philosophical stance determines a holistic picture for the way in which data are to be collected, analysed and interpreted in research (Walliman, 2011). Based on the core assumption of the researcher on the nature of the science, there are research

paradigms which are the philosophy in educational resaerch (Mackenzie & Knipe, 2006). These research paradigms reflects basic assumptions, beliefs, principles and values that conveys the interpretation of the research data (Kivunja & Kuyini, 2017). It has been identifed number of research paradigms in educational research. Among them, the dominants are positivist, interpretivist, critical and pragmatic research paradigms. Each of these paradigms present different phenomena and it is imperative to adopt the most convenient paradigm to answer different research question, which is defined as the philosphy of pragmatism (Antwi & Hamza, 2015).

Philosophical paradigms have sketched along with three major dimensions; ontology, epistemology and axiology (Saunders et al., 2016). Ontology refers to the way a researcher defines the truth and reality of the world (Antwi & Hamza, 2015). Whereas the epistemology describes the process which is followed by a researcher to understand the truth and reality (Saunders et al., 2016). Axiology defines, evaluates and understands the values that are to be incorporated to the different aspects of a research, the participants, the data and the audience which will be reported with the results of a study (Kivunja & Kuyini, 2017).

The ontological question is, “what is the form and nature of the reality?” The researchers, preferring realism, identify that the individual attributes of understanding, is a single reality (Nind et al., 2020). On the other hand, the matters of moral significance fall outside the realism and more constricted towards idealism.

In this study, application of each AI technique for overcoming barriers in communication in green construction might be differently viewed by each expert. Conversely, for the evaluation of the application of AI techniques to overcome the barriers in communication in green construction, idealism may not be suitable. Therefore, the ontological positioning of this study remains in between realism and idealism.

The epistemological question describes the nature of the relationship between the researcher and the possible readers of the study. The answer for this question is influenced

by the answer already given to the ontological question. When the researcher is independent from the subject that is been studied the study has characteristics of positivism. However, in interpretivism the researcher add value to the study through the lived- world experience.

The subjective nature of the applicability of AI techniques in overcoming barriers in communication in green construction draws the research towards interpretivism. Yet, there is a need to maintain the value free nature of the study as much as possible since the application each AI technique need to be applicable and justifiable to the studied context regardless of the researcher's perceptions. Therefore, the knowledge to develop the framework to enhance the effectiveness of communication using AI techniques for successful delivery of green construction in Sri Lanka is not constructed through the interpretation of the respondents who are involved in the research but rather from the context itself, because the respondents were merely a sample from the context.

The axiological question is directly linked to the value concern of the study. A study may be either value free or value laden (Lewthwaite & Nind, 2016). Therefore, the selection of the appropriate methodology depends on the ontology and the epistemology that have been already chosen and the level of value the researcher hopes to add to the study.

The proposed study expected to a framework to enhance the effectiveness of communication using AI techniques for successful delivery of green construction in Sri Lanka. However, the application of AI techniques in green construction project are not yet thoroughly reviewed. Therefore, an accepted truth in questionable. While the researcher has an opinion on application of AI techniques for effective communication in green construction, based on the knowledge gained through reviewing existing literature, experts on the area, based on their experience and expertise knowledge might view applicability of each AI techniques for effective communication differently. Even when the researcher requests an expert to identify the available AI techniques and existing barriers to communication in green construction project obtained from the literature, the perception is subjective, and experts did not construe it the same way the researcher did.

Consequently, this research spins around those interpretative application of AI techniques to overcome the barrier in communication in green construction by means of constructing knowledge.

Nevertheless, once the application of AI techniques to overcome the barrier in communication in green construction was grabbed through the experts' knowledge and opinion, that was evaluated by the professionals who are having a vision for green construction. The applicability of the constructed knowledge was evaluated through Analytical Hierarchical Process (AHP) making it less subjective. Therefore, this study encompassed the features of positivism as well.

Interpretivism relies on multiple truth and perceptions and therefore the conclusion is accepted, influenced by not only the researcher's but also the different judgement of the participants of this study. As incorporating AHP technique to evaluate the application of AI techniques to address the barriers related to effective communication within green construction in Sri Lanka makes the findings of expert interview are less subjective, researcher's beliefs on that knowledge should be objective and free from any bias, is noticeable. Simply, here in this study the researcher played a major role and was a part of it also. Therefore, this study adopted pragmatism as its philosophical perception.

3.4 Approach

Different researchers have argued the choice between the inductive and the deductive research approach for scientific studies. According to Saunders, Lewis and Thornhill (2019), the inductive approach focuses on developing theory and designing a strategy to hypotheses testing whereas the deductive strategy is to theory testing through data collection and analysis. However, in developing a framework to enhance the effectiveness of communication using AI techniques for successful delivery of green construction in Sri Lanka, both the above research approaches did not satisfy the requirement because those methods did not facilitate to evaluate the application of AI techniques to address the barriers related to effective communication within green construction in Sri Lanka. It

means that inductive research approach will only assist in investigating applicability of the AI techniques to address the barriers related to effective communication within green construction, while deductive research approach will assist in assessing the applicability of the AI techniques to address the barriers related to effective communication within green construction. Unlike in inductive and deductive research approach, abductive research approach to illustrate, propose or change the theoretical framework for a particular study before, throughout and even after the research process (Attia & Edge, 2017). Therefore, abductive research approach was involved in this research study since it fulfils both theory developing and evaluating requirement in terms of application of the AI techniques to address the barriers related to effective communication within green construction.

3.5 Methodological Choice

According to paradigm of choices, different phenomena in research context demand different research choices (Newman & Gough, 2020). In pragmatism paradigm, both qualitative and quantitative choices can be adapted while sidestepping the weaknesses in both choices when it is taken separately. The methodological choices include qualitative and quantitative methods. They are further categorised into three methods namely, mono method, multi method and mix method based on the common characteristics (Wright, 2019). In mixed method simple, both qualitative and quantitative method is chosen (Saunders, Lewis & Thornhill, 2019). The complex mixed method encompasses different types of methods representing qualitative and quantitative methods which are convenient to the researcher (Paul, 2017).

Following the literature review, data collection to review the applicability of AI to overcome barriers and issues in communication within green construction in Sri Lanka was done using two different methods and was qualitatively and qualitatively analysed. The identification of possible AI techniques in overcoming each barriers in communication in green construction was done qualitatively whereas the prioritizing of the AI techniques in each barrier in communication in green construction was done

quantitatively. Since these qualitative and quantitative methods were applied at different stages of the research, the methodological choice could be particularised as a partial integrated mixed method research (Greener, 2018). As such this research adopts a simple mixed method as the most suitable methodological choice.

3.6 Strategy

The most appropriate strategy for this study was selected based on the pragmatist philosophical stance. Gläser-Zikuda et al. (2020) expressed that there are research strategies such as experiment, survey, archival research, case study, ethnography, action research, grounded theory and narrative inquiry. There is lack of application of AI in green construction in Sri Lanka. It prevents in depth analysis as there is little or no projects in such nature for launching another type of research strategy to this research. Further, as in the context of Sri Lanka, combining AI and green construction is pioneer research, hence there is a dearth of existing literature available. Hence the research should take a more exploration nature, which is ideally done using a survey approach. A survey collects information from individuals about themselves or the context in which they belong. Among them, survey allows the collection of information from a sample of individuals through their responses to questions (Check & Schutt, 2012). Survey strategy lays the possibility to the researchers to adopt different data collection techniques including both quantitative and qualitative such as questionnaires, interviews and focus group discussions (Antwi & Hamza, 2015). Accordingly based on the pragmatist view of the research, with the available theoretical prepositions and the empirical studies, survey strategy was apprehended as the most suitable strategy to this study. The survey sampling process specifies information about large populations with a known level of precision.

3.6.1 Survey Strategy and Sampling Method

As this study aimed at researching about applying the AI techniques in effective communication in green construction projects in Sri Lanka, the whole stakeholders to the Sri Lankan green construction context and specialists in AI techniques in the Information Technology Industry have to be approached through the selected survey strategy to answer

the research problem. But it is not a realistic or feasible approach as there are a numerous stakeholders even in one green construction project. Therefore, among this whole population, only a part would be accessed. Accordingly, this study adopted a sampling method in survey strategy. The sampling can be defined as approaching units in a defined population (Hoffmeyer-Zlotnik, 2003). Further to the same author, the sampling can be mainly categorised to two groups as probability sampling and non-probability sampling. The sampling method is selected based on the research problem and the type of data analysis of a particular study (Rowley, 2014). As this research study focused on the applying the AI techniques in effective communication in green construction projects in Sri Lanka, the researcher had to approach the respondents who are experienced and knowledgeable on green construction project and AI techniques to present a reliable result. Accordingly, among the whole population of professionals who are competent in green construction and AI application, a sample had to be selected since approaching whole population is not a realistic view. As such, purposive sampling was adopted as the most appropriate sampling method to the study.

The purposive sampling is a non-probability sampling technique which allows to select a sample from the population based on the prescribed purpose over random selection (Tashakkori &Teddlie, 2003). The purposive sampling has been identified as the most effective method where the research focuses on a certain domain which to study with knowledgeable experts within it (Tongco, 2007). The same author expressed that purposive sampling method can embrace in both qualitative and quantitative research approaches. Therefore, this study would adopt the purposive sampling method. The researcher identified the purposes for sampling to approach expert professionals in green construction and AI application. Accordingly, this study selected a sample consist of experts/professionals who has both experience and knowledge in green construction with green accreditation from the GBCSL and the knowledge of applying innovative and emerging technologies to the construction industry and then AI experts with more than 10 years of work experience in Sri Lankan IT industry.

3.7 Time Horizon

Another important aspect for a research study has been identified by Saunders et al. (2019) in proposed research onion is the time frame for the research study. In this layer, mainly cross sectional and longitudinal studies are defined. The data collection at a particular time point is done in a cross-sectional study whereas for a longitudinal study, the data is collected over a longer period of time. This study tried to answer research problem in prevailing context. Therefore, this research study has been identified as a cross sectional study.

3.8 Data Collection Techniques

Literature review, Key informant interviews (KII) for qualitative data and questionnaire survey for quantitative data were conducted formed the data collection techniques used in this study. Hereunder, these two data collection techniques are elaborated with the reasoning for the selection for this study.

3.8.1 Literature review

A literature survey was carried out to collect the secondary data for the study. Since this research aimed at several research areas; communication, green construction and artificial intelligence, the respective resources which focused on each area were studied in the reviewing process. Accordingly, the literature was studied through the journals, conference publications, reports and books in those areas. Initiation for the first, second and third objectives of the study was taken through this literature review.

3.8.2 Key Informants Interview

Key informant interviews (KII) are qualitative in-depth interviews with individuals who perceive actual context in a community. KII allows to approach the individuals in particular community who have first-hand knowledge about the community. In Sri Lankan context, experts in green construction with the knowledge of AI techniques in construction industry and AI experts in IT industry are limited in the number. Therefore, the well-

connected and informed community expert to address this research problem is very less in the number. According to Marshall (1996), if a researcher only approaches the experts of a particular background, the answer for a particular research problem will be one-sided or biased. Interviewing key informants from a broad scope of sectors allows a researcher to approach the underlying research problem from differing standpoints. Therefore, KII was selected as most effective technique for the qualitative data collection in this research as the researcher expected to approach key informants for the research context in construction sector and IT sector. Several steps were followed in planning and implementing KII as the data collection technique to collect qualitative data for the research study. Accordingly, through reviewing the existing literature in the context of effective communication in green construction, possible AI techniques in construction industry and application of AI in effective communication in different context were collected. Based on the reviewed data, it was determined that which data to be needed in the data collection process. Accordingly, the barriers for the effective communication and possible AI techniques in construction industry were chosen as the required information in data collection process.

Through mapping key informants based on the purposive sampling, possible key informants were selected who are experienced and knowledgeable in green construction for more than 10 years of working experience with green accreditation from the GBCSL with the knowledge of applying innovative and emerging technologies to the construction industry and then AI experts with more than 10 years of work experience in Sri Lankan IT industry. According to Kumar (1989) and Marshall (1996), 15 to 25 numbers of the interviews are required when researcher conductining KII. Hence, considering the researcher's judgements, 15 numbers of key informants were selected to conduct fifteen KII. More details of these key informants are presented in Section 4.2.3. Pursuant to the prevailing health guidelines and precautions for COVID-19 pandemic in Sri Lanka, the key informants were approached remotely, and all the fifteen KII were conducted via online platforms of either Zoom Video Communications or Skype. With the permission

of the key informants the interview sessions were recorded while the researcher taking down the notes to gather qualitative data to be analysed.

The atmosphere of these interviews was conversational. There are structured, semi structured and unstructured interview guideline which can be used in interview (Willis, 2007). However, based on the reviewed literature, a semi structured interview guideline was designed as the data collection tool due to it has a scope unlike unstructured guideline and still be flexible unlike structured interview guideline (Jonker & Pennink, 2010). There were four sections in the semi structured interview guideline namely, general introduction to the research, background information of the interviewee, definitions of identified AI techniques with a room to suggest further applicable AI techniques in construction industry and finally a question to explain which AI techniques can be used to overcome barriers related to effective communication among project stakeholders in successfully delivering green construction in Sri Lanka.

3.8.3 Questionnaire Survey

Questionnaire surveys are most common data collection technique either may be open ended or close ended (Rowley, 2014). According to Willis (2007), questionnaire's structured mechanism allows for higher rate of responses within less time. Through KIIs, the application of each of the AI techniques to overcome the barriers in communication in green construction project in Sri Lanka were identified. The fourth objective of this study was not merely to identify the application, but also to evaluate and prioritise the application of each AI technique to overcome the barriers in communication in green construction project in Sri Lanka. The researcher's pragmatism philosophical perception could be established through the quantitative data for this prioritisation purpose other than the qualitative data from KIIs. Therefore, a questionnaire survey was adopted as the data collection technique to collect data quantitatively. Further, the researcher expected to prioritise the best AI technique to overcome the barriers in communication in green construction project in Sri Lanka by comparing other applicable AI techniques identified for the same barrier. Therefore, the analysis of findings through questionnaire survey was

diverse from conventional statistical analysis. Therefore Analytical Hierarchical Process (AHP) was adopted as the data analysis technique for the questionnaire survey. The grounds behind the adoption of this data analysis technique, diversified design adopted and designing the data collection tool for the questionnaire survey are discussed under the data analysis section below.

3.8.4 Validation Questionnaire Survey

Finally, the framework which had been developed based on the primary and secondary data was validated, since it will be used by different types of stakeholders in decision making. The framework would focus on green construction in Sri Lanka, the validation was planned to execute with the practitioners in green construction in Sri Lanka. Hence, all the decision makers in green construction in island wide was to be approached as the population for the validation. However, the approaching each and every decision maker in green construction project was hindered by the time and other resource availability. In general, questionnaire survey allows for higher rate of responses within less time (Willis, 2007). Therefore, a questionnaire was carried out among selected capable participants in green construction in Sri Lanka through judgmental sampling by the researcher to validate the proposed framework to enhance effective communication in green construction in Sri Lanka through techniques in AI.

3.9 Data Analysis

3.9.1 Content Analysis

An in-depth analysis of the findings from KII finalised the first part of the study which laid the base for the later part of the research study. The gathered data was analysed manually with content analysis. In qualitative research approach, content analysis is frequently used to analyse the qualitative data (Wahayuni, 2012). The technique is based on codification of qualitative information for obtaining systematic text description so as to discern patterns in the presentation and reporting of information (Hsieh & Shannon, 2005). Content analysis allows the researcher to interrogate the research data to construct ideas which have been either decided quite in advance or emerged during the process of

analysing primary data. In seeking for evidence that address the initial proposition of the research, the analysis helps to reconstruct the data in a meaningful way. Further to Hsieh and Shannon (2005), the content analysis is a flexible technique to analyse the unstructured text data. Accordingly, for better familiarisation with data, researcher has analysed findings from KII using manual content ananlysis.

3.9.2 Analytic Hierarchy Process (AHP)

AHP can be used to make the decisions when there are multi criteria (Vaidya & Kumar, 2006). Therefore, AHP was employed as the quantitative data analysing technique for this study to analyse the data collected through questionnaire. Being a multi criteria decision making tool, AHP is effective in ranking, evaluating, selecting and predicting decisions (Golden et al., 1989). Further to the authors AHP allows to rank the decision alternative based on both qualitative and quantitative factors. AHP helps to integrate a group consensus. As this research focused on evaluating and prioritising the application of each AI technique to overcome the barriers in communication in green construction project in Sri Lanka, the AHP has been selected as the most appropriate technique for data analysis. Through the findings of the KIIs, the applicable AI techniques for each barrier in communication in green construction project in Sri Lanka were derived. Rather merely rank the applicable AI techniques in one barrier, the comparing each of the applicable AI techniques would draft better evaluation for the application of each AI technique to overcome the barriers in communication in green construction project in Sri Lanka.

3.9.2.1 Key Steps in Analytic Hierarchy Process (AHP)

When a researcher adopted AHP as the data analysing technique for a study, four key steps to be adopted in the data analysing process (Saaty, 2008). These four steps allow to make the result in an organised way to prioritise the available alternatives. Those four key steps in AHP are expressed in Figure 3.2.

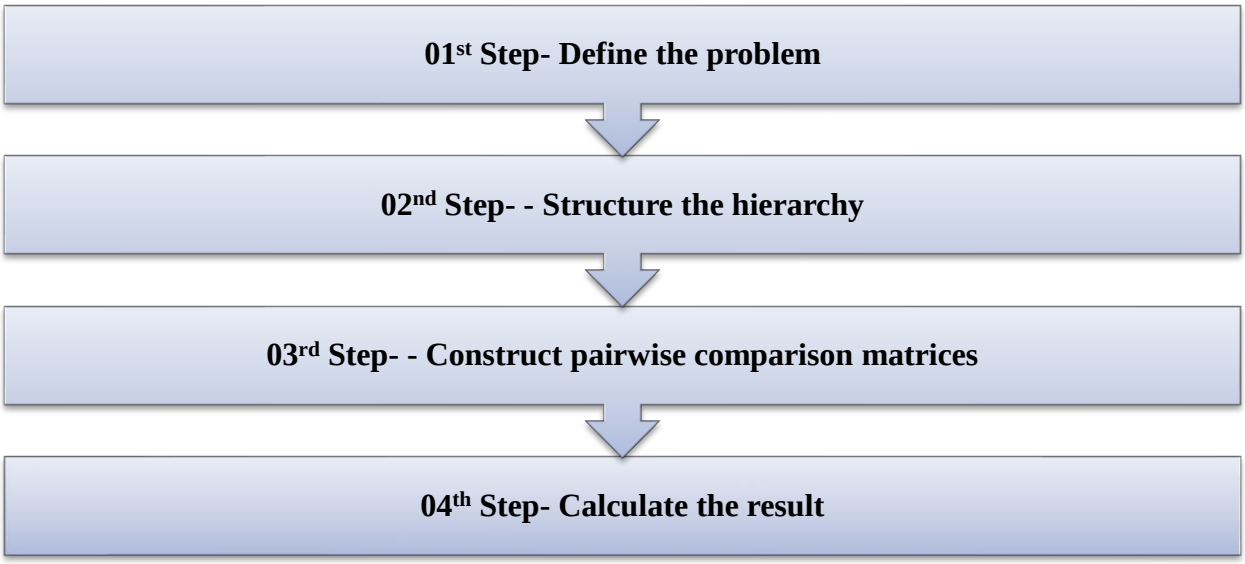


Figure 3-2 - Key Steps in AHP

The following contents will describe the four key steps which were undertaken in this research study.

01 – Define the problem

The research problem of this study is evaluating the application of AI technique to overcome the barriers in communication in green construction. Thus, application of AI techniques to address the barriers related to effective communication within green construction in Sri Lanka was established as the goal of AHP structure to answer the research problem.

02 – Structure the hierarchy

According to the Saaty's (2008) explanation, the hierarchy arrangement in AHP has a top level, intermediate level or levels and finally the lowest level. Structuring the hierarchy for AHP is one of main steps to be undertaken. Figure 3.3 depicted the developed hierarchy for AHP for this study which aimed to answer the research question of evaluating the application of AI technique to overcome the barriers in communication in green construction.

Figure 3.3 shows that there are three levels in this hierarchy structure for AHP. Those levels can be identified as the goal at the top level, main criterion at the intermediate level and finally the alternatives at the lowest level. Accordingly, the goal is the research problem, the main criterion is overcoming the barriers in communication in green construction project in Sri Lanka, and the alternative is the AI techniques. The hierarchy that was developed through KIIs has been described in chapter four.

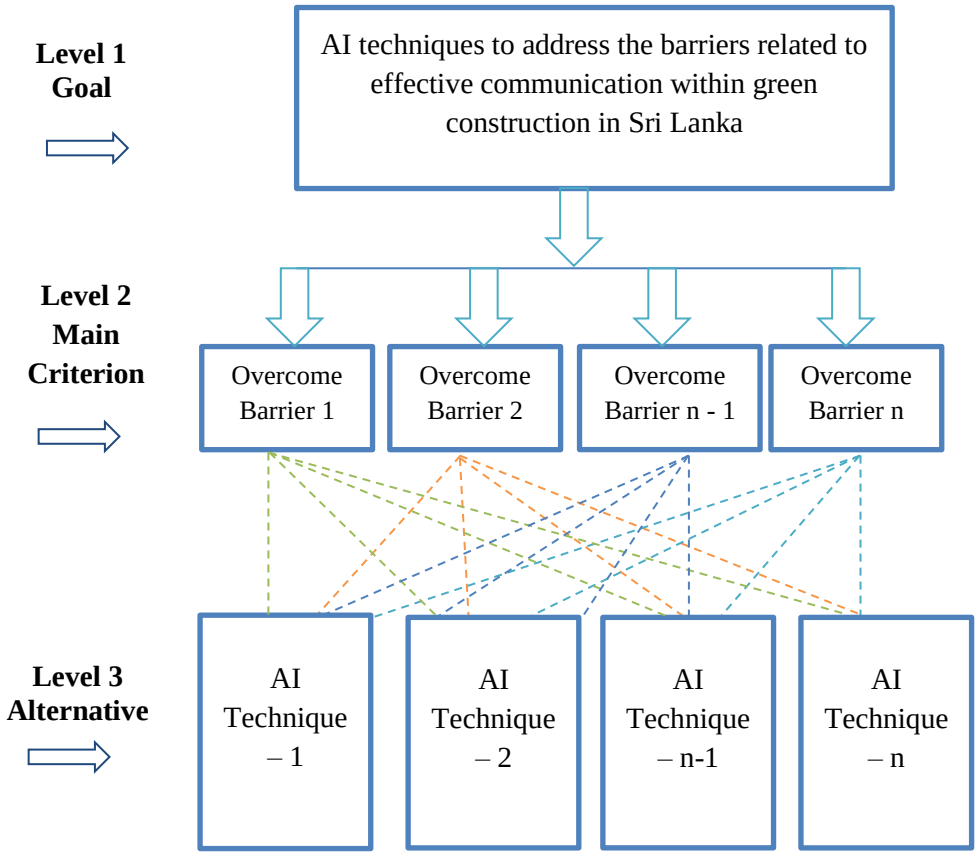


Figure 3-3 - Hierarchy in AHP

03 – Construct pairwise comparison matrices

According to the hierarchy structure for AHP of this study, the most applicable AI techniques which are the alternatives for overcoming barriers in communication in green construction must be identified. Therefore, each applicable AI technique should be

pairwise compared with other applicable AI technique. This pairwise comparison should be done while calibrating on the numerical scale (Saaty, 2008; Vaidya & Kumar, 2006). Saaty (2008) has proposed the fundamental scale for the AHP as shown in Table 3.1. The number of comparisons is determined by n (n-1) /2, where "n" is the number of alternatives in particular level (Vaidya & Kumar, 2006). Equation 3.1 presented the equation to identify the number of comparisons. The size of the matrix in AHP based on respective number of comparisons. Accordingly, when there are "n" number of alternative to pairwise compare, the size of AHP matrix is "n x n" (Teknomo, 2006).

Table 3.1 - Fundamental Scale of Pairwise Comparison

Intensity of Importance	Definition
1 2	Equal importance Weak or Slight
3 4	Moderate importance Moderate Plus
5 6	Strong importance Strong Plus
7 8	Very strong or demonstrated importance Very very strong
9	Extreme importance
Reciprocals of above	If activity *i* has one of the above nonzero numbers assigned to it when it compared with activity *j*, then *j* has the reciprocal value when compared with *i*
1.1 – 1.9	If activities are very close

Source : Adopted from Saaty (2008)

The pairwise comparison table is based on the vector procedure of Saaty (2008). Following that the priority weights have been calculated.

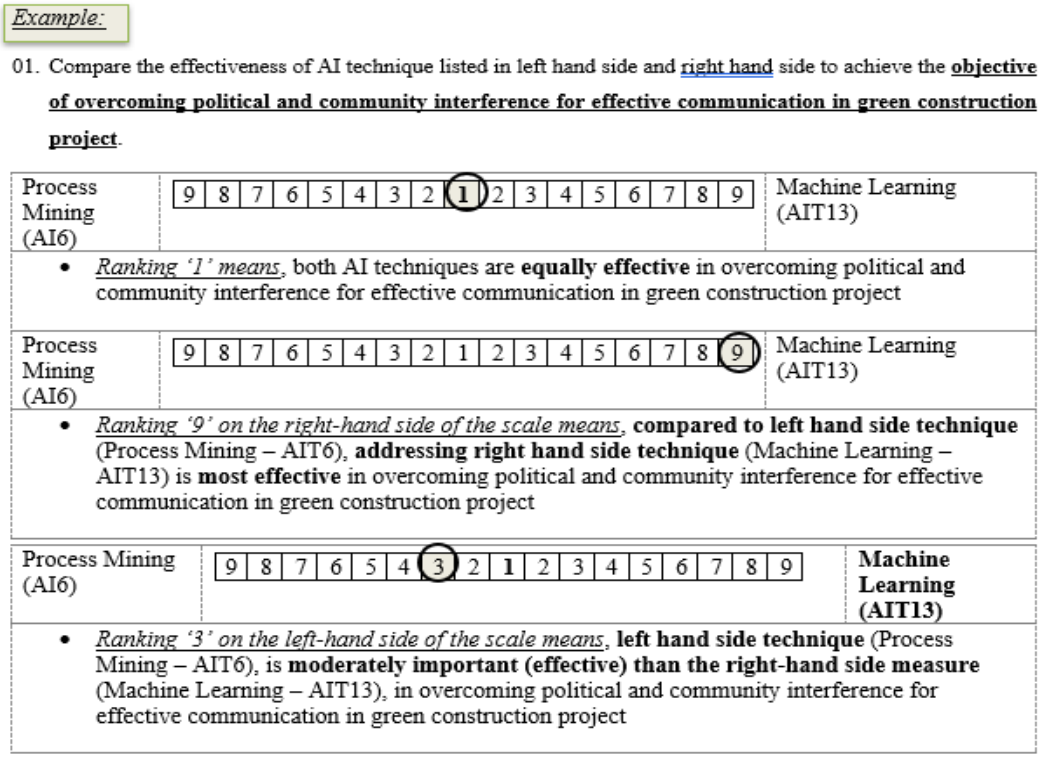
Development of Questionnaire Guideline

Once identified the questionnaire survey as quantitative data collection technique, the questionnaire guideline was utilised to prioritise AI techniques in overcoming the barriers in communication in green construction project. The questionnaire was developed in a way where the respondent was able to do pairwise comparison and to mark the effectiveness of AI techniques in addressing the barriers in communication in green construction project in Sri Lanka. The questionnaire guideline was prepared with outline to the research, instruction to the respondents in filling the questionnaire, room for respondent details and finally the question for pairwise comparison. The design for this pairwise comparison is shown in Figure 3.4.

Process Mining	9 8 7 6 5 4 3 2 **1** 2 3 4 5 6 7 8 9	Machine Learning
02. OBJECTIVE	**To reduce issues in communication in green construction project due to poor listeners in a project**	
Knowledge representation and reasoning	9 8 7 6 5 4 3 2 **1** 2 3 4 5 6 7 8 9	Smart Robotics
	9 8 7 6 5 4 3 2 **1** 2 3 4 5 6 7 8 9	Process Mining
	9 8 7 6 5 4 3 2 **1** 2 3 4 5 6 7 8 9	Natural Language Processing
Smart Robotics	9 8 7 6 5 4 3 2 **1** 2 3 4 5 6 7 8 9	Process Mining
	9 8 7 6 5 4 3 2 **1** 2 3 4 5 6 7 8 9	Natural Language Processing
Process Mining	9 8 7 6 5 4 3 2 **1** 2 3 4 5 6 7 8 9	Natural Language Processing
03. OBJECTIVE	**To reduce issues in communication in green construction project due to poor leaderships**	
Smart Robotics	9 8 7 6 5 4 3 2 **1** 2 3 4 5 6 7 8 9	Cloud Virtual Reality/ Augmented Reality
	9 8 7 6 5 4 3 2 **1** 2 3 4 5 6 7 8 9	Natural Language Processing
Cloud Virtual Reality/ Augmented Reality	9 8 7 6 5 4 3 2 **1** 2 3 4 5 6 7 8 9	Natural Language Processing

Figure 3-4 - Pairwise Comparison in Questionnaire

As shown in Figure 3.4, the respondents were asked to compare the effectiveness of AI technique listed in left hand side and right-hand side to overcome the different barriers for effective communication in green construction project. According to the fundamental scale of pairwise comparison defined by Saaty (2008) shown in Table 3.1, the respondents were instructed to fill the questionnaire.



Example:

01. Compare the effectiveness of AI technique listed in left hand side and right hand side to achieve the **objective of overcoming political and community interference for effective communication in green construction project**.

Process Mining (AI6)	9 8 7 6 5 4 3 2 **1** 2 3 4 5 6 7 8 9	Machine Learning (AIT13)

- *Ranking '1' means*, both AI techniques are **equally effective** in overcoming political and community interference for effective communication in green construction project

Process Mining (AI6)	9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 **9**	Machine Learning (AIT13)

- *Ranking '9' on the right-hand side of the scale means*, **compared to left hand side technique** (Process Mining – AIT6), **addressing right hand side technique** (Machine Learning – AIT13) is **most effective** in overcoming political and community interference for effective communication in green construction project

Process Mining (AI6)	9 8 7 6 5 4 **3** 2 **1** 2 3 4 5 6 7 8 9	**Machine Learning (AIT13)**

- *Ranking '3' on the left-hand side of the scale means*, **left hand side technique** (Process Mining – AIT6), is **moderately important (effective) than the right-hand side measure** (Machine Learning – AIT13), in overcoming political and community interference for effective communication in green construction project

Figure 3-5 - Example for Conducting Pairwise Comparison

Figure 3.5 depicted an example of conducting this pairwise comparison. However, since it has some specific process to be followed in filling this questionnaire, most of the respondents were contacted through online platform of Zoom Video Communications and were explained the step-by-step process while elaborating them the requirement of such pairwise comparison as not to be neglected the effectiveness of any possible AI technique in overcoming the barriers in communication in green construction project in Sri Lanka.

Sample size

AHP technique is very effective and reliable even with a small sample size (Al-Harbi, 2001). As examples here few studies are highlighted. Al-Harbi (2001) and (Peterson et al., 1994) have conducted their study with five respondents. Armacost et al. (1994) was a study where only seven respondents were approached. Hapuarachchi and Jayawickrama (2017) has conducted their study with eight respondents. Mawapanga and Debertin (1996) have conducted their study with eighteen respondents. Thus, this study was formulated and carried out by distributing ten questionnaires among ten respondents who have green accreditation from the GBCSL with the knowledge of applying innovative and emerging technologies to the construction industry and AI experts with more than 10 years of work experience in Sri Lankan IT industry.

04 – Calculate the result

Saaty (2008) has developed the process of calculating the results in AHP. Considering to this study, this final step in AHP gave the relative importance (effectiveness) of each AI technique in overcoming barriers in communication in green construction in Sri Lanka. As described in third step, calculating the weighted figures to identify the relative importance should be done considering the values of pairwise judgment attained under 1-9 scale as presented in Table 3.1 (Teknomo, 2006). When there is more than one response for a pairwise judgment, the geometric mean of each judgement value should be taken first to proceed on calculating the results in AHP (Jayawickrama et al., 2013). Subsequently, the normalised relative weight of that element can be calculated. The normalised values can be used as the AHP resulted weightage (performance score) for each element (AI technique) in the proposing framework (Saaty & Vargas, 2012; Teknomo, 2006).

First, the geometric mean for each AI techniques in overcoming each barrier in communication in green construction in Sri Lanka were calculated. Then, the pairwise comparison were done based on the respondents' answers for each assessment. Secondly,

the entries were normalised. This normalisation techniques fuses the pair wisely evaluated data to attain the results (Saaty & Vargas, 2012). Finally, the consistency calculations were carried out. These calculations were carried on the platform of Microsoft Office Excel for this study (2016).

Number of Comparisons

When there are *n* components to be pairwise compared, number of comparisons to be done can be determined through the formula shown in Equation 3.1.

$$\text{Number of Comparisons} = \frac{n\,(n-1)}{2}$$

Equation 3.1 - Equation for Number of Comparisons

Geometric Mean Calculation

The questionnaire was responded by 10 professionals. Therefore, adhering to Saaty's (2008) fundamental scale for pairwise comparison as shown in Table 3.1, the respondents marked different scale according to their perspective, experience and knowledge. For further calculations, geometric means of those responses were calculated through the platform of Microsoft Office Excel (2016) using in built formula of Geomean Calculation. The arithmetic mean calculates the mean of a set of values in dataset by dividing sum of total values by number of values. Geometric mean allows rather calculating the mean of set of values in a dataset considering the effect of compounding (Jayawickrama et al., 2013).

An example of calculation of Geometric mean calculation for application of AI techniques for Objective 01 is given in Figure 3.6.

Geomean of Scale marked by the respondents

Objective 01	R1	R2	R3	R4	R5	R6	R7	R8	R9	R10	Geometric Mean
AIT1 vs AIT2	5	5	5	7	5	5	3	5	5	5	=GEOMEAN(B9:K9)
AIT1 vs AIT6	5	5	5	7	5	5	3	5	5	5	
AIT1 vs AIT13	3	3	3	5	3	3	3	3	3	3	3.1572
AIT2 vs AIT6	1	1	1	3	1	1	1	1	1	1	1.1161
AIT2 vs AIT13	1	1	1	1	3	1	1	1	1	1	1.1161
AIT6 vs AIT 13	1	1	2	1	1	3	1	4	1	1	1.3741

GEOMEAN(**number1**, [number2], ...)

Figure 3-6 - Geometric Mean Calculation

Pairwise Comparison

After calculating the geometric mean for application of AI techniques for respective objective, the pairwise matrices were developed. In Table 3.2, the geometric mean of the scales (as per in Table 3.1) marked by the respondents for each pairwise comparison of AI techniques for an objective is shown as P1, P2, P3, P4, P5, P6, P7, P8, P9 and P10 in grey shaded area and the reciprocals of them are given in the unshaded area. Sum of respective column is given as A1, A2, A3, A4, and A5.

Table 3.2 – Model for Pairwise Comparison

Objective 1	AIT1	AIT2	AIT3	AIT4	AIT5
AIT1	1	P1	P2	P3	P4
AIT2	1/P1	1	P5	P6	P7
AIT3	1/P2	1/P5	1	P8	P9
AIT4	1/P3	1/P6	1/P8	1	P10
AIT5	1/P4	1/P7	1/P9	1/P10	1
Sum	A1	A2	A3	A4	A5

Normalisation of the Data

AHP use normalisation of the data for “aggregation of criteria with numerical and comparable data” (Vafaei, Ribeiro & Camarinha-Matos, 2016, p.1). Normalising the data is done by dividing the geometric mean of the pairwise judgement by the sum of each column in pairwise comparison matrices shown in Table 3.2. Table 3.3 represents a model

for matrix of normalised data. B1, B2, B3, B4, and B5 indicates the sum of each row in normalisation model. Finally, performance score of each element can be attained as Q1, Q2, Q3, Q4 and Q5. Performance score is calculated by dividing the row sum from the total sum (B).

Table 3.3 – Model for Normalisation of the Data

Objective 01	AIT1	AIT2	AIT3	AIT4	AIT5	SUM	Performance score
AIT1	1 / A1	P1 / A2	P2 / A3	P3 / A4	P4 / A5	B1	B1/B = Q1
AIT2	1/P1 / A1	1 / A2	P5 / A3	P6 / A4	P7 / A5	B2	B2/B = Q2
AIT3	1/P2 / A1	1/P5 / A2	1 / A3	P8 / A4	P9 / A5	B3	B3/B = Q3
AIT4	1/P3 / A1	1/P6 / A2	1/P8 / A3	1 / A4	P10 / A5	B4	B4/B = Q4
AIT5	1/P4 / A1	1/P7 / A2	1/P9 / A3	1/P10 / A4	1 / A5	B5	B5/B = Q5
Sum						B	-

B is the sum of the nomalised sum as indicated in SUM column. The prioritisation of AI techniques in application to overcome an barrier for effective communication in green construction proejct were done based on this calculated performance score of each AI technique.

Consistency Calculation

The Consistency Index (CI) presents the consistency measure for the data set (Goepel, 2013). According to Saaty (2008), AHP is capable in measuring the inconsistency of judgements and then in improving the consistency of the judgement. A Consistency Ratio (CR) which is calculated through a Randomized Index (RI) and the average CI for the data set, gives the consistency measure in AHP. It can be identified four steps in deriving CR in AHP (Saaty & Vargas, 2012; Teknomo, 2006). As the first step in calculating CR in AHP, largest eigen value or principle eigen value (λ_{max}) should be calculated. Subsequently, CI is calculated by using Equation 3.3 as the second step (Saaty & Vargas,

2012). This consistency calculation was adopted since none of main criteria have been assigned with more than 9 alternative AI techniques through KII. The researchers cannot expect that the humans to compare many elements consistently for a larger matrix. The methods for calculating largest eigne value, consistency index (CI), random consistency index (RI) and consistency ratio (CR) are elaborated hereunder.

I. Calculating Largest Eigne Value (λ_{max})

Table 3.4 illustrates the initial model calculation table for λ_{max}. When calculating largest eigen value (λ_{max}), first it should be multifield the weightages (geometric mean) of each entry (P) by the respective performance score (Q) obtained in normalising the data. Then, a new weightage sum (R) should be obtained through adding up each row. P values has been taken as same in the Table 3.2 and respective Q values were taken as same in the Table 3.3.

Table 3.4 – Model Calculations for Largest Eigne Value

Objective 01	AIT1	AIT2	AIT3	AIT4	AIT5	Weig-htage Sum	Weightage Sum Performance score
AIT1	1*Q1	P1*Q2	P2*Q3	P3*Q4	P4*Q5	R1	R1/Q1= S1
AIT2	1/P1*Q1	1*Q2	P5*Q3	P6*Q4	P7*Q5	R2	R2/Q2= S2
AIT3	1/P2*Q1	1/P5*Q2	1*Q3	P8*Q4	P9*Q5	R3	R3/Q3 = S3
AIT4	1/P3*Q1	1/P6*Q2	1/P8*Q3	1*Q4	P10*Q5	R4	R4/Q4 = S4
AIT5	1/P4*Q1	1/P7*Q2	1/P9*Q3	1/P10*Q4	1*Q5	R5	R5/Q5= S5

Then the largest eigne value for the data set can be calculated through Equation 3.2 where *S* values represents the division of performance score upon weightage sum (as in Table 3.4) and *n* is the number of elements which to be pairwise compared.

$$\lambda_{max} = \frac{S1+S2+S3+S4+S5}{n}$$

Equation 3.2 - Equation for Calculating Largest Eigne Value

II. Calculating Consistency Index (CI)

Once λ_{max} is obtained, the Consistency Index (CI) can be derived through Equation 3.3 where λ_{max} is the largest eigne value of data set and *n* is the number of components to be pairwise compared,

$$CI = \frac{\lambda max - n}{(n-1)}$$

Equation 3.3 - Equation for Calculating Consistency Index

III. Determine Random Consistency Index (RI)

In third step of measuring the consistency of data set in AHP, the RI values should be identified (Teknomo, 2006). Saaty and Vargas (2012) has developed the RI values corresponding to the number of components are to be pairwise compared. Table 3.5 presents the RI values for the analysis.

Table 3.5 - RI Values

n	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
RI	0	0	0.52	0.89	1.11	1.25	1.35	1.40	1.45	1.49

Source: (Saaty & Vargas, 2012)

IV. Calculating Consistency Ratio (CR)

Finally, the Consistency Ratio (CR) for the data set can be taken through the division of CI upon respective RI. It can be determined the consistency of the data set based on the CR value. For that Saaty and Vargas (2012) has developed a criterion. If the CR value is equal or less than 0.1 the data (judgment) is consistent. If the CR value is greater than 0.1, the data is not consistent. Hence, that subjective judgment should be revised (Teknomo, 2006).

$$\mathrm{CR} = \frac{\mathrm{CI}}{RI}$$

Equation 3.4 - Equation for Calculating Consistency Ratio

This was the final step in AHP. After that, depending on the performance score of each AI technique, the possible AI technique to overcome a barrier in communication in green construction project in Sri Lanka will be ranked considering their effectiveness in overcoming those barriers.

Develop the Framework to Enhance the Effectiveness of Communication Using AI Techniques in Green Construction in Sri Lanka

Based on findings derived through qualitative data analysis using manual content analysis and quantitative data analysis using AHP, the framework to enhance the effectiveness of communication using AI techniques in green construction in Sri Lanka has been developed. Depending on the performance score of each AI technique, the possible AI technique to overcome a barrier in communication in green construction project in Sri Lanka has been ranked and indicated in the framework. Further, this framework was validated through a questionnaire survey.

3.10 Graphical Representation of the Research Process

Research process can be defined as a set of steps which are to be undertaken when carrying out effective research (Kothari, 2004). Accordingly, even this study was based on a research process. The research process was designed as to achieve following objectives of the study. The research process of achieving those objectives is presented in Figure 3.7 below.

- Objective 1 – To critically review the concept of green construction in a global context and in the context of Sri Lanka
- Objective 2 – To investigate barriers related to effective communication among project stakeholders in successfully delivering green construction in Sri Lanka
- Objective 3 – To critically review Artificial Intelligence (AI) techniques that can be used in construction industry in Sri Lanka

- Objective 4 – To evaluate the application of AI techniques to address the barriers related to effective communication within green construction in Sri Lanka
- Objective 5 – To develop a framework to enhance the effectiveness of communication using AI techniques for successful delivery of green construction in Sri Lanka

First, the research problem was identified in the research process of this study. Then, the research objectives and aims were established. After that, the existing literature was synthesised to identify the green construction in a global context and in the context of Sri Lanka, critically review Artificial Intelligence (AI) techniques used in construction industry and then to recognise the barriers related to effective communication among project stakeholders in successfully delivering green construction in Sri Lanka. After reviewing the literature, the research methodology to answer the research problem was accordingly designed. This chapter descriptively discussed the research philosophy, approach and techniques in the designed research methodology particularly for this study. Then the data collection, analysis, findings, followed by framework development and validations to derive conclusions were done.

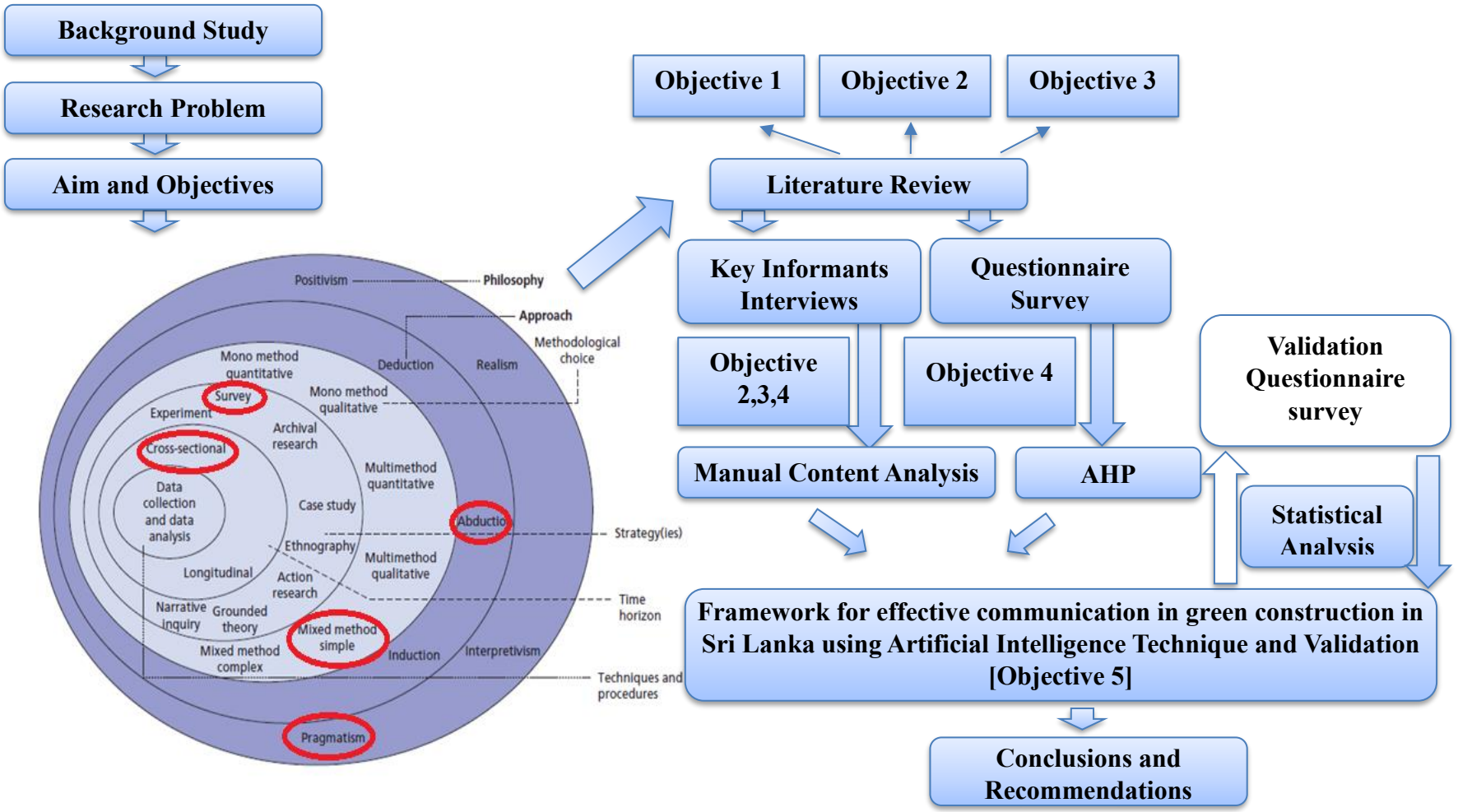


Figure 3-7 - Research Process

3.11 Chapter Summary

Accordingly, this third chapter presented the whole design which was encompassed to solve the research problem. The research process for this study was design based on the research onion, the adopted research philosophy of pragmatism perception, the selected research approach of abduction, the suitable methodological choice of mixed method, the appropriate research strategy as survey within a cross sectional time horizon. Further, KII as the qualitative data collection techniques and questionnaire survey as the quantitative data collection technique were selected. The qualitative data were manually analysed through content analysis and pairwise comparison and prioritisation of quantitative data was done through AHP. The way of accomplishing the research objectives was vividly addressed in this proposed research process. As that, this research study took a systematic approach to solve the research problem.

CHAPTER FOUR

4 ANALYSIS AND RESEARCH FINDINGS

4.1 Introduction

The chapter three described the systematic mechanism adopted to solve the research problem. Chapter four intends to present the analysis of primary data and subsequently the research findings. The primary data for the study was collected through KII, questionnaire survey and validation questionnaire survey as expressed in chapter three. Hereunder, the sample, data, analysis and findings of respective data collection techniques are summarised. The data analysis presents in three separate sections namely analysis and findings of KII, questionnaire survey and validation questionnaire survey. The findings of KII are used to develop the hierarchy for the AHP. Through AHP, each AI technique in overcoming barriers in communication in green construction was given with relative score with regard to the effectiveness. Based on these findings, the framework was developed. Finally, this chapter portrays the validated framework for applying the AI techniques for effective communication in green construction in Sri Lanka. Furthermore, the generalisation of the research finding is discussed.

4.2 Analysis and Findings of Key Informant Interviews

As elaborated in previous chapter, the KIIs have been selected and done to approach wide range of respondents who have first-hand knowledge about communication in green construction project and application of different AI techniques. The findings of KIIs were analysed through manual content analysis and will be presented hereinunder.

4.2.1 Objectives of the Key Informant Interviews

The KII was conducted to partially achieve objective 2, 3 and 4 as shown in Figure 4.1. Stepping on objective 3, first the AI techniques used in construction industry was reviewed through exiting literature. Then, the achievement of objective 2 was completed by finding of further applicable AI techniques in construction industry through KIIs. Considering the objective 3, the barriers related to effective

communication among project stakeholders in successfully delivering conventional construction project and green construction were identified through the literature review.

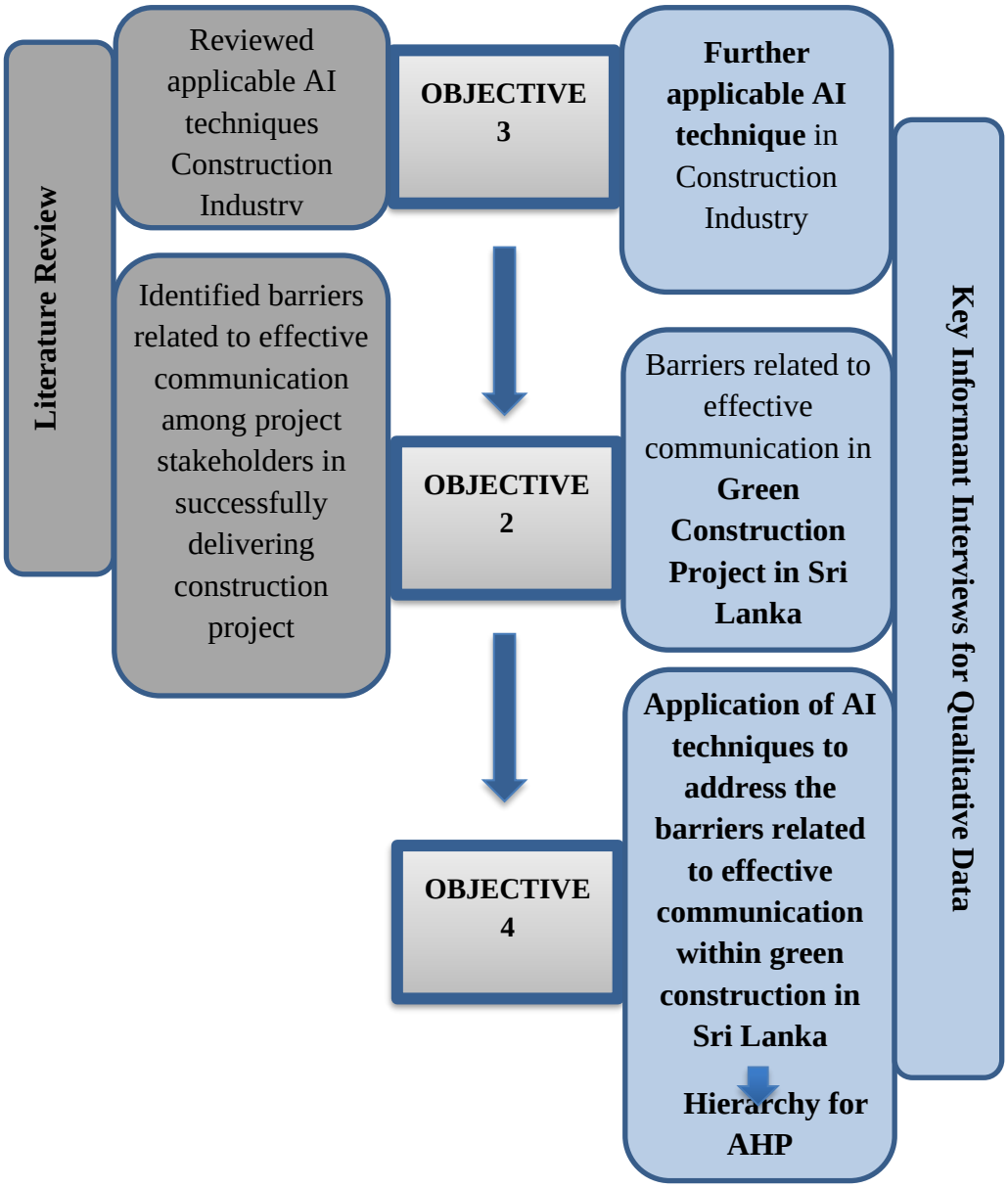


Figure 4-1 - Objectives of Key Informant Interviews

None of the existing studies illustrated the barriers related to effective communication to successfully deliver green construction project in Sri Lanka. Therefore, the achievement of objective 3 was completed by analysing the primary data collected using KII. KII was used to identify new barriers and validate the identified barriers

related to effective communication among project stakeholders in the context of green construction in Sri Lanka. The initiation of objective 4 was taken by analysing the findings of application of AI techniques to address the barriers related to effective communication in green construction in Sri Lanka.

4.2.2 Key Informant Interview Guideline

The key informant interview guideline (Annexure A) was constructed to collect the qualitative data for the research problem from the selected sample. The guideline was arranged comprising three key questions; Question (1) asked to identify further applicable AI technique in construction industry where question (2) asked to validate and identify the barriers related to effective communication among project stakeholders in successfully delivering green construction project in Sri Lanka. Finally, the Question (3) asked to identify the applicable AI techniques to address the barriers related to effective communication in green construction in Sri Lanka. The guideline also presented the objectives of the research and the definition of the thirteen AI identified through literature to facilitate a clear understanding on the techniques among the green construction professionals. Centring to guideline questions, the KIIs were conducted with fifteen (15) experts in green construction and/ or application of Artificial Intelligent until the result yields a solid hierarchical structure for the AHP analysis.

4.2.3 Details of the Key Informants

Through mapping key informants based on the purposive sampling, possible key informants were selected who are experienced and knowledgeable in green construction for more than 10 years of working experience with green accreditation from the GBCSL with the knowledge of applying innovative and emerging technologies to the construction industry and then AI experts with more than 10 years of work experience in Sri Lankan IT industry. The profile of the selected sample of key informants are expressed in Table 4.1.

Table 4.1 – Details of Key Informants

Key Informant	Professional career	Years of experience	Green Accreditation	Remarks
KI 1	Chief Quantity Surveyor	17 years	Yes	17 years' experience with 8 numbers of Green Projects
KI 2	Project Manager	16 years	Yes	16 years' experience with 6 numbers of Green Projects
KI 3	Senior Engineer (Structural)	16 years	Yes	16 years' experience 7 numbers of Green Projects
KI 4	Senior Engineer (MEP)	22 years	Yes	22 years' experience with 8 numbers of Green Projects
KI 5	Architect	18 years	Yes	18 years' experience 8 numbers of Green Projects
KI 6	Quantity Surveyor	20 years	Yes	20 years' experience with 5 numbers of Green Projects
KI 7	Project Manager	20 years	Yes	20 years' experience with 9 numbers of Green Projects
KI 8	Cost Consultant	18 years	Yes	18 years' experience with 8 numbers of Green Projects
KI 9	System Engineer	15years	No	Have knowledge and experience in application of AI
KI 10	Cyber Security Consultant	13 years	No	Have knowledge and experience in application of AI
KI 11	System Engineer	19 years	No	Have knowledge and experience in application of AI
KI 12	Big Data & Data Science Engineer	10.5 years	No	Have knowledge and experience in application of AI
KI 13	Software Engineer	15 years	No	Have knowledge and experience in application of AI
KI 14	System Engineer	21 years	No	Have knowledge and experience in application of AI

Key Informant	Professional career	Years of experience	Green Accreditation	Remarks
KI 15	Software Engineer - Data Engineering	11 years	No	Have knowledge and experience in application of AI

4.2.4 Applicable AI technique in Sri Lankan construction industry

The aforementioned, key informants were asked three key questions (question 1,2 and 3) with the aim of constructing the hierarchy for the AHP as discussed in Section 4.2.2. Firstly, the key informants were asked to identify further applicable AI technique in construction industry (question 1). The answers yield from the key informants for the question asked to identify the applicable AI techniques in Sri Lanka are summarised in Table 4.2.

As shown in Table 4.2, the AI techniques applied in construction industry that were extracted through the literature synthesis were first listed. Then all thirteen AI techniques were validated to the Sri Lankan construction industry. KI2 made a note on that as "*Artificial intelligence takes over many industries all over the world as it has numerous and irreplaceable advantages. Likewise for other industries, the construction industry can be attained vital assist from artificial intelligence. Application of AI in construction industry assists the management of the projects within time, budget and scope limitation. Also, it will increase the efficiency and the productivity for sure. But the welcoming of artificial intelligence by Sri Lankan construction industry is really really harder as a developing industry and exiting mind set of the project participants. However, addressing the barriers, issues and limitation in adopting artificial intelligence into the construction industry should be researched and established as it has more advantages.*". Almost every key informant has highlighted it. Hence, all of fifteen key informants suggested that those thirteen AI techniques can be applied in Sri Lankan construction industry. KI5 added to that, "*Even it is a new aspect to the construction industry, once the identification and overcoming done with respective barriers, the benefits of AI application can be attained even in Sri Lankan Construction industry*." KI8 furthered to that, "*Despite of several barriers, the concepts like automation, robots, distance vision and IoT are trying to get fit in this industry*".

Table 4.2 – Applicable AI techniques in Sri Lankan Construction Industry

Code	AI Techniques	KI 1	KI 2	KI 3	KI 4	KI 5	KI 6	KI 7	KI 8	KI 9	KI 10	KI 11	KI 12	KI 13	KI 14	KI 15
AIT1	Knowledge Representation and Reasoning	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
AIT2	Information Fusion	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
AIT3	Intelligent Optimization	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
AIT4	Smart Robotics	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
AIT5	Computer Vision	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
AIT6	Process Mining	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
AIT7	Cloud Virtual Reality/ Augmented Reality	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
AIT8	Natural Language Processing	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
AIT9	Artificial Internet of Things	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
AIT10	Digital Twin	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
AIT11	4D Printing	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
AIT12	Blockchain	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
AIT13	Machine Learning	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
AIT14	**Reinforcement Learning**	x	x	x	x	x	x	x	x	x	x	x	√	x	x	x
AIT15	**Expert Systems**	x	x	x	x	x	x	x	x	√	√	√	√	√	√	√
AIT16	**Multi Agent Systems**	x	x	x	x	x	x	x	x	√	√	√	√	√	√	√
AIT17	**Fuzzy Logic**	x	√	x	x	√	√	x	x	√	√	√	√	√	√	√

The key informants have identified 4 additional AI techniques that can be adopted to the Sri Lankan construction industry. These AI techniques are, **reinforcement learning (AIT14)**, **expert systems (AIT15)**, **multi agent systems (AIT16)** and **fuzzy logics (AIT17)**. Hereunder, the key informants' clarifications on these additional AI techniques are given.

Reinforcement Learning (AIT14)

KI12 stated that Reinforcement Learning as, "*Reinforcement learning is a machine learning training method based on rewarding desired behaviours and also sometimes punishing undesired ones. In general, a reinforcement learning allows perceive and interpret its environment, take actions and learn through trial and error*". KI12 further illustrated its application in construction industry, "*Reinforcement learning helps to get rid of stalling on lesser goals. With time, the agent learns to avoid the negative and seek the positive. This learning method does unsupervised machine learning through rewards and penalties. In the areas such as resource management and robotics in the construction industry, this method can be implemented*".

Expert Systems (AIT15)

All the key informants from IT industry have introduced that the expert system as an AI technique which can be applied in Sri Lankan construction industry. KI12 highlighted that, *"An expert system can be introduced as a knowledge based application"*. According to KI9, *"Hence, expert systems preserve the human expert's knowledge"*. KI13 added to that, "*Those expert systems can come up with decisions and can provide explanations about how they reached a particular conclusion or advice*". KI15 elaborated that, those expert systems can be used to, "*manage the construction project within established objectives*".

Multi Agent Systems (AIT16)

As well as the expert system, all key informants from IT industry have introduced that the multi agent system as an AI technique that can be implemented in Sri Lankan Construction industry. K13 defined that, "*A multi-agent system is a decision-making*

tool. First, it develops interaction with a particular environment and then make the decisions based on its goals". KI15 explained that "*due to the construction projects are typically run through very dynamic, complex and risky environment, the techniques in artificial intelligence will surely assist in construction management. Among them this multi agent systems will be very effective as it would assist in decision making process considering all aspects in a construction project*".

Fuzzy Logic (AIT17)

All key informants from the IT industry and three of other key informants from construction industry has identified fuzzy logic as an AI technique that can be implemented in Sri Lankan Construction industry. KI10 has stated that, "*fuzzy logic is a method of reasoning to make a decision through an approach similar like humans perform decision making*". KI2 explained that "*the inherent vague and complex atmosphere in a construction project, welcome models running on the base of like fuzzy logic*".

Through the analysis of these findings, the objective 3 of the study; identifying the AI techniques that can be used in construction industry has been completely achieved. Accordingly, altogether seventeen AI techniques has been identified to the context of Sri Lankan construction industry. However, almost all key informants further highlighted that, though there are different advantages, plus points and possibilities are there in applying AI techniques into Sri Lankan construction industry, there are issues and barriers in such application in a context of Sri Lanka and in the context of construction industry.

4.2.5 Barriers Related to Effective Communication in Green Construction Project in Sri Lanka

The second question for the key informants was to validate and identify the barriers related to effective communication among project stakeholders in successfully delivering green construction project in Sri Lanka. The answers yield for the second question from fifteen respondents are summarised in Table 4.3.

Table 4.3 – Barriers to Effective Communication Among Project Stakeholders in Successfully Delivering Green Construction Project in Sri Lanka

Code	Barriers in Communication in Green Construction Projects	KI 1	KI 2	KI 3	KI 4	KI 5	KI 6	KI 7	KI 8	KI 9	KI 10	KI 11	KI 12	KI 13	KI 14	KI 15
B1	Political/community interference	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
B2	Poor listeners	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
B3	Poor leadership	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
B4	Unclear objectives	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
B5	Conflicting cultural values	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
B6	Unclear channels of communication	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
B7	Ineffective reporting system	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
B8	Information filtering	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
B9	Conflicting business/industry ethics	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
B10	Lack of necessary skills	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
B11	Lack of trust	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
B12	Lack of Concern	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
B13	Limited Resources	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
B14	Stereotyping	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
B15	Religious issues	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
B16	Language difficulties	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
B17	Age Differences	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
B18	**Attitude to not change (Reluctance to Change)**	**x**	√	**x**	**x**	√	**x**	√	√	√	**x**	√	**x**	√	**x**	**x**

As shown in Table 4.3, all of seventeen barriers to effective communication among project stakeholders in successfully delivering green construction project which were identified through the literature synthesis were validated to the Sri Lankan construction industry too. KI5 made a note on that as "*These each barrier obviously takes part in the poor communication in any kind of project. Therefore, these are applicable to the green construction and also to the Sri Lankan construction industry too*". Almost every key informant has highlighted it.

Other than that, one more barrier was identified to effective communication among project stakeholders in successfully delivering green construction project in Sri Lanka. That barrier is **attitude to not change (reluctance to change) (B18)**. Altogether seven key informants have identified this as a barrier to effective communication among project stakeholders in successfully delivering green construction project. KI2 explained that "*since traditional work process, behaviours and attitudes are deviated in a green construction project which requires more sustainable and collaborative approach, the conventional mind set and attitudes among project stakeholders barriers green project execution*". Moreover, KI7 stated that, "*this retrograde approach causes due to the attitude to not change pursuant to the processes in the green constructions by the stakeholders*". According to KI9, "*reluctance to change, considering the collaborative working environment barriers the effective communication among the project participants in a green construction project".* KI10 illustrated that*, "Participants' attitude to not to change between traditional construction process and green construction process put a fence for effective dissemination of information in green construction".*

4.2.6 Application of AI techniques to address the barriers related to effective communication within green construction in Sri Lanka

The third question for the key informants was to explain which AI techniques that can be used to overcome barriers related to effective communication among project stakeholders in successfully delivering green construction in Sri Lanka. Table 4.4 expresses a summary of the answers yield for the third question from fifteen respondents.

Table 4.4 – Applicable of AI techniques to address the barriers related to effective communication within green construction in Sri Lanka

Code	Barriers for Effective Communication in Green Construction in Sri Lanka	Code	Applicable AI Technique to Overcome the Barrier for Effective Communication in Green Construction in Sri Lanka
B1	Political/Community Interference	AIT1	Knowledge Representation and Reasoning
		AIT2	Information Fusion
		AIT6	Process Mining
		AIT13	Machine Learning
B2	Poor Listeners	AIT1	Knowledge Representation and Reasoning
		AIT4	Smart Robotics
		AIT6	Process Mining
		AIT8	Natural Language Processing
B3	Poor Leadership	AIT4	Smart Robotics
		AIT7	Cloud Virtual Reality/ Augmented Reality
		AIT8	Natural Language Processing
B4	Unclear Objectives	AIT3	Intelligent Optimization
		AIT7	Cloud Virtual Reality/ Augmented Reality
		AIT9	Artificial Internet of Things
		AIT10	Digital Twin
		AIT13	Machine Learning
		AIT14	**Reinforcement Learning**
B5	Conflicting Cultural Values	AIT4	Smart Robotics
		AIT5	Computer Vision
		AIT8	Natural Language Processing
		AIT9	Artificial Internet of Things
B6	Unclear Channels of Communication	AIT6	Process Mining
		AIT9	Artificial Internet of Things
		AIT12	Blockchain
B7	Ineffective Reporting System	AIT5	Computer Vision
		AIT6	Process Mining
		AIT9	Artificial Internet of Things
		AIT12	Blockchain
B8	Information Filtering	AIT5	Computer Vision
		AIT6	Process Mining
		AIT9	Artificial Internet of Things
		AIT12	Blockchain
B9	Conflicting business/industry ethics	AIT4	Smart Robotics
		AIT7	Cloud Virtual Reality/ Augmented Reality
B10	Lack of necessary skills	AIT7	Cloud Virtual Reality/ Augmented Reality
		AIT14	**Reinforcement Learning**

Code	Barriers for Effective Communication in Green Construction in Sri Lanka	Code	Applicable AI Technique to Overcome the Barrier for Effective Communication in Green Construction in Sri Lanka
B11	Lack of Trust	AIT4	Smart Robotics
		AIT5	Computer Vision
		AIT12	Blockchain
		AIT13	Machine Learning
B12	Lack of Concern	AIT4	Smart Robotics
		AIT9	Artificial Internet of Things
		AIT12	Blockchain
B13	Limited Resources	No suggested AI Technique by Key Informants	
B14	Stereotyping	AIT4	Smart Robotics
		AIT5	Computer Vision
		AIT8	Natural Language Processing
B15	Religious Issues	AIT4	Smart Robotics
		AIT5	Computer Vision
		AIT8	Natural Language Processing
B16	Language Difficulties	AIT4	Smart Robotics
		AIT8	Natural Language Processing
B17	Age Differences	AIT13	Machine Learning
B18	**Attitude to not change (reluctance to change)**	AIT1	Knowledge Representation and Reasoning
		AIT10	Digital Twin

As shown in Table 4.4, the key informants have identified that what AI techniques can be used to overcome the barrier for effective communication in green construction in Sri Lanka. However, none of them has suggested AI technique to overcome the barrier for the effective communication due to the limited resources. KI7 explained that "*absence of required resources for the communication in a green construction project is a physical condition that should be overcome by accommodating the necessary resources for the communication means".* Newly suggested AI techniques other than through the literature survey, **reinforcement learning (AIT14)** has been suggested to overcome two barriers for effective communication in green construction in Sri Lanka. KI12 suggested that unclear objectives (B4) and lack of necessary skills (B10) can be overcome through **reinforcement learning (AIT14)**. KI12 illustrated that, to overcome unclear objectives (B4) in green construction project, **reinforcement learning (AIT14)** "*can be used to simulate construction process of a site. From this, optimal resources like labour, materials, time can be forecasted to make the structure*

process effective and smooth." Further to the same key informant, to overcome lack of necessary skills (B10) through **reinforcement learning (AIT14**) allows that "*presentations via tableau and power BI dashboards. This would help much for higher management to take analytical and reasoning-based decisions*." Key informants have suggested Knowledge Representation and Reasoning (AIT1) and Digital Twin (AI10) to overcome the newly identified barrier of **attitude to not change (reluctance to change) (B18).** Age difference (B17) has been suggested with only one AI technique; Machine Learning (AIT13). KI12 suggested it, emphasizing that "*Machine learning based review applications*" can be used to overcome the issues arisen in communication among the stakeholders in green construction project due to the age difference.

Accordingly, the answers for the third question in KII initiated the fourth objective of the study as shown in Figure 3.3. Further, findings of this section finalise the hierarchy for the AHP as defined in Figure 3.3 and incorporated in the initial draft for the framework to enhance the effectiveness of communication using AI techniques in green construction in Sri Lanka as shown in Figure 4.2.

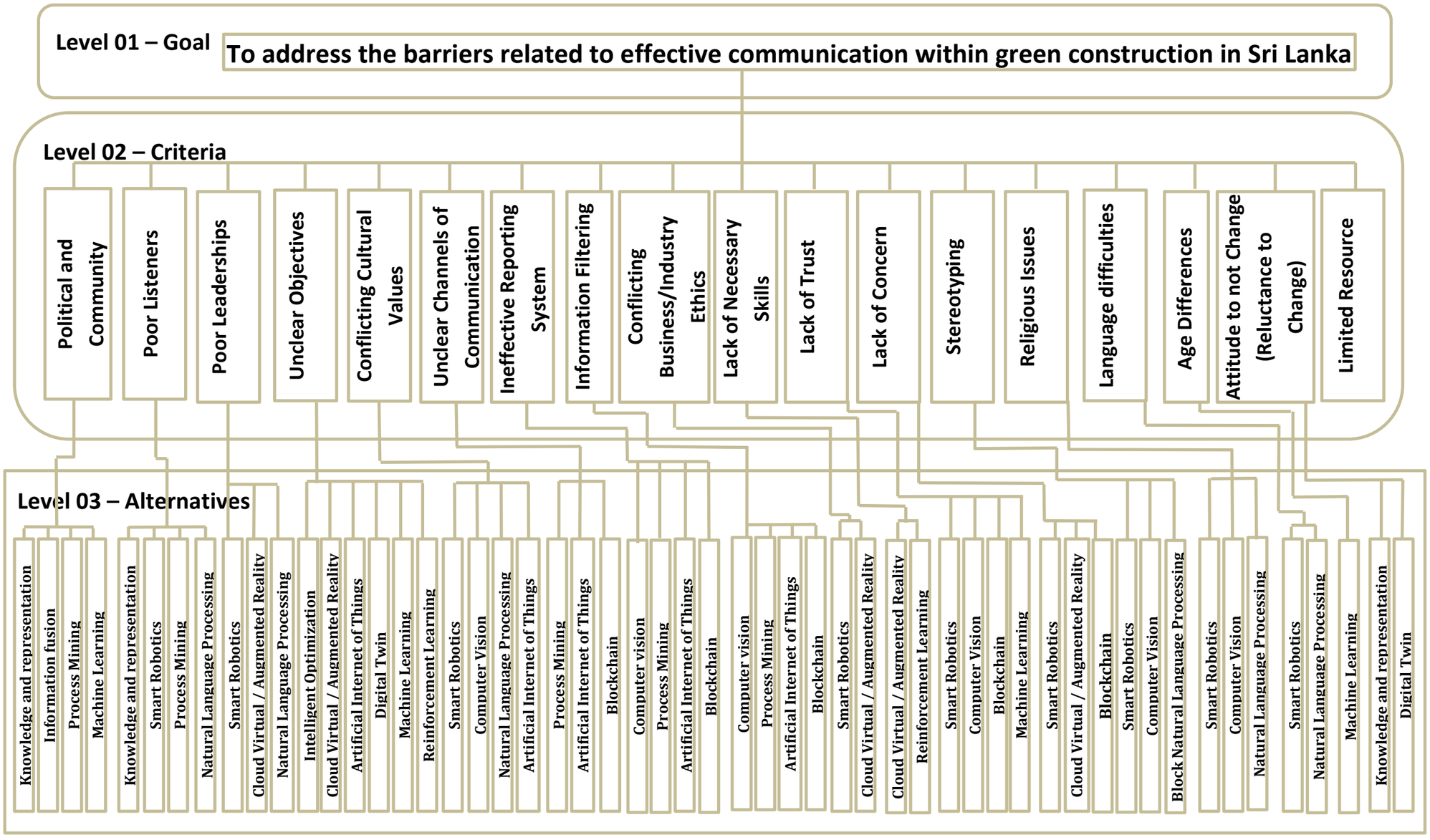


Figure 4-2 – Derived Hierarchy in AHP

4.2.7 Summary of the Key Informant Interviews

The analysis of the findings from KII completed the second and third objective of this study. It validated thirteen AI techniques to be applied in Sri Lankan construction industry and suggested other four more AI techniques. Altogether, findings of KII form a list of seventeen AI techniques that can be applicable in Sri Lankan construction industry when completing objective 3. KII validated seventeen barriers to effective communication in green construction project in Sri Lankan construction industry and introduced one more barrier. Then findings of KII form a list of eighteen barriers to effective communication in green construction project in Sri Lankan construction industry when completing objective 3. Finally, KII initiated the objective 4 of this study. Findings of KII identified that what AI techniques can be used to overcome the barrier for effective communication in green construction in Sri Lanka. It paced the initial step for the objective 4 and finalised the hierarchy yield for the AHP.

4.3 Analysis and Findings of Questionnaire Survey

As elaborated in previous chapter, the questionnaire survey has been selected and done to collect information within the framework of AHP with the limited experts who have experience and knowledge in green construction and / or application of different AI techniques in Sri Lanka. The findings of questionnaire survey were analysed through AHP and will be presented hereinunder. Findings and analysis of data collected through questionnaire survey focused on achieving the objective of this research as follows.

4.3.1 Objectives of the Questionnaire Survey

The application of each AI techniques to overcome the barriers in communication in green construction project in Sri Lanka were identified as an initiation to the fourth objective through KII. However, the fourth objective of evaluating the application of AI techniques to address the barriers related to effective communication within green construction in Sri Lanka objective was not only to identify the application of each AI techniques to overcome the barriers in communication in green construction project in Sri Lanka. The researcher expected to evaluate the application of each AI technique to overcome the barriers in communication in green construction project in Sri Lanka.

Therefore, the researcher expected to prioritise the applicable AI techniques for each barrier in communication in green construction project in Sri Lanka through this questionnaire survey. Accordingly, completion of fourth objective of the study has been attained by findings and analysis of data collected through questionnaire survey.

4.3.2 Structured Questionnaire

A structured questionnaire guideline was utilised to prioritize AI techniques in overcoming the barriers in communication in green construction project. Adhering to the systematic approach of AHP, the questionnaire was developed in a way where the respondent was able to pairwise comparison and to mark the effectiveness of AI techniques in addressing the barriers in communication in green construction project in Sri Lanka. The questionnaire guideline was prepared with outline to the research, instruction to the respondents in filling the questionnaire, room for respondent details and finally the question for pairwise comparison (Annexure B).

4.3.3 Details of the Respondents

Through mapping available experts based on the purposive sampling, this study was formulated and carried out by distributing 10 questionnaires among small sample group of possible 10 respondents who have green accreditation from the GBCSL with the knowledge of applying innovative and emerging technologies to the construction industry and then AI experts with more than 10 years of work experience in Sri Lankan IT industry.

Table 4.5 – Details of Respondents of Questionnaire Survey

Respondents	Profession	Experience	Green Accreditation	Remarks
R1	Project Manager	16 years	Yes	16 years' experience with 6 numbers of Green Projects
R2	Chief Quantity Surveyor	17 years	Yes	17 years' experience with 8 numbers of Green Projects
R3	Architect	18 years	Yes	18 years' experience 8 numbers of Green Projects
R4	Project Manager	20 years	Yes	20 years' experience with 9 numbers of Green Projects
R5	Cost Consultant	18 years	Yes	18 years' experience with 8 numbers of Green Projects
R6	Quantity Surveyor	20 years	Yes	20 years' experience with 5 numbers of Green Projects
R7	System Engineer	14 years	No	Have knowledge and experience in application of AI
R8	Software Engineer	15 years	No	Have knowledge and experience in application of AI
R9	System Engineer	21 years	No	Have knowledge and experience in application of AI
R10	Cyber Security Consultant	12 years	No	Have knowledge and experience in application of AI

4.3.4 Analysis of the Questionnaire Survey

The pairwise compared findings by the respondents were analysed through the AHP as well illustrated in third chapter of this write up. The steps and calculations which were carried out in AHP will be attached as Annexure C to this write up for further reviewing purposes of any followers. Accordingly, hereunder the ranking of each applicable AI techniques in overcoming barriers in communication in green construction project will be shown. It is noteworthy to mention that in this 4.3.4 section, the term objective is referred to the objective in pairwise comparison as in the

structure questionnaire guideline. This term of objective does not refer the objectives of the study.

4.3.4.1 Overcoming issues in communication in green construction project due to political and community interference (B1)

In terms of overcoming issues in communication in green construction project due to political and community interference (Criteria 01), four AI techniques were suggested by the key informants;

- AIT1 – Knowledge Representation and Reasoning
- AIT2 – Information Fusion
- AIT6 – Process Mining
- AIT13 – Machine Learning

Table 4.6 – AHP Score Matrix for Overcoming B1

Criteria 01	AIT1	AIT2	AIT6	AIT13	Performance Score	Rank
AIT1	1.0000	4.9136	4.9136	3.1572	**0.5815**	**1**
AIT2	0.2035	1.0000	1.1161	1.1161	**0.1399**	**3**
AIT6	0.2035	0.8960	1.0000	1.3741	**0.1425**	**2**
AIT13	0.3167	0.8960	0.7277	1.0000	**0.1361**	**4**
sum	1.7238	7.7055	7.7574	6.6475		

Table 4.6 demonstrates the performance score matrix of applicable AI techniques in overcoming issues in communication in green construction project due to political and community interference. The λmax for analysed data is 4.0631 (using Equation 3.2). Accordingly, CI is calculated as 0.0210 as per the Equation 3.3. Hence, the CR value of the pairwise judgments came as 0.0236 pursuant to the Equation 3.4. Therefore, it can be identified that these particular judgements are consistent as the value of CR is lesser than 0.1.

According to the Equation 3.2 here, λ_{max} = (4.1248+4.0682+4.0225+4.0370) / 4

= 4.0631

According to the Equation 3.3 here, CI = (λ_{max} – n)/ (n -1) = (4.0631 -4)/3

= 0.0210

Since there are four AI techniques to be pair wise compared n = 4,

Therefore, applicable RI value according to Table 3.5 ;

RI figure = 0.89

According to the Equation 3.4 here,

CR = CI/RI = 0.0210/0.89

CR = 0.0236 (< 0.1 ∴ This data set is in consistency. Therefore, this data is accepted for further analysis)

As per the analysis of the findings, AIT1 is the highest effective AI technique with 0.5815 score when compares to AIT2 (0.1399), AIT6 (0.1425) and AIT13 (0.1361) respectively. Thus, AIT1 is nearly three times important as others. It emphasised that applying knowledge representation and reasoning is comparatively very effective in overcoming the issues in communication in green construction project due to political and community interference. Furthermore, the close difference among AIT2 and AIT13 reveals both the AIT2 and AIT13 effectiveness in overcoming B1 are almost equally significant. Comparing to AIT2 and AIT13, AIT6 has slightly more effectiveness in overcoming B1.

4.3.4.2 Overcoming issues in communication in green construction project due to poor listeners in a project (B2)

In terms of overcoming issues in communication in green construction project due to poor listeners in a project (Criteria 02), four AI techniques were suggested by the key informants;

- AIT1 – Knowledge Representation and Reasoning
- AIT4 – Smart Robotics
- AIT6 – Process Mining
- AIT8 – Natural Language Processing

Table 4.7 demonstrates the performance score matrix of afore-mentioned applicable AI techniques in overcoming issues in communication in green construction project due to poor listeners in project.

Table 4.7 – AHP Score Matrix for Overcoming B2

Criteria 02	AIT1	AIT4	AIT6	AIT8	Performance Score	Rank
AIT1	1.0000	0.1441	1.0000	0.1441	**0.0681**	**4**
AIT4	6.9406	1.0000	6.2185	3.0000	**0.5679**	**1**
AIT6	1.0000	0.1608	1.0000	0.3333	**0.0812**	**3**
AIT8	6.9406	0.3333	3.0000	1.0000	**0.2828**	**2**
sum	15.8813	1.6382	11.2185	4.4774		

The λmax for analysed data is 4.1344. Accordingly, CI is calculated as 0.0445. Hence, the CR value of the pairwise judgments came as 0.0500. Therefore, it can be identified that these particular judgements are consistent as the value of CR is lesser than 0.1.

According to the Equation 3.3 here, CI = (4.1344 -4)/3 = 0.0445

Since there are four AI techniques to be pair wise compared n = 4,

Therefore, applicable RI value according to Table 3.5 ;

RI figure = 0.89

According to the Equation 3.4 here,

CR = CI/RI = 0.0445/0.89

CR = 0.0500 (< 0.1 ∴ This data set is in consistency. Therefore, this data is accepted for further analysis)

As per the analysis, AIT4 is the highest effective AI technique with 0.5679 score when compares to AIT8 (0.2828), AIT6 (0.0812) and AIT1 (0.0681) respectively. Thus, AIT1 is nearly two times important than the second most effective AI technique (AIT8) overcome B2. It emphasized that applying smart robotics is comparatively very effective in overcoming the issues in communication in green construction project due to poor listeners. Further, AIR8 is nearly three times important than AIT6 and AIT1. Therefore, comparing to AIT6 and AIT1, AIT8 has more effectiveness in overcoming

B2. Furthermore, the close difference among AIT1 and AIT6 reveals both the AIT2 and AIT13 effectiveness in overcoming B2 are almost equally significant.

4.3.4.3 Overcoming issues in communication in green construction project due to poor leadership (B3)

In terms of overcoming issues in communication in green construction project due to poor leadership (Criteria 03), three AI techniques were suggested by the key informants;

- AIT4 – Smart Robotics
- AIT7 – Cloud Virtual Reality/ Augmented Reality
- AIT8 – Natural Language Processing

Table 4.8 demonstrates the performance score matrix of applicable AI techniques in overcoming issues in communication in green construction project due to poor leadership.

Table 4.8 – AHP Score Matrix for Overcoming B3

Criteria 03	AIT4	AIT7	AIT8	Performance Score	Rank
AIT4	1.0000	1.0000	5.9835	**0.4640**	1
AIT7	1.0000	1.0000	5.7249	**0.4573**	2
AIT8	0.1671	0.1747	1.0000	**0.0787**	3
sum	2.1671	2.1747	12.7084		

The λmax for analysed data is 3.002. Accordingly, CI is calculated as 0.0001. Hence, the CR value of the pairwise judgments came as 0.0002. Therefore, it can be identified that these particular judgements are consistent as the value of CR is lesser than 0.1.

According to the Equation 3.3 here, CI = (3.002 -3)/2 = 0.0001

Since there are three AI techniques to be pair wise compared n = 3,

Therefore, applicable RI value according to Table 3.5;

RI figure = 0.52

According to the Equation 3.4 here,

CR = CI/RI = 0.0001/0.52

CR = 0.0002 (< 0.1 ∴ This data set is in consistency. Therefore, this data is accepted for further analysis)

As per the analysis, AIT4 is the highest effective AI technique with 0.4640 score when compares to AIT7 (0.4573) and AIT8 (0.0787) respectively. Furthermore, the close difference among AIT4 and AIT7 reveals both the AIT4 and AIT7 effectiveness in overcoming B3 are almost equally significant. Thus, AIT4 is nearly six times important than the third most effective AI technique (AIT7) in overcoming B3. It emphasized that applying smart robotics and cloud virtual reality/ augmented reality are comparatively very effective in overcoming the issues in communication in green construction project due to poor leadership.

4.3.4.4 Overcoming issues in communication in green construction project due to unclear objectives (B4)

In terms of overcoming issues in communication in green construction project due to unclear objectives (Criteria 04), six AI techniques were suggested by the key informants;

- AIT7 – Cloud Virtual Reality/ Augmented Reality
- AIT3 – Intelligence Optimisation
- AIT9 – Artificial Internet of Things
- AIT10 – Digital Twin
- AIT13 – Machine Learning
- AIT14 – Reinforcement Learning

Table 4.9 demonstrates the performance score matrix of applicable AI techniques in overcoming issues in communication in green construction project due to unclear objectives.

Table 4.9 – AHP Score Matrix of Overcoming B4

Criteria 04	AIT3	AIT7	AIT9	AIT10	AIT13	AIT14	Performance Score	Rank
AIT3	1.0000	2.7663	1.0000	0.1477	0.5774	0.5774	**0.1048**	5
AIT7	0.3615	1.0000	1.0000	0.3333	2.0000	2.0000	**0.1233**	3
AIT9	1.0000	1.0000	1.0000	0.1168	0.1608	0.1608	**0.0552**	6
AIT10	6.7684	3.0000	8.5588	1.0000	5.3481	5.3481	**0.4743**	1
AIT13	1.7321	0.5000	0.5000	0.5000	1.0000	1.0000	**0.1065**	4
AIT14	1.7321	0.5000	6.2185	0.1870	1.0000	1.0000	**0.1358**	2
sum	12.5940	8.7663	18.2773	2.2849	10.0862	10.0862		

The λmax for analysed data is 6.2890. Accordingly, CI is calculated as 0.0578. Hence, the CR value of the pairwise judgments came as 0.0462. Therefore, it can be identified that these particular judgements are consistent as the value of CR is lesser than 0.1.

According to the Equation 3.3 here, CI = (6.2890 -6)/5 = 0.0578

Since there are six AI techniques to be pair wise compared n = 6,

Therefore, applicable RI value according to Table 3.5;

RI figure = 1.25

According to the Equation 3.4 here,

CR = CI/RI = 0.0578/1.25

CR = 0.0462 (< 0.1 ∴ This data set is in consistency. Therefore, this data is accepted for further analysis)

As per the analysis, AIT10 is the highest effective AI technique with 0.4743 score when compares to AIT14 (0.1358), AIT7 (0.1233), AIT13 (0.1065), AIT3(0.1048) and AIT9 (0.0552) respectively. Accordingly, AIT10 is nearly four times effective than the second most effective AI technique (AIT14) in overcoming B4. Furthermore, the close difference among second and third most effective AI techniques AIT14 and AIT7 reveals both the AIT14 and AIT7 effectiveness in overcoming B4 are almost equally significant. Nevertheless, there is also a close difference among fourth and fifth most effective AI techniques AIT13 and AIT3 revealing both the AIT14 and AIT7 effectiveness in overcoming B4 are almost equally significant. Therefore, it is

emphasized that applying digital twin is comparatively very effective in overcoming the issues in communication in green construction project due to unclear objectives.

4.3.4.5 Overcoming issues in communication in green construction project due to conflicting cultural values (B5)

In terms of overcoming issues in communication in green construction project due to conflicting cultural values (Criteria 05), four AI techniques were suggested by the key informants;

- AIT4 – Smart Robotics
- AIT5 – Computer Vision
- AIT8 – Natural Language Processing
- AIT9 – Artificial Internet of Things

Table 4.10 demonstrates the performance score matrix of applicable AI techniques in overcoming issues in communication in green construction project due to conflicting cultural values.

Table 4.10 – AHP Score Matrix of Overcoming B5

Criteria 05	AIT4	AIT5	AIT8	AIT9	Performance Score	Rank
AIT4	1.0000	2.8808	2.5811	2.8808	**0.4711**	1
AIT5	0.3471	1.0000	0.8960	1.0000	**0.1635**	3
AIT8	0.3874	1.1161	1.0000	2.3800	**0.2261**	2
AIT9	0.3471	1.0000	0.4202	1.0000	**0.1393**	4
sum	2.0817	5.9969	4.8972	7.2608		

The λmax for analysed data is 4.0730. Accordingly, CI is calculated as 0.0243. Hence, the CR value of the pairwise judgments came as 0.0002. Therefore, it can be identified that these particular judgements are consistent as the value of CR is lesser than 0.1.

According to the Equation 3.3 here, CI = (4.0730 -4)/3 = 0.0243

Since there are four AI techniques to be pair wise compared n = 4,

Therefore, applicable RI value according to Table 3.5;

RI figure = 0.89

According to the Equation 3.4 here,

CR = CI/RI = 0.0243/0.89

CR = 0.0273 (< 0.1 ∴ This data set is in consistency. Therefore, this data is accepted for further analysis)

As per the analysis, AIT4 is the highest effective AI technique with 0.4711 score when compares to AIT8 (0.2261), AIT5 (0.1635) and AIT9 (0.1393) respectively. Accordingly, AIT4 is nearly two times effective than the second most effective AI technique (AIT8) in overcoming B5. Therefore, it is emphasized that applying smart robotics is comparatively very effective in overcoming the issues in communication in green construction project due to conflicting cultural values.

4.3.4.6 Overcoming issues in communication in green construction project due to unclear channels of communication (B6)

In terms of overcoming issues in communication in green construction project due to unclear channels of communication (Criteria 06), four AI techniques were suggested by the key informants;

- AIT6 – Process Mining
- AIT9 – Artificial Internet of Things
- AIT12 – Blockchain

Table 4.11 demonstrates the performance score matrix of applicable AI techniques in overcoming issues in communication in green construction project due to unclear channels of communication.

Table 4.11 – AHP Score Matrix of Overcoming B6

Criteria 06	AIT6	AIT9	AIT12	Performance Score	Rank
AIT6	1.0000	0.3078	0.1429	**0.0845**	3
AIT9	3.2494	1.0000	0.2910	**0.2342**	2
AIT12	7.0000	3.4364	1.0000	**0.6813**	1
sum	11.2494	4.7442	1.4339		

The λmax for analysed data is 3.0244. Accordingly, CI is calculated as 0.0234. Hence, the CR value of the pairwise judgments came as 0.0002. Therefore, it can be identified that these particular judgements are consistent as the value of CR is lesser than 0.1.

According to the Equation 3.3 here, CI = (3.0244 -3)/2 = 0.0122

Since there are three AI techniques to be pair wise compared n = 3,

Therefore, applicable RI value according to Table 3.5;

RI figure = 0.52

According to the Equation 3.4 here,

CR = CI/RI = 0.0122/0.52

CR = 0.0234 (< 0.1 ∴ This data set is in consistency. Therefore, this data is accepted for further analysis)

As per the analysis, AIT12 is the highest effective AI technique with 0.6813 score when compares to AIT9 (0.2342) and AIT6 (0.0845) respectively. Accordingly, AIT12 is nearly three times effective than the second most effective AI technique (AIT9) in overcoming B6. Therefore, it is emphasized that applying block chain is comparatively very effective in overcoming the issues in communication in green construction project due to unclear channels of communication. Perera et al. (2020) has shown in their study that blockchain is a effective solution to store and manage document in construction indsutry. Accordingly, the finding of this study shows here that blockchain is a good option in overcoming the unclear commucantion channels. Comparatively, AIT6 has the lowest effectiveness among applcaible AI techniques to overcome B6.

4.3.4.7 Overcoming issues in communication in green construction project due to ineffective reporting system (B7)

In terms of overcoming issues in communication in green construction project due to ineffective reporting system (Criteria 07), four AI techniques were suggested by the key informants;

- AIT5 – Computer Visions
- AIT6 – Process Mining
- AIT9 – Artificial Internet of Things
- AIT12 – Blockchain

Table 4.12 demonstrates the performance score matrix of applicable AI techniques in overcoming issues in communication in green construction project due to ineffective reporting system.

Table 4.12 – AHP Score Matrix of Overcoming B7

Criteria 07	AIT5	AIT6	AIT9	AIT12	Performance Score	Rank
AIT5	1.0000	2.8471	0.2105	2.8471	**0.2368**	2
AIT6	0.3512	1.0000	0.2215	1.0000	**0.1039**	4
AIT9	4.7510	4.5144	1.0000	2.8471	**0.5373**	1
AIT12	0.3512	1.0000	0.3512	1.0000	**0.1220**	3
sum	6.4535	9.3615	1.7832	7.6941		

The λmax for analysed data is 4.2519. Accordingly, CI is calculated as 0.0943. Hence, the CR value of the pairwise judgments came as 0.0002. Therefore, it can be identified that these particular judgements are consistent as the value of CR is lesser than 0.1.

According to the Equation 3.3 here, CI = (4.2519-4)/3 = 0.0840

Since there are three AI techniques to be pair wise compared n = 3,

Therefore, applicable RI value according to Table 3.5;

RI figure = 0.52

According to the Equation 3.4 here,

CR = CI/RI = 0.0840/0.59

CR = 0.0943 (< 0.1 ∴ This data set is in consistency. Therefore, this data is accepted for further analysis)

As per the analysis, AIT9 is the highest effective AI technique with 0.5373 score when compares to AIT5 (0.2368), AIT12 (0.1220) and AIT6 (0.1039) respectively.

Accordingly, AIT9 has more than two times of effectiveness comparing to the second most effective AI technique (AIT5) in overcoming B7. Comparatively, AIT6 has the lowest effectiveness among applcaible AI techniques to overcome B7. Therefore, it is emphasized that applying artificial internet of things (AIT9) is comparatively very effective in overcoming the issues in communication in green construction project due to ineffective reporting system.

4.3.4.8 Overcoming issues in communication in green construction project due to information filtering (B8)

In terms of overcoming issues in communication in green construction project due to information filtering (Criteria 08), four AI techniques were suggested by the key informants;

- AIT5 – Computer Visions
- AIT6 – Process Mining
- AIT9 – Artificial Internet of Things
- AIT12 – Blockchain

Table 4.13 demonstrates the performance score matrix of applicable AI techniques in overcoming issues in communication in green construction project due to ineffective reporting system.

Table 4.13 – AHP Score Matrix of Overcoming B8

Criteria 08	AIT5	AIT6	AIT9	AIT12	Performance Score	Rank
AIT5	1.0000	4.0941	0.7490	2.5313	**0.3734**	1
AIT6	0.2443	1.0000	0.5842	1.0000	**0.1415**	3
AIT9	1.3351	1.7118	1.0000	2.5313	**0.3483**	2
AIT12	0.3951	1.0000	0.3951	1.0000	**0.1368**	4
sum	2.9745	7.8058	2.7282	7.0626		

The λmax for analysed data is 4.1165. Accordingly, CI is calculated as 0.0388. Hence, the CR value of the pairwise judgments came as 0.0437. Therefore, it can be identified that these particular judgements are consistent as the value of CR is lesser than 0.1.

According to the Equation 3.3 here, CI = (4.1165-4)/3 = 0.0388

Since there are four AI techniques to be pair wise compared n = 4,

Therefore, applicable RI value according to Table 3.5;

RI figure = 0.89

According to the Equation 3.4 here,

CR = CI/RI = 0. 0388/0.89

CR = 0.0437 (< 0.1 ∴ This data set is in consistency. Therefore, this data is accepted for further analysis)

As per the analysis, AIT5 is the highest effective AI technique with 0.3734 score when compares to AIT9 (0.3483), AIT6 (0.1415) and AIT6 (0.1368) respectively. Accordingly, AIT5 and AIT9 has typically equal effectiveness comparing to the in overcoming B8. Comparatively, AIT12 has the lowest effectiveness among applcaible AI techniques to overcome B8. However, AIT6 and AIT12 has slightly equal effectiveness in overcoming B8. Therefore, it is emphasized that applying computer vision (AIT5) is comparatively very effective in overcoming the issues in communication in green construction project due to information filtering. Schia (2019) has stated that computer vision allows to access the real time site data. Therefore, it can be identified that since real time data are collected and anslysed through the computer vision technique, no information filtering can be expected.

4.3.4.9 Overcoming issues in communication in green construction project due to conflicting business/industry ethics (B9)

In terms of overcoming issues in communication in green construction project due to conflicting business/industry ethics (Criteria 09), two AI techniques were suggested by the key informants;

- AIT4 – Smart Robotics
- AIT7 – Cloud Virtual Reality/ Augmented Reality

Table 4.14 demonstrates the performance score matrix of applicable AI techniques in overcoming issues in communication in green construction project due to conflicting business/industry ethics.

Table 4.14 – AHP Score Matrix of Overcoming B9

Criteria 09	AIT4	AIT7	Performance Score	Rank
AIT4	1.0000	1.7118	**0.6312**	1
AIT7	0.5842	1.0000	**0.3688**	2
sum	1.5842	2.7118		

According to the KII, two AI techniques were suggested to overcome B9. Therefore, there is only one comparison was to be done between AIT4 and AIT7 in the questionnaire survey. Therefore, the data collected through that survey referring to this particular comparison can be considered as in consistency since there was only one pairwise comparison. It confirms that analysed result yield for this one comparison, λ max with 2.000 figure.

Among the two possible AI technique in overcoming B9, smart robotics (AIT4) scored 0.6312 is more effective than AIT7 (0.3688). Therefore, it is emphasized that applying smart robotics (AIT4) is comparatively more effective in overcoming the issues in communication in green construction project due to conflicting industry/ business ethics.

4.3.4.10 Overcoming issues in communication in green construction project due to lack of necessary skills (B10)

To overcome the issues in communication in green construction project due to lack of necessary skills (Criteria 10), two AI techniques were suggested by the key informants;

- AIT7 – Cloud Virtual Reality/ Augmented Reality
- AIT14 – Reinforcement Learning

Table 4.15 demonstrates the performance score matrix of applicable AI techniques in overcoming issues in communication in green construction project due to lack of necessary skills.

Table 4.15 – AHP Score Matrix of Overcoming B10

Criteria 10	AIT7	AIT14	Performance Score	Rank
AIT7	1.0000	0.7248	**0.4202**	2
AIT14	1.3797	1.0000	**0.5798**	1
sum	2.3797	1.7248		

As in overcoming B9, two AI techniques were suggested to overcome B10 through KII. Therefore, there is only one comparison was to be done between AIT7 and AIT14 in the questionnaire survey. Therefore, the data yield from the questionnaire in this comparison has consistency since there was only one pairwise comparison. It confirms that analysed result yield for this one comparison, λ max with 2.000 figure.

Among the two possible AI technique in overcoming B10, reinforcement learning (AIT14) scored 0.5798 is more effective than AIT7 (0.4202). Therefore, it is emphasized that applying reinforcement learning (AIT14) is comparatively more effective in overcoming the issues in communication in green construction project due to conflicting industry/ business ethics. However, the performance scores of both techniques in overcoming B10 show a little difference relatively. Therefore, when selecting the most effective one among two, the related factors for each AI techniques such as cost, available resources, time etc. can be considered.

4.3.4.11 Overcoming issues in communication in green construction project due to lack of trust (B11)

In terms of overcoming issues in communication in green construction project due to lack of necessary skills (Criteria 11), two AI techniques were suggested by the key informants;

- AIT4 – Smart Robotics
- AIT5 – Computer Vision
- AIT12 – Block Chain
- AIT13 – Machine Learning

Table 4.16 demonstrates the performance score matrix of applicable AI techniques in overcoming issues in communication in green construction project due to lack of trust.

Table 4.16 – AHP Score Matrix of Overcoming B11

Criteria 11	AIT4	AIT5	AIT12	AIT13	Performance Score	Rank
AIT4	1.0000	1.0000	1.7321	1.4633	**0.3091**	1
AIT5	1.0000	1.0000	1.4051	1.4051	**0.2902**	2
AIT12	0.5774	0.7117	1.0000	1.0000	**0.1963**	4
AIT13	0.6834	0.7117	1.0000	1.0000	**0.2044**	3
sum	3.2608	3.4234	5.1372	4.8684		

The λmax for analysed data is 4.0046. Accordingly, CI is calculated as 0.0046. Hence, the CR value of the pairwise judgments came as 0.0017. Therefore, it can be identified that these particular judgements are consistent as the value of CR is lesser than 0.1.

According to the Equation 3.3 here, CI = (4.0046-4)/3 = 0.0046

Since there are four AI techniques to be pair wise compared n = 4,

Therefore, applicable RI value according to Table 3.5;

RI figure = 0.89

According to the Equation 3.4 here,

CR = CI/RI = 0. 0046/0.89

CR = 0.0017 (< 0.1 ∴ This data set is in consistency. Therefore, this data is accepted for further analysis)

According to the findings of questionnaire survey, AIT4 is the highest effective AI technique with 0.3091 score when compares to AIT5 (0.2902), AIT13 (0.2044) and AIT13 (0.1963) respectively. Accordingly, AIT4 and AIT5 has typically equal effectiveness comparing to the in overcoming B11. Comparatively, AIT12 has the lowest effectiveness among applcaible AI techniques to overcome B11. Therefore, it is emphasized that applying computer vision (AIT4) is comparatively more effective in overcoming the issues in communication in green construction project due to information filtering.

4.3.4.12 Overcoming issues in communication in green construction project due to lack of concern (B12)

To overcome the issues in communication in green construction project due to lack of concern (Criteria 12), three AI techniques were suggested by the key informants;

- AIT4 – Smart Robotics
- AIT9 – Artificial Internet of Things
- AIT12 – Block Chain

Table 4.17 demonstrates the performance score matrix of applicable AI techniques in overcoming issues in communication in green construction project due to lack of trust.

Table 4.17 – AHP Score Matrix of Overcoming B12

Criteria 12	AIT4	AIT9	AIT12	Performance Score	Rank
AIT4	1.0000	0.8360	1.9105	**0.3706**	2
AIT9	1.1962	1.0000	2.0694	**0.4289**	1
AIT12	0.5234	0.4832	1.0000	**0.2005**	3
sum	2.7196	2.3192	4.9799		

The λmax for analysed data is 3.0011. Accordingly, CI is calculated as 0.0005. Hence, the CR value of the pairwise judgments came as 0.0017. Therefore, it can be identified that these particular judgements are consistent as the value of CR is lesser than 0.1.

According to the Equation 3.3 here, CI = (3.0011-3)/2 = 0.0005

Since there are three AI techniques to be pair wise compared n = 3,

Therefore, applicable RI value according to Table 3.5;

RI figure = 0.52

According to the Equation 3.4 here,

CR = CI/RI = 0. 0046/0.52

CR = 0.0017 (< 0.1 ∴ This data set is in consistency. Therefore, this data is accepted for further analysis)

As per the analysis, AIT9 is the highest effective AI technique with 0.4289 score when compares to AIT4 (0.3706) and AIT12 (0.2005) respectively. Furthermore, the close difference among AIT4 and AIT7 reveals both the AIT4 and AIT7 effectiveness in overcoming B12 are almost equally significant. Thus, AIT9 is nearly two times important than the third most effective AI technique (AIT12) in overcoming B12. It emphasized that applying AIT9 is comparatively more effective in overcoming the issues in communication in green construction project due to lack of concern.

4.3.4.13 Overcoming issues in communication in green construction project due to limited resource (B13)

In terms of overcoming issues in communication in green construction project due to limited resources (Criteria 13) were assigned with none of AI techniques according to the qualitative data collection and analysis. Hence, this criterion has not been subjected to the pairwise comparison in AHP.

4.3.4.14 Overcoming issues in communication in green construction project due to stereotyping (B14)

In terms of overcoming issues in communication in green construction project due to stereotyping (Criteria 14), three AI techniques were suggested by the key informants;

- AIT4 – Smart Robotics
- AIT5 – Computer Vision
- AIT8 – Natural Language Processing

The Table 4.18 presents the result of analysed individual judgements on above listed three AI techniques using AHP in overcoming issues in communication in green construction project due to stereotyping.

Table 4.18 – AHP Score Matrix of Overcoming B14

Criteria 14	AIT4	AIT5	AIT8	Performance Score	Rank
AIT4	1.0000	1.0000	2.2587	**0.4055**	2
AIT5	1.0000	1.0000	2.5477	**0.4220**	1
AIT8	0.4427	0.3925	1.0000	**0.1725**	3
sum	2.4427	2.3925	5.8064		

The λmax for analysed data is 3.0016. Accordingly, CI is calculated as 0.0008. Hence, the CR value of the pairwise judgments came as 0.0015. Therefore, it can be identified that these particular judgements are consistent as the value of CR is lesser than 0.1.

According to the Equation 3.3 here, CI = (3.0016-3)/2 = 0.0008

Since there are three AI techniques to be pair wise compared n = 3,

Therefore, applicable RI value according to Table 3.5;

RI figure = 0.52

According to the Equation 3.4 here,

CR = CI/RI = 0. 0008/0.52

CR = 0.0015 (< 0.1 ∴ This data set is in consistency. Therefore, this data is accepted for further analysis)

As per the analysis, AIT5 (0.4220) is the most effective AI technique over other two AI techniques when overcoming issues in communication in green construction project due to stereotyping. The other two AI techniques; AIT4 (0.4055) and AIT8 (0.1725) are being differ to each other in scoring with a to some extent gap. Those three AI techniques in overcoming issues in communication in green construction project due to stereotyping can arrange according to their level of effectiveness AIT5, AIT4 and AIT8.

4.3.4.15 Overcoming issues in communication in green construction project due to religious issues (B15)

In terms of overcoming issues in communication in green construction project due to religious issues (Criteria 15), three AI techniques were suggested by the key informants;

- AIT4 – Smart Robotics
- AIT5 – Computer Vision
- AIT8 – Natural Language Processing

The Table 4.19 presents the result of analysed individual judgements on above listed three AI techniques using AHP in overcoming issues in communication in green construction project due to religious issues.

Table 4.19 – AHP Score Matrix of Overcoming B14

Criteria 15	AIT4	AIT5	AIT8	Performance Score	Rank
AIT4	1.0000	6.5444	2.7163	**0.6665**	1
AIT5	0.1528	1.0000	1.0000	**0.1432**	3
AIT8	0.3681	1.0000	1.0000	**0.1904**	2
sum	1.5209	8.5444	4.7163		

The λmax for analysed data is 3.0016. Accordingly, CI is calculated as 0.0005. Hence, the CR value of the pairwise judgments came as 0.0015. Therefore, it can be identified that these particular judgements are consistent as the value of CR is lesser than 0.1.

According to the Equation 3.3 here, CI = (3.0016-3)/2 = 0.0008

Since there are three AI techniques to be pair wise compared n = 3,

Therefore, applicable RI value according to Table 3.5;

RI figure = 0.52

According to the Equation 3.4 here,

CR = CI/RI = 0. 0008/0.52

CR = 0.0015 (< 0.1 ∴ This data set is in consistency. Therefore, this data is accepted for further analysis)

The performance score assigned for each AI technique can be expressed in the order of highest to lowest as AIT4 (0.6665), AIT8 (0.1904) and AIT5 (0.1432) respectively. Thus, AIT8 and AIT5 are seen to be equally significant in in overcoming issues in communication in green construction project due to religious issues. AIT4 is nearly more than four times significant than AIT8 and AIT5 when overcoming B15. Thus, it can conclude that out of all the three AI technique, smart robotics (AIT4) is effective to achieve the set Criteria 15.

4.3.4.16 Overcoming issues in communication in green construction project due to language difficulties (B16)

In terms of overcoming issues in communication in green construction project due to language difficulties (Criteria 16), two AI techniques were suggested by the key informants;

- AIT4 – Smart Robotics
- AIT8 – Natural Language Processing

According to the KII, two AI techniques were suggested to overcome B15. Therefore, there is only one comparison was to be done between AIT4 and AIT8 in the questionnaire survey. Therefore, the data collected through that survey referring to this particular comparison can be considered as in consistency since there was only one pairwise comparison. It confirms that analysed result yield for this one comparison, λ max with 2.000 figure.

Table 4.20 – AHP Score Matrix of Overcoming B16

Criteria 16	AIT1	AIT8	Performance Score	Rank
AIT4	1.0000	0.1380	**0.1212**	2
AIT8	7.2482	1.0000	**0.8788**	1
sum	8.2482	1.1380		

Among the two possible AI technique in overcoming B16, natural language processing (AIT8) scored 0.8788 is more effective than AIT4 (0.1212). Therefore, it is emphasized that applying natural language processing (NLP) (AIT8) is nearly four times effective than possible applications of smart robotics in overcoming the issues in communication in green construction project due to language difficulties. The NLP forms computational replicas that resemble the linguistic abilities of human beings (Bilal, et al., 2016). Hence, this finding emphasized the effectiveness of NLP in language difficulties.

4.3.4.17 Overcoming issues in communication in green construction project due to age difference (B17)

In terms of overcoming issues in communication in green construction project due to age difference (Criteria 17) were assigned with one AI technique (AIT13) according to the qualitative data collection and analysis. Hence, this criterion has not been subjected to the pairwise comparison in AHP.

4.3.4.18 Overcoming issues in communication in green construction project due to attitude to not to change (B18)

In terms of overcoming issues in communication in green construction project due to attitude to not to change (reluctance to change) (Criteria 18), two AI techniques were suggested by the key informants;

- AIT1 – Knowledge Representation and Reasoning
- AIT10 – Digital Twin

According to the KII, two AI techniques were suggested to overcome B18. Therefore, there is only one comparison was to be done between AIT1 and AIT10 in the questionnaire survey. Therefore, the data collected through that survey referring to this particular comparison can be considered as in consistency since there was only one pairwise comparison. It confirms that analysed result yield for this one comparison, λ max with 2.000 figure.

Table 4.21 – AHP Score Matrix of Overcoming B18

Criteria 18	AIT1	AIT10	Performance Score	Rank
AIT1	1.0000	0.5486	**0.3543**	2
AIT10	1.8228	1.0000	**0.6457**	1
sum	2.8228	1.5486		

The score distribution possible AI techniques in overcoming B18 demonstrates that AIT10 (0.6457) is more effective than AIT1 (0.3543). Accordingly, digital twin is more effective in overcoming issues in communication in green construction project due to attitude to not to change (reluctance to change).

4.3.5 Summary of the Questionnaire Survey

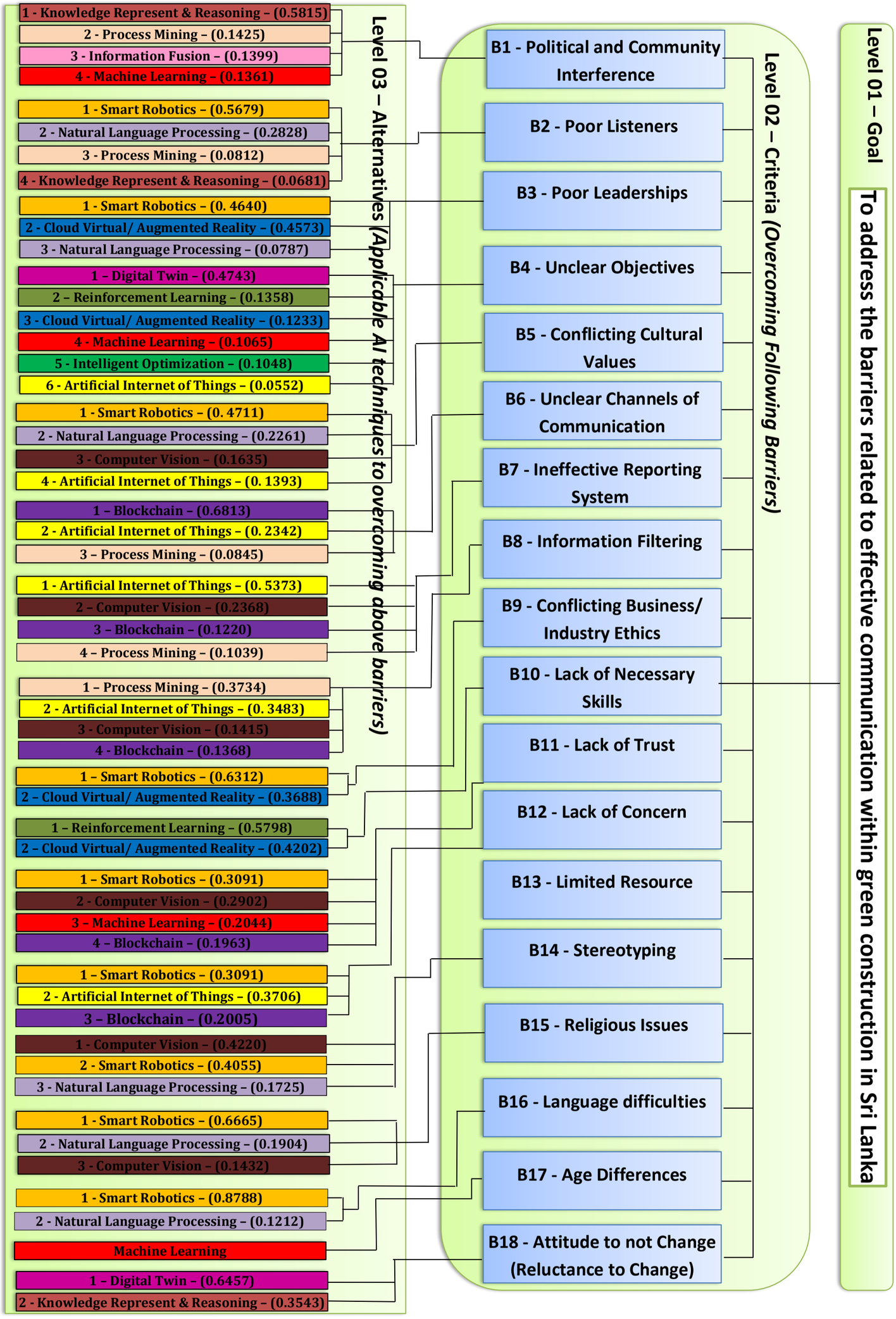
Accordingly, the analysis of the findings of questionnaire survey completed objective 4 of this study. It evaluated performance score of each applicable AI techniques in overcoming barriers in communication in green construction project. It paved the base for objective 5 of this study to develop a framework to enhance the effectiveness of communication using AI techniques for successful delivery of green construction in Sri Lanka.

4.4 Framework to enhance the effectiveness of communication using AI techniques for successful delivery of green construction in Sri Lanka

The framework is proposed based on the findings and analysis of both qualitative and quantitative approach of this study. Hence, the all the findings through KII and questionnaire survey finalised this framework. Figure 4.3 shows the framework to enhance the effectiveness of communication using AI techniques for successful delivery of green construction in Sri Lanka.

4.4.1 Development of Framework

The proposed framework is basically arranged in three levels. Those can be described as the goal at the *top level or first level*, main criteria of communication barriers to be overcome at the *intermediate level or second level* and applicable AI techniques at the *bottom level or third level*. The framework is embedded with 18 communication barriers in the intermediate level or second level and altogether 54 AI techniques at the bottom level or third level. Moreover, a performance score has assigned to each AI techniques and the AI techniques are shown in the order of highest effectiveness to lowest effectiveness based on the performance score in the framework over the AHP findings.


Level 01 – Goal
To address the barriers related to effective communication within green construction in Sri Lanka
Level 02 – Criteria (Overcoming Following Barriers)
B1 - Political and Community Interference
B2 - Poor Listeners
B3 - Poor Leaderships
B4 - Unclear Objectives
B5 - Conflicting Cultural Values
B6 - Unclear Channels of Communication
B7 - Ineffective Reporting System
B8 - Information Filtering
B9 - Conflicting Business/ Industry Ethics
B10 - Lack of Necessary Skills
B11 - Lack of Trust
B12 - Lack of Concern
B13 - Limited Resource
B14 - Stereotyping
B15 - Religious Issues
B16 - Language difficulties
B17 - Age Differences
B18 - Attitude to not Change (Reluctance to Change)
Level 03 – Alternatives (Applicable AI techniques to overcoming above barriers)
1 - Knowledge Represent & Reasoning – (0.5815)
2 - Process Mining – (0.1425)
3 - Information Fusion – (0.1399)
4 - Machine Learning – (0.1361)
1 - Smart Robotics – (0.5679)
2 - Natural Language Processing – (0.2828)
3 - Process Mining – (0.0812)
4 - Knowledge Represent & Reasoning – (0.0681)
1 - Smart Robotics – (0. 4640)
2 - Cloud Virtual/ Augmented Reality – (0.4573)
3 - Natural Language Processing – (0.0787)
1 – Digital Twin – (0.4743)
2 – Reinforcement Learning – (0.1358)
3 - Cloud Virtual/ Augmented Reality – (0.1233)
4 - Machine Learning – (0.1065)
5 - Intelligent Optimization – (0.1048)
6 - Artificial Internet of Things – (0.0552)
1 - Smart Robotics – (0. 4711)
2 - Natural Language Processing – (0.2261)
3 - Computer Vision – (0.1635)
4 - Artificial Internet of Things – (0. 1393)
1 – Blockchain – (0.6813)
2 - Artificial Internet of Things – (0. 2342)
3 – Process Mining – (0.0845)
1 - Artificial Internet of Things – (0. 5373)
2 – Computer Vision – (0.2368)
3 – Blockchain – (0.1220)
4 – Process Mining – (0.1039)
1 – Process Mining – (0.3734)
2 - Artificial Internet of Things – (0. 3483)
3 - Computer Vision – (0.1415)
4 - Blockchain – (0.1368)
1 – Smart Robotics – (0.6312)
2 – Cloud Virtual/ Augmented Reality – (0.3688)
1 – Reinforcement Learning – (0.5798)
2 – Cloud Virtual/ Augmented Reality – (0.4202)
1 – Smart Robotics – (0.3091)
2 - Computer Vision – (0.2902)
3 – Machine Learning – (0.2044)
4 – Blockchain – (0.1963)
1 – Smart Robotics – (0.3091)
2 - Artificial Internet of Things – (0.3706)
3 – Blockchain – (0.2005)
1 - Computer Vision – (0.4220)
2 - Smart Robotics – (0.4055)
3 - Natural Language Processing – (0.1725)
1 - Smart Robotics – (0.6665)
2 - Natural Language Processing – (0.1904)
3 - Computer Vision – (0.1432)
1 - Smart Robotics – (0.8788)
2 - Natural Language Processing – (0.1212)
Machine Learning
1 – Digital Twin – (0.6457)
2 - Knowledge Represent & Reasoning – (0.3543)

4.4.2 Interpreting the Framework

Hereunder, the explanation on interpreting the framework to apply in real world are given.

4.4.2.1 Overcoming a communication barrier through AI technique

If a responsible stakeholder in green construction project in Sri Lanka requires to overcome communication barrier, it may pace down along the particular barrier and identify the applicable AI techniques overcome that barrier. As an example, to overcome the barrier of poor leadership (B3), smart robotics, cloud virtual/ augmented reality or natural language processing can be used.

4.4.2.2 Selecting most effective AI technique to overcome a communication barrier

After pace down along a communication barrier, in third level it shows the applicable AI techniques in the order of most effective to least effective with the numbering of 1,2,3….. Therefore, a responsible stakeholder in green construction project in Sri Lanka can select the most effective AI techniques overcome that barrier and install it for better outcome. As an example, to overcome the barrier of poor leadership (B3), smart robotics is the most effective AI technique.

4.4.2.3 Selecting AI techniques based on the overall effectiveness in overcoming communication barriers

In the framework, each AI technique is given with distinguishable colour code. Hence, a responsible stakeholder in green construction project in Sri Lanka can select most effective AI technique which assists in overcoming several barriers. As an example, the colour coding easily depicted that the AI technique of Reinforcement learning (Dark Green) assists in overcoming unclear objectives and lack of necessary skills in communication barriers. However, Reinforcement learning is the most effective AI technique to overcome the lack of necessary skills in communication in green construction. The effectiveness of cloud virtual and augmented reality is comparatively lower than reinforcement learning. The colour coding easily depicted that the AI technique of cloud virtual and augmented reality (blue) assists in

overcoming four barriers in communication in green projects. Therefore, if each of these four barriers are applied in a particular green construction project, decision makers can select most effective AI technique considering the overall effectiveness rather concerning overcoming one communication barrier.

4.5 Validation of the Framework to enhance the effectiveness of communication using AI techniques

The developed framework to enhance the effectiveness of communication using AI techniques for successful delivery of green construction in Sri Lanka can be used in green construction projects in Sri Lanka. The prioritisation of the AI techniques in overcoming the communication barriers are represented via the performance score of each AI technique are not specific to a context. Nevertheless, the proposed framework will be used by different types if stakeholders in decision making. Therefore, the validation of the real-world application of the developed framework was piloted for a sample of 40 respondents. Those forty respondents were selected based on their current involvement in a green construction project. All forty participants are currently working in a green construction project in Sri Lanka with 10 or more years of working experience. As depicted in Figure 4.4, the respondent rate of the validation questionnaire survey was 92%.

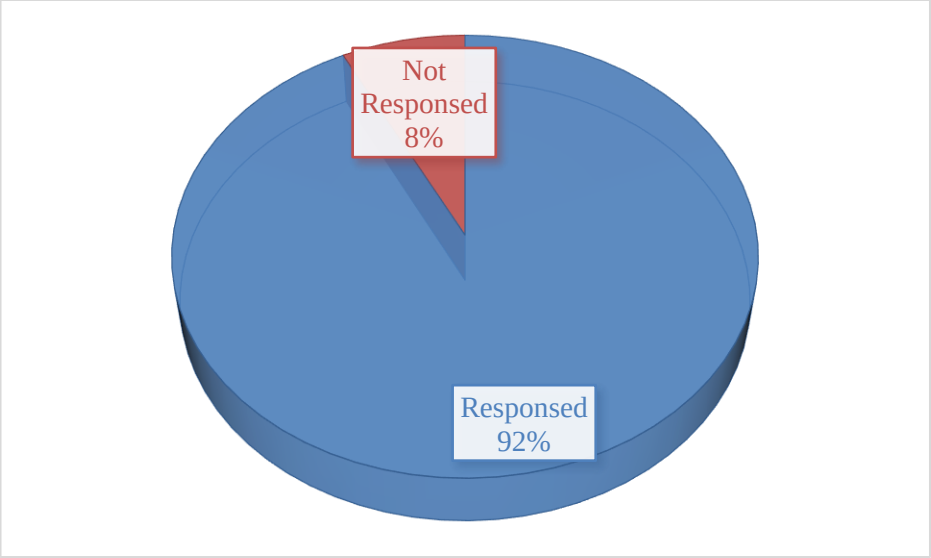


Figure 4-3 - Rate of Response in Validation Survey

Among 40 distributed questionnaires, 37 were responded by the sample. Profile of the respondents in validation survey are demonstrated in Table 4.22.

Table 4.22 – Details of Respondents in Validation Survey

Designation	Number of Years of Experience				Total
	10-14	15-19	20-14	25 or more	
Project Manager		6	5	1	12
Senior Engineer		4	2	2	8
MEP Engineer		1		1	2
Structural Engineer		1	1		2
Senior Architect		2	3		5
Quantity Surveyor	1		2	3	6
Assistant General Manager			1	1	2
Total	1	14	14	8	**37**

The validating questionnaire guideline (Annexure D) was developed targeting on getting the responses for the applicability, readability, clarity of terms and understandability of the developed framework. The factors such as applicability, readability, clarity of terms and understandability were assessed in Table 4.23.

Table 4.23 – Findings of the Validation Survey

	Outstanding	Satisfactory	Moderate
Applicability	27%	57%	16%
Readability	78%	22%	0%
Clarity of Terms	97%	3%	0%
Understandability	41%	32%	27%

Accordingly, 57% of the respondents are satisfied that the application of this framework will be effective in overcoming communication barriers in green construction project in Sri Lanka. 78% of the respondents have indicated that the readability of the framework is in an outstanding level. Further, 97% of the respondents have marked that the clarity of terms used in the framework are in an outstanding level since no abbreviations are incorporated in the framework. Yet only 32% and 41% of the respondent held that understandability of the framework is in a satisfactory and outstanding levels, respectively. Hence, 27% of the respondents indicated that the understandability of the framework at a moderate level.

4.5.1 Applicability of the Framework

As Table 4.23 depicted 57% and 16% of the respondents held that applicability of the framework is in a satisfactory and moderate levels, respectively. The reasons for such interpretation marked by this 73% respondents are shown in Table 4.24.

Table 4.24 – Issues in Applying the Framework

Reasons for issues in applying the framework	Percentage of Responses
Effectiveness is an issue	27%
Since decision makers proceed with available AI techniques, the usefulness of this framework is an issue	36%

The 27% of the respondents has emphasized that the effectiveness of the framework is an issue when applying it to the real word content. Furthermore, the 36% has marked that since responsible parties proceed with available techniques when considering the novelty and available resources for AI application in construction industry, the usefulness of this framework will be limited. However, the researcher here emphasises that this framework can be used in initial decision-making process in adopting AI techniques in a green construction project. Therefore, barriers in adapting those AI techniques have not illustrated through this research and it has been identified as a further research area to this study.

4.5.2 Readability of the Framework

The 22% of the respondents in validation survey has marked that readability of the framework is at a satisfactory level. The reasons for such interpretation marked by this 22% respondents are shown in Table 4.25.

Table 4.25 – Issues in Reading the Framework

Reasons for issues in reading the framework	Percentage of Responses
The structure is not clear	22%
Text is not clear	8%

The 22% of the respondents has marked that the structure of the framework is not clear in terms of the readability of the framework. Further, 8% of the respondents expressed that the text is also not clear in the framework.

4.5.3 Clarity of Term in the Framework

The 3% of the respondents in validation survey has marked that readability of the framework is at a satisfactory level. The reason for such interpretation marked by this 3% respondent is given in Table 4.26.

Table 4.26 – Issues in Clarity of Term in the Framework

Reasons for issues in clarity of term the framework	Percentage of Responses
Unfamiliarity of Words	3%

Since any abbreviations are not incorporated into the framework, the clarity of term in the framework has acquired 97% of outstanding level. The rest of 3% has emphasized that unfamiliarity of wording may affect the clarity of term in the framework.

4.5.4 Understandability of the Framework

As shown in Table 4.23, the 32% and 27% of the respondents in validation survey has marked that understandability of the framework is at a satisfactory level and moderate level respectively. The reasons for such interpretation marked by this 59% respondents are shown in Table 4.25.

Table 4.27 – Issues in Reading the Framework

Reasons for issues in reading the framework	Percentage of Responses
The structure cannot be understood	8%
The Colour Coding cannot be understood	59%
The order of the prioritised AI techniques cannot be understood	11%

The 8% of the respondents has marked that the structure of the framework is not easily understood. Furthermore, considerable portion of respondents (59%) have highlighted that there is a difficulty in identifying the use of the colour coding in the framework.

Moreover, 11% of respondents emphasised that the order of the prioritised AI techniques cannot be easily grabbed and understood.

4.5.5 Suggestions for Further Improvements

Respondents suggested that giving a keynote for interpreting the framework along with it will be maximised the understandability and effectiveness of the framework. Furthermore, some of them has proposed for rearranging the structure of the framework for better readability. Moreover, the colour coding adopted in the bottom level of the framework has been commented. The respondents have highlighted the repetition of same AI techniques in overcoming different barriers. Therefore, the respondents suggested a framework with more convenient arrangement for the industry usage. Nevertheless, the respondents appreciated the potential of this framework to be protracted with pros and cons of adopting each AI technique.

4.5.6 Validated framework to enhance the effectiveness of communication in green construction using AI techniques

Accordingly, the validated framework to enhance the effectiveness of communication in green construction using AI techniques was executed as shown in Figure 4.5. It was a matrix format rather a level structure. The validated framework consisted of rows indicating the barriers for effective communication in green construction and columns indicating the AI techniques. Then each cell presented the applicable AI techniques for overcoming each barrier for effective communication in green construction, with the rank and performance score. Therefore, the readability has maximised through this matrix format over the previously proposed level structure.

	AI Techniques / Barriers	AIT1 Knowledge Representation and Reasoning	AIT2 Information Fusion	AIT3 Intelligent Optimization	AIT4 Smart Robotics	AIT5 Computer Vision	AIT6 Process Mining	AIT7 Cloud Virtual Reality/ Augmented Reality	AIT8 Natural Language Processing	AIT9 Artificial Internet of Things	AIT10 Digital Twin	AIT11 4D Printing	AIT12 Blockchain	AIT13 Machine Learning	AIT14 Reinforcement Learning
B1	Political and Community Interference	[1] 0.5815	[3] 0.1399				[2] 0.1425							[4] 0.1361	
B2	Poor Listeners				[1] 0.5879		[3] 0.812		[2] 0.2828						
B3	Poor Leadership				[1] 0.4640			[2] 0.4573	[3] 0.078						
B4	Unclear Objectives			[5] 0.1048				[3] 0.1233		[6] 0.0552	[1] 0.4743			[4] 0.1065	[2] 0.1358
B5	Conflicting Cultural Values				[1] 0.4711	[3] 0.1635			[2] 0.2261	[4] 0.1393					
B6	Unclear Channels of Communication						[3] 0.0845			[2] 0.2342			[1] 0.6813		
B7	Ineffective Reporting System					[2] 0.2368	[4] 0.1039			[1] 0.5373			[3] 0.1220		
B8	Information Filtering					[3] 0.3734	[1] 0.1415			[2] 0.3483			[4] 0.1368		
B9	Conflicting Business/Industry Ethics				[1] 0.6312			[2] 0.3688							
B10	Lack of Necessary Skills							[2] 0.4202							[1] 0.5798
B11	Lack of Trust				[1] 0.3091	[2] 0.2902							[4] 0.1963	[3] 0.2044	
B12	Lack of Concern				[1] 0.3706					[2] 0.4289			[3] 0.2005		
B13	Limited Resource	x	x	x	x	x	x	x	x	x	x	x	x	x	x
B14	Stereotyping				[2] 0.4055	[1] 0.4220			[3] 0.1725						
B15	Religious Issues				[1] 0.6665	[3] 0.1432			[2] 0.1904						
B16	Language difficulties				[1] 0.1212				[2] 0.8788						
B17	Age Differences	x	x	x	x	x	x	x	x	x	x	x	x	√	x
B18	Reluctance to Change	[2] 0.3543									[1] 0.6457				

Figure 4-4 – Validated Framework to enhance the effectiveness of communication using AI techniques for successful delivery of green construction in Sri Lanka

4.5.7 Generalisation of the Findings

Generalisation can be considered as a measure of how effective the results of a study are for a broader group of sample or situations (Tripp, 1985). This study was only focused on the experience and knowledge level in green construction and AI applications in the sampling of the population for KII, questionnaire survey for pairwise comparison in AHP and questionnaire survey for validation of the developed framework. Because the findings are only from the perspective of the Sri Lankan experts, some of the findings could be different to the findings of similar studies conducted in other countries as the approach towards AI application and green construction are different. Thus, one to one theoretical generalisation of the findings to other context/ countries may not be possible. Nevertheless, when collecting the data for the study, the geographical, contextual factors or size of the projects were not taken into consideration. Therefore, the findings of the study can be generalised into all over the Sri Lanka. Hence, the application of proposed framework can be generalised for any green construction project in Sri Lanka despite of the geographical concerns or scale of the project.

4.6 Chapter Summary

As the research process highlighted in chapter three, this chapter depicted the data collection techniques, analysis, findings and interpretation. The key informant interviews had completed the objective of reviewing the concept of green construction in a global context and in the context of Sri Lanka and critically reviewing Artificial Intelligence (AI) techniques that can be used in construction industry in Sri Lanka. Further, it paved the base for fourth objective in terms of developing the hierarchy for the AHP. The next part of this chapter explained the questionnaire survey which was designed for pairwise comparison under AHP. This chapter presented essential steps in AHP calculations which were conducted using MS excel software and further calculation are annexed to this submission. Accordingly, the development and interpretation of the framework to enhance the effectiveness of communication using AI techniques for successful delivery of green construction in Sri Lanka were illustrated. Then the validation of the framework, its potentials and drawbacks and

suggestions for further improvements were summarised. Finally, the generalisation of the findings of this study was discussed in this chapter.

CHAPTER FIVE

5 CONCLUSIONS AND RECOMMENDATIONS

5.1 Introduction

The chapter four has encompassed all primary research findings and analysis of them. This chapter five will discuss the achievement of each objective of the study based on these research findings and analysis. At the later part of this chapter, it presents the contribution of this research to knowledge and practical contexts. Furthermore, it gives recommendations pertaining to the research findings. Then, further research areas are explored under this research context and limitations encountered while carrying out this research study are explained. Finally, a conclusion for the research study is drafted considering all the research process.

5.2 Accomplishment of the objectives

The research aim of investigating the application of Artificial Intelligent (AI) techniques in addressing the barriers related to effective communication to successfully deliver green construction in Sri Lanka was achieved through the systematic accomplishment of the objectives as follows.

5.2.1 Accomplishment of Objective 01: To critically review the concept of green construction in a global context and in the context of Sri Lanka

The first objective was to critically review the concept of green construction in a global context and in the context of Sri Lanka. Accordingly green construction refers to a set of activities which tries to construct in an environmentally friendly manner throughout the life cycle. Being one of main sector in environmental degradation, the global construction industry developed this concept and adapted soon after. Though Sri Lanka is a developing country with little exposure to the technological advancement, the Sri Lankan construction industry has welcomed the green concept to barrier the continuous and excessive adverse environmental implications (Section 2.1 and Section 2.2). Nevertheless, there are numerous barriers in implementing green construction. Among them, the communication barriers were highlighted as one of major aspect to

be addressed for a successful delivery of green construction (Section 2.2 and Section 2.3).

5.2.2 Accomplishment of Objective 02: To investigate barriers related to effective communication among project stakeholders in successfully delivering green construction in Sri Lanka

The second objective was to investigate barriers related to effective communication among project stakeholders in successfully delivering green construction in Sri Lanka. Considering the objective 3, the barriers related to effective communication among project stakeholders in successfully delivering conventional construction project and green construction were identified through the literature review in Section 2.5. None of the available studies, the barriers related to effective communication among project stakeholders in successfully delivering green construction project in Sri Lanka were illustrated. Therefore, the achievement of second objective was completed by collecting and analysing the findings of validating of identified barriers related to effective communication among project stakeholders in the context of green construction in Sri Lanka and identifying further barriers related to effective communication among project stakeholders in the context of green construction in Sri Lanka through KIIs as illustrated in Section 4.2.4. Then findings of KII form a list of eighteen barriers to effective communication in green construction project in Sri Lankan construction industry while accomplishing the second objective of the study.

5.2.3 Accomplishment of Objective 03: To critically review Artificial Intelligence (AI) techniques that can be used in construction industry in Sri Lanka

The third objective was to critically review Artificial Intelligence (AI) techniques used in Sri Lankan construction industry. The third objective was partially accomplished through the literature survey in Section 2.5 and completed through the analysis of the findings from the KII in Section 4.2.4. Accordingly, thirteen AI techniques that can be implemented in construction industry were identified through the literature survey. The different application of those AI techniques in construction industry and particularly in the realm of concept of green construction were discussed. Key informants at the KIIs, validated thirteen AI techniques to be applied in Sri Lankan

construction industry and suggested other four more AI techniques. Altogether, findings of KII form a list of seventeen AI techniques that can be applicable in Sri Lankan construction industry. Accordingly, the third objective was fully completed.

5.2.4 Accomplishment of Objective 04: To evaluate the application of AI techniques to address the barriers related to effective communication within green construction in Sri Lanka

The fourth objective was to evaluate the application of AI techniques to address the barriers related to effective communication within green construction in Sri Lanka. The initiation for the fourth objective was taken by collecting and analysing the findings of application of AI techniques to address the barriers related to effective communication within green construction in Sri Lanka as in Section 4.2.6. Then, the analysis of the findings of questionnaire survey completed the fourth objective of this study as in 4.3.4. It evaluated performance score of each applicable AI techniques in overcoming barriers in communication in green construction project.

5.2.5 Accomplishment of Objective 05: To develop a framework to enhance the effectiveness of communication using AI techniques for successful delivery of green construction in Sri Lanka

The fifth and final objective of this study was to develop a framework to enhance the effectiveness of communication using AI techniques for successful delivery of green construction in Sri Lanka as in Section 4.4 and Section 4.5. Framework was developed based on the combination of both inductive and deductive interpretation of findings from KII and questionnaire survey as shown in Section 4.4. It is basically arranged in three levels. Goal at the top level, then the communication barriers to be overcome at the intermediate level and finally the applicable AI techniques at the bottom level are the proposed hierarchy in the framework. The framework is embedded with 18 communication barriers in the intermediate level or second level and altogether 54 AI techniques at the bottom level or third level. Moreover, a performance has assigned to each AI techniques and the AI techniques are shown in the order of highest effectiveness to lowest effectiveness based on the performance score in the framework over the AHP findings. The validating of the developed framework was done for the applicability, readability, clarity of terms and understandability through a

questionnaire survey as illustrated in Section 4.5. Accordingly, the following validated framework to enhance the effectiveness of communication in green construction using AI techniques was re produced with more readable and understandable format.

Accordingly, all five objectives of the study were completed. Then, the aim of this research could be accomplished as the developed and validated framework has developed based on the application of Artificial Intelligent (AI) techniques in addressing the barriers related to effective communication to successfully deliver green construction in Sri Lanka.

5.3 Contribution to knowledge

The application of AI techniques into the green construction project or even into the conventional construction project has not yet descriptively been investigated in Sri Lanka. Even in the global context, the application of AI techniques to overcome communication barriers and further in the context of green construction has not yet been descriptively addressed. There is a deficiency in the literature addressing the application of AI techniques in construction industry. Therefore, this research will be recognised as a review to the application of AI techniques into the green construction.

Further, this study developed a list of seventeen applicable AI techniques particularly into the Sri Lankan construction industry. Hence, the future researchers in this context will be attracted by these findings of applicable AI techniques in Sri Lankan construction industry to continue their studies on application AI techniques. Moreover, this study developed a list of eighteen communication barriers in green construction projects in Sri Lanka. It will pave the underlying literature for the future researchers who investigate the communication barriers in general context and particularly in green construction project.

Furthermore, this study presented a list of AI techniques which assist in overcoming the communication barriers in green construction. Accordingly, this study provides a detailed literature for the future studies of application of AI technique in overcoming communication barriers in general context and particularly in green construction.

5.4 Contribution to the Practice

In essence, this study has developed the framework to enhance the effectiveness of communication using AI techniques for successful delivery of green construction in Sri Lanka. If a responsible stakeholder in green construction project in Sri Lanka requires to overcome communication barrier and they have capacity to install AI techniques, they can utilise the framework to select most effective and productive AI techniques in overcoming existing communication barriers in the project. Hence, the practical implications of this study are the space to identify the possible AI techniques for the construction project as whole and the possible application of proposed framework when planning installation of AI techniques in a green construction project to overcome the communication barriers. When a green construction project planning their overall AI installation for the project, decision makers can use this proposed framework and suggest more effective AI technique in terms of having a greater communication among project stakeholders and processes. If Sri Lankan construction industry is perfectly equipped with underlying requirements of applying AI techniques for better performances, this framework will be feasible in every green construction project to have an effective communication. Hence, first the barriers in accommodating AI in construction should be recognised and answered in Sri Lankan construction industry.

5.5 Recommendations

The significance of the effective communication green construction in the Sri Lankan construction industry was highlighted at the initial stage of this research. Moving on that basis, it has been determined the barriers that should be overcome when implementing a green project in Sri Lankan construction industry. Along with literature review on the barriers to the communication, this research assessed them in the industry. Hence, any organisation to a green construction project that is enthusiastic in maximising their communication system, can follow up which type of barriers present in their context through referring the list of communication barriers.

Moreover, if an organisation or else within the project in green construction has already installed or are expecting to install an AI technique into their context, decision-

makers can advise the possibility of overcoming communication barrier referring to the introduced framework. Then, these parties can expand the application of AI technique into different context of the green project including the effective communication in the project. Hence, it is recommended to follow this framework to enhance the effectiveness of communication using AI techniques for successful delivery of green construction in Sri Lanka to be read along with strategies and plans of overall AI application into a particular green construction project.

As discussed in the section interpretation of the framework, the stakeholders in green construction project can select AI techniques to overcome communication barriers, considering the overall effectiveness of the AI techniques in overcoming several communication barriers. Therefore, the recommendation can be given that if an organisation or party to green construction project is severely influenced by one communication barrier, they may apply most effective AI technique for that and then expand it for other applicable barriers. Moreover, if particular communication barrier does not highlight in a green construction project, the AI techniques which has possibilities of overcoming several barriers can be considered in application. In such application, though the effectiveness of overcoming some of barriers, still that AI technique can assist in enhancing the overall communication in green construction project.

5.6 Further Research

This study has paved the base for hardly unexplored research area of applying AI for effective communication in green construction in Sri Lanka. Hence, there are more aspects to be addressed through separate studies. Therefore, this study suggests researching following areas will contribute to the academia and also to the practical context in an appraisable way.

1. This study has only focused on how AI techniques can be applied to overcome the communication barriers in green construction project in Sri Lanka. Hence, further studies can be carried out to analyse of barriers of adopting Artificial Intelligent Techniques for effective communication in green construction project in Sri Lanka.

2. Studies can be carried out to review possible application of Artificial Intelligent Techniques in green construction projects in Sri Lanka since this study's scope was only to address the ineffective communication among project stakeholders in green construction project in Sri Lanka

3. Since AI is an emerging aspect in construction industry, this study particularly focused on AI application. Therefore, further studies can be conducted to suggest other emerging technologies or concepts to overcome the barriers and to enhance the effectiveness in communication in green construction project.

5.7 Limitations

The process of fulfilling the objectives of this research was carried out under several limitations namely less awareness of green concept in industry, unfamiliarity with the AI application of in industry, less availability of professionals with both experience and profound knowledge in green concept and application of AI in Sri Lankan construction industry and in general context the COVID – 19 pandemic. Those limitations impacted on the sample size of key informants in KII to be fifteen and questionnaire survey to be ten respondents as only to address rule of thumb KII and AHP questionnaire survey.

5.8 Conclusions

As a key player in nation's economy, the construction sector constantly deals in a significant range with the environmental, social and economic aspects of the country. The construction sector is a prominent part in nation's economy. However, the construction industry does not only play a vital part in economy. It typically and constantly deals with wide range of environmental and social aspect too. Accordingly, the construction industries implication over environment is not a pleased one. Environmental degradation due to construction projects are vital all over the world. These immeasurable effects of construction over the environment makes a dire requirement of implementing green concept in construction industry. The cooperative environment yield by the green adoption within industry requires effective communication in a green construction project. Nevertheless, there are barriers for such effective communication in a green construction project. Therefore, investigating

strategies to overcome those barriers in communication directly create the cooperative environment where the green constriction is rooted. Accordingly, this study furnished eighteen barriers in communication in green construction project. Those were poor listeners, political/community interference, poor leadership, conflicting cultural values, unclear objectives, ineffective reporting system, unclear channels of communication, lack of trust, conflicting business/industry ethics, lack of concern, information filtering, limited resources, lack of necessary skills, stereotyping, religious issues, language difficulties and age differences. Further to those, specific barrier to the green construction project was identified as reluctance to change.

Though there are barriers in adopting new technologies into the construction industry, still it tries to welcome new aspects for effective and productive outcome. Since the concept such as smart robotics has been discussed even within Sri Lankan construction industry. Therefore, since the effective outcomes from adopting AI techniques in construction industry has been investigated in global context, with the advancement of industry, it will seek possible ways to optimise the application of AI techniques. This study demonstrated the possible seventeen AI techniques that can be applied in Sri Lankan construction industry. Knowledge representation and reasoning, information fusion, intelligent optimization, smart robotics, computer vision, process mining, natural language processing, artificial internet of things, digital twin, 4D printing, cloud virtual reality/ augmented reality, blockchain, machine learning, reinforcement learning, expert systems, multi agent systems and fuzzy logic are those possible AI techniques in Sri Lankan construction industry.

At the final stage of the research, the framework to guide AI application to overcome communication barriers in green construction was developed and validated. It is basically built including three levels, goal at the first level, the communication barriers to be overcome at the intermediate level or second level and applicable AI techniques at the bottom level or third level. After the validation of the proposed framework, a matrix arrangement was developed over the pre proposed level structure. The framework is embedded with eighteen communication barriers in green construction in Sri Lanka and fourteen possible AI techniques to overcome those barriers.

Moreover, a performance score has assigned to each AI techniques and the AI techniques are ranked and shown it in the framework based on the performance score gained through the AHP findings.

Accordingly, this study will give a guidance for identifying communication barriers in green construction, for investigating possible AI technique in construction industry and possible AI techniques to overcome communication barriers in green construction project. The findings of the study are limited Sri Lankan context. Nevertheless, the findings can be generalised to entire Sri Lankan green construction projects.

Furthermore, this research has stepped with a pragmatism stance and mixed methodical choice. Moreover, there scope is limited to the green construction, communication barriers and overcoming them through AI application. Therefore, alternative research design and modified scope will guide further studies and further generalisation to findings of this research.

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ANNEXURE – A

INTERVIEW GUIDELINE FOR KEY INFORMANTS INTERVIEW

KII INTERVIEW GUIDELINES

SECTION I – GENERAL INTRODUCTION TO THE RESEARCH

Research Title

Applicability of Artificial Intelligence Techniques for Effective Communication in Green Construction

Research Aim

This study aims at to investigate the application of Artificial Intelligent (AI) techniques in addressing the barriers related to effective communication to successfully deliver green construction in Sri Lanka.

Research Objectives

1. To critically review the concept of green construction in a global context and in the context of Sri Lanka
2. To critically review Artificial Intelligence (AI) techniques that can be used in construction industry in Sri Lanka
3. To investigate barriers related to effective communication among project stakeholders in successfully delivering green construction in Sri Lanka
4. To evaluate the application of AI techniques to address the barriers related to effective communication within green construction in Sri Lanka
5. To develop a framework to enhance the effectiveness of communication using AI techniques for successful delivery of green construction in Sri Lanka

This interview will be used to address objectives 2,3 and 4.

SECTION II – BACKGROUND INFORMATION OF THE INTERVIEWEE

A. Profession:

..…….....

B. How long is your industry experience?

……..…….

C. Expertise and experience related to AI techniques and/or sustainable construction: ……..……

SECTION III – DEFINITIONS OF AI TECHNIQUES

1. Here giving brief definitions for the AI Techniques that have been identified in the Literature. Please mark the applicability of AI techniques into Sri Lankan Construction industry and suggest any further applicable AI techniques into Sri Lankan Construction industry.

Code	AI techniques	Definitions	Applicability into Sri Lankan Context
AIT1	Knowledge representation and reasoning	Enable computers to rationally understand the available knowledge, facts, and beliefs from the real world, and then make use of them to draw valid conclusions and facilitate logic inference in a transparent and efficient manner	

AIT2	Information fusion	Combined process of information from the source of same object or scene to obtain more complex, reliable and accurate information.	
AIT3	Intelligent optimization	Intelligent optimization is a task of searching for the optimal solution to minimize or maximize an objective function subjected to a set of constraints.	
AIT4	Smart robotics	Construction robots in different functions have been developed based on human requirements, which can automate some manual processes.	
AIT5	Computer vision	Computer vision is a field of artificial intelligence (AI) that enables computers and systems to derive meaningful information from digital images, videos and other visual inputs — and take actions or make recommendations based on that information.	
AIT6	Process mining	Process mining is an analytical discipline for discovering, monitoring, and	

		improving processes as they actually are, by extracting knowledge from event logs readily available in today's information systems.	
AIT7	Cloud VR/ AR	Enables the delivery of user-centric contextual digital content augmented over physical objects on devices like phones, headsets, or head-mounted display (HMD)	
AIT8	Natural language processing	Natural language processing (NLP) is the ability of a computer program to understand human language as it is spoken and written	
AIT9	AIoT	The Artificial Intelligence of Things is the combination of Artificial intelligence technologies with the Internet of things infrastructure to achieve more efficient IoT operations, improve human-machine interactions and enhance data management and analytic	
AIT10	Digital twin	A digital twin is a virtual model designed to accurately reflect a physical object.	

AIT11	4D Printing	Enable 3D printed objects to possess the capability to change its shape by itself over the influence of external stimuli, such as light, heat, electricity, magnetic field, etc	
AIT12	Blockchain	A digital ledger of transactions that is duplicated and distributed across the entire network of computer systems	
AIT13	Machine Learning	A system can learn from data, identify patterns and make decisions with minimal human intervention.	
	Any other (please suggest)		

SECTION IV – ADDRESSING BARRIERS USING AI TECHNIQUES

2. Please mark further communication barriers in green construction projects in Sri Lanka.
3. Please mark which AI techniques (listed above) can be used to overcome barriers related to effective communication among project stakeholders in successfully delivering green construction in Sri Lanka.

Barrier	Applicable AI Techniques	Remarks
Political/community interference		
Poor listeners		
Poor leadership		
Unclear objectives		
Conflicting cultural values		
Unclear channels of communication		
Ineffective reporting system		
Information filtering		
Conflicting business/industry ethics		
Lack of necessary skills		
Lack of trust		
Religious issues		
Language difficulties		
Age Differences		

Thank you for your immense cooperation!

ANNEXURE - B

QUESTIONNAIRE GUIDELINE FOR AHP

QUESTIONNAIRE

APPLICABILITY OF ARTIFICIAL INTELLIGENCE TECHNIQUES FOR EFFECTIVE COMMUNICATION IN GREEN CONSTRUCTION

Research Aim

This study aims at to investigate the application of Artificial Intelligent (AI) techniques in addressing the barriers related to effective communication to successfully deliver green construction in Sri Lanka

Research Objectives

1. To critically review the concept of green construction in a global context and in the context of Sri Lanka
2. To critically review Artificial Intelligence (AI) techniques that can be used in construction industry in Sri Lanka
3. To investigate barriers related to effective communication among project stakeholders in successfully delivering green construction in Sri Lanka
4. To evaluate the application of AI techniques to address the barriers related to effective communication within green construction in Sri Lanka
5. To develop a framework to enhance the effectiveness of communication using AI techniques for successful delivery of green construction in Sri Lanka

Instruction to Respondents

- Please answer all questions from your own experience or from your observations
- This shall be taken up **approximately 45 minutes** of your time.
- You are required to **mark the importance (effectiveness)** of the list out **Artificial Intelligent (AI) Techniques** under the given scale below.

Score	Definition
1	Equal importance
3	Moderate importance
5	Strong importance
7	Very strong importance
9	Extreme importance
2,4,6,8	Intermediate values between the two adjacent judgements

- First **identify the most effective AI technique out of left hand side AI technique and right hand side AI technique to achieve the given objective**
- Please **circle a number in 9-point scale** to **indicate the relative importance** of the identified measure **than the other measure** (see the example)

Example:

01. Compare the effectiveness of AI technique listed in left hand side and right hand side to achieve the **objective of overcoming political and community interference for effective communication in green construction project**.

Process Mining (AI6)	9	8	7	6	5	4	3	2	**1**	2	3	4	5	6	7	8	9	Machine Learning (AIT13)

- *Ranking '1' means*, both AI techniques are **equally effective** in overcoming political and community interference for effective communication in green construction project

Process Mining (AI6)	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Machine Learning (AIT13)

- *Ranking '9' on the right-hand side of the scale means*, **compared to left hand side technique** (Process Mining – AIT6), **addressing right hand side technique** (Machine Learning – AIT13) is **most effective** in overcoming political and community interference for effective communication in green construction project

Process Mining (AI6)	9	8	7	6	5	4	3	2	**1**	2	3	4	5	6	7	8	9	**Machine Learning (AIT13)**

- *Ranking '3' on the left-hand side of the scale means*, **left hand side technique** (Process Mining – AIT6), is **moderately important (effective) than the right-hand side measure** (Machine Learning – AIT13), in overcoming political and community interference for effective communication in green construction project

SECTION A: RESPONDENT DETAILS

01. Designation

……

02. Years of experience in the profession

……. Yes ☐ No ☐

03. Do you have experience in green construction?

If **yes**; how many Years …….

04. Are you aware of Artificial Intelligent Technique? Yes ☐ No ☐

SECTION B: PAIRWISE COMPARISON

- **Compare the effectiveness of addressing the AI technique given below to achieve the given objective for effective communication in green construction project.**

01. **CRITERIA**	**To reduce issues in communication in green construction project due to political and community interference**	
Knowledge and representation	9 8 7 6 5 4 3 2 **1** 2 3 4 5 6 7 8 9	Information fusion
	9 8 7 6 5 4 3 2 **1** 2 3 4 5 6 7 8 9	Process Mining
	9 8 7 6 5 4 3 2 **1** 2 3 4 5 6 7 8 9	Machine Learning
Information fusion	9 8 7 6 5 4 3 2 **1** 2 3 4 5 6 7 8 9	Process Mining
	9 8 7 6 5 4 3 2 **1** 2 3 4 5 6 7 8 9	Machine Learning
Process Mining	9 8 7 6 5 4 3 2 **1** 2 3 4 5 6 7 8 9	Machine Learning
02. CRITERIA	**To reduce issues in communication in green construction project due to poor listeners in a project**	
Knowledge representation and reasoning	9 8 7 6 5 4 3 2 **1** 2 3 4 5 6 7 8 9	Smart Robotics
	9 8 7 6 5 4 3 2 **1** 2 3 4 5 6 7 8 9	Process Mining
	9 8 7 6 5 4 3 2 **1** 2 3 4 5 6 7 8 9	Natural Language Processing
Smart Robotics	9 8 7 6 5 4 3 2 **1** 2 3 4 5 6 7 8 9	Process Mining
	9 8 7 6 5 4 3 2 **1** 2 3 4 5 6 7 8 9	Natural Language Processing
Process Mining	9 8 7 6 5 4 3 2 **1** 2 3 4 5 6 7 8 9	Natural Language Processing
03. CRITERIA	**To reduce issues in communication in green construction project due to poor leaderships**	
Smart Robotics	9 8 7 6 5 4 3 2 **1** 2 3 4 5 6 7 8 9	Cloud Virtual Reality/ Augmented Reality
	9 8 7 6 5 4 3 2 **1** 2 3 4 5 6 7 8 9	Natural Language Processing
Cloud Virtual Reality/ Augmented Reality	9 8 7 6 5 4 3 2 **1** 2 3 4 5 6 7 8 9	Natural Language Processing
04. CRITERIA	**To reduce issues in communication in green construction due to unclear objectives**	
Knowledge representation and reasoning	9 8 7 6 5 4 3 2 **1** 2 3 4 5 6 7 8 9	Intelligent Optimization
	9 8 7 6 5 4 3 2 **1** 2 3 4 5 6 7 8 9	Computer Vision
	9 8 7 6 5 4 3 2 **1** 2 3 4 5 6 7 8 9	Process Mining

	9 8 7 6 5 4 3 2 **1** 2 3 4 5 6 7 8 9	Cloud Virtual Reality/ Augmented Reality
	9 8 7 6 5 4 3 2 **1** 2 3 4 5 6 7 8 9	Artificial Internet of Things
	9 8 7 6 5 4 3 2 **1** 2 3 4 5 6 7 8 9	Digital Twin
	9 8 7 6 5 4 3 2 **1** 2 3 4 5 6 7 8 9	Machine Learning
	9 8 7 6 5 4 3 2 **1** 2 3 4 5 6 7 8 9	Reinforcement Learning
Intelligent Optimization	9 8 7 6 5 4 3 2 **1** 2 3 4 5 6 7 8 9	Computer Vision
	9 8 7 6 5 4 3 2 **1** 2 3 4 5 6 7 8 9	Process Mining
	9 8 7 6 5 4 3 2 **1** 2 3 4 5 6 7 8 9	Cloud Virtual Reality/ Augmented Reality
	9 8 7 6 5 4 3 2 **1** 2 3 4 5 6 7 8 9	Artificial Internet of Things
	9 8 7 6 5 4 3 2 **1** 2 3 4 5 6 7 8 9	Digital Twin
	9 8 7 6 5 4 3 2 **1** 2 3 4 5 6 7 8 9	Machine Learning
	9 8 7 6 5 4 3 2 **1** 2 3 4 5 6 7 8 9	Reinforcement Learning
Computer Vision	9 8 7 6 5 4 3 2 **1** 2 3 4 5 6 7 8 9	Process Mining
	9 8 7 6 5 4 3 2 **1** 2 3 4 5 6 7 8 9	Cloud Virtual Reality/ Augmented Reality
	9 8 7 6 5 4 3 2 **1** 2 3 4 5 6 7 8 9	Artificial Internet of Things
	9 8 7 6 5 4 3 2 **1** 2 3 4 5 6 7 8 9	Digital Twin
	9 8 7 6 5 4 3 2 **1** 2 3 4 5 6 7 8 9	Machine Learning
	9 8 7 6 5 4 3 2 **1** 2 3 4 5 6 7 8 9	Reinforcement Learning
Process Mining	9 8 7 6 5 4 3 2 **1** 2 3 4 5 6 7 8 9	Cloud Virtual Reality/ Augmented Reality
	9 8 7 6 5 4 3 2 **1** 2 3 4 5 6 7 8 9	Artificial Internet of Things
	9 8 7 6 5 4 3 2 **1** 2 3 4 5 6 7 8 9	Digital Twin
	9 8 7 6 5 4 3 2 **1** 2 3 4 5 6 7 8 9	Machine Learning

	9 8 7 6 5 4 3 2 **1** 2 3 4 5 6 7 8 9	Reinforcement Learning
Cloud Virtual Reality/ Augmented Reality	9 8 7 6 5 4 3 2 **1** 2 3 4 5 6 7 8 9	Artificial Internet of Things
	9 8 7 6 5 4 3 2 **1** 2 3 4 5 6 7 8 9	Digital Twin
	9 8 7 6 5 4 3 2 **1** 2 3 4 5 6 7 8 9	Machine Learning
	9 8 7 6 5 4 3 2 **1** 2 3 4 5 6 7 8 9	Reinforcement Learning
Artificial Internet of Things	9 8 7 6 5 4 3 2 **1** 2 3 4 5 6 7 8 9	Digital Twin
	9 8 7 6 5 4 3 2 **1** 2 3 4 5 6 7 8 9	Machine Learning
	9 8 7 6 5 4 3 2 **1** 2 3 4 5 6 7 8 9	Reinforcement Learning
Digital Twin	9 8 7 6 5 4 3 2 **1** 2 3 4 5 6 7 8 9	Machine Learning
	9 8 7 6 5 4 3 2 **1** 2 3 4 5 6 7 8 9	Reinforcement Learning
Machine Learning	9 8 7 6 5 4 3 2 **1** 2 3 4 5 6 7 8 9	Reinforcement Learning
05. CRITERIA	**To reduce issues in communication in green construction project due to conflicting cultural values**	
Smart robotics	9 8 7 6 5 4 3 2 **1** 2 3 4 5 6 7 8 9	Computer vision
	9 8 7 6 5 4 3 2 **1** 2 3 4 5 6 7 8 9	Natural language processing
	9 8 7 6 5 4 3 2 **1** 2 3 4 5 6 7 8 9	Artificial Internet of Things
Computer vision	9 8 7 6 5 4 3 2 **1** 2 3 4 5 6 7 8 9	Natural language processing
	9 8 7 6 5 4 3 2 **1** 2 3 4 5 6 7 8 9	Artificial Internet of Things
Natural language processing	9 8 7 6 5 4 3 2 **1** 2 3 4 5 6 7 8 9	Artificial Internet of Things
06. CRITERIA	**To reduce issues in communication in green construction project due to Unclear channels of communication**	
Process Mining	9 8 7 6 5 4 3 2 **1** 2 3 4 5 6 7 8 9	Artificial Internet of Things
	9 8 7 6 5 4 3 2 **1** 2 3 4 5 6 7 8 9	Blockchain
Artificial Internet of Things	9 8 7 6 5 4 3 2 **1** 2 3 4 5 6 7 8 9	Blockchain

07. CRITERIA	To reduce issues in communication in green construction project due to Ineffective reporting system	
Computer vision	9 8 7 6 5 4 3 2 **1** 2 3 4 5 6 7 8 9	Process Mining
	9 8 7 6 5 4 3 2 **1** 2 3 4 5 6 7 8 9	Cloud Virtual Reality/ Augmented Reality
	9 8 7 6 5 4 3 2 **1** 2 3 4 5 6 7 8 9	Artificial Internet of Things
	9 8 7 6 5 4 3 2 **1** 2 3 4 5 6 7 8 9	4D Printing
	9 8 7 6 5 4 3 2 **1** 2 3 4 5 6 7 8 9	Blockchain
Process Mining	9 8 7 6 5 4 3 2 **1** 2 3 4 5 6 7 8 9	Cloud Virtual Reality/ Augmented Reality
	9 8 7 6 5 4 3 2 **1** 2 3 4 5 6 7 8 9	Artificial Internet of Things
	9 8 7 6 5 4 3 2 **1** 2 3 4 5 6 7 8 9	4D Printing
	9 8 7 6 5 4 3 2 **1** 2 3 4 5 6 7 8 9	Blockchain
Cloud Virtual Reality/ Augmented Reality	9 8 7 6 5 4 3 2 **1** 2 3 4 5 6 7 8 9	Artificial Internet of Things
	9 8 7 6 5 4 3 2 **1** 2 3 4 5 6 7 8 9	4D Printing
	9 8 7 6 5 4 3 2 **1** 2 3 4 5 6 7 8 9	Blockchain
Artificial Internet of Things	9 8 7 6 5 4 3 2 **1** 2 3 4 5 6 7 8 9	4D Printing
	9 8 7 6 5 4 3 2 **1** 2 3 4 5 6 7 8 9	Blockchain
4D Printing	9 8 7 6 5 4 3 2 **1** 2 3 4 5 6 7 8 9	Blockchain
08. CRITERIA	**To reduce issues in communication in green construction project due to Information Filtering**	
Computer vision	9 8 7 6 5 4 3 2 **1** 2 3 4 5 6 7 8 9	Process Mining
	9 8 7 6 5 4 3 2 **1** 2 3 4 5 6 7 8 9	Cloud Virtual Reality/ Augmented Reality
	9 8 7 6 5 4 3 2 **1** 2 3 4 5 6 7 8 9	Artificial Internet of Things
	9 8 7 6 5 4 3 2 **1** 2 3 4 5 6 7 8 9	Blockchain
Process Mining	9 8 7 6 5 4 3 2 **1** 2 3 4 5 6 7 8 9	Cloud Virtual Reality/ Augmented Reality

	9 8 7 6 5 4 3 2 **1** 2 3 4 5 6 7 8 9	Artificial Internet of Things
	9 8 7 6 5 4 3 2 **1** 2 3 4 5 6 7 8 9	Blockchain
Cloud Virtual Reality/ Augmented Reality	9 8 7 6 5 4 3 2 **1** 2 3 4 5 6 7 8 9	Artificial Internet of Things
	9 8 7 6 5 4 3 2 **1** 2 3 4 5 6 7 8 9	Blockchain
Artificial Internet of Things	9 8 7 6 5 4 3 2 **1** 2 3 4 5 6 7 8 9	Blockchain
09. CRITERIA	**To reduce issues in communication in green construction project due to Conflicting business/industry ethics**	
Smart Robotics	9 8 7 6 5 4 3 2 **1** 2 3 4 5 6 7 8 9	Cloud Virtual Reality/ Augmented Reality
10. CRITERIA	**To reduce issues in communication in green construction project due to Lack of necessary skills**	
Cloud Virtual Reality/ Augmented Reality	9 8 7 6 5 4 3 2 **1** 2 3 4 5 6 7 8 9	Reinforcement Learning
11. CRITERIA	**To reduce issues in communication in green construction projects due to Lack of trust**	
Knowledge representation and reasoning	9 8 7 6 5 4 3 2 **1** 2 3 4 5 6 7 8 9	Smart Robotics
	9 8 7 6 5 4 3 2 **1** 2 3 4 5 6 7 8 9	Computer vision
	9 8 7 6 5 4 3 2 **1** 2 3 4 5 6 7 8 9	4D Printing
	9 8 7 6 5 4 3 2 **1** 2 3 4 5 6 7 8 9	Blockchain
	9 8 7 6 5 4 3 2 **1** 2 3 4 5 6 7 8 9	Machine Learning
Smart Robotics	9 8 7 6 5 4 3 2 **1** 2 3 4 5 6 7 8 9	Computer vision
	9 8 7 6 5 4 3 2 **1** 2 3 4 5 6 7 8 9	4D Printing
	9 8 7 6 5 4 3 2 **1** 2 3 4 5 6 7 8 9	Blockchain
	9 8 7 6 5 4 3 2 **1** 2 3 4 5 6 7 8 9	Machine Learning
Computer vision	9 8 7 6 5 4 3 2 **1** 2 3 4 5 6 7 8 9	4D Printing
	9 8 7 6 5 4 3 2 **1** 2 3 4 5 6 7 8 9	Blockchain
	9 8 7 6 5 4 3 2 **1** 2 3 4 5 6 7 8 9	Machine Learning

4D Printing	9 8 7 6 5 4 3 2 **1** 2 3 4 5 6 7 8 9	Blockchain
	9 8 7 6 5 4 3 2 **1** 2 3 4 5 6 7 8 9	Machine Learning
Blockchain	9 8 7 6 5 4 3 2 **1** 2 3 4 5 6 7 8 9	Machine Learning
12. **CRITERIA**	**To reduce issues in communication in green construction projects due to Lack of Concern**	
Computer vision	9 8 7 6 5 4 3 2 **1** 2 3 4 5 6 7 8 9	Cloud Virtual Reality/ Augmented Reality
	9 8 7 6 5 4 3 2 **1** 2 3 4 5 6 7 8 9	Blockchain
Cloud Virtual Reality/ Augmented Reality	9 8 7 6 5 4 3 2 **1** 2 3 4 5 6 7 8 9	Blockchain
13. **CRITERIA**	**To reduce issues in communication in green construction projects due to Stereotyping**	
Computer vision	9 8 7 6 5 4 3 2 **1** 2 3 4 5 6 7 8 9	Cloud Virtual Reality/ Augmented Reality
	9 8 7 6 5 4 3 2 **1** 2 3 4 5 6 7 8 9	Blockchain
Cloud Virtual Reality/ Augmented Reality	9 8 7 6 5 4 3 2 **1** 2 3 4 5 6 7 8 9	Blockchain
14. CRITERIA	**To reduce issues in communication in green construction projects due to Religious Issues**	
Smart Robotics	9 8 7 6 5 4 3 2 **1** 2 3 4 5 6 7 8 9	Computer vision
	9 8 7 6 5 4 3 2 **1** 2 3 4 5 6 7 8 9	Natural language processing
Computer vision	9 8 7 6 5 4 3 2 **1** 2 3 4 5 6 7 8 9	Natural language processing
15. CRITERIA	**To reduce issues in communication in green construction projects due to Language difficulties**	
Smart Robotics	9 8 7 6 5 4 3 2 **1** 2 3 4 5 6 7 8 9	Natural language processing
16. CRITERIA	**To reduce issues in communication in green construction projects due to Attitude to not change (reluctance to change)**	
Knowledge representation and reasoning	9 8 7 6 5 4 3 2 **1** 2 3 4 5 6 7 8 9	Digital Twin

Thank you for your kind co-operation!

ANNEXURE – C

CALCULATIONS IN AHP

Objective 1 - To reduce issues in communication in green construction project due to political and community interference

Geomean of Scale marked by the respondents

Objective 01	R1	R2	R3	R4	R5	R6	R7	R8	R9	R10	GEOMEAN
AIT1 vs AIT2	5	5	5	7	5	5	3	5	5	5	4.9136
AIT1 vs AIT6	5	5	5	7	5	5	3	5	5	5	4.9136
AIT1 vs AIT13	3	3	3	5	3	3	3	3	3	3	3.1572
AIT2 vs AIT6	1	1	1	3	1	1	1	1	1	1	1.1161
AIT2 vs AIT13	1	1	1	1	3	1	1	1	1	1	1.1161
AIT6 vs AIT 13	1	1	2	1	1	3	1	4	1	1	1.3741

Pairwise Comparison Matrice

Objective 01	AIT1	AIT2	AIT6	AIT13
AIT1	1.0000	4.9136	4.9136	3.1572
AIT2	0.2035	1.0000	1.1161	1.1161
AIT6	0.2035	0.8960	1.0000	1.3741
AIT13	0.3167	0.8960	0.7277	1.0000
sum	1.7238	7.7055	7.7574	6.6475

Normalisation

Objective 01	AIT1	AIT2	AIT6	AIT13	SUM	Performance Score
AIT1	0.5801	0.6377	0.6334	0.4750	**0.5815**	**0.5815**
AIT2	0.1181	0.1298	0.1439	0.1679	**0.1399**	**0.1399**
AIT6	0.1181	0.1163	0.1289	0.2067	**0.1425**	**0.1425**
AIT13	0.1837	0.1163	0.0938	0.1504	**0.1361**	**0.1361**
SUM					**1.0000**	

Consistency Calculation

Objective 01	AIT1	AIT2	AIT6	AIT13	Weitage Sum
AIT1	0.5815	0.6874	0.7001	0.4296	**2.3987**
AIT2	0.1184	0.1399	0.1590	0.1519	**0.5692**
AIT6	0.1184	0.1253	0.1425	0.1870	**0.5732**
AIT13	0.1842	0.1253	0.1037	0.1361	**0.5493**

Lamda Max Calculation

AIT1	4.1248
AIT2	4.0682
AIT6	4.0225
AIT13	4.0370
Average (Lamda MaX)	4.0631

Consistency Index

Consistency Index	0.0210

Consistency Ratio

Consistency Ratio	0.0236

Objective 2 - To reduce issues in communication in green construction project due to poor listeners in a project

Geomean of Scale marked by the respondents

Objective 02	R1	R2	R3	R4	R5	R6	R7	R8	R9	R10	GEOMEAN
AIT1 vs AIT4	0.14	0.14	0.11	0.14	0.14	0.14	0.20	0.14	0.14	0.14	0.1441
AIT1 vs AIT6	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.0000
AIT1 vs AIT8	0.14	0.14	0.11	0.14	0.14	0.14	0.20	0.14	0.14	0.14	0.1441
AIT4 vs AIT6	7.00	7.00	7.00	5.00	7.00	7.00	3.00	7.00	7.00	7.00	6.2185
AIT4 vs AIT8	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.0000
AIT6 vs AIT 8	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.3333

Pairwise Comparison Matrice

Objective 02	AIT1	AIT4	AIT6	AIT8
AIT1	1.0000	0.1441	1.0000	0.1441
AIT4	6.9406	1.0000	6.2185	3.0000
AIT6	1.0000	0.1608	1.0000	0.3333
AIT8	6.9406	0.3333	3.0000	1.0000
sum	15.8813	1.6382	11.2185	4.4774

Normalisation

Objective 02	AIT1	AIT4	AIT6	AIT8	SUM	Performance Score
AIT1	0.0630	0.0879	0.0891	0.0322	**0.0681**	**0.0681**
AIT4	0.4370	0.6104	0.5543	0.6700	**0.5679**	**0.5679**
AIT6	0.0630	0.0982	0.0891	0.0744	**0.0812**	**0.0812**
AIT8	0.4370	0.2035	0.2674	0.2233	**0.2828**	**0.2828**
SUM					**1.0000**	

Consistency Calculation

Objective 02	AIT1	AIT4	AIT6	AIT8	Weitage Sum
AIT1	0.0681	0.0818	0.0812	0.0407	**0.2718**
AIT4	0.4724	0.5679	0.5048	0.8484	**2.3936**
AIT6	0.0681	0.0913	0.0812	0.0943	**0.3348**
AIT8	0.4724	0.1893	0.2435	0.2828	**1.1880**

Lamda Max Calculation

AIT1	3.9938
AIT4	4.2144
AIT6	4.1247
AIT18	4.2007
Average (Lamda MaX)	4.1334

Consistency Index

Consistency Index	0.0445

Consistency Ratio

Consistency Ratio	0.0500

Objective 3 -To reduce issues in communication in green construction project due to poor leaderships

Geomean of Scale marked by the respondents

Objective 03	R1	R2	R3	R4	R5	R6	R7	R8	R9	R10	GEOMEAN
AIT4 vs AIT7	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.0000
AIT4 vs AIT8	7.00	5.00	7.00	5.00	7.00	5.00	7.00	7.00	4.00	7.00	5.9835
AIT7 vs AIT8	7.00	5.00	6.00	5.00	7.00	5.00	7.00	7.00	3.00	7.00	5.7249

Pairwise Comparison Matrix

Objective 03	AIT4	AIT7	AIT8
AIT4	1.0000	1.0000	5.9835
AIT7	1.0000	1.0000	5.7249
AIT8	0.1671	0.1747	1.0000
sum	2.1671	2.1747	12.7084

Normalisation

Objective 03	AIT1	AIT2	AIT6	SUM	Performance Score
AIT4	0.4614	0.4598	0.4708	**0.4640**	**0.4640**
AIT7	0.4614	0.4598	0.4505	**0.4573**	**0.4573**
AIT8	0.0771	0.0803	0.0787	**0.0787**	**0.0787**
SUM				**1.0000**	

Consistency Calculation

Objective 03	AIT1	AIT2	AIT6	Weitage Sum
AIT4	0.4640	0.4573	0.4710	**1.3923**
AIT7	0.4640	0.4573	0.4506	**1.3719**
AIT8	0.0776	0.0799	0.0787	**0.2361**

Lamda Max Calculatio

AIT4	3.0003
AIT7	3.0003
AIT8	3.0001
Average (Lamda MaX)	3.0002

Consistency Index

Consistency Index	0.0001

Consistency Ratio

Consistency Ratio	0.0002

Objective4 - To reduce issues in communication in green construction due to unclear objectives

Geomean of Scale marked by the respondents

Objective 04	R1	R2	R3	R4	R5	R6	R7	R8	R9	R10	GEOMEAN
AIT3 vs AIT7	2.0000	3.0000	2.0000	3.0000	3.0000	3.0000	3.0000	3.0000	3.0000	3.0000	2.7663
AIT3 vs AIT9	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
AIT3 vs AIT10	0.1429	0.1429	0.2000	0.1429	0.1429	0.1429	0.1429	0.1429	0.1429	0.1429	0.1477
AIT3 vs AIT13	0.3333	1.0000	0.3333	1.0000	1.0000	0.3333	1.0000	1.0000	0.3333	0.3333	0.5774
AIT3 vs AIT14	0.3333	1.0000	0.3333	1.0000	1.0000	0.3333	1.0000	1.0000	0.3333	0.3333	0.5774
AIT6 vs AIT14	0.3333	0.3333	0.3333	0.3333	0.3333	0.3333	0.3333	0.3333	0.3333	0.3333	0.3333
AIT7 vs AIT9	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
AIT7 vs AIT10	0.3333	0.3333	0.3333	0.3333	0.3333	0.3333	0.3333	0.3333	0.3333	0.3333	0.3333
AIT7 vs AIT13	2.0000	2.0000	2.0000	2.0000	2.0000	2.0000	2.0000	2.0000	2.0000	2.0000	2.0000
AIT7 vs AIT14	2.0000	2.0000	2.0000	2.0000	2.0000	2.0000	2.0000	2.0000	2.0000	2.0000	2.0000
AIT9 vs AIT10	0.1111	0.1429	0.1111	0.1111	0.1429	0.1111	0.1111	0.1111	0.1111	0.1111	0.1168
AIT9 vs AIT13	0.1429	0.1429	0.1429	0.3333	0.1429	0.2000	0.1429	0.1429	0.1429	0.1429	0.1608
AIT9 vs AIT14	0.1429	0.1429	0.1429	0.3333	0.1429	0.2000	0.1429	0.1429	0.1429	0.1429	0.1608
AIT10 vs AIT13	5.0000	7.0000	5.0000	5.0000	5.0000	5.0000	7.0000	5.0000	5.0000	5.0000	5.3481
AIT10 vs AIT14	5.0000	7.0000	5.0000	5.0000	5.0000	5.0000	7.0000	5.0000	5.0000	5.0000	5.3481
AIT13 vs AIT14	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000

Pairwise Comparison Matrice

Objective 04	AIT3	AIT7	AIT9	AIT10	AIT13	AIT14
AIT3	1.0000	2.7663	1.0000	0.1477	0.5774	0.5774
AIT7	0.3615	1.0000	1.0000	0.3333	2.0000	2.0000
AIT9	1.0000	1.0000	1.0000	0.1168	0.1608	0.1608
AIT10	6.7684	3.0000	8.5588	1.0000	5.3481	5.3481
AIT13	1.7321	0.5000	0.5000	0.5000	1.0000	1.0000
AIT14	1.7321	0.5000	6.2185	0.1870	1.0000	1.0000
sum	12.5940	8.7663	18.2773	2.2849	10.0862	10.0862

Normalisation

Objective 04	AIT3	AIT7	AIT9	AIT10	AIT13	AIT14	SUM	Performance Score
AIT3	0.0794	0.3156	0.0547	0.0647	0.0572	0.0572	**0.1048**	**0.1048**
AIT7	0.0287	0.1141	0.0547	0.1459	0.1983	0.1983	**0.1233**	**0.1233**
AIT9	0.0794	0.1141	0.0547	0.0511	0.0159	0.0159	**0.0552**	**0.0552**
AIT10	0.5374	0.3422	0.4683	0.4377	0.5302	0.5302	**0.4743**	**0.4743**
AIT13	0.1375	0.0570	0.0274	0.2188	0.0991	0.0991	**0.1065**	**0.1065**
AIT14	0.1375	0.0570	0.3402	0.0818	0.0991	0.0991	**0.1358**	**0.1358**
SUM								**1.0000**

Consistency Calculation

Objective 04	AIT3	AIT7	AIT9	AIT10	AIT13	AIT14	Weitage Sum
AIT3	0.0552	0.3412	0.0552	0.0701	0.0615	0.0784	**0.6616**
AIT7	0.0200	0.1233	0.0552	0.1581	0.2130	0.2716	**0.8413**
AIT9	0.0552	0.1233	0.0552	0.0554	0.0171	0.0218	**0.3281**
AIT10	0.3736	0.3700	0.4725	0.4743	0.5696	0.7264	**2.9864**
AIT13	0.0956	0.0617	0.0276	0.2372	0.1065	0.1358	**0.6644**
AIT14	0.0956	0.0617	0.3433	0.0887	0.1065	0.1358	**0.8316**

Lamda Max Calculation

AIT3	6.3123
AIT7	6.8214
AIT9	5.9440
AIT10	6.2959
AIT13	6.2379
AIT14	6.1226
Average (Lamda MaX)	6.2890

Consistency Index

Consistency Index	0.0578

Consistency Ratio

Consistency Ratio	0.0462

Objective 5 - To reduce issues in communication in green construction project due to conflicting cultural values

Geomean of Scale marked by the respondents

Objective 05	R1	R2	R3	R4	R5	R6	R7	R8	R9	R10	GEOMEAN
AIT4 vs AIT5	3.00	3.00	3.00	3.00	3.00	2.00	3.00	3.00	3.00	3.00	2.8808
AIT4 vs AIT8	3.00	3.00	1.00	3.00	3.00	2.00	3.00	3.00	3.00	3.00	2.5811
AIT4 vs AIT9	3.00	3.00	3.00	3.00	3.00	2.00	3.00	3.00	3.00	3.00	2.8808
AIT5 vs AIT8	1.00	0.33	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.8960
AIT5 vs AIT9	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.0000
AIT8 vs AIT 9	1.00	3.00	2.00	3.00	3.00	2.00	3.00	2.00	3.00	3.00	2.3800

Pairwise Comparison Matrice

Objective 05	AIT4	AIT5	AIT8	AIT9
AIT4	1.0000	2.8808	2.5811	2.8808
AIT5	0.3471	1.0000	0.8960	1.0000
AIT8	0.3874	1.1161	1.0000	2.3800
AIT9	0.3471	1.0000	0.4202	1.0000
sum	2.0817	5.9969	4.8972	7.2608

Normalisation

Objective 05	AIT4	AIT5	AIT8	AIT9	SUM	Performance Score
AIT4	0.4804	0.4804	0.5271	0.3968	**0.4711**	**0.4711**
AIT5	0.1668	0.1668	0.1830	0.1377	**0.1635**	**0.1635**
AIT8	0.1861	0.1861	0.2042	0.3278	**0.2261**	**0.2261**
AIT9	0.1668	0.1668	0.0858	0.1377	**0.1393**	**0.1393**
SUM					**1.0000**	

Consistency Calculation

Objective 05	AIT4	AIT5	AIT8	AIT9	Weitage Sum
AIT4	0.4711	0.4711	0.5835	0.4012	**1.9269**
AIT5	0.1635	0.1635	0.2025	0.1393	**0.6689**
AIT8	0.1825	0.1825	0.2261	0.3314	**0.9226**
AIT9	0.1635	0.1635	0.0950	0.1393	**0.5613**

Lamda Max Calculation

AIT4	4.0899
AIT5	4.0899
AIT8	4.0811
AIT9	4.0309
Average (Lamda MaX)	4.0730

Consistency Index

Consistency Index	0.0243

Consistency Ratio

Consistency Ratio	0.0273

Objective 6 -To reduce issues in communication in green construction project due to Unclear channels of communication

Geomean of Scale marked by the respondents

Objective 06	R1	R2	R3	R4	R5	R6	R7	R8	R9	R10	GEOMEAN
AIT6 vs AIT9	0.33	0.33	0.33	0.33	0.33	0.33	0.20	0.33	0.25	0.33	0.3078
AIT6 vs AIT12	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.1429
AIT9vs AIT12	0.33	0.33	0.33	0.33	0.20	0.33	0.14	0.33	0.33	0.33	0.2910

Pairwise Comparison Matrice

Objective 06	AIT6	AIT9	AIT12
AIT6	1.0000	0.3078	0.1429
AIT9	3.2494	1.0000	0.2910
AIT12	7.0000	3.4364	1.0000
sum	11.2494	4.7442	1.4339

Normalisation

Objective 06	AIT6	AIT9	AIT12	SUM	Performance Score
AIT6	0.0889	0.0649	0.0996	0.0845	0.0845
AIT9	0.2888	0.2108	0.2030	0.2342	0.2342
AIT12	0.6223	0.7243	0.6974	0.6813	0.6813
SUM				1.0000	

Consistency Calculation

Objective 06	AIT1	AIT2	AIT6	Weitage Sum
AIT6	0.0845	0.0721	0.0973	0.2539
AIT9	0.2745	0.2342	0.1983	0.7069
AIT12	0.5913	0.8048	0.6813	2.0774

Lamda Max Calculation

AIT6	3.0057
AIT9	3.0185
AIT12	3.0490
Average (Lamda MaX)	3.0244

Consistency Index

Consistency Index	0.0122

Consistency Ratio

Consistency Ratio	0.0234

Objective 7 - To reduce issues in communication in green construction project due to Ineffective reporting system

Geomean of Scale marked by the respondents

Objective 07	R1	R2	R3	R4	R5	R6	R7	R8	R9	R10	GEOMEAN
AIT5 vs AIT6	2.00	3.00	3.00	3.00	2.00	4.00	3.00	3.00	3.00	3.00	2.8471
AIT5 vs AIT9	0.33	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.2105
AIT5 vs AIT12	2.00	3.00	3.00	3.00	2.00	4.00	3.00	3.00	3.00	3.00	2.8471
AIT6 vs AIT9	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.33	0.33	0.2215
AIT6 vs AIT12	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.0000
AIT9 vs AIT12	2.00	3.00	3.00	3.00	2.00	4.00	3.00	3.00	3.00	3.00	2.8471

Pairwise Comparison Matrice

Objective 07	AIT5	AIT6	AIT9	AIT12
AIT5	1.0000	2.8471	0.2105	2.8471
AIT6	0.3512	1.0000	0.2215	1.0000
AIT9	4.7510	4.5144	1.0000	2.8471
AIT12	0.3512	1.0000	0.3512	1.0000
sum	6.4535	9.3615	1.7832	7.6941

Normalisation

Objective 07	AIT5	AIT6	AIT9	AIT12	SUM	Performance Score
AIT5	0.1550	0.3041	0.1180	0.3700	**0.2368**	**0.2368**
AIT6	0.0544	0.1068	0.1242	0.1300	**0.1039**	**0.1039**
AIT9	0.7362	0.4822	0.5608	0.3700	**0.5373**	**0.5373**
AIT12	0.0544	0.1068	0.1970	0.1300	**0.1220**	**0.1220**
SUM						**1.0000**

Consistency Calculation

Objective 07	AIT5	AIT6	AIT9	AIT12	Weightage Sum
AIT5	0.2368	0.2957	0.1131	0.3475	**0.9930**
AIT6	0.0832	0.1039	0.1190	0.1220	**0.4281**
AIT9	1.1250	0.4689	0.5373	0.3475	**2.4786**
AIT12	0.0832	0.1039	0.1887	0.1220	**0.4978**

Lamda Max Calculation

AIT5	4.1938
AIT6	4.1219
AIT9	4.6130
AIT12	4.0788
Average (Lamda MaX)	4.2519

Consistency Index

Consistency Index	0.0840

Consistency Ratio

Consistency Ratio	0.0943

Objective 8 - To reduce issues in communication in green construction project due to Information filtering

Geomean of Scale marked by the respondents

Objective 08	R1	R2	R3	R4	R5	R6	R7	R8	R9	R10	GEOMEAN
AIT5 vs AIT6	5.00	7.00	3.00	5.00	7.00	3.00	6.00	4.00	5.00	1.00	4.0941
AIT5 vs AIT9	0.50	1.00	0.33	1.00	1.00	0.33	1.00	1.00	1.00	1.00	0.7490
AIT5 vs AIT12	3.00	5.00	3.00	5.00	4.00	2.00	1.00	3.00	2.00	1.00	2.5313
AIT6 vs AIT9	0.33	0.25	0.33	0.50	1.00	1.00	1.00	0.33	1.00	1.00	0.5842
AIT6 vs AIT12	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.0000
AIT9 vs AIT 12	3.00	5.00	3.00	5.00	4.00	2.00	1.00	3.00	2.00	1.00	2.5313

Pairwise Comparison Matrice

Objective 08	AIT5	AIT6	AIT9	AIT12
AIT5	1.0000	4.0941	0.7490	2.5313
AIT6	0.2443	1.0000	0.5842	1.0000
AIT9	1.3351	1.7118	1.0000	2.5313
AIT12	0.3951	1.0000	0.3951	1.0000
sum	2.9745	7.8058	2.7282	7.0626

Normalisation

Objective 08	AIT5	AIT6	AIT9	AIT12	SUM	Performance Score
AIT5	0.3362	0.5245	0.2745	0.3584	**0.3734**	**0.3734**
AIT6	0.0821	0.1281	0.2141	0.1416	**0.1415**	**0.1415**
AIT9	0.4489	0.2193	0.3665	0.3584	**0.3483**	**0.3483**
AIT12	0.1328	0.1281	0.1448	0.1416	**0.1368**	**0.1368**
SUM					**1.0000**	

Consistency Calculation

Objective 08	AIT5	AIT6	AIT9	AIT12	Weightage Sum
AIT5	0.3734	0.5793	0.2609	0.3464	**1.5599**
AIT6	0.0912	0.1415	0.2035	0.1368	**0.5730**
AIT9	0.4986	0.2422	0.3483	0.3464	**1.4354**
AIT12	0.1475	0.1415	0.1376	0.1368	**0.5634**

Lamda Max Calculation

AIT5	4.1774
AIT6	4.0497
AIT9	4.1214
AIT12	4.1177
Average (Lamda MaX)	4.1165

Consistency Index

Consistency Index	0.0388

Consistency Ratio

Consistency Ratio	0.0437

Objective 9 - To reduce issues in communication in green construction project due to Conflicting business/industry ethics

Geomean of Scale marked by the respondents

Objective 09	R1	R2	R3	R4	R5	R6	R7	R8	R9	R10	GEOMEAN
AIT4 vs AIT7	3.00	1.00	3.00	4.00	3.00	2.00	1.00	1.00	1.00	1.00	1.7118

Pairwise Comparison Matrix

Objective 09	AIT4	AIT7
AIT4	1.0000	1.7118
AIT7	0.5842	1.0000
sum	1.5842	2.7118

Normalisation

Objective 09	AIT4	AIT7	SUM	Performance Score
AIT4	0.6312	0.6312	**0.6312**	**0.6312**
AIT7	0.3688	0.3688	**0.3688**	**0.3688**
SUM			**1.0000**	

Consistency Calculation

Objective 09	AIT4	AIT7	Weightage Sur
AIT4	0.6312	0.6312	**1.2625**
AIT7	0.3688	0.3688	**0.7375**

Lamda Max Calculatio

AIT4	2.0000
AIT7	2.0000
Average (Lamda MaX	2.0000

Objective 10 - To reduce issues in communication in green construction project due to Lack of necessary skills

Geomean of Scale marked by the respondents

Objective 10	R1	R2	R3	R4	R5	R6	R7	R8	R9	R10	GEOMEAN
AIT7 vs AIT14	1.00	1.00	1/3	1.00	1/5	1/3	0.20	1.00	1/3	1/3	0.7248

Pairwise Comparison Matrix

Objective 10	AIT7	AIT14
AIT7	1.0000	0.7248
AIT14	1.3797	1.0000
sum	2.3797	1.7248

Normalisation

Objective 10	AIT7	AIT14	SUM	Performance Score
AIT7	0.4202	0.4202	0.4202	0.4202
AIT14	0.5798	0.5798	0.5798	0.5798
SUM			1.0000	

Consistency Calculation

Objective 10	AIT7	AIT14	Weightage Sum
AIT7	0.4202	0.4202	0.8404
AIT14	0.5798	0.5798	1.1596

Lamda Max Calculation

AIT7	2.0000
AIT14	2.0000
Average (Lamda MaX	2.0000

Objective 11 - To reduce issues in communication in green construction project due to Lack of trust

Geomean of Scale marked by the respondents

Objective 11	R1	R2	R3	R4	R5	R6	R7	R8	R9	R10	GEOMEAN
AIT4 vs AIT5	1	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.0000
AIT4 vs AIT12	3.00	1.00	1.00	3.00	3.00	1.00	1.00	3.00	3.00	1.00	1.7321
AIT4 vs AIT13	1.00	1.00	3.00	1.00	3.00	1.00	1.00	5.00	1.00	1.00	1.4633
AIT5 vs AIT12	1.00	1.00	2.00	1.00	3.00	1.00	1.00	5.00	1.00	1.00	1.4051
AIT5 vs AIT13	1.00	1.00	2.00	1.00	3.00	1.00	1.00	5.00	1.00	1.00	1.4051
AIT12 vs AIT 13	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.0000

Pairwise Comparison Matrix

Objective 11	AIT4	AIT5	AIT12	AIT13
AIT4	1.0000	1.0000	1.7321	1.4633
AIT5	1.0000	1.0000	1.4051	1.4051
AIT12	0.5774	0.7117	1.0000	1.0000
AIT13	0.6834	0.7117	1.0000	1.0000
sum	3.2608	3.4234	5.1372	4.8684

Normalisation

Objective 11	AIT4	AIT5	AIT12	AIT13	SUM	Performance Score
AIT4	0.3067	0.2921	0.3372	0.3006	**0.3091**	**0.3091**
AIT5	0.3067	0.2921	0.2735	0.2886	**0.2902**	**0.2902**
AIT12	0.1771	0.2079	0.1947	0.2054	**0.1963**	**0.1963**
AIT13	0.2096	0.2079	0.1947	0.2054	**0.2044**	**0.2044**
SUM					**1.0000**	

Consistency Calculation

Objective 11	AIT4	AIT5	AIT12	AIT13	Weightage Sum
AIT4	0.3091	0.2902	0.3399	0.2991	**1.2384**
AIT5	0.3091	0.2902	0.2758	0.2872	**1.1623**
AIT12	0.1785	0.2066	0.1963	0.2044	**0.7857**
AIT13	0.2113	0.2066	0.1963	0.2044	**0.8185**

Lamda Max Calculation

AIT5	4.0060
AIT6	4.0047
AIT9	4.0033
AIT12	4.0045
Average (Lamda MaX)	4.0046

Consistency Index

Consistency Index	0.0015

Consistency Ratio

Consistency Ratio	0.0017

Objective 12 -To reduce issues in communication in green construction project due to Lack of Concern

Geomean of Scale marked by the respondents

Objective 12	R1	R2	R3	R4	R5	R6	R7	R8	R9	R10	GEOMEAN
AIT4 vs AIT9	0.50	1.00	1.00	1.00	0.33	1.00	1.00	1.00	1.00	1.00	0.8360
AIT4 vs AIT12	3.00	3.00	2.00	1.00	3.00	2.00	1.00	3.00	2.00	1.00	1.9105
AIT9 vs AIT12	4.00	3.00	2.00	1.00	5.00	2.00	1.00	3.00	2.00	1.00	2.0694

Pairwise Comparison Matrice

Objective 12	AIT4	AIT9	AIT12
AIT4	1.0000	0.8360	1.9105
AIT9	1.1962	1.0000	2.0694
AIT12	0.5234	0.4832	1.0000
sum	2.7196	2.3192	4.9799

Normalisation

Objective 12	AIT4	AIT9	AIT12	SUM	Performance Score
AIT4	0.3677	0.3605	0.3837	**0.3706**	**0.3706**
AIT9	0.4398	0.4312	0.4155	**0.4289**	**0.4289**
AIT12	0.1925	0.2084	0.2008	**0.2005**	**0.2005**
SUM				**1.0000**	

Consistency Calculation

Objective 12	AIT4	AIT9	AIT12	Weitage Sum
AIT4	0.3706	0.3585	0.3831	**1.1123**
AIT9	0.4433	0.4289	0.4150	**1.2872**
AIT12	0.1940	0.2072	0.2005	**0.6018**

Lamda Max Calculation

AIT4	3.0012
AIT9	3.0014
AIT12	3.0007
Average (Lamda MaX)	3.0011

Consistency Index

Consistency Index	0.0005

Consistency Ratio

Consistency Ratio	0.0011

Objective 14 -To reduce issues in communication in green construction project due to Stereotyping

Geomean of Scale marked by the respondents

Objective 14	R1	R2	R3	R4	R5	R6	R7	R8	R9	R10	GEOMEAN
AIT4 vs AIT5	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.0000
AIT4 vs AIT8	2.00	3.00	2.00	2.00	3.00	3.00	2.00	2.00	2.00	2.00	2.2587
AIT5 vs AIT8	2.00	3.00	4.00	2.00	3.00	5.00	2.00	2.00	2.00	2.00	2.5477

Pairwise Comparison Matrix

Objective 14	AIT4	AIT5	AIT8
AIT4	1.0000	1.0000	2.2587
AIT5	1.0000	1.0000	2.5477
AIT8	0.4427	0.3925	1.0000
sum	2.4427	2.3925	5.8064

Normalisation

Objective 14	AIT4	AIT5	AIT8	SUM	Performance Score
AIT4	0.4094	0.4180	0.3890	**0.4055**	**0.4055**
AIT5	0.4094	0.4180	0.4388	**0.4220**	**0.4220**
AIT8	0.1812	0.1641	0.1722	**0.1725**	**0.1725**
SUM				**1.0000**	

Consistency Calculation

Objective 14	AIT4	AIT5	AIT8	Weightage Sum
AIT4	0.4055	0.4220	0.3896	**1.2171**
AIT5	0.4055	0.4220	0.4395	**1.2670**
AIT8	0.1795	0.1657	0.1725	**0.5177**

Lamda Max Calculation

AIT4	3.0019
AIT9	3.0021
AIT12	3.0008
Average (Lamda MaX)	3.0016

Consistency Index

Consistency Index	0.0008

Consistency Ratio

Consistency Ratio	0.0015

Objective 15 -To reduce issues in communication in green construction project due to Religious Issues

Geomean of Scale marked by the respondents

Objective 15	R1	R2	R3	R4	R5	R6	R7	R8	R9	R10	GEOMEAN
AIT4 vs AIT5	7.00	5.00	7.00	7.00	7.00	7.00	5.00	7.00	7.00	7.00	6.5444
AIT4 vs AIT8	3.00	1.00	3.00	2.00	3.00	3.00	3.00	5.00	3.00	3.00	2.7163
AIT5 vs AIT8	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.0000

Pairwise Comparison Matrix

Objective 15	AIT4	AIT5	AIT8
AIT4	1.0000	6.5444	2.7163
AIT5	0.1528	1.0000	1.0000
AIT8	0.3681	1.0000	1.0000
sum	1.5209	8.5444	4.7163

Normalisation

Objective 15	AIT4	AIT5	AIT8	SUM	Performance Score
AIT4	0.6575	0.7659	0.5759	**0.6665**	**0.6665**
AIT5	0.1005	0.1170	0.2120	**0.1432**	**0.1432**
AIT8	0.2420	0.1170	0.2120	**0.1904**	**0.1904**
SUM				**1.0000**	

Consistency Calculation

Objective 15	AIT4	AIT5	AIT8	Weightage Sum
AIT4	0.6665	0.9370	0.5171	**2.1206**
AIT5	0.1018	0.1432	0.1904	**0.4354**
AIT8	0.2453	0.1432	0.1904	**0.5789**

Lamda Max Calculation

AIT4	3.1819
AIT9	3.0409
AIT12	3.0409
Average (Lamda MaX)	3.0879

Consistency Index

Consistency Index	0.0439

Consistency Ratio

Consistency Ratio	0.0845

Objective 16 - To reduce issues in communication in green construction project due to Language difficulties

Geomean of Scale marked by the respondents

Objective 16	R1	R2	R3	R4	R5	R6	R7	R8	R9	R10	GEOMEAN
AIT41 vs AIT8	0.14	0.14	0.14	0.11	0.11	0.14	0.17	0.14	0.14	0.14	0.1380

Pairwise Comparison Matrix

Objective 16	AIT1	AIT8
AIT4	1.0000	0.1380
AIT8	7.2482	1.0000
sum	8.2482	1.1380

Normalisation

Objective 16	AIT1	AIT8	SUM	Performance Score
AIT4	0.1212	0.1212	0.1212	0.1212
AIT8	0.8788	0.8788	0.8788	0.8788
SUM			1.0000	

Consistency Calculation

Objective 16	AIT1	AIT8	Weightage Sum
AIT4	0.1212	0.1212	0.2425
AIT8	0.8788	0.8788	1.7575

Lamda Max Calculation

AIT4	2.0000
AIT8	2.0000
Average (Lamda MaX	2.0000

Objective 18 - To reduce issues in communication in green construction project due to Attitude to not to change (reluctance to change)

Geomean of Scale marked by the respondents

Objective 18	R1	R2	R3	R4	R5	R6	R7	R8	R9	R10	GEOMEAN
AIT1 vs AIT10	1.00	0.33	1.00	1.00	0.33	0.20	1.00	1.00	0.33	0.33	0.5486

Pairwise Comparison Matrix

Objective 18	AIT1	10
AIT1	1.0000	0.5486
AIT10	1.8228	1.0000
sum	2.8228	1.5486

Normalisation

Objective 18	AIT1	AIT10	SUM	Performance Score
AIT1	0.3543	0.3543	0.3543	0.3543
AIT10	0.6457	0.6457	0.6457	0.6457
SUM			1.0000	

Consistency Calculation

Objective 18	AIT1	AIT10	Weightage Sur
AIT1	0.3543	0.3543	0.7085
AIT10	0.6457	0.6457	1.2915

Lamda Max Calculatio

AIT1	2.0000
AIT10	2.0000
Average (Lamda MaX	2.0000

APPENDIX – D

VALIDATION QUESTIONNAIRE

VALIDATION QUESTIONNAIRE GUIDELINES

SECTION I – GENERAL INTRODUCTION TO THE RESEARCH

Research Title

Applicability of Artificial Intelligence Techniques for Effective Communication in Green Construction

Research Aim

Aim of this study is to elaborate how barriers and issues in communication within green construction can be overcome through Artificial Intelligent while accomplishing greater communication among project participants for successful green project delivery

Research Objectives

1. To critically review the concept of green construction in a global context and in the context of Sri Lanka
2. To critically review Artificial Intelligence (AI) techniques used in construction industry
3. To investigate barriers related to effective communication among project stakeholders in successfully delivering green construction in Sri Lanka
4. To evaluate the application of AI techniques to address the barriers related to effective communication within green construction in Sri Lanka
5. To develop a framework to enhance the effectiveness of communication using AI techniques for successful delivery of green construction in Sri Lanka

This interview will be used to address validate the developed framework in Objective 5.

SECTION II – BACKGROUND INFORMATION OF THE RESPONDENTS

A. Profession:

……

B. How long is your industry experience?

…….

SECTION III – DEFINITIONS OF AI TECHNIQUES

Herewith it is attached a developed framework to enhance the effectiveness of communication using AI techniques for successful delivery of green construction in Sri Lanka in Appendix 1 to this guideline.

APPLICABILITY OF THE FRAMEWORK

1. Please mark the level of applicability of this framework into the green construction project in Sri Lanka.

	Outstanding	Satisfactory	Moderate
Applicability			

2. Please mark or suggest the reasons if you have marked the level as satisfactory or moderate in applicability of this framework into the green construction project in Sri Lanka.

Reasons	
Effectiveness is an issue	
(Please specify any other)	

READABILITY OF THE FRAMEWORK

3. Please mark the level of readability of this framework into the green construction project in Sri Lanka.

	Outstanding	Satisfactory	Moderate
Readability			

4. Please mark or suggest the reasons if you have marked the level as satisfactory or moderate in readability of this framework into the green construction project in Sri Lanka.

Reasons	
The structure is not clear	
Text is not clear	
(Please specify any other)	

CLARITY OF TERM IN THE FRAMEWORK

5. Please mark the level of clarity of term in this framework into the green construction project in Sri Lanka.

	Outstanding	Satisfactory	Moderate
Clarity of Term			

6. Please mark or suggest the reasons if you have marked the level as satisfactory or moderate in clarity of term in this framework into the green construction project in Sri Lanka.

Reasons	
Unfamiliarity of Words	
(Please specify any other)	

UNDERSTANDABILITY OF THE FRAMEWORK

7. Please mark the level of understandability of this framework into the green construction project in Sri Lanka.

	Outstanding	Satisfactory	Moderate
Understandability			

8. Please mark or suggest the reasons if you have marked the level as satisfactory or moderate in readability of this framework into the green construction project in Sri Lanka.

Reasons	
The structure cannot be understood	
The Color Coding cannot be understood	
The order of the prioritised AI techniques cannot be understood	
(Please specify any other)	

9. Suggest improvements for this framework into the green construction project in Sri Lanka.

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Thank you for your immense cooperation!