THE POTENTIAL OF INTEGRATING BLOCKCHAIN TECHNOLOGY INTO SMART SUSTAINABLE CITY DEVELOPMENT

TAN XIAN YI

A project report submitted in partial fulfilment of the requirements for the award of Bachelor of Science (Honours) Quantity Surveying

Lee Kong Chian Faculty of Engineering and Science
Universiti Tunku Abdul Rahman

September 2021

DECLARATION

I hereby declare that this project report is based on my original work except for citations and quotations which have been duly acknowledged. I also declare that it has not been previously and concurrently submitted for any other degree or award at UTAR or other institutions.

Signature : *Tan Xian Yi*

Name : Tan Xian Yi

ID No. : 1600792

Date : 1/9/2021

APPROVAL FOR SUBMISSION

I certify that this project report entitled **"THE POTENTIAL OF INTEGRATING BLOCKCHAIN TECHNOLOGY INTO SMART SUSTAINABLE CITY DEVELOPMENT"** was prepared by **TAN XIAN YI** has met the required standard for submission in partial fulfilment of the requirements for the award of Bachelor of Science (Honours) Quantity Surveying at Universiti Tunku Abdul Rahman.

Approved by,

Signature : ______________________

Supervisor : Dr Wong Phui Fung

Date : 23/09/2021

Signature : ______________________

Co-Supervisor : ______________________

Date : ______________________

ACKNOWLEDGEMENTS

I would like to thank everyone who assisted me in bringing this project to a successful completion. It was a genuine pleasure for me to express my heartfelt thanks to my research supervisor, Dr. Wong Phui Fung, for her invaluable advice, enormous patience and tremendous support throughout the research progress. In addition, I would like to express my sincere gratitude to my Final Year Project coordinator, Dr. Lew Yoke Lian, for the effort contributed in leading the student towards attaining the goal.

Moreover, I would like to express my appreciation to my beloved parents and friends who had supported and encouraged me throughout the project preparation process. Lastly, I would like to extend my gratefulness to all the participants who spent their precious time to take part in the questionnaire surveys for this research.

ABSTRACT

The exponential growth of urban population has led to the urban challenges in political, economic, environmental and social aspects. This is mainly due to the inefficiency of existing built environment which is unable to meet the rising demand of population for basic amenities and resources. Hence, the implementation of smart sustainable city with the integration of blockchain technology has become an effective antidote to resolve and ameliorate the overwhelming urban issues. Numerous previous studies were conducted on blockchain technology and smart sustainable city. However, these studies generally focused on the overview of incorporating blockchain technology into smart sustainable city and there are limited existing studies that comprehensively analyse the potential applications of blockchain technology in smart sustainable city development in Malaysia context. Therefore, this study aims to investigate the potential of integrating blockchain technology into smart sustainable city development in Malaysia from construction practitioners' perspectives. Seven smart applications of blockchain technology in smart sustainable city were identified such as Smart Governance, Smart Transportation, Smart Supply Chain Management, Smart Healthcare, Smart Education, Smart Asset and Smart Utility. Questionnaires were designed and distributed to the construction practitioners within Klang Valley and a total of 153 responses were collected. The data collected was analysed using Cronbach's Alpha Reliability Test, Arithmetic Mean, Mann-Whitney U Test and Kruskal-Wallis Test. The findings revealed that Smart Healthcare is highly accepted by the construction practitioners and the Smart Governance is of utmost importance. Besides, there is no significant difference between genders in accepting the blockchain technology. The findings likewise showed that different age groups and educational levels have different acceptance levels on the applications of blockchain technology. The findings of this study are expected to make useful contributions by conveying the construction practitioners' acceptance level towards the applications of blockchain technology and their perspectives on the importance of these applications to the local government and planners as well as the relevant implementing

organisations and stakeholders in developing the framework for the smart sustainable city development in Malaysia.

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LIST OF ABBREVIATIONS

AI	Artificial Intelligence
ANOVA	Analysis of Variance
BQSM	The Board of Quantity Surveyors Malaysia
CIDB	Construction Industry Development Board
CLT	Central Limit Theorem
E-voting	Electronic Voting
ICT	Information and Communication Technologies
IoT	Internet of Things
IT	Information Technology
P2P	Peer-to-Peer
PoW	Proof-of-Work
SAS	Statistical Analysis System
SPSS	Statistical Package for the Social Sciences
SSC	Smart Sustainable City
UTAR	Universiti Tunku Abdul Rahman

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CHAPTER 1

INTRODUCTION

1.1 Introduction

This chapter provides an outline of this research, which consists of the background of study, problem statement, aim, objectives, research methodology, research scope and chapter outlines.

1.2 Background of Study

In recent decades, the rate of population living in the urban agglomerations rockets as a result of urbanisation, pollution, depletion of resource and climatic, demographic and social change (Wong, et al., 2020). As claimed by the United Nations (2018), the cities were experiencing rapid growth of population as it is estimated that 84% of the world's population has moved to the town areas in the year of 2018, which exceeds the initial prediction by 29%. The rapid growth of urban population has led to significant rising demand for the basic amenities and resources in the cities (PWC, 2018). Bibri and Korgstie (2017) asserted that cities are the prime consumers of the energy resources as approximately 70% of the resources on earth are consumed by the metropolitan areas. However, in view of the inefficiency of existing built environment, high density of urban population, and increasing intensity of economic and social activities, mountainous challenges are overwhelming the developers, planners and government of these cities. These challenges include depleting resources, inefficient government services, unaffordable living cost, insufficient public transportation and degradation of environment (PWC, 2018; Bibri and Korgstie, 2017).

In order to combat the urban challenges especially the straining resources engendered by the meteoric rise in global urban population, the governments of the metropolises around the world begin to implement the "smart" concept by optimising the use of tangible assets such as natural resources, networks of energy distribution and transportation facilities; and intangible assets which consist of organisational capital, intellectual capital and human capital (Bhushan, et al., 2020). On top of that, "smart" concept is adopted with the objective of ensuring the ability of future generations to achieve an ideal standard of living. In regards to this aspiration, the concept of "Smart City" is emerged and cities around the globe are urged to undergo evolution and transformation into smart cities in order to construct a sustainable city environment and safeguard good quality of life among the citizens (Bhushan, et al., 2020).

Smart city is defined as a high-density urban area with the adoption of information and communication technologies (ICT) for connecting and managing the essential infrastructures and services with the aim to improve the efficiency and operational sustainability in environmental, economic, and social aspects (Treiblmaier, Rejeb and Strebinger, 2020). In the early stages, smart cities projects predominantly utilise technological platforms, communications networks and hardware to monitor and control the local public services like traffic, water supply and energy (ITU-T, 2020). However, as time goes by, the focus of smart cities has gradually shifted from a pure technological perspective to the effective enhancement of services provided to the citizens (ITU-T, 2020). Smart cities intend to benefit the residents in respect to the prosperity and quality of life through the utilisation of scarce resources, implementation of efficient energy management, amelioration of environmental issues, enhancement of services in health and educational aspects, effective administration of transportation and transparent governance (Han and Kim, 2021; Wong, et al., 2020).

As the formation of smart city requires innovation and technology, blockchain technology is an ideal option to assist in achieving the goals of smart city. Blockchain is defined as a form of digital and distributed ledger technology which keeps all transactions' records that are carried out across a peer-to-peer network (PWC, 2018). The features possessed by blockchain technology which include immutability, encryption, transparency, programmability, consensus and data distribution enable it to complement the formation of smart cities (PWC, 2018). The application of these unique characteristics in respective fields such as politics, economy, environment and social can contribute to more effective and efficient management of the cities. For instance, the benefits are securing data communication, forming traceable and immutable contracts, encouraging citizens' participation in smart city development, easing business registration procedures, facilitating the access to health and educational records and so forth (Karale and Ranaware, 2019). With that, this research intends to further investigate the application of blockchain technology in smart sustainable city (SSC) development.

1.3 Problem Statement

Studies in respect to the application of blockchain technology in SSC have been conducted extensively throughout these years. Most of the studies focused on the overview of the blockchain application in smart city. For instance, the definition and characteristics of smart city, and the definition, versions, components, structure, requirements for application, mechanism, application and evaluation of blockchain are explained by Salha, El-Hallaq and Alastal (2019). The concept and fields of application of blockchain technology in smart cities are stressed out by Treiblmaier, Rejeb and Strebinger (2020). The study of PWC (2018) provided the explanation concerning the concept, uses and social benefits of integrating blockchain technology into smart cities in India. Similarly, the potential applications of blockchain in several sectors which include governance, education, culture, science, innovation, engagement of citizens, well-being, health, safety, economy, transportation, energy, built environment, water and waste management and natural environment are reviewed by Shen and Pena-Mora (2018). However, these two studies have neglected the potentials of blockchain in other areas such as mobility and assets management.

As for the study conducted by Bhushan, et al. (2020), this study mainly focused on the existing requirements and problems of security in smart city. Similarly, Pieroni, et al. (2018), Andoni, et al. (2019) and Khattak, et al. (2020) solely outlined the integration of blockchain technology in smart energy sector. The opportunities and challenges of adopting blockchain in the energy sector are also highlighted by Andoni, et al. (2019). Moreover, the integration of blockchain into health aspect, community aspect and manufacturing aspect are discussed by Gul, et al. (2021), Aggarwal, et al. (2019) and Leng, et al. (2020) respectively. On the other hand, Jaffe, et al. (2017), Cui, et al. (2019) and Tanwar, et al. (2020) focused on reviewing the potential of integrating blockchain in a particular sector which are mobility, supply chain management and healthcare respectively.

Based on these studies, it can be identified that the existing studies primarily focused on discussing the concept, features and the uses of applying blockchain technology into smart city, while there is a lesser emphasis on organised analysis of blockchain technology and the connection of it with the sustainability components for a smart city. Besides, these existing studies have inadequate review of the integration of blockchain technology in SSC which covers the smart and sustainable elements fully as a whole (Wong, et al., 2020). Some of the studies solely presented the adoption of blockchain technology in one particular component instead of including all the important components in SSC. Nevertheless, limited past researches profoundly studied the application of blockchain technology in developing SSC in Malaysia. Therefore, there is a lack of explanation regarding the potential of integrating blockchain technology into SSC development in Malaysia, in which both smart and sustainable elements are incorporated. Hence, this research aims to fill up this gap by investigating the potential of integrating blockchain technology into the development of SSC in Malaysia. By doing that, the future prospects of developing SSC in Malaysia with the integration of blockchain technology can be evaluated.

1.4 Research Aim

This research aims to uncover the potential of integrating blockchain technology into the development of smart sustainable city in Malaysia.

1.5 Research Objectives

In order to attain the aim of this research, three objectives are formulated.

i. To determine the acceptance of construction practitioners towards the application of blockchain technology for smart sustainable city development in Malaysia.
ii. To evaluate the importance of the potentials of blockchain technology application for smart sustainable city development in Malaysia.

iii. To discover the influence of social demographics of construction practitioners in accepting the blockchain technology for smart sustainable city development in Malaysia.

1.6 Research Methodology

Quantitative approach was adopted in this study by distributing questionnaires. The questionnaire prepared in Google Form was distributed by sending emails, sharing the e-survey link on social media platforms and sending questionnaires to the construction practitioners on the LinkedIn platform. Analysis and tabulation of data collected were conducted via Cronbach's Alpha Reliability Test, Arithmetic Mean, Mann-Whitney U Test and Kruskal-Wallis Test.

1.7 Research Scope

The scope of this research is narrowed down to construction practitioners within Klang Valley which does not set boundaries on the respondents' age, working experience, and position in the company. The aim is to collect as many responses as possible from the industry which is diverse in the demographic profiles.

1.8 Chapter Outlines

There are a total of five chapters assembled to form the structure of this research. First and foremost, chapter one provides an introduction of this research and it is inclusive of the background of this study, problem statement, aim and objectives of this research, scope of research, outlines of this chapter and the summary of this chapter.

The literature review of this study is presented in chapter two. This chapter discusses in detail about the potential applications of blockchain technology in the formation of smart sustainable city in accordance with the analysis from preceding studies.

Next, the methodology applied in the collection and evaluation of data in order to achieve the aim and objectives of this research is examined in chapter three. This chapter consists of the research methods, rationale of research selection, implementation of strategy, process of data collection and approaches of analysis.

As for chapter four, it covers the detailed interpretation of collected data and the results of analysis. Lastly, chapter five summarises the achievement of research objectives and the contributions of this study. It likewise includes the limitations encountered during this research coupled with the recommendations for future study.

1.9 Summary of Chapter

In a nutshell, there was a research gap on the potential of integrating blockchain technology into SSC development which led to the focus of this study. The problem statement was identified followed by the clarification of a research aim and the proposal of three objectives. In addition, the methodology applied in conducting this research and the chapter outline were discussed under this chapter.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter assembles the review of related literature on the potential of integrating blockchain technology into SSC development in Malaysia. The definition and background of SSC and blockchain technology will be provided in the beginning of this chapter, followed by the investigation and evaluation of the potential of SSC development with the integration of blockchain technology. A summary of chapter will be included at the end of this chapter.

2.2 Smart Sustainable City

A systematic discussion with regard to the definition, concept and benefits of SSC is provided in the following subsections.

2.2.1 Definition of Smart Sustainable City

SSC is defined as an innovative city supported by ICT and other relevant tools with the goals of achieving improved life quality, increased efficiency and competitiveness of the cities' operating systems and infrastructural elements, associated with the fulfilment of future generations' needs in respect of economic, social, environmental and cultural aspect (ITU-T, 2016; ITU-T, 2014). According to Bouzguenda, Alalouch and Fava (2019), both 'smart' and 'sustainable' features are the enablers of a SSC. In general terms, a SSC is a city with the adoption of ICT which aims to tackle a broad spectrum of political, economic, social and environmental issues in order to enhance and improve the sustainability of the city as well as the life quality of present and future inhabitants.

2.2.2 Concept of a Smart Sustainable City

SSC is an aggregate concept consisting of three elements, which are smart, sustainable and city, as illustrated in Figure 2.1. Höjer and Wangel (2014) asserted that cities can be transformed into a sustainable area even if the adoption of smart technologies, which is ICT, is omitted. Similarly, the application of ICT in cities can neglect sustainable development. In addition, ICT can be applied for sustainable development in other circumstances apart from cities. SSC is only established with the combination of these three elements, in which ICT is applied in the city, making it a sustainable place to live. Bouzguenda, Alalouch and Fava (2019) stressed that it is crucial to twin "smart" element with "sustainable" element in SSC in order to achieve favourable outcomes. ICT plays an important role in SSC planning as it is involved in providing support to the cities and contributing to sustainable development during the operation and management of urban systems (Bibri and Krogstie, 2017).

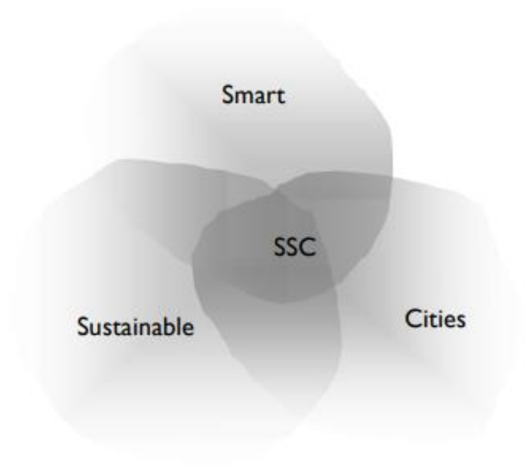

Figure 2.1: Elements of SSC
(Source: Höjer and Wangel, 2014)

2.2.3 Benefits of Smart Sustainable City Development

The world is facing a huge wave of urban growth as the United Nations (2018) claimed that the percentage of the population growth in the cities is predicted to increase at a steady pace towards 68% by 2050. A surge in urban population coupled with rapid urbanisation, albeit an emblem of community development, exerts immense pressure on the urban systems which operate and manage the urban life, amenities, services and administration (Bibri and Krogstie, 2017). The existing built environments with non-automated and non-digital facilities are experiencing enormous issues associated with sustainability challenges which tend to endanger the cities (Bibri and Krogstie, 2017). The issues pertaining to sustainability include, but not limited to, scarcity of resources, high energy consumption, environmental pollution, massive congestion, saturated transportation system, expansive poverty, social inequality and poor public health (Ibrahim, El-Zaart and Adams, 2018; Bibri and Krogstie, 2017).

The emergence of SSC seems to be an antidote to the intractable issues caused by the unprecedented urbanisation. SSC is a city comprising the fusion of ‘smart’ and ‘sustainable’ features. Bhushan, et al. (2020) postulated that ‘smart’ in SSC refers to the intention to improve a city’s ‘smartness’ by upgrading the economic, environmental and social benchmarks of the urban. As for ‘sustainable’, it indicates a city’s ability to maintain the balance of ecosystem while conducting its operations (Bhushan, et al., 2020). The purpose of introducing the concept of SSC is to lead the six dimensions in the city towards smartness without neglecting the city’s sustainability from the outset of urban development. These six dimensions consist of economy, environment, governance, living, mobility and people as portrayed in Figure 2.2 (Ibrahim, El-Zaart and Adams, 2018). Giffinger, et al. (2007) highlighted that the six dimensions of SSC are referred to competitiveness, natural resources, participation, quality of life, transportation and ICT, and social and human capital respectively. The fusion of ‘smart’ and ‘sustainable’ features in SSC is able to bring about a number of desirable outcomes in the six dimensions aforementioned.

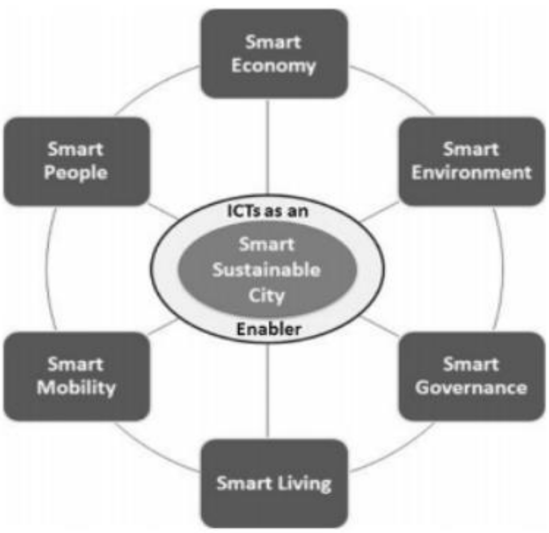

Figure 2.2: Six dimensions of SSC

(Source: Ibrahim, El-Zaart and Adams, 2018)

The economic aspect in SSC is enhanced through the adoption of effective partnerships, shaping the value added of business models and the integration of advanced technologies (Lee, Phaal and Lee, 2013). The adoption of e-business and e-commerce practices is of great importance as it can act as a contributor to the steady growth of economy as well as the escalation of efficiency in the business world (Bhushan, et al., 2020). On the other hand, Canning, O'Dwyer and Georgakopoulos (2019) and Batty (2013) underlined that a carbon free economy can be realised in SSC through the application of low carbon technologies with high efficiency and reliability.

The environmental sustainability in a SSC is attainable with the support of ICT. Besides maintaining high standards for energy consumption, the development of smart grids can lead to the production of smart sustainable energy via the use of smart metering and efficient public lighting (Chhaya, et al., 2018; Eremia, Toma and Sanduleac, 2017). The natural resources available will also be utilised and distributed judiciously to the inhabitants in SSC.

United Nation (2014) asserted that the government in a SSC should strive hard to ensure the openness and transparency of the governance and take into account the inhabitants' opinions in the decision making process. The government also bears the responsibility in formulating mechanisms which can promote autonomy and enhance the administrative control of citizens in SSC (Vanolo, 2014).

The living quality of the present residents and their future generations in a SSC is emphasised. Ling (2005) stated that through the application of monitoring tools and the proper management of population within an urban area with space constraints, better quality of life can be attained. Furthermore, in order to upgrade the living standard of the population, policies regarding to the incorporation of resource efficiency, regeneration of ageing regions, improvement of systems' strengths and integration of design in line with the environmental sustainability should be established (Yigitcanlar, et al., 2019; Aoun, 2013; Chourabi, et al., 2012)

Moreover, SSC is capable of ameliorating the mobility, accelerating movement of the population and reducing traffic congestion (Antwi-Afari, et al., 2021). Silva, Khan and Han (2018) outlined that the existence of real-time communication capabilities enables the transportation systems to act efficiently in accordance with the real-time data. By accessing the latest information concerning the streets’ congestion level, the residents in SSC can select the best route and transportation medium among the alternatives provided (Silva, Khan and Han, 2018).

The improvement on the last dimension which focuses on the social and human capital can be accomplished through the provision of an environment which promotes continuous learning and investment in human capital (Yigitcanlar, et al., 2019; United Nations, 2014; Hollands, 2008). Knowledge regarding ICT, digital and technological skills is imparted to the population in SSC. The knowledge and skills acquired can contribute towards the enhancement of SSC in future.

2.3 Blockchain Technology

The definition, types and features of blockchain technology are explained explicitly in the following subsections.

2.3.1 Definition of Blockchain Technology

Blockchain is defined comprehensively by Treiblmaier (2018) as a digital, decentralised and distributed ledger which stores the committed transactions chronologically in order to safeguard the permanence and immutability of the records. Generally, blockchain is a sequence of constantly expanding cryptographic blocks with the capability of recording the data relevant to all the transactions conducted across a peer-to-peer network (Bhushan, et al., 2020; PWC, 2018).

2.3.2 Types of Blockchain Technology

As stated by Bhushan, et al. (2020), blockchain can be grouped into three major categories in accordance with control mechanism and authentication. These three types of blockchain are public blockchain, private blockchain and consortium blockchain (Bhushan, et al., 2020).

Public blockchain is a decentralised and open network with the provision of full freedom to all participating nodes in performing mining independent of its organisation and activities like reading, writing, evaluating and inspecting of blockchain (Bhushan, et al., 2020; Manimuthu, et al., 2019). In spite of the freedom provided in creating blocks, public blockchain is exposed to higher risk and relatively vulnerable against the Sybil attack (Douceur, 2002). Proof-of-Work (PoW) consensus mechanism has been regarded as the most efficient mechanism in dealing with such attacks because it only allows the adversaries to take over the control of transactions if they obtain more than half of the total mining power. Nevertheless, the high complexity in computation makes public blockchain and PoW inappropriate to be applied in dealing with vast amounts of data (Chen and Wang, 2019; Yang, Chen and Xiang, 2018).

On the contrary, in a private blockchain, sharing of data is only allowed within a specific group of people or an organisation. Private blockchain establishes restriction of accessibility by new users or unknown to ensure that only the selected individual and team or any user invited by controlling authority is allowed to manage and control the mining process (Puthal, et al., 2018). On top of that, the transactions in a private blockchain can only be performed by controlling nodes with granted permission.

As for consortium blockchain, it is a blockchain formed by the consolidation of public blockchain and private blockchain (Bhushan, et al., 2020). Bhushan, et al. (2020) claimed that the formation of consortium blockchain is associated with a multi-signature scheme, hence, the responsibilities of consensus and authentication of blocks are shared among a specified group of individuals. The immutability and irreversibility of consortium blockchain are vulnerable against tampering attacks as approvals and signatures from all controlling nodes are required for the validation of blocks (Bhushan, et al., 2020). This provides an opportunity for the controlling nodes to collaborate maliciously for the alteration of transaction records.

2.3.3 Features of Blockchain Technology

Being an emerging technology, blockchain is expected to act as an unprecedented paradigm which is able to unleash its desirable attributes and assist in the formation of SSC by enhancing the operations in political, economic, social and environmental aspects. The favourable features possessed by blockchain technology include decentralisation, mutual consensus, transparency, immutability, detrusting and interoperability.

2.3.3.1 Decentralisation

Blockchain technology is decentralised with the delegation of controlling power among the contributory members in the blockchain network (Hewa, Ylianttila and Liyanage, 2021). Transactions have been conventionally taken place and endorsed by a central authority with the existence of dedicated central trusted intermediaries down the ages (Bhushan, et al., 2020). In this regard, Bhushan, et al. (2020) stated that the use of centralised system is the key contributor to the undesirable performances accompanied with additional cost incurred. These issues can be circumvented by blockchain technology as no central authority, intermediary of trust or centralised third party is required in managing the democratised peer-to-peer (P2P) network that guarantees higher level of safety and expediency (Bhushan, et al., 2020; Xi, 2020; PWC, 2018).

Private and public keys are used in signing the transactions and the records are documented in chronological order to ease the users in tracking the transactions without relying on intermediate record maintenance (Singh, et al., 2020). Dominant monopoly over information does not exist in blockchain technology as the data is recorded, kept and updated collectively in the distributed network (Wong, et al., 2020; PWC, 2018). Therefore, every party on-board in the blockchain network is entitled to access and verify the multiple transactions.

2.3.3.2 Mutual Consensus

Treiblmaier (2019) articulated that decentralisation of blockchain is made possible owing to the adoption of innovation consensus protocols across a network of nodes. Consensus protocols define the rules for the creation of new blocks and the addition of new data to the newly created blocks (Treiblmaier, 2019). These rules ensure that the participants agree on the validity of data insertion, the existence of a consistent set and storage of data in the distributed ledger (ITU-T, 2020).

In accordance with Aste, Tasca and Di Matteoet (2017), the chronological and exact order of the creation, execution and modification of each transaction are validated by the consensus protocol in blockchain. Wong, et al. (2020) further elaborated that consensus on the chronological order is imperative because it establishes the ownership for digital assets and the rights of the individuals involved.

2.3.3.3 Transparency

Transparency is an inherent feature possessed by blockchain technology and it tends to be the subset of decentralisation. Traditional centralised systems, such as banks, are responsible and accustomed to keep and manage all the transaction records privately thus diminishing the transparency of records. Unlike the operations of conventional central servers, blockchain technology is highly transparent as all the transactions recorded are distributed across the network and can be accessed by every node in a blockchain network (Sanka, et al., 2021; Bhushan, et al., 2020). The ownership of data is shared and transaction records stored in blockchain can be queried by each participant which makes the information open, consistent and reliable (Shahnaz, Qamar and Khalid, 2019; Yang, 2019).

The transparency feature of blockchain enables it to act as a fraud detector and tools for auditing and public services (Yang, 2019). Hence, in a blockchain network, fraudulent activities and centralised 'Black Box' concept are completely eradicated, thus maximising the transparency in computation (Hewa, Ylianttila and Liyanage, 2021).

2.3.3.4 Immutability

The immutability of blockchain technology is a favourable trait enabled through the use of cryptography (Bhushan, et al., 2020). The records of transactions in blockchain are resistant to malicious tampering due to the presence of cryptographic links (Hewa, Ylianttila and Liyanage, 2021). Hewa, Ylianttila and Liyanage (2021) stressed that the cryptographic link between the data blocks is arranged chronologically thereby establishing the chain of integrity. Digital signatures using hashing techniques and asymmetric key cryptography are commonly applied for the verification of record's integrity.

Moreover, Gupta, Sinha and Bhushan (2020) further explained that the cryptographic links ensure that the records in the distributed ledger are unalterable because a slight change in any block will result in changes of all the subsequent blocks. Besides, in accordance with the blockchain consensus protocol, immutability of data is attainable as at least 51% of nodes' control power are required in order to make any changes (Wong, et al., 2020; Puthal, et al., 2018). The immutability of blockchain enhances the integrity of data on the distributed ledger as the likelihood of fraudulent activities is negligible (Hewa, Ylianttila and Liyanage, 2021; Tseng and Shang, 2021).

2.3.3.5 Detrusting

Trust is an essential element in conventional trading. Sun, Yan and Zhang (2016) asserted that trust has historically underpinned business and a reliable third party is often required. Therefore, mutual trust relationships are required to be taken care of and this plagues the participants (Yang, 2019). Besides, additional costs are incurred due to the involvement of trusted intermediaries. Nevertheless, Yang (2019) stated that blockchain which is implemented in a decentralised system enables the data to be transferred between the participants in a "trust-free" manner.

By acting as a viable alternative, blockchain can eliminate the involvement of intermediaries, thus minimising the operational costs and maximising the efficiency of operation (Sun, Yan and Zhang, 2016). Through the adoption of P2P network protocols and purely mathematical methods, the relationships between the participants are formed by blockchain in a P2P, decentralised and distributed structure. All the information of transactions is being stored in each block of the blockchain and further enhanced by the hash function and consensus protocol, causing the data to be detrusting (Yang, 2019).

2.3.3.6 Interoperability

Gordon and Catalini, (2018) mentioned that blockchain provides a platform for the digital exchange of data, without requiring a traditional intermediary. Interoperability of blockchain technology enables the communication between distinct information technology systems and software applications, exchange of information, the use of data obtained through the data switching process and the synchronisation of services (Sanka, et al., 2021; Gordon and Catalini, 2018).

Interoperation can significantly facilitate the accessibility to relevant information required thus eliminating the redundancy in administrative processes and enhancing the efficiency of operations. For instance, through the application of blockchain, the medical records of patients all along can be shared between clinics and hospitals which contributes to the provision of appropriate diagnosis, medications and treatments to the patients.

2.4 Potential Applications of Blockchain Technology in Smart Sustainable City

As a prominent disruptive innovation in computing paradigm, blockchain technology has the capability to facilitate the development of SSC through its integration in several potential aspects, including Smart Governance, Smart Transportation, Smart Supply Chain Management, Smart Healthcare, Smart Education, Smart Asset and Smart Utility.

2.4.1 Smart Governance

Blockchain technology has the potential to complement the Smart Governance in a SSC through the enhancement of government services' quality, development of individuals' credit system and government's credibility (Hou, 2017).

Wong, et al. (2020) asserted that immutable and transparent records of government information is attainable by interconnecting and keeping these data which includes tax revenues, donation funds, incomes, expenses, contracts in a blockchain network. Blockchain is able to create multi-layer data access policies which can prevent the unauthorised party from accessing, modifying, deleting or misusing the government documents (Bagloee, et al., 2021). The application of blockchain can ensure the integrity, authenticity and security of the government records. Blockchain eradicates the management and control of data by centralised agencies or organisations which is inefficient meanwhile reducing corruption and strengthening the credibility of government (Bagloee, et al., 2021; Wong, et al., 2020; Xi, 2020).

Electronic-voting (e-voting) is a potential application of blockchain technology in Smart Governance (Xie, et al., 2019). Traditional paper-based voting systems are typically overwhelmed with irregularity, collusion and corruption (Bagloee, et al., 2021). As stated by Wong, et al. (2020), blockchain can form a decentralised voting platform from conduct of election, registration of voter, transaction of vote, tallying of vote, verification of vote. Blockchain can prevent the manipulation of voting results owing to its unique attributes which includes tamper-proofing and the elimination of trusted third parties (Xie, et al., 2019). As the integration of blockchain provides reliability to the e-voting systems, hence, environmental sustainability in SSC can be maintained as the conventional paper-based voting systems can be replaced. Apart from that, Ølnes, Ubacht and Janssen (2017) claimed that smart contract based on blockchain technology can store and authenticate the identity of every voter to ensure that only eligible citizens are entitled to cast a vote once. A democratic e-voting system which is secure and transparent can be achieved by integrating blockchain technology (Wong, et al., 2020).

Blockchain is capable of assisting in the digital identity management. Traditionally, the identification for individuals is done by the provision of identity cards, birth certificates, passports and so forth by the government bodies and organisations (Sanka, et al., 2021). Sanka, et al. (2021) further explained that these forms of identification are relatively more vulnerable to losses, theft and frauds. Additionally, the conventional identity management systems have insufficient capacity to store the increasing personal data of citizens securely due to rapid urban population growth. The involvement of multiple layers and documents in the identity verification process might be time-consuming, laborious and frustrating (Wong, et al., 2020). The existence of blockchain enables the citizens in SSC to store the personal data and identity securely. The accessibility of the personal data can be controlled and managed autonomously by the citizens themselves. This means that only the specific organisations and agencies can access the personal data upon the authorisation of the citizen. In light of this, issues that arise due to identity theft can be minimised. Wong, et al. (2020) also outlined that blockchain can ease the process of detecting and verifying identity as no trusted third party or multiple paper documents are required.

2.4.2 Smart Transportation

The advancement of ICT in recent years has become the cradle of Smart Transportation. The notion of Smart Transportation aims to improve the safety of vehicles on road, enhance the efficiency of travelling and provide convenience to the road users (Bhushan, et al., 2020). Blockchain with its own distinguishing features is able to assist in achieving the goals of Smart Transportation.

The efficiency of traffic and safety of vehicles can be attained through the sharing of information relating to the road conditions and traffic congestions. Therefore, it is imperative to adopt an effective, trusted and decentralised system to manage large amounts of vehicle and traffic data practically and to avoid single point of failure (Wong, et al., 2020). The generation of real-time traffic data is enabled by the integration of traffic data with Internet of Things (IoT) sensors and blockchain. This allows the local authorities to access the latest traffic data and eases them in performing surveillance and management of the traffic conditions. According to Wong, et al. (2020), the road users can obtain instant updates on the traffic conditions and proposed alternative routes and transportation mediums in the event of massive traffic congestion or accidents. On top of that, blockchain-based incentive mechanism is proposed by Xie, et al. (2019) for the purpose of encouraging the road users to share messages relevant to road and traffic conditions.

Nevertheless, high mobility of vehicles and ever-changing traffic conditions often leads to the spreading of misleading and inaccurate data which would degrade the road safety and mobility efficiency. The distributed nature of blockchain coupled with the transparency and immutability features make it a suitable option to deploy a decentralised trust management system in vehicular and traffic networks (Xie, et al., 2019). Blockchain technology provides a reliable and consistent public ledger to store the trust values of all vehicles rated by the neighbouring vehicles and evaluated by the road side units (Bhushan, et al., 2020). Therefore, the trustworthiness of the received messages regarding the traffic conditions can be significantly increased (Xie, et al., 2019).

Shen and Pena-Mora (2018) stated that ride sharing and online taxi-hailing is getting more common in recent years. However, the personal safety during transportation sharing is vulnerable to criminal issues such as harassment, assault and robbery (Chaudhry, et al., 2018). Fortunately, Wong, et al. (2020) highlighted that a blockchain-based system can contribute to a more secure storage of drivers' and passengers' personal data thereby facilitating the verification of identities during the engagement of ride sharing services in order to safeguard the personal safety. Blockchain enables the ride sharing services to operate on a P2P trustless basis without the need of intermediaries such as Uber and Grab (Nagel, et al., 2019).

Blockchain can be used in storing the vehicles' data. The lifespan of an automobile normally ranges from 10 years to 20 years and this information is crucial as it ensures that the buyers of used cars are not deceived by the sellers. Blockchain is able to safeguard the rights and benefits of the vehicles buyers by creating a secured, trusted and decentralised platform in which all the vehicles' data is stored immutably and managed systematically (Wong, et al., 2020).

In order to improve the operation efficiency in transportation ticketing, it is essential to implement a more efficient ticketing system in SSC. The ticketing system adopted should connect all types of transportation mediums, including bus, trains and planes (Wong, et al., 2020). In this case, blockchain is an ideal choice to act as a single platform which is responsible to sell digital tickets, facilitate transactions for all transportation mediums through the use of digital tokens and store transaction records. This can prevent the users from visiting numerous ticketing machines or counters for the purchase of tickets.

Despite utilising the features of blockchain to enhance the intelligence transportation systems, the maintenance of sustainability in terms of transportation is also emphasised in SSC. In this regard, the development of green transportation system, which is electric vehicle, has gained increased attention and popularity throughout these years (Bhushan, et al., 2020). Electric vehicles are powered by batteries that can be recharged at charging stations (Bhushan, et al., 2020). However, the number of charging stations is relatively lesser than petrol stations thus leading to the fear of exhausting battery power. In response to this issue, the integration of blockchain which is a P2P technology allows the trading of excess electricity between individuals and entities without the involvement of intermediaries. The drivers of electric vehicles are connected to each other on a blockchain network and this provides a great flexibility for them to trade electricity whenever required. Besides, as referred to Kang, et al. (2017), the electricity trading system based on consortium blockchain is able to record the electricity transactions as well as improving the transaction safety and security among the electric vehicles. Aggarwal, et al. (2019) outlined that the electricity pricing and trading between electric vehicles and charging stations tend to be optimised with the existence of security and trust.

2.4.3 Smart Supply Chain Management

A supply chain is formed by the involvement of a number of entities in the flow of services, information and products (Mentzer, et al., 2011). Supply chain is the key enabler of quotidian production, delivery and sale of a huge number of products across the globe (Xie, et al., 2019). However, Bhushan, et al. (2020) stated that the entities involved in the supply chain such as retailers, distributors, transporters and suppliers possess finite knowledge regarding the product life cycle. This knowledge is of utmost importance for the entities to forecast market trends and optimise decision-making process. Product information is also essential in developing the trust of consumers towards the particular products. Hence, the sharing of data has become a priority in supply chain management.

The advent of blockchain technology enables the product and business information to be stored securely and provides a transparent, automatic and trusted data sharing platform to the entities involved in supply chains (Wong, et al., 2020; Xie, et al., 2019). Xie, et al. (2019) explained that the entities can utilise the information obtained to make appropriate business decisions in terms of the allocation of capital, management of inventories, optimisation of manufacturing activities and so on. Moreover, as the authenticity of products can be verified easily, the consumers will have more confidence and trust towards the products in the market.

Product traceability is a major concern in supply chain management. Blockchain eases the tracking and verification process by providing a secure and transparent platform to keep the records of supply and trading of goods (Sanka, et al., 2021). All the entities involved in an end-to-end supply chain can track the products at any time without relying on the central authorities. Besides, the records stored in blockchain are tamper-proof thus preventing the malicious alteration of data and enhancing data integrity. With regards to this, trusted relationships between the entities, for instance, supplier-customer relationship, can be established (Bagloee, et al., 2021). Furthermore, the immutable records of products from manufacturing till the usage by end consumers in blockchain can be tracked in detail, therefore the entry of counterfeit products in the market can be averted (Bhushan, et al., 2020). Besides, Xie, et al. (2019) claimed that blockchain can be applied in supply chain management to collect and store the reliable shipment tracking information which is essential for product traceability.

Food supply chain with high transparency and trust is crucial in SSC to ensure the quality and safety of food. The agricultural and food traceability is another potential application of blockchain technology (Xie, et al., 2019). The development of real-time indicators is enabled by blockchain to track and analyse the factors affecting the food, for example, humidity and temperature (Bagloee, et al., 2021). On top of that, blockchain can assist in tracing the origins of food easily thus preventing the contamination of products effectively and efficiently in the event of outbreak of disease such as Covid-19 pandemic (Wong, et al., 2020; Bagloee, et al., 2021).

2.4.4 Smart Healthcare

The exponential population growth rate has led to the contradiction between superfluous healthcare demands and finite resources (Xie, et al., 2020). The notion of Smart Healthcare is introduced to bridge the gap between the demand and supply, at the same time enhancing the intelligence, efficiency and sustainability of this domain (Silva, Khan and Han, 2018). Smart Healthcare has evolved from obsolete traditional healthcare systems through the incorporation of sophisticated medical inventions and promising innovative technologies. Blockchain as an emerging technology possesses the potential to facilitate the realisation of Smart Healthcare.

The rapid urban population growth has resulted in the quotidian generation of a substantial amount of medical data (Xie, et al., 2019). Medical data plays an important role in assisting the medical practitioners to provide appropriate diagnosis and prescribe proper medication to the patients. However, in conventional medical systems, the medical data are scattered across a vast number of medical institutions such as hospitals and clinics. This brings about the difficulties in tracing the patients' complete record of medical history thus leading to significant adverse effects on the accuracy and efficiency of diagnosis (Wong, et al., 2020). Fortunately, blockchain technology is able to store immense amounts of the medical data collectively in a secure and immutable manner (Xie, et al., 2019). Besides preserving the data's integrity, the integration of blockchain technology in Smart Healthcare allows the interoperation between the medical service providers owing to the absence of individual central systems and distinct databases (Sanka, et al., 2021). The overall quality of healthcare services is improved as the sharing of medical data has facilitated the delivery of relatively more effective and customised healthcare assistance (Treiblmaier, Rejeb and Strebinger, 2020). Figure 2.3 shows that the sharing, accessibility, security and traceability of data are promoted by blockchain technology. This enables the patients to avoid the trouble of carrying multiple medical reports for any medical consultation (Sanka, et al., 2021; Karale and Ranaware, 2019).

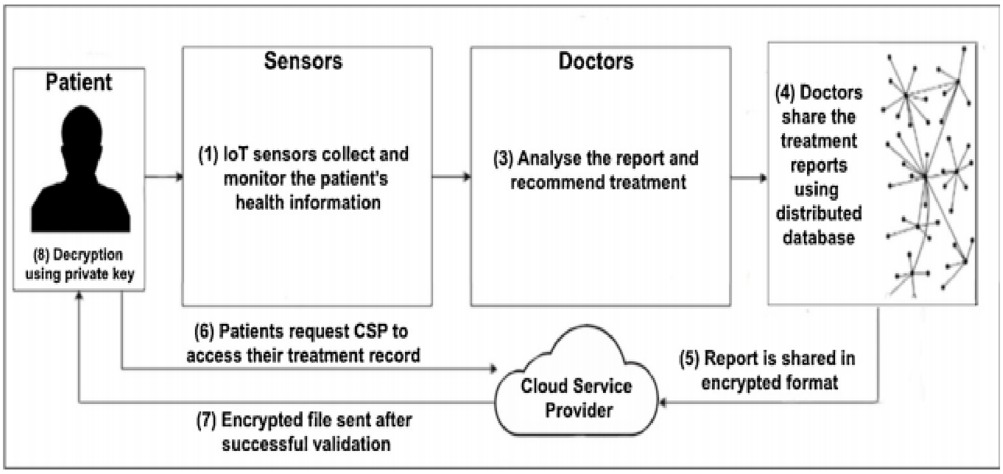

Figure 2.3: Application of Blockchain Technology in Smart Healthcare (Source: Bhushan, et al., 2020)

In addition, the accessibility of medical records uploaded in blockchain can be flexibly controlled and managed by the respective patients (Bhushan, et al., 2020). The patients' medical records are only accessible by the authorised users (Xie, et al., 2019). This indicates that the medical data stored in blockchain is free from unauthorised manipulation as a medical centre can only access the complete medical history of a patient upon the authorisation of the patients (Wong, et al., 2020). Moreover, Wong, et al. (2020) highlighted that blockchain empowers the real-time decision making to be made in remote areas according to real-time information.

Insurance industry which is considered as a part of Smart Healthcare can obtain benefits through the integration of blockchain technology. There are several layers of intermediaries involved in the insurance industry, thus causing the insurance claim's approval process to become troublesome and frustrating

(Salha, El-Hallaq and Alastal, 2019). However, with the application of blockchain, this process can be simplified as medical data can be accessed easily without the need of intermediaries. By applying blockchain, insurance frauds or attempts to claim the same insurance from more than one insurance company can be avoided (Sanka, et al., 2021).

On the other hand, Karale and Ranaware (2019) claimed that blockchain is able to assist in the formation of transparent pharmaceutical supply chains. The pharmaceutical fabrications throughout the supply chain to the final users can be registered and authenticated using blockchain technology (Nagel, et al., 2019). Plus, the provenances of critical drugs, blood and organs are recorded in the blockchain thus preventing the illegal trading of drugs and illegal trafficking of organs. Besides, by storing the official medical licenses of the medical practitioners in a blockchain network, fraudulent healthcare service providers can be eliminated in Smart Healthcare (PWC, 2018).

In accordance with the satisfying properties and benefits aforementioned, blockchain technology possesses the potential to cope with the issues that arose from Covid-19 pandemic, including the inconsistency of medical data and low efficiency in providing healthcare services. Due to the interoperability of blockchain technology, medical data are easily accessible thereby reducing the time to provide accurate treatment to the infected patients. Vaccine tracing can be facilitated by blockchain from the manufacturer throughout the supply chain all the way to the individuals who receive the injection of vaccines (Bernama, 2021). This subsequently eases the preparation of Digital Health Certificate which meets international standards to facilitate the movements of travelling and border crossing (Bernama, 2021).

2.4.5 Smart Education

According to Salha, El-Hallaq and Alastal (2019), student records, faculty records, educational certificates and so forth are the key assets in the field of education. It is imperative to verify the authenticity of the data sources and to ensure the trustworthiness of these records as they need to be shared among the stakeholders (PWC, 2018). Blockchain can be integrated in the educational system to maintain and manage the educational records generated endlessly. As the records stored in blockchain cannot be modified or deleted, therefore the data integrity can be protected and the counterfeit and fraudulent attempts can be detected. Moreover, the storing of personal data regarding the education practitioners such as educational backgrounds and credentials in blockchain can result in increased levels of students' trust and confidence.

On the other hand, blockchain as a secure ledger allows the individuals to own their respective digital certificates instead of being kept by a centralised authority (Ismail and Materwala, 2019). Individuals are entitled to manage their educational data autonomously and specify the accessibility flexibly. For instance, an individual can grant access permission to an employer to access the academic credentials during an interview. In such conditions, the hassle of visiting multiple educational institutions to obtain educational credentials can be diminished. Besides, the immutability feature of blockchain ensures the authenticity of educational records thereby eradicating the need of attestations and maximising the fairness of evaluation in the recruitment process (Bagloee, et al., 2021; PWC, 2018). Universiti Tunku Abdul Rahman (UTAR) is one of the higher educational institutions which makes use of the blockchain's benefits by issuing UTAR Blockchain Certificate. The educational institutions and students can avoid keeping tonnes of paper documents and subsequently maintain the environmental sustainability.

Bandara, Loras and Arraiza (2018) proposed a blockchain-secured digital syllabus. The digital syllabus normally consists of course summary, course description, course objectives and content, similar to the materials provided in physical classes. The students are able to access the digital syllabus easily at any time on the P2P network. This is especially useful nowadays as the students are restricted from attending physical classes due to the outbreak of Covid-19 pandemic. Blockchain is used to store the digital syllabus owing to its immutability feature. This can ensure that the content of syllabus is free from tampering which will jeopardize the learning and understanding of the students.

2.4.6 Smart Asset

Blockchain can be deployed to manage transactions of land, property and housing, owing to the existence of smart contracts (Wong, et al. 2020; Rebrisoreanu, et al. 2018). In a conventional property market, the details of transactions, buyers and sellers are kept collectively under a centralised system.

Hence, a trusted intermediary has been involved in the transactions for several decades to assist in the delivery of data (Tseng and Shang, 2021; Puthal, et al., 2018). Wong, et al. (2020) outlined that the dependence on the trusted third party causes all the participants to incur additional expenditure as they are required to make payment for the services provided by authorised intermediary. Plus, it is infuriating when the buyers and sellers are required to go through a time-consuming and laborious transaction process where a number of black and white documents need to be prepared for verification and agreement (Wong, et al., 2020). In this case, blockchain with its decentralised attribute is able to build a network for the purchase, sale and rent of property in SSC besides providing a platform for the exchange and storage of data (Dewan and Singh, 2020; Wong, et al. 2020). By incorporating blockchain in this domain, the users' identities can be verified effortlessly, and the records of property transactions kept in blockchain are unforgeable. Hence, the involvement of the traditional written agreements and authorised third parties can be eliminated. This contributes to speedy transaction process and reduction in transaction costs as the buyers and sellers can avoid preparing numerous documents and going through layers of intermediaries during the process.

Property development process is likewise a potential application of blockchain. Wong, et al. (2020) articulated that blockchain can provide assistance in several phases of the property development process, which are land registration, design, construction and maintenance. Blockchain was proposed to be applied in the registration of land and other properties to prevent undesirable losses of public registers due to fraud and corruption (ITU-T, 2020; Rebrisoreanu, et al., 2018).

Moreover, as the details of lands are kept in the distributed network, hence the buyers can verify the ownerships of lands and apply for land registration via blockchain system instead of going through various land registration and land transfer systems such as the Torrens System and the Deeds System. In addition, based on ITU-T (2020), blockchain with the use of smart contracts allows the changes in ownership to be made in real time. Apart from that, the combination of blockchain and building information modelling enables the drawings, specifications, approvals, reports and records captured to be stored immutably thus ensuring the transparency and accuracy of data throughout the lifespan of an asset (Wong, et al., 2020).

In the field of facilities management, the routine for the repair and maintenance of infrastructures can be accessed easily via blockchain thus ensuring that they are maintained regularly in compliance with the schedule. Pursuant to Salha, El-Hallaq and Alastal (2019), automatic payments can be initiated by smart contracts upon the completion of works by the main contractor or procurement of construction materials. Hence, late payment as one of the most common issues in the property development process can be avoided and disputes arising between developer and main contractor for the late payment issues can be reduced significantly.

2.4.7 Smart Utility

Smart Utility can be divided into several categories which include energy management, waste management, carbon detection and pollution monitoring. Smart grid with the adoption of blockchain technology was proposed for the management of energy. Smart grid is a decentralised, secure, economical, efficient and sustainable P2P based power grid system where energy is traded between consumers and the service provider (Bhushan, et al., 2020). Kaur, et al. (2018) stated that there are several smart devices deployed in smart grid to form a power supply chain network. These smart devices include, but not limited to smart meters, smart appliances and energy utilisation resources.

Electrical energy as the commonest commodity is mostly produced from fossil energy and this leads to numerous adverse environmental effects. In order to ameliorate the environmental issues, renewable energy such as solar energy is gaining popularity among the prosumers. The incorporation of blockchain technology in the smart grid domain forms a decentralised electricity trading market which enables the prosumers to convert the surplus energy into tokens and sell them to other consumers (Wong, et al., 2020; Xie, et al., 2019). Wong, et al. (2020) further elaborated that the electricity system is decentralised as the payments and transactions of energy trading are conducted automatically through the smart contract deployed on the blockchain without the involvement of any intermediary.

Smart grid has the ability to supply the energy to commercial, social and industrial areas in a SSC. Diurnal generation of immense amounts of data relevant to smart grid activities such as meter readings and the conduct of digital transactions for energy payment require a promising technology to provide security, data transparency and data sources (Aggarwal, et al., 2019). The application of blockchain is an ideal choice to enhance the smart grid systems. Gao, et al. (2018) mentioned that blockchain can be used to achieve data security by creating a trusted-based system which is able to prevent the malicious alteration of meter readings by third parties in smart grid network. Additionally, Aggarwal, et al. (2018) created a secure EnergyChain blockchain model design which is able to store and access the data produced from smart meters. The integration of blockchain can ensure the security of transactions conducted as well as protecting the privacy of the consumer (Aggarwal, et al., 2019).

Furthermore, dynamic pricing in smart grids which aims to provide highly flexible real-time pricing options to the users on the basis of consumption profiles and energy availability requires data to travel over various insecure channels (Bhushan, et al., 2020). This exposes the dynamic pricing to the risk of being controlled by untrusted entity which updated the price profiles intentionally thus leading to the losses of smart grid and the users (Aggarwal, et al., 2019). Bhushan, et al. (2020) outlined that blockchain technology has the potential to provide a reliable and secure platform for energy internet ecosystems as the alterations of consumption profiles, energy availability and price profiles are restricted.

On the other hand, waste management plays an important role in maintaining the sustainability of a SSC. Blockchain with the incorporation of IoT sensors and Artificial Intelligence (AI) in the waste management which covers the collection of waste, disposal of waste, recycling of waste and recovery of waste, can improve the efficiency of the operations of managing waste. For example, the household wastes which are accumulated to a certain level will be detected by the IoT sensors thus notifying the relevant authorities for waste collection and disposal. This can effectively safeguard the cleanliness and hygiene of the environment in SSC as the piled-up wastes are managed regularly. Based on Wong, et al. (2020), the possession of real-time tracking capabilities is the key enabler for the optimisation of waste collection schedule and routes. This in turn leads to the utilisation of fuel by waste collection trucks as the schedules for waste collection can be planned properly in advance (Wong, et al., 2020).

Besides, Shen and Pena-Mora (2018) reviewed that the carbon footprints of house appliances, goods, vehicles, tools and equipment can be tracked by using blockchain technology. This allows the manufacturers, suppliers and consumers to have a better understanding of the impacts of each product on the environment thereby improving the carbon emission compliance (Wong, et al., 2020). Wong, et al. (2020) explained that carbon footprints are recorded in blockchain for the determination of carbon tax charges, where applicable, to discourage potential consumers from buying products with high carbon emissions.

Blockchain-based system with the integration of ubiquitous IoT sensors is able to monitor the quality of the environment in SSC by detecting the changes in hyperlocal air quality and toxicity levels (ITU-T, 2020). Monitoring the levels of pollution is essential for the authorities and communities in SSC to implement immediate and efficient strategies in order to combat pollution and tackle the issues caused by pollution (ITU-T, 2020; Wong, et al., 2020).

2.5 Summary of Blockchain Application in Smart Sustainable City

Figure 2.4 summarises the findings obtained from literature review. The summary consists of the features of blockchain technology and the smart applications of blockchain technology in SSC. There are six features of blockchain technology accompanied with seven smart applications of blockchain technology in SSC. The six features covered are decentralisation, mutual consensus, transparency, immutability, detrusting and interoperability. Smart Governance, Smart Transportation, Smart Supply Chain Management, Smart Healthcare, Smart Education, Smart Asset and Smart Utility are the seven smart applications of blockchain technology, alongside with their respective aspects involved. Figure 2.4 indicates that blockchain with its distinguishing features is able to complement the implementation of SSC through its application in a broad spectrum of domains.

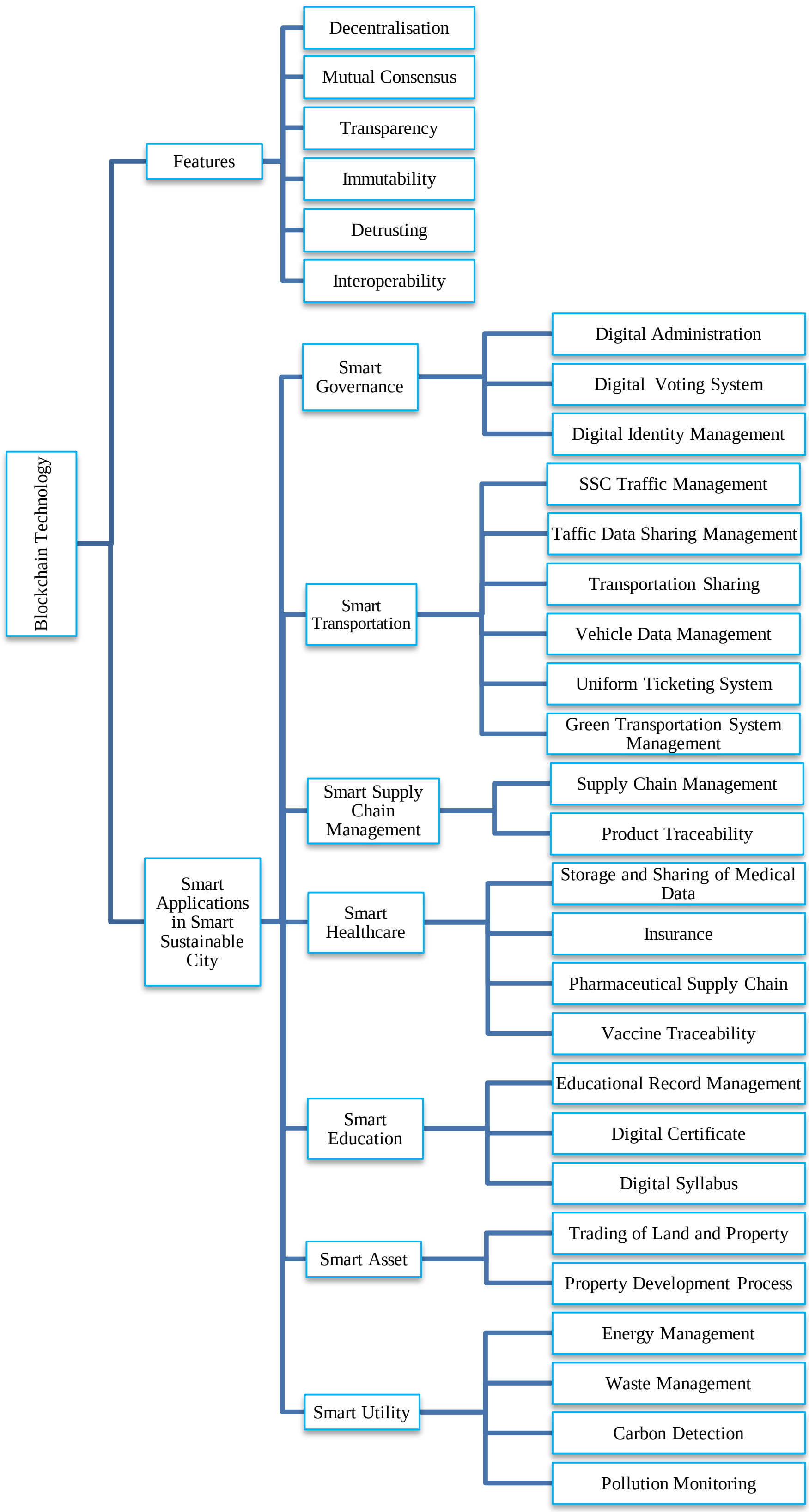

Figure 2.4: Features and Smart Applications of Blockchain Technology in SSC

2.6 The Influence of Social Demographic on Technology Adoption

This study intends to explore the relationship between the social demographics of construction practitioners and their acceptance towards the adoption of blockchain technology in SSC. The results allow the evaluation of how each social demographic affects their acceptance in technology adoption. Baker, Al-Gahtani and Hubona (2007) stated that demographic factors such as gender, age and educational level are able to influence the adoption of technology.

Gender has been regarded as a factor that influences the intention of accepting the latest technology (Goswami and Dutta, 2016). Venkatesh and Morris (2000) asserted that the attitude towards technology differs according to gender. Van Slyke, Comunale and Belanger (2002) found out that males are more likely to try new technology as compared to females. Besides, males are generally more confident in using technologies like computers than females (Braak, 2004). This is because males are more technologically skilled than females (Shaouf and Altaqqi, 2018). On the other hand, females tend to be less experienced, less competent and encounter more technical challenges in using technologies. Hence, females would be more anxious than males in utilising technologies and this would reduce their self-efficacy, which in turn lead to increased perceptions of the effort needed in using technologies (Venkatesh, et al., 2003).

Furthermore, every generation has different attitude towards the adoption of technology. Kasasa (2021) outlined that the first adopter of new technologies is typically the youngest generation and the technologies are then slowly adopted by the older generations. Different age groups can be categorised into four categories of generations which are baby boomers, generation X, millennials or generation Y and generation Z. Baby boomers are referred to the individuals born between 1946 to 1961 (Ismail, Aziz and Wahab, 2019). Karr (2021) stated that the pioneers that adopted home computers were baby boomers. However, baby boomers are less likely to adopt the latest technologies at this point of life due to the fear and anxiety of using unfamiliar technologies (Karr, 2021; Tsertsidis, Kolkowska and Hedström, 2019). In addition, Friedberg (2003) outlined that employees who aged above 60 years old tend to use a computer less frequently than the employees who aged below 60 years old. This is because older adults will face challenges in technology adoption due to low computer or internet literacies and rapid changes in cognitive and physical functions of technology (Wildenbos, Peute and Jaspers, 2018; Adebayo, Durey and Slack-Smith, 2017). Individuals who were born in 1962 to 1976 are categorised as generation X (Ismail, Aziz and Wahab, 2019). Karr (2021) highlighted that this generation would like to utilise internet, smartphones and applications to communicate. As for the millennials or generation Y, they were born between 1977 to 1999 (Ismail, Aziz and Wahab, 2019). Individuals from generation Y are digital natives which adopts and uses technology broadly (Karr, 2021; Linnes and Metcalf, 2017). Individuals born after 1999 are grouped into generation Z (Ismail, Aziz and Wahab, 2019). These individuals tend to contact technologies such as smartphones and tablets at a younger age than other generations and are more comfortable in adopting new technologies (Linnes and Metcalf, 2017).

Moreover, a number of previous studies discovered that individuals with higher education level tend to accept and adopt new technologies more quickly than less-educated individuals (Lleras-Muney and Lichtenberg, 2002; Krueger, 1993; Wozniak, 1987; Wozniak, 1984; Welch, 1970). It seems that education could positively affect the individuals' perceptions of the latest technologies (Abu-Shanab,2011). Riddell and Song (2012) stated that education contributes to the rising usage of computers at work as well as the use of technologies that allow the employees to perform higher order tasks. Bucciarelli, Odoardi and Muratore (2010) asserted that only employees who possess appropriate knowledge and equipped with relevant skills are able to manage the latest technologies efficiently. On top of that, a higher proportion of skilled and educated workers in the manufacturing facility would increase the likelihood to adopt computer-aided design (CAD) machines to carry out design and engineering tasks, and vice versa (Riddell and Song, 2012). On the other hand, individuals with lower educational level tend to resist the changes brought by new technologies owing to the lower technological self-efficacy (Noh, Mustafa and Ahmad, 2014). With inadequate confidence to adopt the latest technologies, less-educated individuals tend to perform poorly on tasks related to the new technologies.

2.7 Summary of Chapter

In short, the definition, concept and benefits of SSC were presented in detail at the beginning of the chapter. Blockchain technology was subsequently defined and the types and features of blockchain technology were reviewed. The potential applications of blockchain technology in SSC were then scrutinised in the following subsections. Besides, the influence of social demographics on the adoption of technology was discussed after summarising the blockchain's application in SSC. This chapter ended with a summary of findings from literature review on blockchain technology which encompasses its features and smart applications in SSC.

CHAPTER 3

METHODOLOGY AND WORK PLAN

3.1 Introduction

This chapter comprises the determination and explanation about the research method and data collection procedures. Firstly, both quantitative and qualitative research approaches are discussed and compared. The selection between these two research methods is subsequently being justified. Next, the methods adopted in reviewing literature, collecting data, designing and distributing questionnaire surveys, determining the target respondents and deciding data analysis for collected data are likewise scrutinised. Lastly, this chapter ended with a summary of chapter.

3.2 Research Method

Research is defined by Saunders, Lewis and Thornhill (2019) as a process that is conducted systematically with an explicit purpose for the discovery of fact. Creswell (2015) stated that a research process generally consists of three steps in data collection and analysis to improve the understanding of a topic. These three steps are the posing of questions, collection of data for answering the questions and presentation of answers to the questions (Creswell, 2015). Daniel (2016) further explained that the combination of reasoning and experiences is involved in uncovering the truth. As for research method, it is referred to the plans and procedures for research which comprise the steps from broad assumptions to comprehensive methods of collecting data, analysing data and interpreting data (Creswell and Creswell, 2018).

In accordance with Creswell and Creswell (2018), there are three distinct research methods, which are quantitative, qualitative and mixed research approaches. As its name implies, mixed research approach is a fusion of the components of both quantitative and qualitative research approaches. Each research method possesses its respective strengths, weaknesses and suitable applications.

3.2.1 Quantitative Research Approach

Creswell and Creswell (2018) defined quantitative research approach as a method where the relationship among variables is examined to test the objective theories. These variables are measurable using instruments, thus enabling the analysis of numbered data through the use of statistical procedures. Quantitative research approach involves using tools such as surveys and questionnaires in collecting quantitative data for statistical analyses and interpretations in order to answer instrument based questions (Creswell and Creswell 2018; McCusker and Gunaydin, 2014). It is relatively more efficient to use quantitative data and it is able to be used in testing hypotheses. Besides being able to test a theory and explanation, quantitative research method is suitable to be applied in three types of research problems. These three research problems include determination of factors affecting an outcome, the utility of intervention and understanding the prime predictions of outcomes (Creswell and Creswell, 2018).

There are various benefits derivable from the application of quantitative research approach. Savings in time, resources and efforts is one of the advantages of this research method owing to the use of statistical data (Daniel, 2016). As statistical data such as numbers are measurable and interpretable via computer statistical programmes during the research analyses, the time required in data evaluation and results description will be reduced significantly. Moreover, this research method is replicable with consistent results as it relies on hypothesis testing and complies with the objectives and guidelines provided (Lichtman, 2013). However, the use of quantitative data might lead to the missing of contextual details (McCusker and Gunaydin, 2014). In addition, to cope with the possible uncertainties in quantitative research approach, the possession of knowledge, personal experiences and familiarity in technical, scientific writing, statistics and computer statistical programs is essential (Creswell and Creswell, 2018).

3.2.2 Qualitative Research Approach

According to Creswell and Creswell (2018), qualitative research approach is used to explore and understand the meaning an individual or a group ascribes to a social or human issue. This research method emphasises on looking at the research inductively and focusing on the individual meaning to report on a situation’s complexity (Creswell and Creswell, 2018). Qualitative research method generally aims to answer open-ended questions and questions regarding ‘what’, ‘how’ and ‘why’ of a situation instead of answering ‘how many’ or ‘how much’ (McCusker and Gunaydin, 2014). It is ideal to apply qualitative research approach when a concept or situation requires exploration and understanding as only few studies have been conducted on it. Qualitative research method is also applicable if there is an understudied sample or ignorance of the essential variables to be examined.

Qualitative research is favourable to be used because it is able to create a significantly broader understanding of behaviours and real life situations. This is because qualitative data instruments are applied during the data collection from participants in their natural settings which gives a full description of the research with regards to the participants involved (Daniel, 2016). Furthermore, Daniel (2016) mentioned that the system of collecting primary qualitative data in this research approach is unique which enables the researcher to produce distinctive descriptions and facts. However, qualitative research approach does not possess replicability as there is no means for the verification of the statements produced due to the elimination of scientific methods and investigation processes (Daniel, 2016; Cohen, Manion and Morrison, 2011). Therefore, the results of qualitative research approach are not consistent and reliable as the explanations are given based on the interpretations of the researchers (Leed and Ormrod, 2014; De Vaus, 2014). This indicates that each individual with different understanding will provide distinct interpretations and explanations.

3.3 Justification of Selection

The research method chosen in this study was quantitative research approach. The main purpose of this study is to discover the potential of integrating blockchain technology into SSC development in Malaysia. Quantitative research approach was selected because a large group of respondents was needed as the research sample and abundant statistical data will be generated in identifying the perspectives of respondents on the integration of blockchain technology into SSC. Survey research was adopted among all types of quantitative methods available as questionnaires can be distributed to a large group of targeted respondents in a shorter period of time. In this regard, a substantial amount of data can be collected speedily and efficiently. The ranking system can be established during the data analysis phases in order to determine the construction practitioners' acceptance towards the blockchain's application in SSC and the importance of blockchain's potential applications. As scientific methods and statistical programs were adopted to interpret the collected data, hence, the results produced will be more consistent and reliable.

It is considered less suitable to adopt qualitative research approach in this study due to the involvement of a huge number of participants. It is comparatively more time-consuming to conduct interviews for the number of respondents required. The time taken to complete an interview process is definitely longer than the time used in filling up a questionnaire. Apart from that, qualitative research approach is less preferable as qualitative method generally focuses on interpretations of data based on personal views, feelings and understandings. This will lead to lower reliability and consistency of the results of interpretations as compared to the use of numbers and measurable figures in quantitative research approach. Moreover, the data gathered from an individual interview is unable to represent the whole construction practitioners' community. Hence, quantitative method was chosen as the results acquired can represent all the construction practitioners in Klang Valley as a whole.

3.4 Literature Review

A literature review is defined by Creswell (2015) as the description and summary of historical and present state of data acquired from the journal articles, books and other documents which is relevant to the research topic. The primary purposes of reviewing literature are to fill in the research gaps as well as extending the existing studies (Marshall & Rossman, 2016; Cooper, 2010). Besides sharing the results of existing studies in the related field, a literature review also provides a benchmark for the comparison of results with the existing findings (Creswell and Creswell, 2018). Despite the absence of a specific method to conduct literature review, a systematic process of conducting literature review is recommended by Creswell and Creswell (2018) to extract, assess and summarise a literature.

In this research, the process of conducting literature review consisted of six steps. Firstly, the key words of this study were identified at the outset of this process. The keywords identified include ‘potential applications’, ‘blockchain technology’ and ‘smart sustainable city’. Next, the journals articles, books and conference papers were searched from computerised databases such as Google Scholar and ScienceDirect using the key terms identified. Around 50 journal articles and conference papers which were related to the research topic were located at the third step. The holdings obtained were then evaluated and filtered at the fourth step to ensure that the data is central to the topic and is able to make useful contributions by enhancing the understanding of the topic. At the phase of conducting literature review, the knowledge areas in the past researches were scrutinised and a gap in the knowledge area was identified. At the end of the process, the literature review was written by referring to the existing studies selected in discussing the concept and benefits of SSC and the types, features and potential applications of blockchain technology in SSC. Figure 2.4 was then illustrated to provide a summary of the features of blockchain technology and the smart applications of blockchain technology in SSC.

3.5 Quantitative Data Collection

Quantitative approach was adopted in this study for the collection of data as a large number of respondents is required to produce the statistical results from samples to a population (Creswell and Creswell, 2018). In this study, the data to be collected was primary data and it was collected through the distribution of questionnaires. Questionnaire was chosen as it is a prominent data collection mechanism which allows the information to be gathered efficiently.

3.5.1 Questionnaire Design

In this research, the first page of the questionnaire was designed to act as a cover page. It consisted of the researcher’s personal data accompanied with a brief introduction of the questionnaire. Then, the definitions of blockchain technology and SSC were inserted in the following section. In view of the justifications aforementioned, all the questions prepared were close-ended questions and these questions were grouped into three sections, namely Section A, Section B and Section C. All the questions designed were either multiple choice questions or questions with scale. In Section A, questions were designed to obtain the demographic profiles of the respondents and to achieve the third objective of this study. The participants were required to answer the questions by selecting their respective gender, age group, profession in construction industry, years of working in the construction field and highest educational level.

As for the questions in Section B, they were designed to attain the first objectives in this study. This section aimed to measure the respondents' acceptance level on the integration of blockchain technology in SSC. Five-point Likert scale was applied in the questions where the respondents were required to rate their acceptances towards the application of blockchain technology into SSC in Malaysia. For Section C, it mainly targeted on obtaining the respondents' viewpoints concerning the level of importance for the potential applications of blockchain technology in SSC. Table 3.1 provides a summary of the questionnaire's design in this study. A questionnaire survey sample is attached in the Appendix.

Table 3.1: Summary of Questionnaire's Design

Section	A	B	C
Type of Question	Multiple choice questions	5-point Likert scale of acceptance level	5-point Likert scale of importance level
Number of Questions/Statements	5	30	30
Scale	Nominal	Ordinal	Ordinal
Purpose of Questions	To obtain the respondents' demographic information and achieve objective 3 of this study	To achieve the objective 1 of this study	To achieve the objective 2 of this study

3.5.2 Sampling Determination

Sampling determination refers to the identification of the representative of the entire targeted population. Creswell (2015) defined population as a group of people who possess identical features. For instance, a population of quantity surveyors is made up of all quantity surveyors. As for representative, it refers to the individuals chosen from a sample of a population which allow the researcher to generalize the findings and eventually draw a conclusion regarding the population as a whole (Creswell, 2015).

Snowball sampling was adopted for the determination of sample in this study as it is able to recruit a huge number of respondents for this research. Snowball sampling is a non-probability sampling where the respondents are requested to determine the individuals who are the representatives of the population. This indicates that the electronic questionnaires that were delivered to a particular construction practitioner can be forwarded by him/her multiple times to the other construction practitioners who are working in the same or different organisations.

Nevertheless, the population for this research is extremely broad and it is nearly impossible to collect data from all the construction practitioners in Klang Valley. Hence, Central Limit Theorem (CLT) was applied to determine the sample size for research. Sample size is referred to the size of the subgroup of the population of interest. A minimum sample size of 30 is sufficient to be held by CLT (Kwak and Kim, 2017).

3.5.3 Questionnaire Distribution

In this research, the electronic questionnaire was created using online Google Form and distributed in three ways to the construction practitioners within Klang Valley regardless of the respondents' age, working experience, and position in the company. The first method was to distribute by sending emails to the construction practitioners, whereas the second method was to share the e-survey links on the social media platforms aforesaid, which were WhatsApp, WeChat, Messenger, Facebook, Twitter and Instagram. The third method was sending questionnaires to the construction practitioners on the LinkedIn platform. The email addresses of the construction firms were obtained by browsing the official websites of Construction Industry Development Board

(CIDB), the Board of Quantity Surveyors Malaysia (BQSM), Board of Architects Malaysia and Board of Engineers Malaysia. The duration for the distribution of questionnaires and collection of data from the participants was approximately five weeks.

3.6 Data Analysis

In this study, data analysis was conducted after the collection of data by using Statistical Package for the Social Sciences (SPSS). Four statistical tests were adopted for the analysis of data, which are Cronbach's Alpha Reliability Test, Arithmetic Mean, Mann-Whitney U Test and Kruskal-Wallis Test

3.6.1 Cronbach's Alpha Reliability Test

Cronbach's Alpha Reliability Test was used to measure the internal consistency or reliability of the responses for Likert scaled questions. The value of Cronbach's alpha ranges from zero to one (Bujang, Omar and Baharum, 2018). Higher Cronbach's alpha value indicates higher internal consistency. On the contrary, if the Cronbach's alpha value is low, the internal consistency is low.

The consistency of quantitative data is considered acceptable when the Cronbach's alpha value is equal or greater than 0.7, whereas when the Cronbach's alpha value is lower than 0.5, the internal consistency is unacceptable. Excellent internal consistency is achieved when the Cronbach's Alpha value is equal or greater than 0.9 (Siswaningsih, et al., 2017).

3.6.2 Arithmetic Mean

The arithmetic mean is sometimes known as mean (Brase and Brase, 2009). Arithmetic mean is used to calculate the average of a set of numerical values thus identifying the centre tendency of a group of quantitative data. To compute arithmetic mean, all the values need to be added up, followed by the division of the sum by the total number of values (Brase and Brase, 2009). The objective of adopting Arithmetic Mean in this study was to determine the mean of the smart applications of blockchain technology in SSC thus enabling the ranking of the acceptance level and importance level of each smart application.

On the other hand, as 5-point Likert scale questions were designed in the questionnaire survey, hence, the collected data were Likert scaled and possessed an interval level of measurement (Pimentel, 2010). In this study, the importance level and acceptance level were grouped into three categories, which are low level, moderate level and high level. To ensure the difference of every interval is constant and uniform, each interval is obtained by dividing 4 intervals by 3 categories (Nyutu, Cobern and Pleasants, 2021; Pimentel, 2010). The difference of the categories' interval ranges from 1.32 to 1.33, in which the huge differences in first, middle and last intervals are eliminated (Pimentel, 2010). Table 3.2 shows the intervals for each level of importance and acceptance.

Table 3.2: Scale to Measure Level of Acceptance and Level of Importance (Pimentel, 2010)

Level of Acceptance/Level of Importance	Interval
Low	1.00 – 2.33
Moderate	2.34 – 3.67
High	3.68 – 5.00

3.6.3 Mann-Whitney U Test

Mann-Whitney U Test is a non-parametric test used to evaluate the significant differences between two independent groups when the dependent variable is of ordinal type but not normally distributed (Nachar, 2008). In this study, different genders have different viewpoints and concerns in accepting blockchain technology. Hence, Mann-Whitney U Test was applied to determine whether there are any statistical differences between male and female.

The two groups of gender would be the independent variables whereas the acceptance level on blockchain technology was the dependent variable. To assess the differences between the independent and dependent variables, two hypotheses are formulated as follows:

- H_0 (null hypothesis): There is no significant difference in accepting the blockchain technology between the genders.
- H_1 (alternative hypothesis): There is a significant difference in accepting the blockchain technology between the genders.

3.6.4 Kruskal-Wallis Test

Kruskal-Wallis Test is an alternative to the one-way analysis of variance (ANOVA) (Ostertagová, Ostertag and Kováč, 2014). Kruskal-Wallis Test was adopted to examine the significant differences of two or more groups of independent variables on a dependent variable.

In this research, the independent variables were the age group and highest educational level. As for the dependent variable, it was the acceptance level on blockchain technology. The dependent variable was measured by Likert Scale. Kruskal-Wallis Test was applied to analyse the differences in acceptance level on the blockchain technology's application in SSC between the groups of age and highest education level.

Two types of hypotheses, namely H_0 and H_1 are formulated below to identify the difference on the acceptance level of blockchain's application due to different age groups and educational levels of construction practitioners,

- H_0 (null hypothesis): There is no significant difference in accepting the blockchain technology between the different age groups/educational levels.
- H_1 (alternative hypothesis): There is a significant difference in accepting the blockchain technology between the different age groups/educational levels.

3.7 Summary of Chapter

In conclusion, quantitative research approach was adopted in this study to achieve the research aim and objectives. Quantitative method was selected due to its ability to collect abundant data within a short duration. The data were collected through the distribution of questionnaires to the construction practitioners in Klang Valley. The analysis of collected data was performed by using Cronbach's Alpha Reliability Test, Arithmetic Mean, Mann-Whitney U Test and Kruskal-Wallis Test.

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Introduction

This chapter discusses the data analyses' results of the data obtained from the questionnaire surveys. It begins with a summary of demographic background of the survey's respondents. Then, Cronbach's Alpha Reliability Test was adopted to determine the data's reliability. The Arithmetic Means of the acceptance and importance level of the smart applications were then computed and ranked. Next, Mann-Whitney U Test was conducted to examine the significant difference in the acceptance level of blockchain between the genders. Kruskal-Wallis Test was applied to determine whether there is a difference in the acceptance level of blockchain between the different age groups and educational levels. This chapter ends with a conclusion that provides an overall summary of the analysed results.

4.2 Demographic Background of Respondents

153 responses were received through the distribution of questionnaire surveys to the construction practitioners within Klang Valley. The demographic data of the respondents is summarised in Table 4.1.

Table 4.1: Demographic Profile

Demographic Data	Frequency (n)	Percentage (%)
Gender		
Male	81	52.9
Female	72	47.1
Age Group		
21 years old and below	31	20.3
22 – 44 years old	87	56.9
45 – 59 years old	28	18.3
60 years old and above	7	4.6

Table 4.1 (Continued)

Demographic Data	Frequency (n)	Percentage (%)
Profession		
Architect	21	13.7
Engineer	23	15.0
Main Contractor	4	2.6
Project Manager	8	5.2
Quantity Surveyor	77	50.3
Sub-Contractor	9	5.9
Supplier	5	3.3
Others	6	4.1
Years of Working Experience		
Less than 6 years	93	60.8
6 - 10 years	19	12.4
11 - 15 years	1	0.7
16 - 20 years	6	3.9
More than 20 years	34	22.2
Highest Educational Level		
High School	3	2.0
Sijil Pelajaran Malaysia (SPM)	6	3.9
Sijil Tinggi Persekolahan Malaysia (STPM)	1	0.7
Diploma	23	15.0
Bachelor's Degree	86	56.2
Master's Degree	28	18.3
Doctoral Degree	6	3.9

Table 4.1 shows the frequencies and percentages of the respondents in different demographic traits. Based on Table 4.1, out of 153 respondents, 81 of them are male and 72 of them are female. Furthermore, the age groups of respondents are categorised into 4 groups, which are below 21 years old (20.3%), 22 – 44 years old (56.9%), 45 – 59 years old (18.3%) and 60 years old and above (4.6%).

On the other hand, the profession of respondents can be grouped into 8 categories, including Quantity Surveyor (50.3%), Engineer (15.0%), Architect (13.7%), Sub-Contractor (5.9%), Project Manager (5.2%), Supplier (3.3%), Main Contractor (2.6%) and Others (6%). Regarding the years of working experience, a majority of 93 respondents have less than 6 years working experience, whereas there is only 1 respondent who has 11 to 15 years of working experience. Besides, there are 34 respondents with more than 20 years working experience. The number of respondents with 6 to 10 years working experience and 16 to 20 years working experience are 19 and 6 respectively.

In terms of educational level, there are 3 high school graduates, 6 SPM certificate holders and 1 STPM certificate holder. Moreover, there are 23 Diploma graduates, 86 Bachelor's Degree graduates, 28 Master's Degree graduates and 6 Doctoral Degree graduates.

4.3 Cronbach's Alpha Reliability Test

In this research, Cronbach's Alpha Reliability Test was conducted to analyse the reliability of data of Section B and Section C in the questionnaire survey. According to Table 4.2, the Cronbach's Alpha values computed for Section B and Section C were 0.936 and 0.923 respectively, which indicate that the data collected possess excellent internal consistency (Siswaningsih, et al., 2017). Hence, it can be concluded that the data obtained for both sections are reliable to be used for further analysis purposes in this research.

Table 4.2: Reliability Statistics of Section B and Section C

Section	Cronbach's Alpha	Cronbach's Alpha Based on Standardised Items	N of Items
Section B: Acceptance Towards the Application of Blockchain Technology for Smart Sustainable City Development in Malaysia	.936	.940	30

Table 4.2 (Continued)

Section	Cronbach's Alpha	Cronbach's Alpha Based on Standardised Items	N of Items
Section C: The Importance of the Potentials of Blockchain Technology Application for Smart Sustainable City Development in Malaysia	.923	.928	30

4.4 Arithmetic Mean

In this section, the acceptance and importance level of the applications of blockchain technology for SSC development in Malaysia were ranked and discussed according to the 153 responses collected.

4.4.1 Mean Ranking of Acceptance Towards the Main Smart Application of Blockchain Technology

Table 4.3 illustrates the overall mean ranking of the acceptance towards the main smart applications of blockchain technology for SSC development in Malaysia. The seven main smart applications include Smart Governance, Smart Transportation, Smart Supply Chain Management, Smart Healthcare, Smart Education, Smart Asset and Smart Utility. Overall, the mean scores of all the main smart applications exceed 3.68 and this indicates that the acceptance level towards these smart applications is high, as pursuant to Table 3.2.

Table 4.3: Overall Mean Ranking of Acceptance Towards the Main Smart Applications of Blockchain Technology

Code	Smart Application in SSC	Mean	Rank	Level of Acceptance
AD	Smart Healthcare	4.31	1	High
AC	Smart Supply Chain Management	4.27	2	High
AB	Smart Transportation	4.21	3	High
AG	Smart Utility	4.18	4	High

Table 4.3 (Continued)

Code	**Smart Application in SSC**	**Mean**	**Rank**	**Level of Acceptance**
AE	Smart Education	4.00	5	High
AA	Smart Governance	3.86	6	High
AF	Smart Asset	3.84	7	High

According to Table 4.3, the application of blockchain technology in Smart Healthcare (**AD**) is ranked highest with the mean value of 4.31. This indicates that a majority of the respondents are able to accept the application of Smart Healthcare in order to substitute the traditional healthcare systems which are inadequate to cope with the escalating healthcare demand (Wong, et al., 2020). This is because the respondents perceive that good health is the foundation of happiness as the saying goes, "Health is wealth" (Xie, et al., 2019).

Next, the mean value of 4.27 enables the Smart Supply Chain Management (**AC**) to be ranked second. This is generally because the data of products and businesses can be stored and shared using a transparent platform and the information available can facilitate the decision-making process (Wong, et al., 2020; Xie, et al., 2019). Besides, the supply chain industry is full of challenges concerning the increasing costs and efficiency in the supply of products to retailers and consumers (Salha, El-Hallaq and Alastal, 2019). Hence, the application of blockchain technology in supply chain management is highly accepted by the respondents as blockchain technology with its distinguishing features are able to offer a potential solution to these issues.

On the other hand, the lowest rank of Smart Asset (**AF**) indicates that it is the least acceptable among all the main smart applications in the Malaysia context. However, its mean value of 3.84 implies that this application is highly accepted by the respondents. This is because it is able to establish a digitalised process that automates the registration of property thus reducing the cost and time taken (PWC, 2018). ITU-T (2020) outlined that the changes in ownership can be conducted in real-time by using smart contracts, thus maximising the efficiency of processes.

4.4.2 Mean Ranking of the Acceptance Towards the Sub-Smart Application of Blockchain Technology

The means of 30 sub-smart applications of blockchain technology are ranked and tabulated in Table 4.4. Table 3.2 shows that the scale range of high acceptance level is 3.68 – 5.00, whereas the scale interval of low acceptance level is 1.00 – 2.33. As for moderate level of acceptance, its scale range is 2.34 – 3.67. Hence, based on Table 4.4, the sub-smart applications which are ranked from 1st to 26th are highly acceptable, while the acceptance level towards the remaining sub-smart applications is moderate.

Based on Table 4.4, the sub-smart application with the highest mean ranking is **AB1** = "Data about the road conditions and traffic congestions shall be available real-time and anytime" which is categorised under "Smart Transportation (**AB**)" with a mean value of 4.66. This shows that the availability of real-time traffic data is strongly accepted by the respondents. The provision of latest information enables the road users to be aware of the current conditions of road and traffic thereby taking alternative routes in the event of traffic jams or accidents. This contributes to the improvement of road safety and travel efficiency as well as maximising the convenience of road users (Bhushan, et al., 2020).

Besides, the second highest mean ranking also comes from the "Smart Transportation (**AB**)" category, which is **AB5** = "Ticketing machines or counters for numerous transportation mediums are replaced by a single digital platform that sells digital tickets for all transportation mediums such as buses, trains and planes", with mean value of 4.56. This sub-smart application is highly acceptable by the respondents because it maximises the convenience by allowing the citizens to purchase the tickets of multiple transportation mediums via a single platform. According to Wong, et al. (2020), the uniformity of a single platform facilitates the transactions and refrains the citizens from going to multiple ticketing machines or desks or surfing numerous websites, which are troublesome.

Apart from that, **AD1** = "Medical reports' hardcopies are replaced by the storage of complete medical history in a digital platform which can be accessed by the medical practitioners upon authorisation by the patients" which is under the category of "Smart Healthcare (**AD**)" has the same ranking with

AB5 as their mean values are the same. This sub-smart application is highly accepted as the respondents perceive that it can avoid the troubles of keeping and carrying tonnes of medical reports' hardcopies during medical consultation (Sanka, et al., 2021; Karale and Ranaware, 2019). Besides, the confidentiality of medical records and health data can be safeguarded as the patients possess full access and control of these information. Bagloee, et al. (2021) highlighted that the patients can select the level of detail accessible, the provision and revocation of viewing rights as well as the duration they feel necessary to facilitate the diagnosis process. Nowadays, the patients are facing health barriers as their medical records are scattered and kept in isolation which lead to limited information available to the medical service providers. This sub-smart application can increase the patients' choices by empowering the citizens to share their complete medical data with different medical practitioners (Bagloee, et al., 2021).

The fourth highest mean ranking is **AG5** = "Data about the changes in the environmental quality shall be available real time and anytime to citizens" under the category of "Smart Utility (**AG**)", with the mean value of 4.54. This reveals that the respondents have high concern for the quality of environment. The real-time data pertaining to changes in temperature or toxicity levels can act as a warning to the citizens about natural disasters, for instance, fires, floods or earthquakes. By understanding the current climate-related risks that are faced by the cities and communities, the relevant authorities and citizens can develop strategies in dealing with them (ITU-T, 2020).

On the other hand, the second lowest mean ranking is **AA1** = "The management and control of data by centralised agencies or organisations such as banks and lawyers are eliminated" which is under the category of "Smart Governance (**AA**)" with mean value 3.46. In spite of the moderate level of acceptance, this sub-smart application is regarded to be less acceptable by the respondents as compared to other sub-smart applications. In Malaysia's setting, the centralised organisations are deemed to be more reliable for the improved consistency, rationality and soundness of data. For instance, from the respondents' perception, centralised architecture of the banking institutions enables the clients' data to be stored in the central server whereby the data administration is eased, the risks of data loss are minimised and the data integrity can be maintained owing to the existence of central data records (Xi, 2020). Hence, it is apparent that the heavy reliance of Malaysians on banks and lawyers that act as intermediaries has led to the low acceptance towards the use of blackchain technology in data management as blockchain removes the need of intermediaries.

Furthermore, **AF1** = "Transactions of land, property and housing can be carried out between buyers and sellers without relying on intermediaries such as lawyers to prepare paper documents for verification and agreements as the data of properties, buyers and sellers stored in digital platform can be exchanged and verified" under "Smart Asset (**AF**)" category is the sub-smart application with the lowest mean-ranking. In view of this, it can be deduced that in the Malaysia context, this sub-smart application is the least acceptable among all the sub-smart application. This is mainly because the respondents have been handling the exchange of data and the transferral of assets with the involvement of a trusted intermediary in the past decades (Puthal, et al., 2018). This brings about the over-reliance of respondents on the intermediaries thereby leading to the reluctance of respondents to obviate the need for intermediaries. The reliance on intermediaries is reassuring as it is their responsibility to ensure a secure exchange and they are accountable to any failures or breaches of security (Puthal, et al., 2018).

Table 4.4: Mean Ranking of Acceptance Towards the Application of Blockchain Technology for SSC Development in Malaysia

Code	Smart Application in SSC	Mean	Rank	Level of Acceptance
AB1	Data about the road conditions and traffic congestions shall be available real-time and anytime.	4.66	1	High
AB5	Ticketing machines or counters for numerous transportation mediums are replaced by a single digital platform that sells digital tickets for all transportation mediums such as buses, trains and planes.	4.56	2	High
AD1	Medical reports' hardcopies are replaced by the storage of complete medical history in a digital platform which can be accessed by the medical practitioners upon authorisation by the patients.	4.56	2	High
AG5	Data about the changes in the environmental quality shall be available real time and anytime to citizens.	4.54	4	High
AB2	The personal data of drivers and passengers is stored in a digital platform which is accessible upon authorisation to facilitate the verification of identities during ride sharing such as Grab car.	4.48	5	High
AD6	The numbers of vaccination doses produced and injected to the individuals are traceable in a digital platform without involving intermediaries.	4.48	5	High

Table 4.4 (Continued)

Code	Smart Application in SSC	Mean	Rank	Level of Acceptance
AG3	The operations of waste management which include the collection, disposal, recycling and recovery of wastes are enhanced as the relevant authorities are instantly notified when the wastes are piled up to a certain level without involving any intermediaries.	4.47	7	High
AD7	The origins of critical drugs, blood and organs are traceable without involving intermediaries to ensure the drugs, blood and organs are obtained legally.	4.39	8	High
AG1	Data related to energy activities such as meter readings and the conduct of digital transactions for energy payment is stored in a digital platform where the data is unalterable by third parties.	4.39	8	High
AD5	Official medical licenses of medical practitioners are stored in a digital platform where data is immutable to prevent the theft of medical licenses by fraudulent healthcare service providers.	4.37	10	High
AB4	Hardcopies of vehicles' documents are replaced by the storage of vehicles' data in a digital platform where data is immutable to prevent modification of data and maximise reliability of data.	4.30	11	High
AC3	The origins of food supply chain are traceable real-time without intermediaries to ensure the quality and safety of food.	4.29	12	High

Table 4.4 (Continued)

Code	Smart Application in SSC	Mean	Rank	Level of Acceptance
AD4	The records of pharmaceutical supply chains such as medicines are stored in a digital platform which is transparent and easily traceable without relying on the intermediaries.	4.29	12	High
AC2	The shipment tracking information is synchronised reliably in a digital platform in real time which facilitates traceability.	4.28	14	High
AD3	The process of claiming insurance should be simplified as the medical data can be obtained without going through multiple layers of intermediaries.	4.26	15	High
AE2	Paper-based certificates are replaced with digital certificates which are immutable and manageable by the students themselves.	4.26	15	High
AA2	Traditional paper-based voting system is replaced with e-voting system which is more transparent and secured.	4.24	17	High
AC1	The records of products from manufacturing, processing, transporting, storage and delivery are stored in a digital platform and the accessibility are granted to the authorised parties to allow tracing of products without involving any intermediaries	4.24	17	High
AF2	The construction drawings, specifications, approvals, reports and records involved in the property development process are stored in digital platform which is more secured as the data are immutable.	4.22	19	High

Table 4.4 (Continued)

Code	Smart Application in SSC	Mean	Rank	Level of Acceptance
AE3	Physical lecture notes are replaced by digital learning syllabus which consists of content similar with the materials provided in physical classes.	3.99	20	High
AG2	The surplus renewable energy is sold by the prosumers to other consumers where the payment and transactions of energy trading are conducted automatically without involving any intermediaries.	3.92	21	High
AA3	The provision of identity cards, birth certificates and passports are replaced by the storage of personal data and identities in digital platform where the accessibilities of data are controlled by the citizens themselves.	3.88	22	High
AF3	Automatic payments are initiated after the construction works are completed or construction materials are procured by the main contractors.	3.88	22	High
AD2	Digital medical data can be shared between medical service providers due to the absence of centralised systems and distinct databases.	3.81	24	High
AE1	Educational records of students and the credentials of education practitioners are stored in a digital platform which is more systematic without the involvement of centralised authority such as schools, colleges or universities.	3.76	25	High

Table 4.4 (Continued)

Code	Smart Application in SSC	Mean	Rank	Level of Acceptance
AB6	Electricity can be traded between the drivers of electric vehicles whenever required without involving any intermediaries or relying on charging stations such as ChargeEV.	3.68	26	High
AB3	Ride sharing services can be carried out between the drivers and passengers without involving intermediaries such as Uber and Grab.	3.60	27	Moderate
AG4	Carbon footprints of house appliances, goods, vehicles, tools and equipment are tracked without involving intermediaries and recorded in digital platform to determine carbon tax charges, where applicable.	3.56	28	Moderate
AA1	The management and control of data by centralised agencies or organisations such as banks and lawyers are eliminated.	3.46	29	Moderate
AF1	Transactions of land, property and housing can be carried out between buyers and sellers without relying on intermediaries such as lawyers to prepare paper documents for verification and agreements as the data of properties, buyers and sellers stored in digital platform can be exchanged and verified.	3.41	30	Moderate

4.4.3 Mean Ranking of the Importance of the Main Smart Application of Blockchain Technology

Table 4.5 shows the overall mean ranking of the importance of blockchain technology's main smart applications for SSC development in Malaysia. Smart Governance, Smart Transportation, Smart Supply Chain Management, Smart Healthcare, Smart Education, Smart Asset and Smart Utility are the seven main smart applications analysed. Based on Table 4.5, the highest mean value is 4.63 whereas the lowest mean value is 4.11. This means that all the main smart applications are within the range of high level of importance in accordance with Table 3.2.

Table 4.5: Overall Mean Ranking of the Importance of the Main Smart Application of Blockchain Technology

Code	Smart Application in SSC	Mean	Rank	Level of Importance
BA	Smart Governance	4.63	1	High
BE	Smart Education	4.51	2	High
BB	Smart Transportation	4.50	3	High
BD	Smart Healthcare	4.47	4	High
BG	Smart Utility	4.33	5	High
BC	Smart Supply Chain Management	4.28	6	High
BF	Smart Asset	4.11	7	High

As depicted in Table 4.5, Smart Governance (**BA**) has the highest mean ranking with mean value of 4.63. This result reveals that the respondents perceive that Smart Governance is extremely important as it enhances citizen engagement, eases the interactions with government services, and contributes to a better life quality as well as easier access to services (Bagloee, et al., 2021). Besides, the application of blockchain in Smart Governance results in maximised transparency thereby supporting the initiatives of reducing corruption and fraud (Ølnes, Ubacht and Janssen, 2017). This is crucial because transparency promotes accountability and increases the confidence of citizens towards the government.

The next highest mean ranking is Smart Education (**BE**) with a mean score of 4.51. It can be observed that the respondents are aware of the importance and positive influence of education on urban wealth (Bhushan, et al., 2020). Bhushan, et al. (2020) expressed that social infrastructure which comprises human capital and intellectual capital is the pillar of SSC. Therefore, in order to achieve a more progressive SSC, cities should focus on the investment in human capital instead of blindly believing that the cities can be automatically transformed and enhanced solely by IT itself (Hollands, 2008).

On the other hand, the lowest mean ranking is Smart Asset (**BF**) expresses that it is the least important out of the seven main smart applications, but its mean value of 4.11 indicates that its importance level is high as pursuant to Table 3.2. In Smart Asset, the approvals, inspection reports and self-certification of the respective lands and properties are recorded (PWC, 2018). Hence, Smart Asset is vital as it can benefit the citizens by providing an unalterable 360-degree view of the assets (Karale and Ranaware, 2019). Additionally, by looking at the holistic view of the assets, the rights of assets' owners are protected, the authenticity of title can be clarified and the disputes in respect of ownership can be resolved easily (Ølnes, Ubacht and Janssen, 2017). Besides, it is important because the changes in ownership can be made in real time thereby reducing 90% of the operational costs, meanwhile shortening the property registration duration as the need for legal professionals in the processes is eliminated (ITU-T, 2020).

4.4.4 Mean Ranking of the Importance of the Sub-Smart Application of Blockchain Technology

Table 4.6 summarises the means and rankings of the 30 sub-smart applications of blockchain technology. Based on Table 3.2, the scale ranges for high, moderate and low levels of importance are 3.68 – 5.00, 2.34 – 3.67 and 1.00 – 2.33 respectively. By referring to Table 4.6, all the sub-smart applications have high level of importance because all the mean scores exceed 3.68.

According to Table 4.6, the top mean ranking of sub-smart application is **BB1** = "Alternative routes and transportation mediums could be proposed instantly to the drivers and public transportation users during traffic congestions or accidents owing to the sharing of the real-time data of road conditions and traffic congestions" under the category of "Smart Transportation (**BB**)", with mean value of 4.73. The application of blockchain in Smart Transportation is important based on the results because it allows the relevant authorities to optimise the routing strategies and schedules (Treiblmaier, Rejeb and Strebinger, 2020). The alternative routes or transportation mediums will then be proposed to the citizens and this enables the citizens to reach their destinations within expected duration. Besides, by using the routes or transportation mediums suggested, the citizens can avoid being caught in a traffic jam during rush hours that will subsequently provoke frustration and anxiety. On top of that, the instant traffic data can contribute to substantial reduction in the petrol expenses as well as the emission of fossil fuels due to the efficient management of road and traffic (Wong, et al., 2020).

Furthermore, **BB3** = "Authenticity of the drivers' and passengers' identities stored in a digital platform should be verified instantly upon authorisation to safeguard the personal safety during transportation sharing" which also comes from the category of "Smart Transportation (**BB**)" has the second highest mean ranking with the mean score of 4.71. This result signifies that personal safety has become a great concern of the respondents because safety is a growing major issue in the ride sharing services (Chaudhry, et al., 2018). Chaudhry, et al. (2018) asserted that there are chances of experiencing assault, violence, harassment or attack that will threaten the lives of drivers or passengers. Hence, the application of blockchain technology which facilitates the verification of identities is of utmost importance to make sure that the personal safety is secured from the beginning till the end of the journey (Chaudhry, et al., 2018).

In addition, **BA2** = "The conduct of election, registration of voter, transaction of vote, tallying of vote, verification of vote should be conducted in a transparent and systematic way to prevent manipulation of voting results" which is categorised under "Smart Governance (**BA**)" is also ranked second with the mean value of 4.71. The respondents agree that this sub-smart application is crucial as it enables the formation of a trusted, secure, transparent and democratised SSC (Xie, et al., 2019). This sub-smart application of blockchain becomes increasingly important during the outbreak of Covid-19 pandemic because it not only allows the citizens access to secure e-voting procedures, but at the same time maintaining the public health and the democracy and transparency of the electoral process (Treiblmaier, Rejeb and Strebinger, 2020).

The next top ranking sub-smart application is **BE1** = "Education records should be stored in a transparent and secured digital platform to ensure the data integrity as the data cannot be modified and deleted" under the category of "Smart Education (**BE**)" with a mean score of 4.66. The sub-smart application is imperative to ensure that the education data shared to the stakeholders via automated consent mechanisms is secure and transparent thereby eliminating the need of attestations (PWC, 2018). Besides, this sub-smart application guarantees the authenticity of education records thus contributing to the fairness of evaluation coupled with the transparency and equity in the recruitment of employees (Bagloee, et al., 2021).

On the other hand, **BF1** = "Trading of land and property should be simplified as the involvement of traditional written agreement and multi-layer authorised intermediaries are eliminated" which is under "Smart Asset (**BF**)" category has the lowest mean ranking with mean value of 3.71. This implies that in the context of Malaysia, this sub-smart application tends to be the least important out of the 30 sub-smart applications. Akin to the reason whereby **AF1** is the least acceptable, **BF1** is perceived to be the least important as the respondents are accustomed to the need of intermediaries in executing the transactions which are relatively more complicated throughout the ages (Puthal, et al., 2018). Moreover, Tseng and Shang (2021) and Wong, et al. (2020) highlighted that traditional intermediaries play a pivotal role in the conventional property market activities as the information is kept under a centralised system which is opaque. Hence, the citizens are habituated to the involvement of traditional intermediaries who provide assistance in the delivery of data (Tseng and Shang, 2021).

Table 4.6: Mean Ranking of the Importance of the Sub-Smart Application of Blockchain Technology Application

Code	Smart Application in SSC	Mean	Rank	Level of Importance
BB1	Alternative routes and transportation mediums could be proposed instantly to the drivers and public transportation users during traffic congestions or accidents owing to the sharing of the real-time data of road conditions and traffic congestions.	4.73	1	High
BA2	The conduct of election, registration of voter, transaction of vote, tallying of vote, verification of vote should be conducted in a transparent and systematic way to prevent manipulation of voting results.	4.71	2	High
BB3	Authenticity of the drivers' and passengers' identities stored in a digital platform should be verified instantly upon authorisation to safeguard the personal safety during transportation sharing.	4.71	2	High
BE1	Education records should be stored in a transparent and secured digital platform to ensure the data integrity as the data cannot be modified and deleted.	4.66	4	High
BA1	Government information such as tax revenues, incomes, expenses and contracts should be kept in a transparent digital network to ensure integrity and security of government records.	4.63	5	High
BB2	Traffic data in a digital network should be managed instantly and shared to the drivers to prevent the spreading of misleading and inaccurate traffic data.	4.59	6	High

Table 4.6 (Continued)

Code	Smart Application in SSC	Mean	Rank	Level of Importance
BD5	The official medical licenses of the medical practitioners should be stored in a digital network to eliminate fraudulent healthcare service providers and increase the confidence of patients towards the healthcare services provided.	4.58	7	High
BG2	The data produced from smart meter should be stored in a digital platform which is more secured to prevent the alteration of meter readings by third party.	4.58	7	High
BG5	Quality of environment, changes in hyperlocal air quality and toxicity levels should be monitored to allow the authorities and communities to take immediate actions against the pollution.	4.58	7	High
BD4	The origins of critical drugs, blood and organs should be recorded in a digital platform to prevent the illegal trading of drugs and illegal trafficking of organs.	4.57	10	High
BA3	Personal data and identities should be stored in a digital platform instead of providing identity cards to prevent losses, theft and frauds.	4.56	11	High
BD1	Medical data should be stored in a digital platform and shared between medical service providers upon authorised by the patients to allow the efficient delivery of effective healthcare assistance.	4.56	11	High

Table 4.6 (Continued)

Code	Smart Application in SSC	Mean	Rank	Level of Importance
BG3	Household wastes which are accumulated to certain level should be detected and notified the relevant authorities for waste collection and disposal.	4.56	11	High
BE3	Digital learning syllabus should be initiated to enable the students to access the content of syllabus at any time.	4.55	14	High
BD6	The supply chain of vaccine should be traceable from the manufacturer, delivery and until the individuals who receive the injection of vaccines.	4.52	15	High
BB5	Single digital ticketing system should be established to allow the citizens to purchase the digital tickets of various transportation mediums such as buses, trains and planes from one platform instead of visiting numerous ticketing machines or counters.	4.48	16	High
BF3	The routine for the repair and maintenance of facilities stored in a digital platform should be accessed easily by a facility manager to ensure the facilities are maintained regularly.	4.48	16	High
BB4	Data of vehicles such as cars should be stored in a transparent and systematic digital network to ensure the integrity of data thereby protecting the rights and benefits of the second-hand vehicles buyers.	4.47	18	High

Table 4.6 (Continued)

Code	Smart Application in SSC	Mean	Rank	Level of Importance
BC1	Information of the supply chain should be shared to the parties involved in a supply chain to facilitate them in forecasting market trends and deciding on the capital allocation, inventories management and manufacturing activities optimisation.	4.47	18	High
BD3	The pharmaceutical fabrications such as medicines throughout the supply chain to the final users should be registered and authenticated thus forming a transparent pharmaceutical supply chain.	4.34	20	High
BE2	Digital certificate should be issued to avoid the students from keeping tonnes of documents' hardcopies.	4.32	21	High
BD2	Insurance claims' process should be streamlined without the involvement of intermediaries in obtaining the medical data required for the claiming process.	4.25	22	High
BC3	The supply chain of food and agricultural goods should be available real time and their origins should be traceable and make available to the relevant parties.	4.20	23	High
BF2	The data of an asset should be stored in a digital platform which is more transparent and systematic to safeguard the accuracy of data throughout the life span of the asset.	4.18	24	High
BC2	Real time shipment tracking information should be stored in a digital platform where the verification and traceability of products can be conducted at any time.	4.17	25	High

Table 4.6 (Continued)

Code	Smart Application in SSC	Mean	Rank	Level of Importance
BG4	Carbon footprints of a product should be tracked and the information should be available to consumers so that they have a better understanding and awareness on the effects of each product making on the environment.	4.12	26	High
BF4	Payments should be made automatically and instantly upon completion of construction and procurement to eliminate issues caused by late payments.	4.06	27	High
BB6	Trading of electricity should be conducted instantly between the drivers of electric vehicles whenever required to prevent exhaustion of electricity as there are fewer charging stations available.	4.05	28	High
BG1	Surplus renewable energy should be converted by prosumers into digital tokens and sell to consumers in an electricity trading market without any intermediaries.	3.80	29	High
BF1	Trading of land and property should be simplified as the involvement of traditional written agreement and multi-layer authorised intermediaries are eliminated.	3.71	30	High

4.5 Mann-Whitney U Test

Mann-Whitney U test was adopted to identify the significant difference in accepting the blockchain technology between the gender groups. A p-value of 0.05 was used in this test.

Two hypotheses are generated for this test as below:
Null hypothesis (H_0): If $p > 0.05$, there is no significant difference in accepting the blockchain technology between the genders. The null hypothesis (H_0) is failed to reject.
Alternative hypothesis (H_1): If $p \leq 0.05$, there is a significant difference in accepting the blockchain technology between the genders. The alternative hypothesis (H_1) is accepted.

Table 4.7 represents the results of the Mann-Whitney U test based on different gender groups in accepting the blockchain technology. The test has revealed that the acceptance level towards all the sub-smart applications of blockchain technology has an asymptotic significance greater than 0.05, which ranges from 0.057 to 0.966. This implies that the null hypothesis (H_0) is failed to reject. This study fails to reject no significant difference observed between genders in accepting the blockchain technology. The finding in this research refutes Venkatesh and Morris (2000) who asserted that the viewpoint towards technology varies according to gender.

Table 4.7: Mann-Whitney U Test on Gender

Code	Smart Application in SSC	Mann-Whitney U	Wilcoxon W	Z	Asymp. Sig. (2-tailed)
AA1	The management and control of data by centralised agencies or organisations such as banks and lawyers are eliminated.	2461.000	5089.000	-1.806	0.071
AA2	Traditional paper-based voting system is replaced with e-voting system which is more transparent and secured.	2849.000	5477.000	-.268	0.789
AA3	The provision of identity cards, birth certificates and passports are replaced by the storage of personal data and identities in digital platform where the accessibilities of data are controlled by the citizens themselves.	2724.500	6045.500	-.777	0.437
AB1	Data about the road conditions and traffic congestions shall be available real-time and anytime.	2906.500	5534.500	-.043	0.966
AB2	The personal data of drivers and passengers is stored in a digital platform which is accessible upon authorisation to facilitate the verification of identities during ride sharing such as Grab car.	2805.000	6126.000	-.460	0.646
AB3	Ride sharing services can be carried out between the drivers and passengers without involving intermediaries such as Uber and Grab.	2455.500	5083.500	-1.777	0.076

Table 4.7 (Continued)

Code	Smart Application in SSC	Mann-Whitney U	Wilcoxon W	Z	Asymp. Sig. (2-tailed)
AB4	Hardcopies of vehicles’ documents are replaced by the storage of vehicles’ data in a digital platform where data is immutable to prevent modification of data and maximise reliability of data.	2904.000	5532.000	-.050	0.960
AB5	Ticketing machines or counters for numerous transportation mediums are replaced by a single digital platform that sells digital tickets for all transportation mediums such as buses, trains and planes	2508.000	5136.000	-1.756	0.079
AB6	Electricity can be traded between the drivers of electric vehicles whenever required without involving any intermediaries or relying on charging stations such as ChargeEV.	2601.000	5229.000	-1.235	0.217
AC1	The records of products from manufacturing, processing, transporting, storage and delivery are stored in a digital platform and the accessibility are granted to the authorised parties to allow tracing of products without involving any intermediaries	2782.500	5410.500	-.576	0.565
AC2	The shipment tracking information is synchronised reliably in a digital platform in real time which facilitates traceability.	2899.500	6220.500	-.071	0.943

Table 4.7 (Continued)

Code	Smart Application in SSC	Mann-Whitney U	Wilcoxon W	Z	Asymp. Sig. (2-tailed)
AC3	The origins of food supply chain are traceable real-time without intermediaries to ensure the quality and safety of food.	2691.000	5319.000	-.945	0.344
AD1	Medical reports' hardcopies are replaced by the storage of complete medical history in a digital platform which can be accessed by the medical practitioners upon authorisation by the patients.	2705.500	5333.500	-.895	0.371
AD2	Digital medical data can be shared between medical service providers due to the absence of centralised systems and distinct databases.	2690.000	5318.000	-.879	0.379
AD3	The process of claiming insurance should be simplified as the medical data can be obtained without going through multiple layers of intermediaries.	2705.000	5333.000	-.841	0.400
AD4	The records of pharmaceutical supply chains such as medicines are stored in a digital platform which is transparent and easily traceable without relying on the intermediaries.	2615.000	5243.000	-1.284	0.199
AD5	Official medical licenses of medical practitioners are stored in a digital platform where data is immutable to prevent the theft of medical licenses by fraudulent healthcare service providers.	2484.000	5112.000	-1.796	0.072

Table 4.7 (Continued)

Code	Smart Application in SSC	Mann-Whitney U	Wilcoxon W	Z	Asymp. Sig. (2-tailed)
AD6	The numbers of vaccination doses produced and injected to the individuals are traceable in a digital platform without involving intermediaries.	2752.500	5380.500	-.680	0.496
AD7	The origins of critical drugs, blood and organs are traceable without involving intermediaries to ensure the drugs, blood and organs are obtained legally.	2782.000	5410.000	-.548	0.584
AE1	Educational records of students and the credentials of education practitioners are stored in a digital platform which is more systematic without the involvement of centralised authority such as schools, colleges or universities.	2643.500	5271.500	-1.056	0.291
AE2	Paper-based certificates are replaced with digital certificates which are immutable and manageable by the students themselves.	2785.500	5413.500	-.530	0.596
AE3	Physical lecture notes are replaced by digital learning syllabus which consists of content similar with the materials provided in physical classes.	2490.000	5118.000	-1.711	0.087
AF1	Transactions of land, property and housing can be carried out between buyers and sellers without relying on intermediaries such as lawyers to prepare	2422.000	5050.000	-1.906	0.057

Table 4.7 (Continued)

Code	Smart Application in SSC	Mann-Whitney U	Wilcoxon W	Z	Asymp. Sig. (2-tailed)
	paper documents for verification and agreements as the data of properties, buyers and sellers stored in digital platform can be exchanged and verified.				
AF2	The construction drawings, specifications, approvals, reports and records involved in the property development process are stored in digital platform which is more secured as the data are immutable.	2640.000	5268.000	-1.129	0.259
AF3	Automatic payments are initiated after the construction works are completed or construction materials are procured by the main contractors.	2630.500	5258.500	-1.156	0.248
AG1	Data related to energy activities such as meter readings and the conduct of digital transactions for energy payment is stored in a digital platform where the data is unalterable by third parties.	2861.000	6182.000	-.225	0.822
AG2	The surplus renewable energy is sold by the prosumers to other consumers where the payment and transactions of energy trading are conducted automatically without involving any intermediaries.	2638.000	5266.000	-1.127	0.260

Table 4.7 (Continued)

Code	Smart Application in SSC	Mann-Whitney U	Wilcoxon W	Z	Asymp. Sig. (2-tailed)
AG3	The operations of waste management which include the collection, disposal, recycling and recovery of wastes are enhanced as the relevant authorities are instantly notified when the wastes are piled up to a certain level without involving any intermediaries.	2661.000	5289.000	-1.058	0.290
AG4	Carbon footprints of house appliances, goods, vehicles, tools and equipment are tracked without involving intermediaries and recorded in digital platform to determine carbon tax charges, where applicable.	2846.500	5474.500	-.266	0.790
AG5	Data about the changes in the environmental quality shall be available real time and anytime to citizens.	2692.000	6013.000	-.946	0.344

4.6 Kruskal-Wallis Test

The Kruskal-Wallis was conducted to assess the significant differences in accepting the blockchain on different age groups and educational levels of the respondents. The significance differences can be determined by examining the p-value of 0.05 and the degree of freedom that is obtained by deducting 1 from the number of groups used for analysis. In this study, there are three different age groups and three different educational levels under investigation, thus, the critical chi-square value is 5.991, which is identified by the degree of freedom of 2.

4.6.1 Kruskal-Wallis Test on Age Group

The two hypotheses formulated are as follows:

Null hypothesis (H_0): If the H-value is less than 5.991, there is no significant difference in accepting the blockchain technology between the different age groups.

Alternative hypothesis (H_1): If the H-value is more than 5.991, there is a significant difference in accepting the blockchain technology between the different age groups.

Table 4.8 summarises the results of Kruskal-Wallis Test. There are a total of 27 sub-smart applications with asymptotic significance less than 0.05 coupled with chi-square value larger than 5.991. Hence, the null hypothesis (H_0) is rejected for these 27 sub-smart applications. The sub-smart applications which failed to reject no difference are **AD4** = "The records of pharmaceutical supply chains such as medicines are stored in a digital platform which is transparent and easily traceable without relying on the intermediaries", **AF2** = "The construction drawings, specifications, approvals, reports and records involved in the property development process are stored in digital platform which is more secured as the data are immutable" and **AF3** = "Automatic payments are initiated after the construction works are completed or construction materials are procured by the main contractors".

Table 4.8: Kruskal-Wallis Test on Age Group

Code	Smart Application in SSC	Chi-square	Asymptotic Significance
AA1	The management and control of data by centralised agencies or organisations such as banks and lawyers are eliminated.	20.144	**.000***
AA2	Traditional paper-based voting system is replaced with e-voting system which is more transparent and secured.	32.180	**.000***
AA3	The provision of identity cards, birth certificates and passports are replaced by the storage of personal data and identities in digital platform where the accessibilities of data are controlled by the citizens themselves.	25.425	**.000***
AB1	Data about the road conditions and traffic congestions shall be available real-time and anytime.	23.645	**.000***
AB2	The personal data of drivers and passengers is stored in a digital platform which is accessible upon authorisation to facilitate the verification of identities during ride sharing such as Grab car.	16.831	**.000***
AB3	Ride sharing services can be carried out between the drivers and passengers without involving intermediaries such as Uber and Grab.	12.332	**.002***
AB4	Hardcopies of vehicles' documents are replaced by the storage of vehicles' data in a digital platform where data is immutable to prevent modification of data and maximise reliability of data.	7.196	**.027***

Table 4.8 (Continued)

Code	Smart Application in SSC	Chi-square	Asymptotic Significance
AB5	Ticketing machines or counters for numerous transportation mediums are replaced by a single digital platform that sells digital tickets for all transportation mediums such as buses, trains and planes	17.842	**.000***
AB6	Electricity can be traded between the drivers of electric vehicles whenever required without involving any intermediaries or relying on charging stations such as ChargeEV.	13.847	**.001***
AC1	The records of products from manufacturing, processing, transporting, storage and delivery are stored in a digital platform and the accessibility are granted to the authorised parties to allow tracing of products without involving any intermediaries	9.408	**.009***
AC2	The shipment tracking information is synchronised reliably in a digital platform in real time which facilitates traceability.	16.707	**.000***
AC3	The origins of food supply chain are traceable real-time without intermediaries to ensure the quality and safety of food.	10.598	**.005***
AD1	Medical reports’ hardcopies are replaced by the storage of complete medical history in a digital platform which can be accessed by the medical practitioners upon authorisation by the patients.	24.135	**.000***
AD2	Digital medical data can be shared between medical service providers due to the absence of centralised systems and distinct databases.	22.486	**.000***

Table 4.8 (Continued)

Code	**Smart Application in SSC**	**Chi-square**	**Asymptotic Significance**
AD3	The process of claiming insurance should be simplified as the medical data can be obtained without going through multiple layers of intermediaries.	16.458	**.000***
AD4	The records of pharmaceutical supply chains such as medicines are stored in a digital platform which is transparent and easily traceable without relying on the intermediaries.	2.988	.225
AD5	Official medical licenses of medical practitioners are stored in a digital platform where data is immutable to prevent the theft of medical licenses by fraudulent healthcare service providers.	8.280	**.016***
AD6	The numbers of vaccination doses produced and injected to the individuals are traceable in a digital platform without involving intermediaries.	7.999	**.018***
AD7	The origins of critical drugs, blood and organs are traceable without involving intermediaries to ensure the drugs, blood and organs are obtained legally.	12.485	**.002***
AE1	Educational records of students and the credentials of education practitioners are stored in a digital platform which is more systematic without the involvement of centralised authority such as schools, colleges or universities.	19.324	**.000***
AE2	Paper-based certificates are replaced with digital certificates which are immutable and manageable by the students themselves.	22.127	**.000***

Table 4.8 (Continued)

Code	Smart Application in SSC	Chi-square	Asymptotic Significance
AE3	Physical lecture notes are replaced by digital learning syllabus which consists of content similar with the materials provided in physical classes.	15.103	**.001***
AF1	Transactions of land, property and housing can be carried out between buyers and sellers without relying on intermediaries such as lawyers to prepare paper documents for verification and agreements as the data of properties, buyers and sellers stored in digital platform can be exchanged and verified.	9.628	**.008***
AF2	The construction drawings, specifications, approvals, reports and records involved in the property development process are stored in digital platform which is more secured as the data are immutable.	2.894	.235
AF3	Automatic payments are initiated after the construction works are completed or construction materials are procured by the main contractors.	.087	.957
AG1	Data related to energy activities such as meter readings and the conduct of digital transactions for energy payment is stored in a digital platform where the data is unalterable by third parties.	7.406	**.025***
AG2	The surplus renewable energy is sold by the prosumers to other consumers where the payment and transactions of energy trading are conducted automatically without involving any intermediaries.	11.912	**.003***

Table 4.8 (Continued)

Code	**Smart Application in SSC**	**Chi-square**	**Asymptotic Significance**
AG3	The operations of waste management which include the collection, disposal, recycling and recovery of wastes are enhanced as the relevant authorities are instantly notified when the wastes are piled up to a certain level without involving any intermediaries.	10.518	**.005***
AG4	Carbon footprints of house appliances, goods, vehicles, tools and equipment are tracked without involving intermediaries and recorded in digital platform to determine carbon tax charges, where applicable.	17.595	**.000***
AG5	Data about the changes in the environmental quality shall be available real time and anytime to citizens.	10.186	**.006***

Note: **Bold*** indicates the asymptotic significance less than 0.05

The mean rank of the 27 sub-smart applications are obtained through the conduct of Kruskal-Wallis Test and tabulated in Table 4.9. In order to meet the requirement of CLT which is to achieve a minimum sample size of 30 for each age group, the age groups of respondents are further classified into 3 groups, which are "**21 years old and below**" (generation Z), "**22-44 years old**" (generation Y) and "**45 years old and above**" (generation X and baby boomers).

According to Table 4.9, the respondents from generation X and baby boomers (45 years old and above) in Malaysia have the lowest level of acceptance towards these 27 sub-smart applications of blockchain technology. The key contributors typically include, but not limited to low level of technology literacy, unfamiliarity about the latest technologies, deep-rooted fear and apprehension in dealing with a completely new technology, lack of adaptability, need of substantial time in learning, and forgetfulness (Tsertsidis, Kolkowska and Hedström, 2019).

Besides, the results reveal that out of 27 sub-smart applications, the mean ranking of the group of "21 years old and below" is higher than the group of "22 - 44 years old" for 22 of them. It can be inferred that being the first generation that truly grows up with technology, generation Z (21 years old and below) tends to be more comfortable and open in accepting new technologies (Linnes and Metcalf, 2017).

In particular, there is a significant difference between "21 years old and below" and "45 years old and above" for **AA3** = "The provision of identity cards, birth certificates and passports are replaced by the storage of personal data and identities in digital platform where the accessibilities of data are controlled by the citizens themselves", **AB2** = "The personal data of drivers and passengers is stored in a digital platform which is accessible upon authorisation to facilitate the verification of identities during ride sharing such as Grab car", **AD1** = "Medical reports' hardcopies are replaced by the storage of complete medical history in a digital platform which can be accessed by the medical practitioners upon authorisation by the patients" and **AE2** = "Paper-based certificates are replaced with digital certificates which are immutable and manageable by the students themselves". This higher mean rank of the group of "21 years old and below" signifies that generation Z inclines to go digital in storing their personal data in numerous domains whereby the control and administration of data are in their hands (Linnes and Metcalf, 2017). Contrastingly, the storage of personal information in a digital platform is unfavourable to the group of generation X and baby boomers. Anxiety arises when they are required to manage their own data using technologies which are completely new to them (Tsertsidis, Kolkowska and Hedström, 2019). It can be deduced that lower level of technology literacy has reduced their confidence in keeping and managing their data digitally.

In terms of “Smart Education (**AE**)”, there are significant different perspectives between “21 years old and below” and “45 years old and above” on the sub-smart application **AE3** = “Physical lecture notes are replaced by digital learning syllabus which consists of content similar with the materials provided in physical classes”. It can be inferred that generation Z who is tech-savvy is more receptive in accepting digital learning syllabus that contains the contents similar to the materials provided in physical classes because it offers portability and strengthens continuous learning especially in the present world where the students are required to stay at home to reduce the risk of being infected by coronaviruses (Bandara, Loras and Arraiza, 2018; Linnes and Metcalf, 2017). Nevertheless, the respondents of generation X and baby boomers who are the users of traditional physical lecture notes regard the use of digital learning syllabus as less beneficial and acceptable because it is challenging to read the materials online over a longer period of time (Linnes and Metcalf, 2017). Moreover, these respondents mostly emphasise on their health at this stage of life. In light of this, they have higher preference for physical lecture notes whereby the adverse effects engendered by long periods of digital learning via mobile devices such as eye strain can be effectively avoided.

On the other hand, the mean ranking of the group of “22 – 44 years old” is higher than the group of “21 years old and below” for **AB3** = “Ride sharing services can be carried out between the drivers and passengers without involving intermediaries such as Uber and Grab”, **AD2** = “Digital medical data can be shared between medical service providers due to the absence of centralised systems and distinct databases”, **AE1** = “Educational records of students and the credentials of education practitioners are stored in a digital platform which is more systematic without the involvement of centralised authority such as schools, colleges or universities”, **AF1** = “Transactions of land, property and housing can be carried out between buyers and sellers without relying on intermediaries such as lawyers to prepare paper documents for verification and agreements as the data of properties, buyers and sellers stored in digital platform can be exchanged and verified" and **AG4** = "Carbon footprints of house appliances, goods, vehicles, tools and equipment are tracked without involving intermediaries and recorded in digital platform to determine carbon tax charges, where applicable". The higher mean rank of generation Y (22 – 44 years old) shows a higher acceptance towards these sub-smart applications. **AB3**, **AE1** and **AF1** is highly accepted as the elimination of intermediaries and centralised authority streamlines and expedites the process of engaging ride sharing services, managing educational records and conducting property transaction (Dewan and Singh, 2020; Wong, et al. 2020; Nagel, et al., 2019; PWC, 2018). This is favourable to the respondents from generation Y who are typically buried with work, busy running errands and taking care of children. Besides, **AD2** is highly accepted by generation Y because they are more focused on their health due to the busy lifestyle and opting for the delivery of accurate and effective health assistance (Treiblmaier, Rejeb and Strebinger, 2020). Apart from that, for **AG4**, the higher acceptance level of the group of "22 – 44 years old" implies that the respondents of generation Y pay closer attention to the carbon emission of products than the respondents of generation Z as they are more aware of the detrimental effects of carbon emission that would jeopardise the quality of environment as well as the human's health. Generation Y aims to safeguard the future of their progenies by reducing the carbon emissions through the adoption of this sub-smart application (Shen and Pena-Mora, 2018).

Table 4.9: Mean Rank of Acceptance Towards the Application of Blockchain Technology for SSC Development in Malaysia on Age Group

Code	Smart Application	Age Group	N	Mean Rank
AA1	The management and control of data by centralised agencies or organisations such as banks and lawyers are eliminated.	**21 years old and below**	**31**	**90.42**
		22 - 44 years old	87	82.95
		45 years old and above	*35*	*50.33*
AA2	Traditional paper-based voting system is replaced with e-voting system which is more transparent and secured.	**21 years old and below**	**31**	**96.77**
		22 - 44 years old	87	83.10
		45 years old and above	*35*	*44.31*
AA3	The provision of identity cards, birth certificates and passports are replaced by the storage of personal data and identities in digital platform where the accessibilities of data are controlled by the citizens themselves.	**21 years old and below**	**31**	**86.00**
		22 - 44 years old	87	85.81
		45 years old and above	*35*	*47.13*
AB1	Data about the road conditions and traffic congestions shall be available real-time and anytime.	**21 years old and below**	**31**	**91.39**
		22 - 44 years old	87	81.91
		45 years old and above	*35*	*52.04*

Table 4.9 (Continued)

Code	Smart Application	Age Group	N	Mean Rank
AB2	The personal data of drivers and passengers is stored in a digital platform which is accessible upon authorisation to facilitate the verification of identities during ride sharing such as Grab car.	**21 years old and below**	**31**	**98.56**
		22 - 44 years old	87	76.55
		45 years old and above	*35*	*59.01*
AB3	Ride sharing services can be carried out between the drivers and passengers without involving intermediaries such as Uber and Grab.	21 years old and below	31	83.40
		22 - 44 years old	**87**	**83.52**
		45 years old and above	*35*	*55.11*
AB4	Hardcopies of vehicles' documents are replaced by the storage of vehicles' data in a digital platform where data is immutable to prevent modification of data and maximise reliability of data.	**21 years old and below**	**31**	**89.11**
		22 - 44 years old	87	78.00
		45 years old and above	*35*	*63.79*
AB5	Ticketing machines or counters for numerous transportation mediums are replaced by a single digital platform that sells digital tickets for all transportation mediums such as buses, trains and planes	**21 years old and below**	**31**	**98.89**
		22 - 44 years old	87	76.12
		45 years old and above	*35*	*59.80*

Table 4.9 (Continued)

Code	**Smart Application**	**Age Group**	**N**	**Mean Rank**
AB6	Electricity can be traded between the drivers of electric vehicles whenever required without involving any intermediaries or relying on charging stations such as ChargeEV.	**21 years old and below**	**31**	**86.56**
		22 - 44 years old	87	82.71
		45 years old and above	*35*	*54.34*
AC1	The records of products from manufacturing, processing, transporting, storage and delivery are stored in a digital platform and the accessibility are granted to the authorised parties to allow tracing of products without involving any intermediaries	**21 years old and below**	**31**	**86.68**
		22 - 44 years old	87	80.17
		45 years old and above	35	*60.54*
AC2	The shipment tracking information is synchronised reliably in a digital platform in real time which facilitates traceability.	**21 years old and below**	**31**	**85.61**
		22 - 44 years old	87	83.10
		45 years old and above	*35*	*54.20*
AC3	The origins of food supply chain are traceable real-time without intermediaries to ensure the quality and safety of food.	**21 years old and below**	**31**	**86.52**
		22 - 44 years old	87	80.93
		45 years old and above	*35*	*58.80*

Table 4.9 (Continued)

Code	**Smart Application**	**Age Group**	**N**	**Mean Rank**
AD1	Medical reports' hardcopies are replaced by the storage of complete medical history in a digital platform which can be accessed by the medical practitioners upon authorisation by the patients.	**21 years old and below**	**31**	**98.89**
		22 - 44 years old	87	78.79
		45 years old and above	*35*	*53.16*
AD2	Digital medical data can be shared between medical service providers due to the absence of centralised systems and distinct databases.	21 years old and below	31	79.11
		22 - 44 years old	**87**	**87.78**
		45 years old and above	*35*	*48.34*
AD3	The process of claiming insurance should be simplified as the medical data can be obtained without going through multiple layers of intermediaries.	**21 years old and below**	**31**	**86.29**
		22 - 44 years old	87	83.50
		45 years old and above	*35*	*52.61*
AD5	Official medical licenses of medical practitioners are stored in a digital platform where data is immutable to prevent the theft of medical licenses by fraudulent healthcare service providers.	**21 years old and below**	**31**	**93.24**
		22 - 44 years old	87	75.63
		45 years old and above	35	*66.01*
AD6	The numbers of vaccination doses produced and injected to the individuals are traceable in a digital platform without involving intermediaries.	**21 years old and below**	**31**	**89.29**
		22 - 44 years old	87	78.41
		45 years old and above	*35*	*62.60*

Table 4.9 (Continued)

Code	Smart Application	Age Group	N	Mean Rank
AD7	The origins of critical drugs, blood and organs are traceable without involving intermediaries to ensure the drugs, blood and organs are obtained legally.	**21 years old and below**	**31**	**98.68**
		22 - 44 years old	87	73.59
		45 years old and above	*35*	*66.29*
AE1	Educational records of students and the credentials of education practitioners are stored in a digital platform which is more systematic without the involvement of centralised authority such as schools, colleges or universities.	21 years old and below	31	82.29
		22 - 44 years old	**87**	**86.03**
		45 years old and above	*35*	*49.86*
AE2	Paper-based certificates are replaced with digital certificates which are immutable and manageable by the students themselves.	**21 years old and below**	**31**	**103.69**
		22 - 44 years old	87	75.20
		45 years old and above	*35*	*57.84*
AE3	Physical lecture notes are replaced by digital learning syllabus which consists of content similar with the materials provided in physical classes.	**21 years old and below**	**31**	**100.02**
		22 - 44 years old	87	74.77
		45 years old and above	*35*	*62.16*

Table 4.9 (Continued)

Code	Smart Application	Age Group	N	Mean Rank
AF1	Transactions of land, property and housing can be carried out between buyers and sellers without relying on intermediaries such as lawyers to prepare paper documents for verification and agreements as the data of properties, buyers and sellers stored in digital platform can be exchanged and verified.	21 years old and below	31	79.74
		22 - 44 years old	**87**	**83.72**
		45 years old and above	*35*	*57.87*
AG1	Data related to energy activities such as meter readings and the conduct of digital transactions for energy payment is stored in a digital platform where the data is unalterable by third parties.	**21 years old and below**	**31**	**94.10**
		22 - 44 years old	87	73.59
		45 years old and above	*35*	*70.34*
AG2	The surplus renewable energy is sold by the prosumers to other consumers where the payment and transactions of energy trading are conducted automatically without involving any intermediaries.	**21 years old and below**	**31**	**88.63**
		22 - 44 years old	87	80.78
		45 years old and above	*35*	*57.30*
AG3	The operations of waste management which include the collection, disposal, recycling and recovery of wastes are enhanced as the relevant authorities are instantly notified when the wastes are piled up to a certain level without involving any intermediaries.	**21 years old and below**	**31**	**96.85**
		22 - 44 years old	87	73.47
		45 years old and above	*35*	*68.20*

Table 4.9 (Continued)

Code	Smart Application	Age Group	N	Mean Rank
AG4	Carbon footprints of house appliances, goods, vehicles, tools and equipment are tracked without involving intermediaries and recorded in digital platform to determine carbon tax charges, where applicable.	21 years old and below	31	66.48
		22 - 44 years old	**87**	**89.16**
		45 years old and above	*35*	*56.10*
AG5	Data about the changes in the environmental quality shall be available real time and anytime to citizens.	**21 years old and below**	**31**	**90.77**
		22 - 44 years old	87	78.51
		45 years old and above	*35*	*61.04*

Note:

Bold indicates the highest mean rank

Italic indicates the lowest mean rank

4.6.2 Kruskal-Wallis Test on Educational Level

The two hypotheses formulated are as follows:

Null hypothesis (H_0): If the H-value is less than 5.991, there is no significant difference in accepting the blockchain technology between the different education levels.

Alternative hypothesis (H_1): If the H-value is more than 5.991, there is a significant difference in accepting the blockchain technology between the different education levels.

According to Table 4.10, there are 20 sub-smart applications of blockchain technology that are revealed to have asymptotic significance less than 0.05 accompanied with chi-square value larger than 5.991. This result shows that there is a significant difference between different educational levels in accepting these 20 sub-smart applications of blockchain technology. Thus, the null hypothesis (H_0) is rejected for these 20 sub-smart applications.

Table 4.10: Kruskal-Wallis Test on Educational Level

Code	Smart Application	Chi-square	Asymptotic Significance
AA1	The management and control of data by centralised agencies or organisations such as banks and lawyers are eliminated.	10.610	**.005***
AA2	Traditional paper-based voting system is replaced with e-voting system which is more transparent and secured.	19.975	**.000***
AA3	The provision of identity cards, birth certificates and passports are replaced by the storage of personal data and identities in digital platform where the accessibilities of data are controlled by the citizens themselves.	19.929	**.000***
AB1	Data about the road conditions and traffic congestions shall be available real-time and anytime.	11.774	**.003***
AB2	The personal data of drivers and passengers is stored in a digital platform which is accessible upon authorisation to facilitate the verification of identities during ride sharing such as Grab car.	2.225	.329
AB3	Ride sharing services can be carried out between the drivers and passengers without involving intermediaries such as Uber and Grab.	5.757	.056
AB4	Hardcopies of vehicles’ documents are replaced by the storage of vehicles’ data in a digital platform where data is immutable to prevent modification of data and maximise reliability of data.	1.345	.510

Table 4.10 (Continued)

Code	Smart Application	Chi-square	Asymptotic Significance
AB5	Ticketing machines or counters for numerous transportation mediums are replaced by a single digital platform that sells digital tickets for all transportation mediums such as buses, trains and planes.	4.283	.118
AB6	Electricity can be traded between the drivers of electric vehicles whenever required without involving any intermediaries or relying on charging stations such as ChargeEV.	14.648	**.001***
AC1	The records of products from manufacturing, processing, transporting, storage and delivery are stored in a digital platform and the accessibility are granted to the authorised parties to allow tracing of products without involving any intermediaries	13.947	**.001***
AC2	The shipment tracking information is synchronised reliably in a digital platform in real time which facilitates traceability.	16.004	**.000***
AC3	The origins of food supply chain are traceable real-time without intermediaries to ensure the quality and safety of food.	8.450	**.015***
AD1	Medical reports' hardcopies are replaced by the storage of complete medical history in a digital platform which can be accessed by the medical practitioners upon authorisation by the patients.	15.919	**.000***
AD2	Digital medical data can be shared between medical service providers due to the absence of centralised systems and distinct databases.	17.596	**.000***

Table 4.10 (Continued)

Code	Smart Application	Chi-square	Asymptotic Significance
AD3	The process of claiming insurance should be simplified as the medical data can be obtained without going through multiple layers of intermediaries.	15.162	**.001***
AD4	The records of pharmaceutical supply chains such as medicines are stored in a digital platform which is transparent and easily traceable without relying on the intermediaries.	6.816	**.033***
AD5	Official medical licenses of medical practitioners are stored in a digital platform where data is immutable to prevent the theft of medical licenses by fraudulent healthcare service providers.	11.212	**.004***
AD6	The numbers of vaccination doses produced and injected to the individuals are traceable in a digital platform without involving intermediaries.	5.807	.055
AD7	The origins of critical drugs, blood and organs are traceable without involving intermediaries to ensure the drugs, blood and organs are obtained legally.	6.358	**.042***
AE1	Educational records of students and the credentials of education practitioners are stored in a digital platform which is more systematic without the involvement of centralised authority such as schools, colleges or universities.	10.679	**.005***
AE2	Paper-based certificates are replaced with digital certificates which are immutable and manageable by the students themselves.	7.941	**.019***

Table 4.10 (Continued)

Code	Smart Application	Chi-square	Asymptotic Significance
AE3	Physical lecture notes are replaced by digital learning syllabus which consists of content similar with the materials provided in physical classes.	1.806	.405
AF1	Transactions of land, property and housing can be carried out between buyers and sellers without relying on intermediaries such as lawyers to prepare paper documents for verification and agreements as the data of properties, buyers and sellers stored in digital platform can be exchanged and verified.	6.686	**.035***
AF2	The construction drawings, specifications, approvals, reports and records involved in the property development process are stored in digital platform which is more secured as the data are immutable.	1.948	.378
AF3	Automatic payments are initiated after the construction works are completed or construction materials are procured by the main contractors.	.198	.906
AG1	Data related to energy activities such as meter readings and the conduct of digital transactions for energy payment is stored in a digital platform where the data is unalterable by third parties.	1.833	.400
AG2	The surplus renewable energy is sold by the prosumers to other consumers where the payment and transactions of energy trading are conducted automatically without involving any intermediaries.	10.045	**.007***

Table 4.10 (Continued)

Code	**Smart Application**	**Chi-square**	**Asymptotic Significance**
AG3	The operations of waste management which include the collection, disposal, recycling and recovery of wastes are enhanced as the relevant authorities are instantly notified when the wastes are piled up to a certain level without involving any intermediaries.	5.975	0.50
AG4	Carbon footprints of house appliances, goods, vehicles, tools and equipment are tracked without involving intermediaries and recorded in digital platform to determine carbon tax charges, where applicable.	13.775	**.001***
AG5	Data about the changes in the environmental quality shall be available real time and anytime to citizens.	13.719	**.001***

Note: **Bold*** indicates the asymptotic significance less than 0.05

The mean rank of 20 sub-smart applications are displayed in Table 4.11. To fulfil the criteria of the CLT where the sample size of each group of educational levels is equal or greater than 30, the respondents with educational level of “High School”, “Sijil Pelajaran Malaysia (SPM)”, “Sijil Tinggi Persekolahan Malaysia (STPM)” and “Diploma” are grouped as the “**Low**” educational level; the respondents with educational level of “Bachelor’s Degree is classified as the “**Medium**” educational level; the respondents with educational level of “Master’s Degree” and “Doctoral Degree” are categorised as the “**High**” educational level. Therefore, the difference in viewpoints between the respondents of “Low”, “Medium” and “High” educational level is investigated.

Overall, the respondents with “Low” educational level show the lowest acceptance level towards these 20 sub-smart applications of blockchain technology. The underlying reason is the lack of technological self-efficacy and lack of awareness on the advantages of blockchain technology due to the inadequate knowledge on the integration of blockchain technology coupled with the absence of a good exposure on the ways to carry out the blockchain-related activities. In view of this, it is not surprising that the negative attitudes such as unwillingness to take risks, lack of confidence, inertia to change, fear of deviating from the usual norms are derived, thereby diminishing the desire to accept and adopt blockchain technology (Noh, Mustafa and Ahmad, 2014). This finding is consistent with the previous studies of Lleras-Muney and Lichtenberg (2002), Krueger (1993), Wozniak (1987), Wozniak (1984) and Welch (1970) which proclaims that there is a positive correlation between the educational level and the acceptance level towards technology adoption.

Besides, as depicted in Table 4.11, it is noticed that out of 20 sub-smart applications, the mean ranking of the “Medium” educational level is higher than the mean ranking of the “High” educational level for 13 of them. Notwithstanding the openness towards the application of blockchain technology, in the context of Malaysia, the respondents with “High” educational level have presented a certain extent of reservation towards the sub-smart applications of blockchain technology and are relatively more prudent in accepting the new technology. This is because with the possession of more knowledge regarding blockchain technology, these respondents are aware of the risks associated with the technology (Abu-Shanab, 2011). On the other hand, an inference can be derived from the findings that the respondents with "Medium" educational level generally focus on the benefits that can be availed through the integration of blockchain technology instead of the possible risks, thereby showing higher propensity in accepting the applications of blockchain technology.

Nonetheless, in terms of "Smart Transportation (**AB**)", the respondents with "High" educational level express high level of acceptance towards **AB1** = "Data about the road conditions and traffic congestions shall be available real-time and anytime" and **AB6** = "Electricity can be traded between the drivers of electric vehicles whenever required without involving any intermediaries or relying on charging stations such as ChargeEV". This signifies that these individuals acknowledge the importance of blockchain technology in providing real-time data that proposes alternative routes and transportation mediums in the event of standstill traffic or accidents, as well as the flexibility to trade electricity whenever required (Wong, et al., 2020; Bhushan, et al., 2020).

Apart from that, high attention is paid by the respondents with "High" educational level on **AD1** = "Medical reports' hardcopies are replaced by the storage of complete medical history in a digital platform which can be accessed by the medical practitioners upon authorisation by the patients", **AD5** = "Official medical licenses of medical practitioners are stored in a digital platform where data is immutable to prevent the theft of medical licenses by fraudulent healthcare service providers" and **AD7** = "The origins of critical drugs, blood and organs are traceable without involving intermediaries to ensure the drugs, blood and organs are obtained legally" which are under the category of "Smart Healthcare (**AD**)". It is perceived that there is an increasing attention on health among the respondents with "High" educational level whereby this group of respondents are inclined to yield health benefits through the storage of the comprehensive medical records that empowers the provision of more effective and accurate diagnosis (Sanka, et al., 2021; Treiblmaier, Rejeb and Strebinger, 2020; Karale and Ranaware, 2019). Besides, **AD5** and **AD7** is highly accepted by this group of respondents because the transparency of the provenances of critical drugs, bloods, organs and official medical licenses is able to remove fraudulent medical activities and medical practitioners thus building up the confidence towards the healthcare assistance provided (PWC, 2018).

Moreover, the respondents with "High" educational level exhibit highest level of acceptance towards the sub-smart applications of **AE2** = "Paper-based certificates are replaced with digital certificates which are immutable and manageable by the students themselves" under the category of "Smart Education (**AE**)" and **AG5** = "Data about the changes in the environmental quality shall be available real time and anytime to citizens" under the "Smart Utility (**AG**)" category. **AE2** is highly acceptable because the use of unalterable digital certificates can effectively prevent the highly educated citizens from keeping a substantial amount of paper-based certificates which are vulnerable to loss. On the other hand, the high acceptance level towards **AG5** expresses the major concern of the respondents with "High" educational level on the availability of data pertaining the surrounding environment and indicates their readiness to take preventive measures against the environmental issues (ITU-T, 2020; Wong, et al., 2020).

Table 4.11: Mean Rank of Acceptance Towards the Application of Blockchain Technology for SSC Development in Malaysia on Educational Level

Code	**Smart Application**	**Educational Level**	**N**	**Mean Rank**
AA1	The management and control of data by centralised agencies or organisations such as banks and lawyers are eliminated.	*Low*	*33*	*56.92*
		Medium	**86**	**84.06**
		High	34	78.63
AA2	Traditional paper-based voting system is replaced with e-voting system which is more transparent and secured.	*Low*	*33*	*49.11*
		Medium	**86**	**84.84**
		High	34	84.24
AA3	The provision of identity cards, birth certificates and passports are replaced by the storage of personal data and identities in digital platform where the accessibilities of data are controlled by the citizens themselves.	*Low*	*33*	*49.70*
		Medium	86	**85.62**
		High	34	81.69
AB1	Data about the road conditions and traffic congestions shall be available real-time and anytime.	*Low*	*33*	*58.11*
		Medium	86	81.69
		High	**34**	**83.47**

Table 4.11 (Continued)

Code	**Smart Application**	**Educational Level**	**N**	**Mean Rank**
AB6	Electricity can be traded between the drivers of electric vehicles whenever required without involving any intermediaries or relying on charging stations such as ChargeEV.	*Low*	*33*	*52.77*
		Medium	86	82.66
		High	**34**	**86.21**
AC1	The records of products from manufacturing, processing, transporting, storage and delivery are stored in a digital platform and the accessibility are granted to the authorised parties to allow tracing of products without involving any intermediaries	*Low*	*33*	*58.47*
		Medium	**86**	**86.24**
		High	34	71.62
AC2	The shipment tracking information is synchronised reliably in a digital platform in real time which facilitates traceability.	*Low*	*33*	*59.15*
		Medium	**86**	**87.45**
		High	34	67.88
AC3	The origins of food supply chain are traceable real-time without intermediaries to ensure the quality and safety of food.	*Low*	*33*	*62.00*
		Medium	**86**	**84.31**
		High	34	73.06
AD1	Medical reports' hardcopies are replaced by the storage of complete medical history in a digital platform which can be accessed by the medical practitioners upon authorisation by the patients.	*Low*	*33*	*54.32*
		Medium	86	81.05
		High	**34**	**88.78**

Table 4.11 (Continued)

Code	**Smart Application**	**Educational Level**	**N**	**Mean Rank**
AD2	Digital medical data can be shared between medical service providers due to the absence of centralised systems and distinct databases.	*Low*	*33*	*50.77*
		Medium	**86**	**86.48**
		High	34	78.47
AD3	The process of claiming insurance should be simplified as the medical data can be obtained without going through multiple layers of intermediaries.	*Low*	*33*	*53.08*
		Medium	**86**	**85.34**
		High	34	79.12
AD4	The records of pharmaceutical supply chains such as medicines are stored in a digital platform which is transparent and easily traceable without relying on the intermediaries.	*Low*	*33*	*62.85*
		Medium	**86**	**83.03**
		High	34	75.47
AD5	Official medical licenses of medical practitioners are stored in a digital platform where data is immutable to prevent the theft of medical licenses by fraudulent healthcare service providers.	*Low*	*33*	*56.89*
		Medium	86	82.40
		High	**34**	**82.85**
AD7	The origins of critical drugs, blood and organs are traceable without involving intermediaries to ensure the drugs, blood and organs are obtained legally.	*Low*	*33*	*62.03*
		Medium	86	79.77
		High	**34**	**84.53**

Table 4.11 (Continued)

Code	Smart Application	Educational Level	N	Mean Rank
AE1	Educational records of students and the credentials of education practitioners are stored in a digital platform which is more systematic without the involvement of centralised authority such as schools, colleges or universities.	*Low*	*33*	*56.88*
		Medium	**86**	**84.84**
		High	34	76.69
AE2	Paper-based certificates are replaced with digital certificates which are immutable and manageable by the students themselves.	*Low*	*33*	*64.83*
		Medium	86	75.75
		High	**34**	**91.97**
AF1	Transactions of land, property and housing can be carried out between buyers and sellers without relying on intermediaries such as lawyers to prepare paper documents for verification and agreements as the data of properties, buyers and sellers stored in digital platform can be exchanged and verified.	*Low*	*33*	*60.50*
		Medium	**86**	**82.58**
		High	34	78.91
AG2	The surplus renewable energy is sold by the prosumers to other consumers where the payment and transactions of energy trading are conducted automatically without involving any intermediaries.	*Low*	*33*	*57.76*
		Medium	**86**	**83.52**
		High	34	79.18
AG4	Carbon footprints of house appliances, goods, vehicles, tools and equipment are tracked without involving intermediaries and recorded in digital platform to determine carbon tax charges, where applicable.	*Low*	*33*	*53.18*
		Medium	**86**	**85.22**
		High	34	79.32

Table 4.11 (Continued)

Code	**Smart Application**	**Educational Level**	**N**	**Mean Rank**
AG5	Data about the changes in the environmental quality shall be available real time and anytime to citizens.	*Low*	*33*	*55.82*
		Medium	86	80.74
		High	**34**	**88.09**

Note:

Bold indicates the highest mean rank

Italic indicates the lowest mean rank

4.7 Summary of Chapter

This chapter has discussed comprehensively the level of acceptance and importance of the applications of blockchain technology for SSC development in Malaysia. A total of 153 responses were received and the data collected were analysed using Cronbach's Alpha Reliability Test, Arithmetic Mean, Mann-Whitney U Test, and Kruskal-Wallis Test.

The results of Arithmetic Mean revealed that for the level of acceptance, "Smart Healthcare (**AD**)" is highly acceptable whereas "Smart Asset (**AF**)" is less acceptable. As for the importance level, "Smart Governance (**BA**)" is the most important while "Smart Asset (**BF**)" is the least important. Furthermore, Mann-Whitney U Test showed that there is no significant difference in accepting the blockchain technology between the genders. Apart from that, Kruskal-Wallis Test portrayed that there is a significant difference in accepting the blockchain technology between three different age groups and educational levels.

CHAPTER 5

CONCLUSIONS AND RECOMMENDATIONS

5.1 Introduction

This chapter summarises all the chapters of this research. The chapter begins with the discussion of the research objectives accomplished. Next, the contributions of this research to the development of SSC in Malaysia is highlighted. Lastly, the limitations encountered during this study are identified and the recommendations for future studies are suggested.

5.2 Accomplishment of Research Objectives

The population in the cities is escalating at a rapid pace over the last few decades. Cities around the world are experiencing numerous political, economic, environmental and social challenges. This is due to the inability of the existing built environment to cope with the increased demand for the basic amenities and resources. Therefore, it is significant to implement SSC with the integration of blockchain technology that possesses a number of favourable features. Nonetheless, there are limited previous studies that provide an in-depth analysis on potential applications of blockchain technology in developing SSC in Malaysia. Hence, this study aims to uncover the potential of integrating blockchain technology into the development of SSC in Malaysia. In light of this, three research objectives are formulated, and the accomplishments of these research objectives are discussed in the following subsections. Figure 5.1 summarises the main findings obtained from this study.

5.2.1 Objective 1: To determine the acceptance of construction practitioners towards the application of blockchain technology for smart sustainable city development in Malaysia

The first objective of this study was accomplished by reviewing the secondary sources of information whereby the 7 main smart applications of blockchain technology, which are Smart Governance, Smart Transportation, Smart Supply Chain Management, Smart Healthcare, Smart Education and Smart Asset were identified. These 7 main smart applications of blockchain were then broken down into 30 sub-smart applications to discuss in detail about the various kinds of applications in each domain. Subsequently, by applying Arithmetic Mean analysis on the data collected via the distribution of questionnaire surveys, the acceptance level towards the 7 main smart applications and the 30 sub-smart applications of blockchain technology were ranked and tabulated in Table 4.3 and Table 4.4 respectively.

The results revealed that among the 7 main smart applications, the level of acceptance towards Smart Healthcare (**AD**) is the highest, followed by Smart Supply Chain Management (**AC**), Smart Transportation (**AB**), Smart Utility (**AG**), Smart Education (**AE**) and Smart Governance (**AA**). As for Smart Asset (**AF**), it is the least acceptable main smart application.

Besides, in the context of Malaysia, the sub-smart application with the highest level of acceptance is **AB1** = "Data about the road conditions and traffic congestions shall be available real-time and anytime", whereas **AF1** = "Transactions of land, property and housing can be carried out between buyers and sellers without relying on intermediaries such as lawyers to prepare paper documents for verification and agreements as the data of properties, buyers and sellers stored in digital platform can be exchanged and verified" is the least acceptable sub-smart application from the respondents' perspective.

5.2.2 Objective 2: To evaluate the importance of the potentials of blockchain technology application for smart sustainable city development in Malaysia

The second research objective was attained by undergoing the process identical to the process of achieving the first research objective. Table 4.5 and Table 4.6 showed the importance level of the 7 main smart applications and the 30 sub-smart applications of blockchain technology respectively.

The results portrayed that Smart Governance (**BA**) is deemed to be the most important main smart application, contrastingly, Smart Asset (**BF**) is the least important main smart application in Malaysia's setting. Smart Education (**BE**), Smart Transportation (**BB**), Smart Healthcare (**BD**), Smart Utility (**BG**) and Smart Supply Chain Management (**BC**) were ranked accordingly succeeding Smart Governance (**BA**).

On the other hand, it was noticed that **BB1** = “Alternative routes and transportation mediums could be proposed instantly to the drivers and public transportation users during traffic congestions or accidents owing to the sharing of the real-time data of road conditions and traffic congestions” is of the utmost importance, whereas **BF1** = “Trading of land and property should be simplified as the involvement of traditional written agreement and multi-layer authorised intermediaries are eliminated” is perceived to be the least important sub-smart application among all the sub-smart applications.

5.2.3 Objective 3: To discover the influence of social demographics of construction practitioners in accepting the blockchain technology for smart sustainable city development in Malaysia

The third research objective was achieved through the conduct of Mann-Whitney U Test and Kruskal-Wallis Test to investigate the significant differences in viewpoints between the respondents of distinct social demographics in accepting the blockchain technology. Gender, age and educational level of the respondents were analysed. As revealed by Mann-Whitney U test, this study fails to reject no significant difference observed between genders in accepting the blockchain technology

Besides, the results of Kruskal-Wallis Test indicated that there are 27 sub-smart applications that show significant differences between the age groups. The significant differences in acceptance level occur between the respondents of “21 years old and below” and “45 years old and above” for all the 27 sub-smart applications, except for **AB3** = “Ride sharing services can be carried out between the drivers and passengers without involving intermediaries such as Uber and Grab”, **AD2** = “Digital medical data can be shared between medical service providers due to the absence of centralised systems and distinct databases”, **AE1** = “Educational records of students and the credentials of education practitioners are stored in a digital platform which is more systematic without the involvement of centralised authority such as schools, colleges or universities”, **AF1** = “Transactions of land, property and housing can be carried out between buyers and sellers without relying on intermediaries such as lawyers to prepare paper documents for verification and agreements as the data of properties, buyers and sellers stored in digital platform can be exchanged and verified” and **AG4** = “Carbon footprints of house appliances, goods, vehicles, tools and equipment are tracked without involving intermediaries and recorded in digital platform to determine carbon tax charges, where applicable”, where the significant differences are observed between the respondents of “22 - 44 years old” and “45 years old and above”.

Furthermore, 20 sub-smart applications were found to have significant differences between the three education levels. The significant differences in acceptance level between the respondents with “High” educational level and “Low” educational level are observed in **AB1** = “Data about the road conditions and traffic congestions shall be available real-time and anytime”, **AB6** = “Electricity can be traded between the drivers of electric vehicles whenever required without involving any intermediaries or relying on charging stations such as ChargeEV”, **AD1** = “Medical reports’ hardcopies are replaced by the storage of complete medical history in a digital platform which can be accessed by the medical practitioners upon authorisation by the patients”, **AD5** = “Official medical licenses of medical practitioners are stored in a digital platform where data is immutable to prevent the theft of medical licenses by fraudulent healthcare service providers”, **AD7** = “The origins of critical drugs, blood and organs are traceable without involving intermediaries to ensure the drugs, blood and organs are obtained legally”, **AE2** = “Paper-based certificates are replaced with digital certificates which are immutable and manageable by the students themselves” and **AG5** = “Data about the changes in the environmental quality shall be available real time and anytime to citizens”; while the significant differences between the respondents with “Medium” educational level and “Low” educational level are discovered in the remaining 13 sub-smart applications.

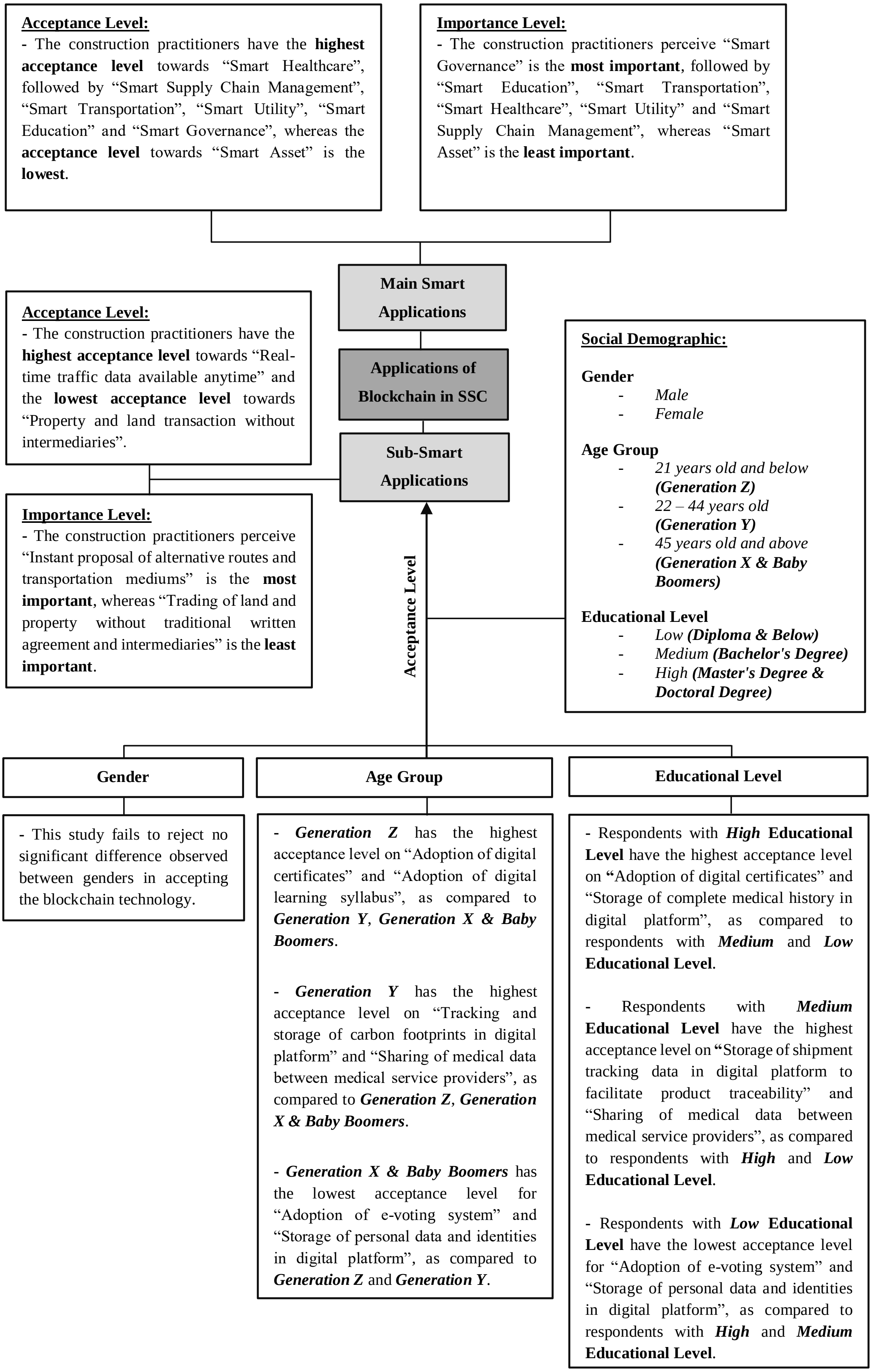

Figure 5.1: Summary of Key Findings

5.3 Research Contributions

This study provides an insight into the integration of blockchain technology in the development of SSC in Malaysia to the Federal Department of Town and Country Planning as well as all the relevant implementing agencies and stakeholders. This study plays a pivotal role in expressing the construction practitioners' acceptance towards the applications of blockchain technology and their viewpoints on the importance of the applications. The level of acceptance and importance of the blockchain's applications can be taken into account in developing an overall blueprint for the future development of SSC in Malaysia, whereby an emphasis can be placed on the applications that are perceived to be more acceptable and important.

Moreover, the findings of this study are expected to prompt the local government in providing good exposures and relevant courses on the adoption of blockchain technology to the citizens from generation X and baby boomers as well as the citizens with “Low” educational level. By doing so, there is a higher chance of shifting their attitudes in accepting blockchain technology and empowering them to adapt to the new norm after the implementation of SSC.

On top of that, this research has contributed to the expansion of knowledge in the existing literature. Besides filling up the identified research gap, this study likewise serves as a reference for other researchers in conducting relevant studies.

5.4 Research Limitation

There are four main limitations identified in conducting this research. First, this study merely investigated a minority of construction practitioners within Klang Valley and this may be inaccurate to represent the entire Malaysia's population. There may be different attitudes and perspectives towards the integration of blockchain technology into SSC development in Malaysia between the construction practitioners from Klang Valley and other states of Malaysia.

Second, the adoption of quantitative research method has restricted the provision of in-depth and detailed justifications on the respondents' viewpoints. Due to the absence of open-ended questions in the questionnaire surveys, only numerical descriptions of the respondents can be obtained.

Third, an unbalanced distribution of respondents was discovered, as pursuant to Table 4.1. For instance, Table 4.1 shows that there are merely 7 respondents who are “60 years old and above” and 28 respondents are “45 – 59 years old”, whereas 87 respondents are “22 – 44 years old” and 31 respondents are “21 years old and below”. Thus, the initial 4 age groups were further divided into 3 age groups, namely “21 years old and below”, “22 – 44 years old” and “45 years old and above”, due to the insufficiency of respondents to fulfil the requirement of CLT. This reveals that the accuracy of the Kruskal-Wallis Tests’ results may be affected due to the inadequacy of respondents for each demographic group.

Fourth, among all the social demographics, this study only investigated the diverse attitudes of respondents with different genders, age groups and educational levels in accepting the blockchain technology. This diminishes the discoveries of the influence of other kinds of social demographics on the technology acceptance that are able to assist the relevant parties in developing the framework of SSC with the integration of blockchain technology in Malaysia.

5.5 Research Recommendation

There are some recommendations suggested to overcome the research limitations aforementioned in the future studies. First, the scope of research can be broadened by including the respondents from other regions in Malaysia to produce a more accurate and reliable result that can represent the population of Malaysia as a whole.

Second, the adoption of mixed research approach is suggested in conducting future researches. Mixed research approach incorporates the strengths of both quantitative and qualitative research approaches thus enabling the researchers to look into different viewpoints holistically. The use of interviews enables the interviewees to further justify the quantitative data, whereas the quantitative data obtained from questionnaire surveys can be used to support the descriptive findings obtained from the conduct of interviews. This brings forth enhanced findings in terms of reliability and richness.

Third, it is recommended to attain a balanced sample size for each demographic group in the future studies to safeguard the accuracy and reliability of the statistical analysis results. This can be accomplished by paying close attention to the response rate of every demographic group and distributing more questionnaires to the respondents from the demographic groups with lower response rate.

Fourth, the future researchers are recommended to scrutinise the relationship between other social demographics and the acceptance level of blockchain technology in their studies. The demographic groups suggested include, but not limited to, ethnicity, marital status and income level. By doing so, the influence of these social demographics in accepting the blockchain technology could be fully explored and enable the relevant parties to make better decisions based on the more comprehensive findings attained.

5.6 Summary of Chapter

This chapter has summarised the background, gap, aim, objectives and findings of this research. Besides, the contributions of this study were identified and discussed. Furthermore, the limitations in this research were addressed, followed by the provision of recommendations to improve the future studies.

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APPENDICES

Appendix A: Questionnaire

Dear Sir/Madam,

I am Tan Xian Yi, a final year undergraduate student who is pursuing Bachelor of Science (Honours) Quantity Surveying in Universiti Tunku Abdul Rahman (UTAR). I am currently conducting a survey for my final year project entitled "The Potential of Integrating Blockchain Technology into Smart Sustainable City Development" as a partial fulfilment of the programme structure. The purpose of this research is to identify the potential of integrating blockchain technology into the development of smart sustainable city in Malaysia.

This questionnaire consists of THREE (3) sections and it would take approximately 10 to 15 minutes to complete. I would like to express my appreciation for your participation in this survey and I believe that your professionalism and experiences will significantly contribute to the success of this research. Your responses given for this survey will be kept confidential and remained anonymous. The responses will be solely used for academic purposes.

If you have any questions regarding to this survey, please do not hesitate to contact me for further information and clarification.

Student name: Tan Xian Yi
Contact number: 018-6673132
E-mail: celinetxy@1utar.my

Thank you for your participation and precious time.

Blockchain technology is a digital, decentralised and distributed ledger which records all the transactions carried out across a peer-to-peer network. In general, blockchain is a technology which keeps all the information and transaction records carried out between individuals or organisations without involving any central authority, intermediaries or trusted third party. For instance, the trading of stock has always involved numerous intermediaries such as brokers. This leads to lengthy trading process as a number of stages and bureaucracy are involved. By applying blockchain technology, the trading of stock can be carried out without any intermediaries and the stock exchange process can be sped up significantly.

Smart sustainable city is a city which incorporates both 'smart' and 'sustainable' elements to improve quality of life, enhance efficiency and competitiveness of its operating systems and infrastructures as well as fulfilling the economic, social, environmental and cultural needs of the future generations. The integration of blockchain technology in political, economic, social and environmental aspects is expected to compliment the formation of smart sustainable city.

Section A: Demographic Section

Please tick (√) in the relevant box.

What is your gender?

o Male

o Female

What is your age group?

o 21 years old and below

o 22-44 years old

o 45-59 years old

o 60 years old and above

What is your profession in construction industry?

o Architect

o Engineer

o Main Contractor

o Project Manager

o Quantity Surveyor

o Sub-Contractor

o Other, please specify ___________

How long have you been working in the construction industry?

o Less than 6 years

o 6 – 10 years

o 11 – 15 years

o 16 – 20 years

o More than 20 years

What is your highest educational level?

o High School

o Sijil Pelajaran Malaysia (SPM)

o Sijil Tinggi Persekolahan Malaysia (STPM)

o Foundation

o Diploma

o Bachelor's Degree

o Master's Degree

o Doctoral Degree

o Other, please specify __________

Section B: Acceptance Towards the Application of Blockchain Technology for Smart Sustainable City Development in Malaysia

This section measures your acceptance level on the integration of blockchain technology into smart sustainable city development in Malaysia. Rate your acceptance level for the following statements on a scale of 1 (Strongly Unacceptable) to 5 (Strongly Acceptable).

Strongly Unacceptable	Unacceptable	Neutral	Acceptable	Strongly Acceptable
1	**2**	**3**	**4**	**5**

	Smart Governance	**1**	**2**	**3**	**4**	**5**
1	The management and control of data by centralised agencies or organisations such as banks and lawyers are eliminated.					
2	Traditional paper-based voting system is replaced with e-voting system which is more transparent and secured.					
3	The provision of identity cards, birth certificates and passports are replaced by the storage of personal data and identities in digital platform where the accessibilities of data are controlled by the citizens themselves.					
	Smart Transportation	**1**	**2**	**3**	**4**	**5**
4	Data about the road conditions and traffic congestions shall be available real-time and anytime.					
5	The personal data of drivers and passengers is stored in a digital platform which is accessible upon authorisation to facilitate the verification of identities during ride sharing such as Grab car.					
6	Ride sharing services can be carried out between the drivers and passengers without involving intermediaries such as Uber and Grab.					
7	Hardcopies of vehicles' documents are replaced by the storage of vehicles' data in a digital platform where data is immutable to prevent modification of data and maximise reliability of data.					
8	Ticketing machines or counters for numerous transportation mediums are replaced by a single digital platform that sells digital tickets for all transportation mediums such as buses, trains and planes.					
9	Electricity can be traded between the drivers of electric vehicles whenever required without involving any					

	intermediaries or relying on charging stations such as ChargeEV.					
	Smart Supply Chain Management	**1**	**2**	**3**	**4**	**5**
10	The records of products from manufacturing, processing, transporting, storage and delivery are stored in a digital platform and the accessibility are granted to the authorised parties to allow tracing of products without involving any intermediaries.					
11	The shipment tracking information is synchronised reliably in a digital platform in real time which facilitates traceability.					
12	The origins of food supply chain are traceable real-time without intermediaries to ensure the quality and safety of food.					
	Smart Healthcare	**1**	**2**	**3**	**4**	**5**
13	Medical reports' hardcopies are replaced by the storage of complete medical history in a digital platform which can be accessed by the medical practitioners upon authorisation by the patients.					
14	Digital medical data can be shared between medical service providers due to the absence of centralised systems and distinct databases.					
15	The process of claiming insurance should be simplified as the medical data can be obtained without going through multiple layers of intermediaries.					
16	The records of pharmaceutical supply chains such as medicines are stored in a digital platform which is transparent and easily traceable without relying on the intermediaries.					
17	Official medical licenses of medical practitioners are stored in a digital platform where data is immutable to prevent the theft of medical licenses by fraudulent healthcare service providers.					

18	The numbers of vaccination doses produced and injected to the individuals are traceable in a digital platform without involving intermediaries.					
19	The origins of critical drugs, blood and organs are traceable without involving intermediaries to ensure the drugs, blood and organs are obtained legally.					
	Smart Education	**1**	**2**	**3**	**4**	**5**
20	Educational records of students and the credentials of education practitioners are stored in a digital platform which is more systematic without the involvement of centralised authority such as schools, colleges or universities.					
21	Paper-based certificates are replaced with digital certificates which are immutable and manageable by the students themselves.					
22	Physical lecture notes are replaced by digital learning syllabus which consists of content similar with the materials provided in physical classes.					
	Smart Asset	**1**	**2**	**3**	**4**	**5**
23	Transactions of land, property and housing can be carried out between buyers and sellers without relying on intermediaries such as lawyers to prepare paper documents for verification and agreements as the data of properties, buyers and sellers stored in digital platform can be exchanged and verified.					
24	The construction drawings, specifications, approvals, reports and records involved in the property development process are stored in digital platform which is more secured as the data are immutable.					
25	Automatic payments are initiated after the construction works are completed or construction materials are procured by the main contractors.					
	Smart Utility	**1**	**2**	**3**	**4**	**5**

26	Data related to energy activities such as meter readings and the conduct of digital transactions for energy payment is stored in a digital platform where the data is unalterable by third parties.					
27	The surplus renewable energy is sold by the prosumers to other consumers where the payment and transactions of energy trading are conducted automatically without involving any intermediaries.					
28	The operations of waste management which include the collection, disposal, recycling and recovery of wastes are enhanced as the relevant authorities are instantly notified when the wastes are piled up to a certain level without involving any intermediaries.					
29	Carbon footprints of house appliances, goods, vehicles, tools and equipment are tracked without involving intermediaries and recorded in digital platform to determine carbon tax charges, where applicable.					
30	Data about the changes in the environmental quality shall be available real time and anytime to citizens.					

Section C: The Importance of the Potentials of Blockchain Technology Application for Smart Sustainable City Development in Malaysia

This section contains a list of the potential applications of blockchain technology in smart sustainable city development in Malaysia. Rate your level of importance for the following statements on a scale of 1 (Not Important) to 5 (Very Important).

Not Important	**Less Important**	**Neutral**	**Important**	**Very Important**
1	**2**	**3**	**4**	**5**

	Smart Governance	**1**	**2**	**3**	**4**	**5**
1	Government information such as tax revenues, incomes, expenses and contracts should be kept in a transparent					

		1	2	3	4	5
	digital network to ensure integrity and security of government records.					
2	The conduct of election, registration of voter, transaction of vote, tallying of vote, verification of vote should be conducted in a transparent and systematic way to prevent manipulation of voting results.					
3	Personal data and identities should be stored in a digital platform instead of providing identity cards to prevent losses, theft and frauds.					
	Smart Transportation	**1**	**2**	**3**	**4**	**5**
4	Alternative routes and transportation mediums could be proposed instantly to the drivers and public transportation users during traffic congestions or accidents owing to the sharing of the real-time data of road conditions and traffic congestions.					
5	Traffic data in a digital network should be managed instantly and shared to the drivers to prevent the spreading of misleading and inaccurate traffic data.					
6	Authenticity of the drivers' and passengers' identities stored in a digital platform should be verified instantly upon authorisation to safeguard the personal safety during transportation sharing.					
7	Data of vehicles such as cars should be stored in a transparent and systematic digital network to ensure the integrity of data thereby protecting the rights and benefits of the second-hand vehicles buyers.					
8	Single digital ticketing system should be established to allow the citizens to purchase the digital tickets of various transportation mediums such as buses, trains and planes from one platform instead of visiting numerous ticketing machines or counters.					
9	Trading of electricity should be conducted instantly between the drivers of electric vehicles whenever required					

		1	2	3	4	5
	to prevent exhaustion of electricity as there are fewer charging stations available.					
	Smart Supply Chain Management	**1**	**2**	**3**	**4**	**5**
10	Information of the supply chain should be shared to the parties involved in a supply chain to facilitate them in forecasting market trends and deciding on the capital allocation, inventories management and manufacturing activities optimisation.					
11	Real time shipment tracking information should be stored in a digital platform where the verification and traceability of products can be conducted at any time.					
12	The supply chain of food and agricultural goods should be available real time and their origins should be traceable and make available to the relevant parties.					
	Smart Healthcare	**1**	**2**	**3**	**4**	**5**
13	Medical data should be stored in a digital platform and shared between medical service providers upon authorised by the patients to allow the efficient delivery of effective healthcare assistance.					
14	Insurance claims' process should be streamlined without the involvement of intermediaries in obtaining the medical data required for the claiming process.					
15	The pharmaceutical fabrications such as medicines throughout the supply chain to the final users should be registered and authenticated thus forming a transparent pharmaceutical supply chain.					
16	The origins of critical drugs, blood and organs should be recorded in a digital platform to prevent the illegal trading of drugs and illegal trafficking of organs.					
17	The official medical licenses of the medical practitioners should be stored in a digital network to eliminate fraudulent healthcare service providers and increase the confidence of patients towards the healthcare services provided.					

18	The supply chain of vaccine should be traceable from the manufacturer, delivery and until the individuals who receive the injection of vaccines.					
	Smart Education	**1**	**2**	**3**	**4**	**5**
19	Education records should be stored in a transparent and secured digital platform to ensure the data integrity as the data cannot be modified and deleted.					
20	Digital certificate should be issued to avoid the students from keeping tonnes of documents' hardcopies.					
21	Digital learning syllabus should be initiated to enable the students to access the content of syllabus at any time.					
	Smart Asset	**1**	**2**	**3**	**4**	**5**
22	Trading of land and property should be simplified as the involvement of traditional written agreement and multi-layer authorised intermediaries are eliminated.					
23	The data of an asset should be stored in a digital platform which is more transparent and systematic to safeguard the accuracy of data throughout the life span of the asset.					
24	The routine for the repair and maintenance of facilities stored in a digital platform should be accessed easily by a facility manager to ensure the facilities are maintained regularly.					
25	Payments should be made automatically and instantly upon completion of construction and procurement to eliminate issues caused by late payments.					
	Smart Utility	**1**	**2**	**3**	**4**	**5**
26	Surplus renewable energy should be converted by prosumers into digital tokens and sell to consumers in an electricity trading market without any intermediaries.					
27	The data produced from smart meter should be stored in a digital platform which is more secured to prevent the alteration of meter readings by third party.					

28	Household wastes which are accumulated to certain level should be detected and notified the relevant authorities for waste collection and disposal.	
29	Carbon footprints of a product should be tracked and the information should be available to consumers so that they have a better understanding and awareness on the effects of each product making on the environment.	
30	Quality of environment, changes in hyperlocal air quality and toxicity levels should be monitored to allow the authorities and communities to take immediate actions against the pollution.	