

**Examining the Factors affecting the sustainability of
blockchain technology in higher education using a hybrid
SEM-ANN approach**

دراسة العوامل المؤثرة على استدامة تقنية سلسلة الكتل في التعليم العالي
باستخدام منهج هجين يجمع بين المعادلات الهيكلية الهجينة والشبكات العصبية
الاصطناعية

by

MOHAMMED SALEM MATAR AL SHAMSI

**A thesis submitted in partial fulfilment
of the requirements for the degree of
DOCTOR OF PHILOSOPHY IN COMPUTER SCIENCE
at**

The British University in Dubai

October 2022

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DECLARATION

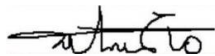
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ABSTRACT

Blockchain technology has received considerable attention during the last few years. Blockchain technology permits the creation of a distributed record of a decentralized digital event in which data and related transactions are not controlled by a third party. However, little is known concerning what affects their sustainable use for educational purposes. Consequently, there are three primary goals for this research. A systematic review is conducted to address the research gaps in the literature on Blockchain adoption from the lens of information system (IS) models and theories. The systematic review included empirical studies published between January 2010 and December 2021 on the topic of blockchain adoption. Among the 918 articles, 30 articles were critically analyzed based on the inclusion criteria. This research, therefore, develops a theoretical model based on extracting constructs from the protection motivation theory (PMT) and expectation confirmation model (ECM) to understand the sustainable use of blockchain in higher education. The developed model was then tested based on data collected through an online survey from 374 university students in the UAE who used blockchain technology for educational purposes. The model was empirically validated using a hybrid structural equation modelling-artificial neural network (SEM-ANN) approach. The hypotheses testing results reinforced most of the suggested hypotheses in the developed model. The sensitivity analysis results for model 1 revealed that satisfaction has the most considerable effect on the sustainable use of blockchain technology with 100% normalized importance, followed by perceived usefulness (58.8%), perceived severity (12.1%), and response cost (9.2%). Besides, the sensitivity analysis for model 2 showed that perceived usefulness has the most considerable effect on the sustainable use of blockchain technology with 100% normalized importance.

However, expectation confirmation has 29.2%. Theoretically, integrating the PMT and ECM will add significant value to the validation of the two theories in general and the blockchain in specific. Practically, understanding the impact of security factors would assist in understanding the effect of security incidents on the sustainable use of technology in higher educational institutions. In addition, governments, academia, businesses, and individuals often tend to share resources over a distributed ledger secured by means of cryptography. Blockchain technology also helps in facilitating the traceable, secure, and verifiable exchange of educational data across institutions effectively. Methodologically, the use of SEM-ANN in validating such theoretical models is rarely used, and hence, it would add value to the existing literature by measuring the non-linear relationships among the factors.

الخلاصة

حظيت تقنية سلسلة الكتل باهتمام كبير خلال السنوات القليلة الماضية. حيث تسمح تقنية سلسلة الكتل بإنشاء سجل موزع لحدث رقمي لامركزي لا يتحكم فيه طرف ثالث بالبيانات والمعاملات ذات الصلة. ومع ذلك، لا يُعرف الكثير فيما يتعلق بما يؤثر على استخدامها المستدام للأغراض التعليمية. وبالتالي، هناك ثلاثة أهداف أساسية لهذا البحث. يتم إجراء مراجعة منهجية لمعالجة الثغرات البحثية في أدبيات اعتماد سلسلة الكتل من منظور نماذج ونظريات نظام المعلومات (IS). تضمنت المراجعة المنهجية دراسات تجريبية نُشرت بين يناير 2010 وديسمبر 2021 حول موضوع تبني سلسلة الكتل. من بين 918 مقالة، تم تحليل 30 مقالة بشكل نقدي بناءً على معايير التضمين. لذلك، يطور هذا البحث نموذجًا نظريًا يعتمد على استخراج التركيبات من نظرية تحفيز الحماية (PMT) ونموذج ضمان التوقع (ECM) لفهم الاستخدام المستدام لسلسلة البلوك شين في التعليم العالي. ثم تم اختبار النموذج المطور بناءً على البيانات التي تم جمعها من خلال استطلاع عبر الإنترنت من 374 طالبًا جامعيًا في الإمارات العربية المتحدة ممن استخدموا تقنية سلسلة الكتل للأغراض التعليمية. تم التحقق من صحة النموذج تجريبيًا باستخدام نهج نمذجة المعادلة الهيكلية الهجينة - الشبكة العصبية الاصطناعية (SEM-ANN). عززت نتائج اختبار الفرضيات معظم الفرضيات المقترحة في النموذج المطور. كشفت نتائج تحليل الحساسية للنموذج 1 أن الرضا له التأثير الأكبر على الاستخدام المستدام لتكنولوجيا سلسلة الكتل مع أهمية طبيعية 100٪، تليها الفائدة المتصورة (58.8٪)، والشدة المتصورة (12.1٪)، وتكلفة الاستجابة (9.2٪). إلى جانب ذلك، أظهر تحليل الحساسية للنموذج 2 أن الفائدة المتصورة لها التأثير الأكبر على الاستخدام المستدام لتكنولوجيا سلسلة الكتل مع أهمية طبيعية بنسبة 100٪. ومع ذلك، فإن تأكيد التوقع قد وصل إلى 29.2٪. من الناحية النظرية، فإن دمج PMT و ECM سيضيف قيمة كبيرة للتحقق من صحة النظريتين بشكل عام وسلسلة الكتل بشكل خاص. عمليًا، من شأن فهم تأثير العوامل الأمنية أن يساعد في فهم تأثير الحوادث الأمنية على الاستخدام المستدام للتكنولوجيا في مؤسسات التعليم العالي. بالإضافة إلى ذلك، غالبًا ما تميل الحكومات والأوساط الأكاديمية والشركات والأفراد إلى مشاركة الموارد عبر دفتر أستاذ موزع مؤمن عن طريق التشفير. تساعد تقنية سلسلة الكتل أيضًا في تسهيل التبادل الآمن والقابل للتحقق من البيانات التعليمية عبر المؤسسات بشكل فعال. من الناحية المنهجية، نادرًا ما يتم استخدام نمذجة المعادلات الهيكلية والشبكة العصبية الاصطناعية في التحقق من صحة مثل هذه النماذج النظرية، وبالتالي، فإنها ستضيف قيمة إلى الأدبيات الحالية عن طريق قياس العلاقات غير الخطية بين العوامل..

DEDICATION

I dedicate this thesis to the people who gave me everything, believed in me and supported me in every stage of my life. To my parents with love, my wife, my brothers, my sisters, and of course to my Children Humaid, Aisha and Shamma.

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LIST OF ABBREVIATIONS

Abbreviation	Meaning
PMT	Protection Motivation Theory
ECM	Expectation Confirmation Model
IoT	Internet of Thing
AI	Artificial Intelligence
UN	United Nation
SCM	supply chain management
PRISMA	Systematic Reviews and Meta-analyses
TAM	Technology acceptance model
UTAUT	Unified Theory of Acceptance and Use of Technology
TOE	Technology-organization-environment
IDT	Innovation diffusion theory
TRI2	
ISS	
TTF	Task-Technology Fit
TPB	Theory of planned behaviour
TRA	Theory of Reasoned Action
TAM3	Technology acceptance model 3
UTAUT2	Unified Theory of Acceptance and Use of Technology 2
IBM	“International Business Machines” Corporation
SPSS	Statistical Package for the Social Sciences – Series of Software Packages Used for Data Analysis
PLS – SEM	Partial Least Squares - Structural Equation Model

HE	Higher Education
SU	Sustainability
PS	Perceived severity
PV	Perceived Vulnerability
SE	Self-efficacy
RE	Response Efficacy
RC	Response Costs
EC	Expectation Confirmation
SA	Satisfaction
PU	Perceived usefulness
SEM	Structural equation modelling
CB-SEM	Covariance based-Structural Equation Modeling
IS	Information system
CA	Cronbach's Alpha
AVE	Average Variance Extracted
HTMT	Heterotrait–Monotrait ratio
DV	Discriminant validity
CI	confidence intervals
VIF	variance inflation factor
CR	composite reliability
NFI	normed fit index
SRMR	root-mean square residual
dULS	squared Euclidean distance
dG	geodesic distance

CHAPTER 1

INTRODUCTION

1. Introduction

This chapter provides a complete overview of the research. This chapter goes through the research problem's definition, as well as the motivation and goals. In addition, it contains an overview of the study topics, techniques used, assumptions, and the limitations faced. Finally, the thesis outline and chapters are provided in this chapter.

1.1.Overview

Blockchain technology executes based on peer to peer network based on a decentralized approach (Esmat *et al.*, 2021). This manages and stores the data using the distributed consensus without the involvement of a third-party or central authority to monitor the transactions (Nakamoto, 2008). This has been associated with several blocks where data are separately stored with hash functionality (Crosby *et al.*, 2016). Therefore, it becomes immutable and tamper-proof technology (Beck *et al.*, 2018). On the other hand, this technology has been adopted in several applications due to its benefits with security and privacy. Blockchain-driven smart education has recently attracted a lot of interest, and relevant system frameworks and important technologies are described (Gong *et al.*, 2019). A record of transactions is maintained across several computers that are linked in a peer-to-peer network in a system. Hence, it allows the creation of a decentralized environment where data are not under the control of any third-party organization (Satoshi Nakamoto, 2008). While there is a plethora of research regarding the sustainability of blockchain across various sectors, there is a scarce of knowledge regarding what impacts its sustainability use in higher education environments. Further, it has been noticed

through a systematic review that examined the impact of security factors on the sustainable use of the technology is neglected.

1.2. Research Motivation

Blockchain technology is incorporated into higher education that transforms to secure transactions with innovative technology(Raimundo, 2021). However, various issues occurred in blockchain sustainability that caused difficulties in sustainability blockchain-based smart learning. It is necessary to understand the importance of blockchain sustainability, but complications should also be underlined while implementing any technological changes(Ullah *et al.*, 2021). There are issues required to be identified in the transformational process to make the operations successful. The educational institution should determine the appropriate way to enhance the abilities and competencies of the educational sectors by implementing blockchain strategies(Shah *et al.*, 2021). However, it is becoming difficult for the educational sector to introduce technology within the university sectors due to less awareness and a lack of security.

Less managerial role in the transformation and poor security management is a major reasons for the failure of blockchain sustainability(Turkanović *et al.*, 2018). It is necessary to recognize the management of technological changes in the organization and ways that have been adopted by the educational sectors to assist in sustainability(Salah, Ahmed and Eldahshan, 2020). This blockchain sustainability is being considered by the educational department to focus on improving students' and faculty's experiences(Kirkwood and Price, 2014). Educational departments are nowadays focusing on managing their student's certificates on a secure platform to improve security and prevent data piracy issues(Vidal, Gouveia and Soares, 2020). Failure in this domain can dramatically reduce and gain benefits from the opportunities. These highlighted issues will contribute towards better strategic planning for the implementation of an effective

information technology system(Shah *et al.*, 2021). Moreover, it would be supported to indicate the barriers that can occur in the future to avoid any consequences. Better management and sustainability with an affirmative approach can lead organizations to encounter challenges that are highlighted and bring an effective blockchain with a machine learning approach. The application of blockchain technology is carrying on conceptual progress in the higher education sector, where it has added substantial value by ameliorating efficiency, effectiveness, privacy control, technological improvement and security of data management mechanisms (Alammary *et al.*, 2019). Moreover, blockchain technology constitutes a potential threat to the universities' monopoly of formal accreditation. Likewise, the research argued that even if it offers privacy and security, malicious attacks and data leakage can be a threatening barrier which makes education institutions difficult to trust blockchain technology (Xu *et al.*, 2017).

Several educational institutions are reluctant to share all data on a blockchain network, and they cannot decide about the type of data and services to be offered through the blockchain network (Sharples and Domingue, 2016). The most institution already has a standard procedure for managing educational activities; blockchain technology requires extensive process alteration in the institutions' set procedures. The blockchain system will integrate all students' and educational data into blockchain ledgers. The immutability feature makes it challenging for educational institutions to implement new information storage laws or correct inaccurate data (Mitchell, Hara and Sheriff, 2019). Blockchain technology still has immaturity issues, such as low usability and complex settings. It does not promise transactional privacy, as data and values of each public key are publicly visible (Kosba *et al.*, 2016). As per the research, the amount of attention generated by blockchain serves as a reminder that organizations can no longer maintain traditional ways of doing things but would need to embrace change. Technology will radically

transform operations, and organizations need to be prepared (L. Wong *et al.*, 2020). Moreover, this work highly focuses on mitigating the below problems based on the systematic review, and the results showed that there is a lack of studies regarding the continued use of blockchain technology in general and specifically in higher education and security factors of sustainability blockchain technology in higher education.

1.3.Problem Definition

The sustainability of new technologies is fundamental to ensuring a positive perception of their use (Taherdoost, 2019). It is important to examine the factors that influence a technology's acceptance or rejection in the field of human-computer interaction (Al-Emran and Granić, 2021).

Acceptance or suitability of various information technology in different settings and domains has been discussed in many studies. There was a discussion about the acceptance of multiple technologies, including cryptocurrency (Alzahrani and Daim, 2019), education (Antonietti, Cattaneo and Amenduni, 2022), higher education (Mostafa Al-Emran *et al.*, 2020), smart wearable devices (Basoglu, Ok and Daim, 2017; Peng *et al.*, 2022), smart phone and mobile service (Kargin, Basoglu and Daim, 2009; Aldhaban, Daim and Harmon, 2015), telemedicine (Kim, Alanazi and Daim, 2015; Garavand *et al.*, 2022) and adopt the WhatsApp platform (Agrawal, 2021). There are also several domains involved, but they are not limited to banking (Mansour *et al.*, 2022), healthcare (Daim, Basoglu and Topacan, 2013; Spatar *et al.*, 2019; Alrahbi, Khan and Hussain, 2021), agriculture (Curry *et al.*, 2021), transportation (Dewan *et al.*, 2022) and hospitality (M. Sharma *et al.*, 2021).

The education sector with blockchain technology requires more enhancement for better management that provides more results, especially in higher education (Vidal, Gouveia and

Soares, 2020). In the research, several pieces of literature related to blockchain technology based on sustainability are analyzed that emphasize the utilization of blockchain in diverse applications (Abeyratne and Radmehr P. Monfared, 2016). However, there is a minimum quantity of materials that are being extracted due to the challenges of minimum availability of evidence on blockchain technology sustainability. Information is more specified on blockchain sustainability without diagnosing the methods of its implementation. In addition, there is less amount of work on how environmental and personal factors that pose a threat affect sustainability. As a result of the threat, two cognitive processes are initiated: threat appraisal and coping appraisal. During the threat appraisal process, the factors associated with the behaviour that may be dangerous are evaluated, including the intrinsic and extrinsic rewards that someone receives for taking the action, the severity of the danger, and the individual's vulnerability to that danger. A coping appraisal procedure assesses the level of self-efficacy and response efficacy associated with maintaining a level of self-awareness in the face of threats and averting them (self-efficacy and response efficacy), in relation to the costs associated with protective behavior (response cost). The perspective of PMT can be used to explain the role of security concerns in affecting continued intentions to use blockchain technology in the future by examining the impact of security concerns. A coping appraisal, on the other hand, is strengthened by factors such as Self-efficacy, Response efficacy, and Response costs. Accordingly, a number of empirical findings suggest that the PMT may provide a new avenue to encouraging the adoption of new technologies in the future (Gurung, Luo and Liao, 2009).

The literature indicates that pre-adoption performance expectations can play an important role in consumption-driven confirmation, which, in turn, can influence post-adoption perceived usefulness, post-adoption perceived security and the level of user satisfaction. A huge

contribution is made by the framework's integration of concepts related to pre-and post-adoption, as well as how the two are related (Gupta, Yousaf and Mishra, 2020a). The expectation confirmation dimension in ECM has been assumed to have a significant impact on perceived usefulness and satisfaction. As per the systematic review conducted in this research, the majority of the studies only focus on the success and approaches that assist in changing the operational process through innovation done by blockchain technology. Moreover, most of the studies focused on adoption and acceptance and few on continued use; however, no research on the sustainability of blockchain technology. The new techniques should also come up with a solution to deal with failure in the execution process while implementing. Future challenges should be identified for dealing with the barriers that occur at the time of new development. Analyzing and understanding the changes that occur in terms of technological and traditional approaches with the utilization of blockchain technology are required for suitable implementation.

1.4.Aims and Objectives

The main aim of this study is to understand the impact of coping appraisal and threat appraisal on blockchain sustainability in higher education through the integration of PMT and ECM. the following are the research objectives:

- 1- To analyze the existing blockchain literature to identify the most frequent factors, domains, and theoretical models.
- 2- To build an integrated research model through the combination of PMT and ECM for understanding the factors affecting the sustainability of blockchain technology in higher education.

- 3- To validate the developed model using a hybrid structural equation modelling-artificial neural network (SEM-ANN) approach.

1.5. Research Questions

While there is a plethora of research regarding the sustainability of blockchain across various sectors, there is scarce knowledge regarding what impacts its sustainable use in higher education environments. Further, it has been noticed through the systematic review that examines the impact of security factors on the continued use of the technology is neglected. Therefore, there is a need to examine those factors in order to sustain the use of blockchain in higher education. Specifically, the following research questions can be formulated:

RQ1: What are the most frequent factors affecting the adoption of blockchain technology, studied domains, and leading theoretical models?

RQ2: What is the suitable model for understanding the factors affecting the sustainability of blockchain technology in higher education?

RQ3: To what extent would the proposed model be able to predict the sustainability of blockchain technology?

1.6. Significance of the research

This work intends to provide successful blockchain sustainably use in higher education. Despite much research based on the sustainability of blockchain in higher education, the sustainability use of blockchain is highly challenged, and further research is required. The key contributions of this thesis can be summed up below:

- To Provide a systematic review of the literature on technology sustainability in the higher education domain.

- To examine the determinants affecting the sustainable use of blockchain technology by university students.
- To examine factors that influence the sustainable use of blockchain technology in higher educational.
- To develop an integrated theoretical model for blockchain sustainability in higher education.

1.7. Research Scope

The scope of this study focuses on the sustainable use of blockchain technology in the higher education domain in United Arab of Emirates (UAE) universities. In order to evaluate the research model, surveys will be used as a tool for collecting data from university students enrolled in four different universities in the United Arab of Emirates, including The British University in Dubai (BUID), Higher Colleges of Technology (HCT), UAE University (UAEU), and University of Dubai (UD).

1.8. Thesis organization

The thesis has been structured as below:

Table 1. Thesis structure

Chapter #	Summary
Chapter 1	This chapter will provide an overview of the research, define the research challenge, and discuss the motives for conducting the research. In addition, the chapter will outline the objectives, developed questions, and techniques to be used in order to achieve the study objectives.

Chapter 2	An analysis of the existing literature regarding block-chain technology sustainability in higher education will be included in the chapter. Moreover, the chapter will discuss the integration of acceptance models and develop a hybrid model for technology acceptance in higher education.
Chapter 3	The chapter will present the employed approach to examine the widely used technology acceptance models in higher education. The chapter will discuss the most confirmed relationships between those models and the validation of these relationships by other researchers. Finally, the chapter will include the development of hypotheses and a research model as a theoretical foundation to conduct this research.
Chapter 4	This chapter describes the methodology and the study instrument used for conducting this research. Indeed, this chapter will explain the survey structure. Details about the developed questionnaire, target population, and data collection will explain.
Chapter 5	The findings of the study will be presented in this chapter. This chapter will explain the analysis of the collected surveys in detail. In addition, the methods that can be used to fit the theoretical study model with the collected data will be presented, and the creation of the final study model. The research hypotheses will be validated, and the results will be presented.

Chapter 6	The limitations of the research, the theoretical and practical implications, and the conclusions will be included in this chapter. The chapter will conclude with recommendations for future research and work
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CHAPTER 2

LITERATURE REVIEW

2. Literature Review

2.1. Overview

This chapter will present a review of the literature on the sustainable use of Blockchain technology in the higher education domain. As part of a comprehensive evaluation of the literature, 30 papers from 902 that were published between 2010 and 2021 were considered and analyzed as a part of a systematic review. Further, the results indicated inadequate exposure to studying the actual use of Blockchain technologies and their sustainability use. It is also essential to report that existing studies have examined the sustainability of Blockchain technologies from the lens of the organizational level, with little attention paid to the individual level. This review is believed to improve our understanding by revealing the full potential of Blockchain sustainability and opening the door for further research opportunities. It is necessary to investigate the integration of elements from various acceptance models in order to build integrated models for the sustainable use of block-chain technology in higher education. The built integrated model may be used to analyze the sustainability of blockchain technology in higher education by specific user types or other types in general.

2.1.1. Blockchain Technology

Blockchain technology operates as a distributed ledger system, storing data used in transactions or communication in a publicly accessible network of digital blocks (Moll and Yigitbasioglu, 2019). These blocks contain timestamps and digital signatures, making them virtually unchangeable (Satoshi Nakamoto, 2008; Kokina, Mancha and Pachamanova, 2017). ‘Hashing’

is a method of arranging digital blocks based on complex mathematical logic (Satoshi Nakamoto, 2008) to create a chain of blocks, hence the term blockchain (Angelis and Ribeiro, 2019; Harris and Wonglimpiyarat, 2019). A peer-to-peer approach is being used to develop blockchain applications that enable organizations to exchange services, information, and goods without relying on the third party to verify identities, verify transactions or enforce commitments. In other words, removing the need for many intermediaries, as it currently occurs. At first, this may result in increased efficiency and cost savings for firms and other organizations by allowing faster transactions to be disseminated and synchronized across a number of different but fewer parties (Davidson, Filippi and Potts, 2016). In the financial industry, cryptocurrency is one of the most recent and significant innovations, and blockchain technology has been implemented as the platform for cryptocurrencies (Alzahrani and Daim, 2019). The development and operation of cryptocurrencies like Bitcoin and Ethereum, and others, is the most significant use of blockchain technology. Apart from financial services, blockchain technology is also being used in other domains, for example, governance, education, business operations, supply chain management, international trade, and taxation (Kimani *et al.*, 2020; Pólvara *et al.*, 2020). The recent review by (Centobelli *et al.*, 2021) of blockchain studies in management found that many researchers have utilized blockchain information technologies in a variety of domains, such as artificial intelligence, consortium blockchains, security and privacy, supply chain management, and edge computing. Scholars agree that blockchain offers several potential benefits that will assist organizations in meeting the demands of the Fourth Industrial Revolution (Dai and Vasarhelyi, 2017; Pham, Tran and Nakashima, 2018; Moll and Yigitbasioglu, 2019; Singh *et al.*, 2019), even though it is still in its nascent stage (Ahluwalia, Mahto and Guerrero, 2020). According to (Lee, 2019), blockchain will be a significant change to many of the current accounting and finance applications, as well as paving the way for a

completely new industrial infrastructure to emerge. Among the reasons why blockchain is appealing to businesses: it optimizes business processes, supports transparent data sharing, improves collaboration efficiency, reduces operating costs, and enables the creation of a system that doesn't require explicit incorporation of trust in its control, as is the case with supply chains (Francisco and Swanson, 2018).

The significance of Blockchain technology is increasing (Zhao, Fan and Yan, 2016). IBM added that around 33% of C-suite executives itemized that Blockchain is being discovered by them or was involved actively in past projects (IBM, 2017). The research and development community at large is already aware of the potential of upcoming technologies, along with discovering many different applications across a wide array of industries (Christidis and Devetsikiotis, 2016). The development of Blockchain applications can be classified into three generations: (i) Blockchain 1.0 is used for cryptocurrency transactions, (ii) Blockchain 2.0 is used for financial applications, and (iii) Blockchain 3.0 is used for other industrial applications, such as government, health, science, and Internet of Things (IoT) (Zhao, Fan and Yan, 2016).

Blockchain assists in tracing and verifying multistep transactions that require traceability and verification (Livingston *et al.*, 2018). It minimizes compliance costs and accelerates data transfer processing. Perhaps the worthiest value of adopting Blockchains is the enhanced security provided to users while making transactions. This feature builds confidence between consumers and industry partners, protects privacy, and increases transparency in tracing transactions. Despite the tremendous opportunities of Blockchain technologies, their sustainability across many domains is still in short supply (Agi and Jha, 2022). Their low sustainability rates stem from inadequate knowledge regarding the factors affecting their use (Lu *et al.*, 2021). To draw a holistic view of the factors affecting Blockchain sustainability, we need to understand the theories/models through which these factors are derived. Understanding those factors through

the lenses of these theories/models would help scholars and practitioners prepare future policies and procedures for effectively employing Blockchain technologies across various sectors. By inspecting the existing reviews on Blockchain, it has been observed that there is inadequate knowledge about the main research methods used in Blockchain sustainability and the primary domains involving Blockchain applications(Kimani *et al.*, 2020).

According to (Woodside and Woodside, 2017), Blockchain technology can be described as a decentralized information technology that has its roots embedded in immutable, shared, and well-distributed ledgers, which are implemented in order to keep a record of transactions in terms of building trust. The author also acknowledges that the technology is disruptive in nature and possesses the potential to bring about a significant transformation in the field of data collection and new computing technology (Park, 2021). As has been observed by the author, stakeholders tend to implement blockchain models and technologies in several domains, including finance, the healthcare industry, supply chain, maritime transport, etc.

As has been deduced by (Wong *et al.*, 2021), Blockchain technology has emerged as a transformational technology over the last decade. It has made its impact across several industries. The author further states that even though there have been doubts and arguments during the emergence of the technology regarding whether or not the technology would make any real impact in the industry, eventually, the sustainability of the technology has become widely popular over time. (Jiang, 2010) identifies the several benefits in terms of the implementation of the technology. These benefits include; tracing information effectively, providing transparency, and being much more trustworthy than any other traditional technologies. The author further states that the technology provides better tolerance prevents data from being tampered with, and even maintains the integrity of the data. As has been

identified in the paper, several stakeholders have implemented the technology along with IoT and AI (Artificial Intelligence) to extract better outcomes. The paper also states the importance of Blockchain in terms of addressing issues in relation to sustainability.

In healthcare, Blockchains can be used to reduce the communication and computational burden in data management (Ismail, Materwala and Zeadally, 2019). This can be achieved through a secure transaction for a group of networks. Large amounts of healthcare data can also be managed using smart contract systems (Khatoon, 2020). Additionally, linking medical devices to a Blockchain platform can connect patients, doctors, and providers to better understand who is complying with treatments and their consequences. In education, Blockchain applications can be used for certificate/degree verification, students assessments, credit transfer, data management, and admission purposes (Bhaskar, Tiwari and Joshi, 2020). Academic credential verification is essential for employers and other authorities to affirm the validity of an academic degree. Blockchain technologies allow students to access their official certificates under the protection and control of their universities (Vidal, Soares and Blockchain, 2019; Pólvara *et al.*, 2020).

According to (Stratopoulos, Victor and Hua (Jonathan), 2018), it is pretty necessary for every stakeholder to understand the way the blockchain cycle is adopted. Some of the most crucial benefits of understanding the blockchain sustainability cycle the right way are; Firstly, in the long run, it contributes in terms of helping the adopters regarding analyzing the implementation risk and the duration of competitive advantage. In addition, it also helps all the investors and analysts in terms of evaluating the market reactions and developing strategies in accordance with the development of organizations. Moreover, possessing a proper understanding of the

sustainability cycle also enables regulators in terms of formulating strategies and procedures regarding the development of new technologies.

2.1.2. Blockchain in Higher education

Investing in technology solutions is a major part of higher-education organizations' decision-making and community service efforts(Ahmed, Daim and Basoglu, 2007). As has been identified by (Yumna *et al.*, 2019), there is always a need to identify and implement the latest and innovative technologies, like blockchain, in order to ensure the growth of the educational field. According to the author, blockchain models play a significant and crucial role in the field of education by performing effective data management. The operational procedure of a blockchain model in the educational field happens in a few steps. These steps involve; providing data security, maintaining system trust, managing the global database, and performing a formative evaluation. It has been observed by the author that numerous initiatives have been implemented by several educational institutions in terms of using blockchain technology. The author has observed that the University of Nicosia has implemented the technology in terms of managing the student database and keeping track of their certificates. The paper also identifies how MIT (Massachusetts Institute of Technology) has put together an innovative new machine learning technology based on the structure of Blockchain, in order to monitor the records of all the students.

According to (Bucea-Manea-țoniș *et al.*, 2021), blockchain technology has been implemented in order to ensure the growth of education and in terms of developing an infrastructure that supports the action of effective data management. The author identifies how schools and educational institutions play a significant role in ensuring the proper upbringing of students. Blockchain has coalesced a higher-education system with sustainable options from the

viewpoint of knowledge-providing and management systems. Massive Online Open-source Contents (MOOCs) have gained attention during times of pandemic (Bucea-Manea-țoniș *et al.*, 2021). The education system has connected 1.6 billion students through the MOOC system for ready content and effective learning designs that can very well have the potential to replace traditional schooling. The incident actually occurred in the country of Spain. Researchers have implemented hybrid models of the education system in modern days like Khan Academy, Tutellus, GardBase, and ODEM, which are backed by university certificates and distributed across the globe in a decentralized pattern (Bucea-Manea-țoniș *et al.*, 2021). As has been identified by the author, technology ensures that less-informed people get to interact with their well-learned peers, and this ensures the development of an effective communication chain.

As has been deduced by (Park, 2021), the implementation of blockchain technology can be performed in order to accomplish several other tasks in relation to education administration and data management via shared ledgers. These applications include; hiring school staff by implementing smart contracts, contributing to continual professional development, managing performance objectives and payments, etc. According to (Park, 2021), most of the research work in relation to the application of a blockchain model tends to speculate the attributes of the blockchain technology rather than applying the technology for real. The author also addresses how a Japanese organization claims to have successfully implemented the technology in relation to “open and secure sharing of academic proficiency and progress records”, and it has been observed the blockchain technology can be implemented in three areas in relation to learning, these areas are; the records of learning processes, performing formative assessments, and learning activities design and implementation. The author also mentions how a team of Hong Kong based researchers (Zhong *et al.*, 2018) proposed the idea of implementing the Ethereum

1.0 blockchain in order to ensure effective learning of vocabulary. But he also mentions that the study is just conceptual modelling, and the potential application of the technology is yet to be performed.

2.1.3. Sustainability and Blockchain

Globally, attention and commitments to sustainability are increasing as part of the United Nations 2030 agenda for sustainability development; 17 sustainability development goals have been identified with 169 targets ('UN, Transforming our world: the 2030 agenda for sustainable development', 2015). Elkington's bottom-line concept is one of the most accredited for evaluating sustainability in terms of socio-economic and environmental factors(K. Elkington, 1998). Big Data, IoT, AI and Block Chain are some of the identified to be path-breaking technologies that are integrated, aiming to promote sustainability in various sectors(Centobelli *et al.*, 2021). Blockchain is recognized as a technology that is disseminated and is the most trusted for sharing data securely across the globe (Lu, 2018). As a technology that is still very much in development, blockchains are a disruptive and digital transformation driver based on a new paradigm for computing and information flow (Saber *et al.*, 2019; Jović *et al.*, 2020). Implementation of blockchain is initiated in several domains by widening the horizons from the original application of Finance to other sectors such as healthcare (Lu, 2018), smart cities (Horst Treiblmaier, Abderahman Rejeb and Andreas Strebing, 2020), maritime(Jović *et al.*, 2020), energy (Lu, 2018), supply chain and logistics (Saber *et al.*, 2019), education and many more. Traceability and transparency stand as key capabilities of block chain making it a trustworthy technology in comparison to other traditional technologies. Traceability and transparency stand as key capabilities of block chain making it a trustworthy technology in comparison to other traditional technologies. Compared to traditional data, blockchain data is more fault-tolerant,

immutable, tamper-proof, and secure (Paliwal, Chandra and Sharma, 2020). Several industries also integrated blockchain technology with other latest branches of technologies such as IOT and AI to achieve better levels of service and security of data (Lu, 2018). Sustainability issues can be addressed with the help of block chain technology. "Tracking potential social and environmental conditions that might pose environmental, health, and safety concerns" (Saber *et al.*, 2019) is an important use case of block chain-based applications. Traceability plays an important role in contributing towards SDGs, particularly SDGs 8, 9 and 12 (Wang, Han and Beynon-Davies, 2019). Several studies were conducted to state and prove that blockchain technology is an enabler to enhance traceability which therefore established that sustainability is achieved in manufacturing and supply chains. (Jović *et al.*, 2020; Paliwal, Chandra and Sharma, 2020). With blockchains, sustainability can also be verified with quantifiable and meaningful metrics (Paliwal, Chandra and Sharma, 2020). As a result, blockchain technology is increasingly being used to address sustainability issues. Blockchain technology is a distributed ledger introduced for cryptocurrency in 2008 by Satoshi Nakamoto (Satoshi Nakamoto, 2008). In October 2008, Bitcoin was released (Clohessy and Acton, 2019). In the second generation, smart contracts were introduced for assets and trust agreements (Grech and Camilleri, 2017). It was initiated by Ethereum, one of the most renowned Blockchain-based software platforms. The next wave of Blockchain technologies will focus on scaling and addressing transaction processing times and bottlenecking problems. There are three categories of Blockchains, including public, proprietary, and permissioned. As a public Blockchain, anyone can join, leave, contribute, read, and audit the Blockchain network, as it is decentralized, self-governed, and authority-free. Bitcoin represents an instance of public Blockchain. The private Blockchain, in contrast, is a closed network with a verified and authentic invitation that is only available for trusted and selected parties. This means only the Blockchain owner has the authority to edit,

delete, or override entries on the Blockchain. The last type is referred to as permissioned Blockchain, which permits anyone to join after their identity is verified. Each individual is given specific permissions on the network to perform specific processes. In the supply chain, suppliers, for instance, could manage a permissioned Blockchain for their business partners and customers with different access rights. On the other hand, customers can only be allowed to read product documents, whereas wholesalers and suppliers have access to edit information about the goods and delivery.

Due to its intrinsic characteristics in maintaining transaction transparency across various entities, Blockchain has received much attention from different industries. The primary example is the use of cryptocurrencies in finance (Tapscott, 2017; Fosso Wamba *et al.*, 2018). Further, pharmaceutical, transportation, origin-to-consumer, legal, and regulatory areas are other non-financial domains that have witnessed prompt sustainability and use of Blockchain applications (Perez, 2018). Moreover, other applications have emerged regarding the use of Blockchain in the healthcare industry (Purv, Kar and Davies, 2019; Sodhro *et al.*, 2019), the chemical industry (Takhar and Liyanage, 2018), and big data (Chae, 2019). Blockchain technology is viewed as a significant component of the fourth industrial revolution that has facilitated changing the structure of the global economy and enhancing the opportunities for innovation, development, and improved quality of life. Furthermore, a Blockchain-based digital government often streamlines processes, protects data, and reduces abuse and fraud while instantaneously boosting accountability and trust.(Parmentola *et al.*, 2022) Governments, businesses, and individuals share resources through a distributed ledger protected by cryptography. By eliminating single points of failure, it protects government and citizen data.

To understand these issues, this systematic review aimed to provide a holistic view of Blockchain sustainability through the lenses of technology adoption theories and models and to identify the main research gaps that would guide future research. Therefore, to review the exiting literature, this study poses the following research questions:

1. Q1: What are the main research methods and domains in the selected studies?
2. Q2: What are the main theories/models used for studying the use of Blockchain?
3. Q3: What are the most frequent external factors affecting the use of Blockchain?
4. Q4: What is the primary purpose of the reviewed studies?
5. Q5: Who are the target participants in the selected studies?

2.2. State-of-the-art of Blockchain technologies

A synthesis of the previously published reviews was performed to understand the current state-of-the-art of Blockchain technologies. Table 2 shows the earlier review studies conducted on Blockchain technology. This subject has recently gained extensive international interest and attention. It can be noticed that Blockchain technology has been studied across several disciplines, including energy, healthcare, agriculture, education, logistics, and supply chain management. Some reviews have examined the underlying Blockchain technology, such as cryptography, peer-to-peer networking, distributed storage, consensus algorithms, and smart contracts (Andoni *et al.*, 2019; Chukwu and Garg, 2019; Li, Greenwood and Kassem, 2019). Other reviews were interested in highlighting the laws and regulations governing this technology (Wang, Han and Beynon-Davies, 2018). Some of the reviews focused on the educational applications built using Blockchain technologies, their benefits, and the obstacles to implementation (Alammary *et al.*, 2019). Another review identified organizational theories

and discussed their application in adopting Blockchain technologies in logistics and supply chain management (Kummer *et al.*, 2020). It can be observed that the existing reviews have neglected to review the factors affecting Blockchain sustainability from the perspective of technology sustainability theories/models. In addition, there is insufficient knowledge about the main research methods used in Blockchain sustainability and the primary domains involving Blockchain applications. Therefore, this systematic review aimed to provide a comprehensive review of Blockchain sustainability by examining the main research methods, domains, technology acceptance models/theories, influential factors, research objectives, and target participants.

Table 2. Previous review studies on Blockchain technologies

Source	Review Type	Number of Reviewed Studies	Domain	Aim
(Agbo, Mahmoud and Eklund, 2019)	Systematic review	65 studies	Healthcare	To review the use of Blockchain technology in healthcare.
(Andoni <i>et al.</i> , 2019)	Systematic review	140 studies	Energy	To review and examine the basic ideas that drive Blockchain technology, such as systems design and distributed consensus methods. It also concentrated on Blockchain solutions for the energy industry and enlightened the state-of-the-art issues by extensively analyzing the literature and existing business cases.
(Hölbl <i>et al.</i> , 2018)	Systematic review	33 studies	Healthcare	To demonstrate the potential use of Blockchain technologies, their obstacles, and future research directions in healthcare.
(Queiroz <i>et al.</i> , 2018)	Systematic review	27 studies	Supply chain management	To explain the most common Blockchain applications in supply chain management (SCM). It also covered the critical disruptions and problems resulting from Blockchain sustainability in SCM and how the future of Blockchains in SCM holds.
(Alammary <i>et al.</i> , 2019)	Systematic review	31 studies	Education	

				To review the applications of Blockchain in education and provide an insight into the main benefits and obstacles of implementation.
(Wang, Han and Beynon-Davies, 2018)	Systematic review	29 studies	Supply chain	To evaluate how Blockchain technologies would affect supply chain practices and policies in the future.
(Chukwu and Garg, 2019)	Systematic review	61 studies	Healthcare	To review the prototypes, frameworks, and implementations of Blockchain in healthcare.
(Bermeo-Almeida <i>et al.</i> , 2018)	Systematic review	10 studies	Agriculture	To review current research subjects, significant contributions, and benefits of using Blockchain technologies in agriculture.
(Kummer <i>et al.</i> , 2020)	Systematic review	22 studies	Logistics and supply chain management	To identify the most relevant organizational theories used in Blockchain literature in the context of logistics and supply chain management (LSCM). It also examined the content of those organizational theories to formulate relevant research questions for investigating the sustainability of Blockchain technologies in LSCM.
(Lu, 2019)	Review	-	General (not specific to a particular domain)	To examine the Blockchain and its related essential features, concerns (IoT, security, and data management), and industrial applications. It also provides potential difficulties and future directions.
(Tandon <i>et al.</i> , 2020)	Systematic review	42 studies	Healthcare	To figure out how Blockchain technologies can be used in the healthcare domain.
(Liu <i>et al.</i> , 2021)	Systematic review	35 studies	Governance	To provide scholars and practitioners with directions on using Blockchain applications in governance research.
(Karger, 2020)	Systematic review	32 studies	General (not specific to a particular domain)	To offer the most recent state of research on the potential combination of AI and Blockchain technologies and discuss the possible advantages of such a combination.
(Dujak and Sajter, 2021)	Review	-	Supply chain and logistics	To explain and describe the idea of Blockchain and its use in logistics and supply chains.
(Lo <i>et al.</i> , 2019)	Systematic review	35 studies	IoT	To evaluate academic solutions and approaches to integrating Blockchain with IoT.
(Namasudra <i>et al.</i> , 2021)	Review	-	General (not specific to a particular domain)	To discuss the fundamentals of Blockchain technologies and their technical details.
(Alshamsi, Al-Emran and Shaalan, 2022)	Systematic review	30 studies	General (not specific to a particular domain)	To provide a thorough review of Blockchain sustainability by examining the main research methods, domains, technology acceptance models/theories, influential factors, research objectives, and target participants.

2.3. Systematic Review Methodology

Based on findings from studies published in different digital journals and databases, this review empirically discusses and explores the sustainability of blockchain technology in higher education. As presented in Figure 1, this review was conducted according to the guidelines of Preferred Reporting Items for Systematic Reviews and Meta-analyses (PRISMA) (Moher *et al.*, 2009, 2016; Mostafa Al-Emran *et al.*, 2018; Alqudah, Al-Emran and Shaalan, 2021). Various phases were involved in identifying and collecting the relevant studies in this review: defining the inclusion/exclusion criteria, selecting sources and digital databases, specifying search strategies, and conducting the classification analysis.

2.3.1. Inclusion / Exclusion Criteria

Table 3 lists the inclusion and exclusion criteria for the publications that were critically evaluated in this review. It is essential to follow the prescribed criteria to determine if research is legitimate for inclusion in the subsequent phases of analysis and to guarantee consistency among the examined studies.

Table 3. Inclusion and exclusion criteria.

ID	Inclusion Criteria	Exclusion Criteria
1	Should be published between 2010 and 2021.	Studies involving Blockchain but without a theoretical model.
2	Should involve a theoretical model for evaluating Blockchain.	Studies involving a theoretical model but without a Blockchain.
3	Should measure the sustainability, acceptance, or continued use of Blockchain.	-----
4	Should be written in the English language.	Studies written in languages other than English.

2.3.2. Data Sources and Search Strategy

In this study, the surveyed articles were collected from a wide range of online databases, including Emerald, IEEE, ScienceDirect, Springer, MDPI, and Google Scholar. The selected databases were searched to collect studies that were published between January 2010 and December 2020, and the search for these studies was undertaken in April 2021. The keywords used in the search include (“Blockchain”) AND (“sustainability” OR “acceptance” OR “use” OR “intention to use” OR “continued use” OR “continuous intention”). Choosing the keywords is essential since it determines which articles are to be retrieved (Vítor and Monteiro, 2016). Using the above search strategies, the search results retrieved 902 articles. Of those, 218 were marked as duplicates, so we removed them from the analysis. Thus, the overall number of the remaining articles becomes 684. We have applied the inclusion and exclusion criteria for each of these studies. Accordingly, 30 studies met these criteria and were kept for the final analysis. The search and refinement stages were carried out using the “Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA)” (Moher *et al.*, 2016). Figure 1 shows the PRISMA flow diagram.

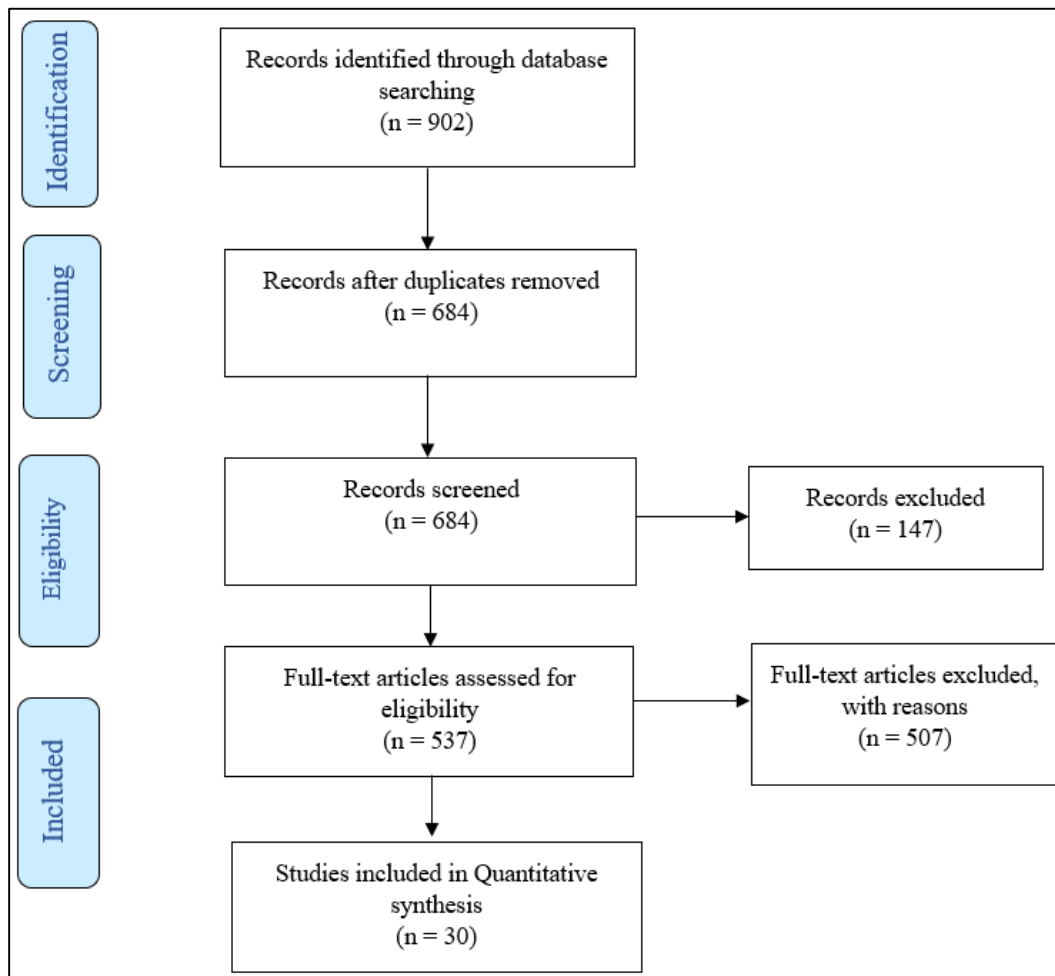


Figure 1. PRISMA Flowchart

2.3.3. Quality Assessment

Along with the inclusion and exclusion criteria, quality assessment is another crucial factor to consider (M. Al-Emran, Mezhuyev, Kamaludin and Shaalan, 2018). A nine-criteria checklist was adopted from Alqudah et al. (Alqudah, Al-Emran and Shaalan, 2021) and Al-Emran et al. (M. Al-Emran, Mezhuyev, Kamaludin and Shaalan, 2018) as a quality assessment and used to provide a method for evaluating the quality of the research papers that were kept for the final analysis ($n = 30$). Table 4 illustrates the quality assessment checklist. The primary purpose of the checklist was not to criticize any scholar's work, and the checklist was adapted from those

suggested by Kitchenham and Charters (Kitchenham and Charters, 2007). Each question in the checklist was scored according to the three-point scale, with an answer of “Yes” being worth 1 point, an answer of “No” being worth 0 points, and an answer of “Partially” being worth 0.5 points. Therefore, each study could receive an accumulated score between 0 and 9. The higher the total scores a study attained, the higher the degree to which the study addressed the research questions. This was ensured by assessing each study against the nine quality assessment criteria. For each study, the first and second authors assigned scores to the nine quality assessment criteria independently to ensure accuracy. Differences in assigning scores between the two authors were resolved through discussion and further review of the disputed articles. Table 5 presents the quality assessment results of all 30 studies. It is evident that all studies passed the quality assessment, and they were eligible for final analysis.

Table 4. Quality assessment checklist.

#	Questions
1	Is the research aim specified clearly?
2	Did the study achieve its aim?
3	Are the variables considered by the study clearly indicated?
4	Is the context/discipline of the study clearly defined?
5	Are the data collection methods sufficiently detailed?
6	Are the measures’ reliability and validity clearly described?
7	Are the statistical techniques used to analyze the data sufficiently described?
8	Do the findings add to the literature?
9	Does the study add to your knowledge or understanding?

2.3.4. Results of Systematic Review

Drawing upon the 30 research studies analyzed in this systematic review, we have reported the findings to answer the formulated research questions. Table 21 (Appendix B) provides a brief description of all the analyzed studies.

2.3.5. Main Research Methods

Figure 2 depicts the distribution of studies according to the research method used in data collection. It is evident that questionnaire surveys represent the primary research method used in 77% of the analyzed Blockchain sustainability studies. However, only 10% of the Blockchain sustainability studies relied on interviews in collecting their data.

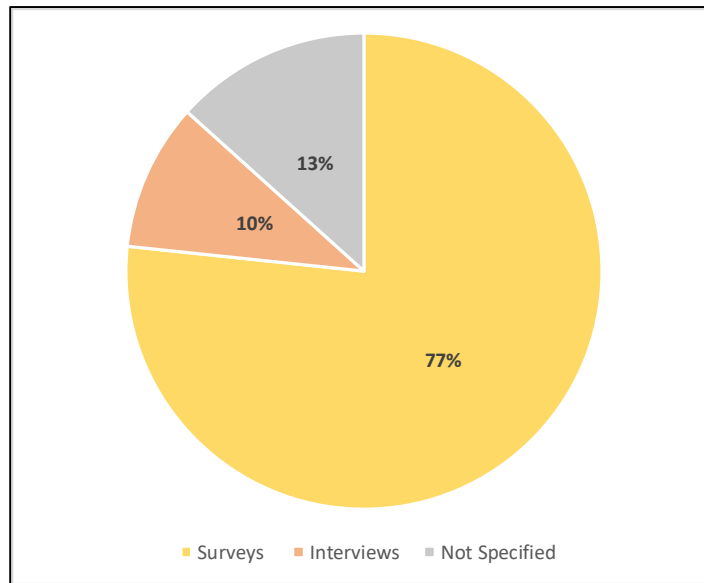


Figure 2.Distribution of studies by research methods.

2.3.6. Main Domains

Blockchain applications have been extensively used across many domains/sectors. The collected studies were analyzed according to these domains/sectors to provide an overview of the current status of Blockchain applications. Figure 3 depicts the main domains/sectors in which

Blockchain applications were adopted. It can be seen that supply chain management dominates the list, with 12 studies. This is followed by education and agriculture, with three studies each. In the supply chain, organizations can automate physical assets and create a decentralized steady record of all transactions, making it possible to track assets from production to delivery or use by end-users. Other applications include maritime shipping (Yang, 2019), organizing decisions (Kamble *et al.*, 2021), and executing operations (L. W. Wong *et al.*, 2020).

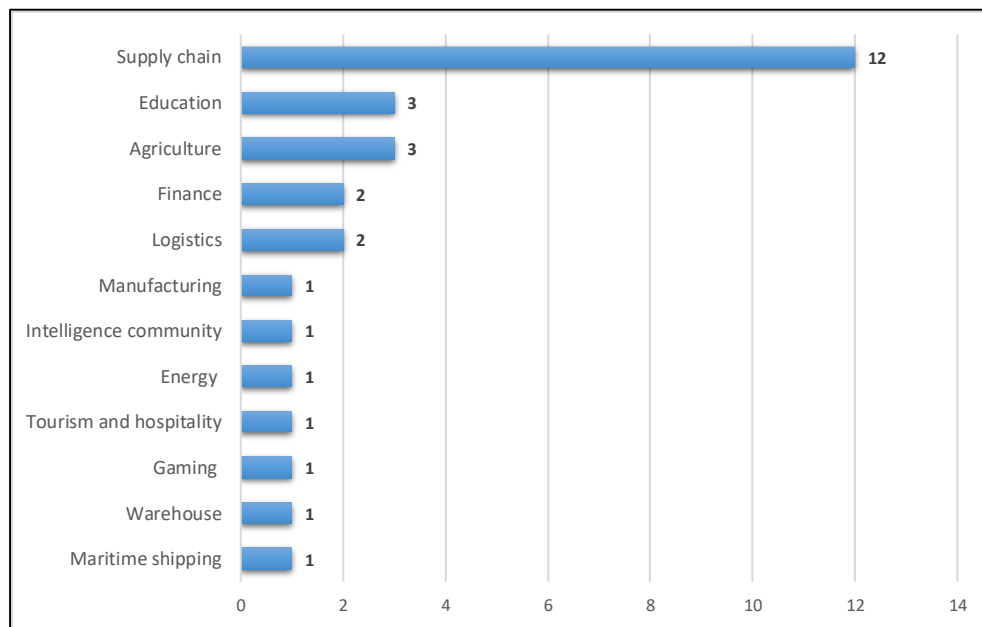


Figure 3.Main domains in Blockchain sustainability.

As we aimed to examine the sustainability of Blockchain technologies, the collected articles were analyzed from the perspective of technology sustainability theories/models, as shown in Figure 4. It can be seen that the “technology acceptance model (TAM)” is the most common model in studying Blockchain sustainability, with 14 studies. This is followed by the “technology-organization-environment (TOE)” ($n = 8$), “unified theory of acceptance and use of technology (UTAUT)” ($n = 7$), and “innovation diffusion theory (IDT)” ($n = 5$). The rest of

the theories/models appeared only once in the examined studies (i.e., TRI2, ISS, TTF, TPB, TRA, and TAM3).

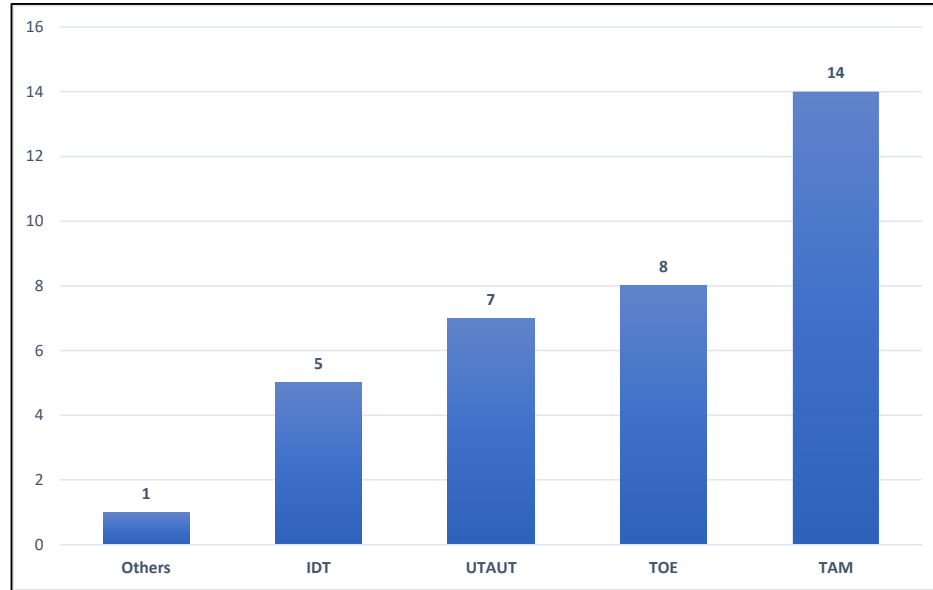


Figure 4. Distribution of studies by technology sustainability models/theories.

2.3.7. Most Frequent External Factors Affecting the Use of Blockchain

The low sustainability rates of many technologies, with no exceptions to Blockchain, stem from inadequate knowledge regarding the factors affecting their use. Therefore, we have analyzed the collected studies to identify the most common external factors affecting the sustainability of Blockchain technologies, as shown in Figure 5. Trust appeared to be the most common factor affecting the sustainability of Blockchain technologies ($n = 17$). This is followed by the perceived cost and social influence, with 11 studies each, then by facilitating conditions ($n = 10$), performance expectancy, effort expectancy, and information security, with seven studies each.

Apart from the collected studies, we have also analyzed the existing literature on Blockchain to determine the barriers affecting its sustainability. Security risk (Esmaeilian *et al.*, 2020; Böckel,

Nuzum and Weissbrod, 2021) and privacy risk (Kouhizadeh, Sarkis and Zhu, 2019; Esmaeilian *et al.*, 2020; Hatzivasilis *et al.*, 2021) were among the main risks that negatively affect the use of Blockchain technologies. High energy costs (Esmaeilian *et al.*, 2020; Ajwani-Ramchandani *et al.*, 2021; Böckel, Nuzum and Weissbrod, 2021) and investment costs (Demestichas and Daskalakis, 2020; Upadhyay *et al.*, 2021; Yildizbasi, 2021) represent the main costs of using Blockchain technologies. Organizations also impose some barriers to using Blockchain technologies, such as organizational policies (Hew *et al.*, 2020; Erol *et al.*, 2021; Kouhizadeh, Saberi and Sarkis, 2021a), organizational culture (Ada *et al.*, 2021; Bekrar *et al.*, 2021; Hatzivasilis *et al.*, 2021; Kouhizadeh, Saberi and Sarkis, 2021b), lack of knowledge and management support (Bekrar *et al.*, 2021; Erol *et al.*, 2021; Gopalakrishnan, Hall and Behdad, 2021), and lack of collaboration and coordination (Ada *et al.*, 2021; Çetin, De Wolf and Bocken, 2021; Erol *et al.*, 2021). It is also imperative to mention that adopting Blockchain is hindered by some technological barriers, such as technological immaturity (Esmaeilian *et al.*, 2020; Bekrar *et al.*, 2021; Böckel, Nuzum and Weissbrod, 2021), reluctance to change (Kouhizadeh, Zhu and Sarkis, 2020; Shojaei *et al.*, 2021; Yildizbasi, 2021), interoperability issues (Wang *et al.*, 2020; Bekrar *et al.*, 2021; Bressanelli *et al.*, 2021; Erol *et al.*, 2021; Yildizbasi, 2021), and scalability issues (Kouhizadeh, Sarkis and Zhu, 2019; Esmaeilian *et al.*, 2020; Erol *et al.*, 2021). Cultural differences (Romero-Hernández and Romero, 2018; Ada *et al.*, 2021; Kouhizadeh, Saberi and Sarkis, 2021b) are also considered a barrier to Blockchain sustainability. This is mainly because users rely on themselves when seeking advice related to using Blockchains in individualistic societies, while they rely on others in collectivistic cultures.

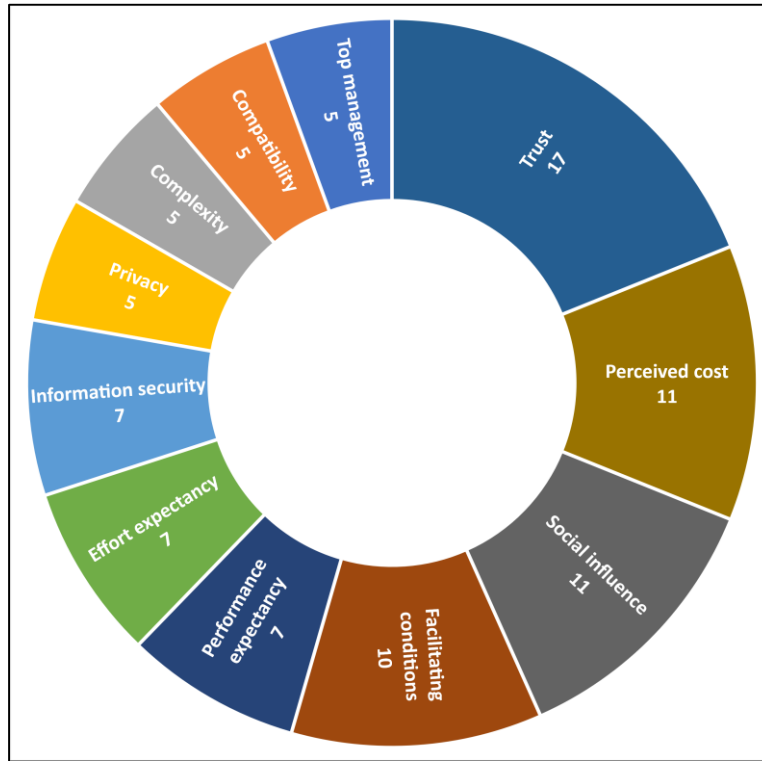


Figure 5.Most common external factors affecting Blockchain sustainability.

2.3.8. Primary Purpose of the Reviewed Studies

There are three different concepts within the technology sustainability domain, including sustainability, acceptance, and post- sustainability /continuous intention. Sustainability is usually measured by potential users who have not yet used the technology, whereas actual users measure acceptance. The post- sustainability /continuous intention measures the continued use of the technology after a sufficient period of users' experience. It is essential to understand the purpose of the analyzed studies concerning the previously mentioned concepts to understand where we stand on Blockchain sustainability. It has been noticed that 80% of the analyzed studies concentrated on measuring Blockchain sustainability, followed by 10% for both acceptance and continuous intention.

2.3.9. Target Participants in the Selected Studies

To understand who evaluated the use of Blockchain technologies, we have classified the analyzed studies in terms of participants, as depicted in Figure 6. Fifty per cent of the analyzed studies relied on the top management to evaluate the use of Blockchain technologies. This was followed by experts and consultants (28%), academics (13%), and students (5%).

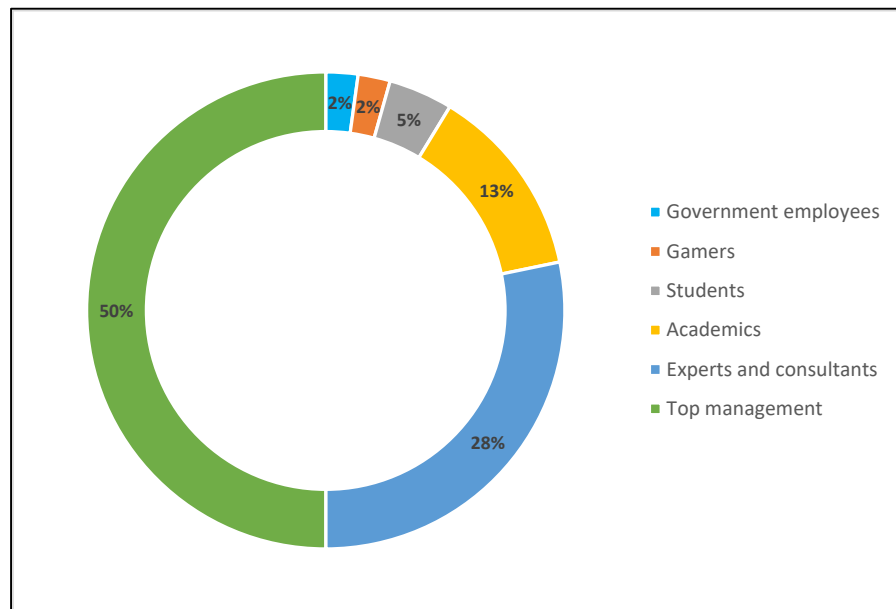


Figure 6. Distribution of studies by participants.

2.3.10. Discussion of the systematic review results

It is imperative to understand what impacts the sustainability of new technologies, such as Blockchain. Adopting any technology relies on the determinants affecting its users (Al-Emran, Mezhuhev and Kamaludin, 2018; M. Al-Emran, Mezhuhev, Kamaludin and AlSinani, 2018; Al Shamsi, Al-Emran and Shaalan, 2022). A forecasting report illustrates the positive evolution of the Blockchain market between 2017 and 2024 (Chernov and Chernova, 2018). While this magnitude was USD 800 million in 2017, it is estimated to reach USD 20,550 million in 2024.

Therefore, it is vital to gain more insights into what impacts the sustainability of Blockchain technologies across many sectors to improve and sustain their usage. Hence, this systematic review was carried out to analyze the sustainability of Blockchain technologies from the lenses of technology sustainability theories/models.

The results showed that questionnaire surveys represent the primary research method used in 77% of the analyzed Blockchain sustainability studies. These outcomes agree with some of the earlier systematic reviews in the technology sustainability domain (Wu *et al.*, 2012; Crompton, Burke and Gregory, 2017; Al-Marroof and Al-Emran, 2021; Al-Saedi and Al-Emran, 2021), which concluded that questionnaire surveys were the most common data collection method. In terms of the Blockchain, these results contradict what Frizzo-Barker *et al.* (Frizzo-Barker *et al.*, 2020) reported, in which comparative studies were the primary method used in most of the analyzed articles. Drawing upon the findings of this systematic review, it is suggested that further research would consider the mixed-research approach by involving interviews or focus groups besides using questionnaire surveys. This is because qualitative approaches provide more insights into the cause–effect relationships among the factors affecting Blockchain sustainability.

Regarding the main domains/sectors through which the analyzed studies were carried out, supply chain management dominates the list with 12 studies, followed by education and agriculture, with three studies each. While our findings agree with (Taherdoost, 2022), who found that supply chain management is the dominating sector concerning studies related to Blockchain sustainability, it contradicts what is reported by (Frizzo-Barker *et al.*, 2020), who suggested that banking and finance was the primary sector. Regardless of the differences between this review and the previously conducted reviews, understanding Blockchain

sustainability across many domains is still in short supply due to the limited number of applications.

Concerning the prevailing technology sustainability theories/models, the results pointed out that the TAM is the most common model in studying Blockchain sustainability, with 14 studies. This is followed by the TOE ($n = 8$), UTAUT ($n = 7$), and IDT ($n = 5$). In the same vein, (Taherdoost, 2022) found that TAM and TOE were the most dominating models in studying Blockchain sustainability. TAM is still a valid model for evaluating large-scale emerging technologies (M. Al-Emran *et al.*, 2020; Al-Emran and Granić, 2021), where Blockchain is not an exception. These results indicate that studies focusing on the individual level have mainly relied on TAM, while those examining the organizational level have relied on TOE. Further research might consider other sustainability models that have yet to be used in the existing literature, such as UTAUT2, ECM, PMT, etc.

For the influential factors affecting Blockchain sustainability, trust was seen to be the most common factor affecting the sustainability of Blockchain technologies ($n = 17$). This was followed by the perceived cost and social influence, with 11 studies each, as well as facilitating conditions ($n = 10$), performance expectancy, effort expectancy, and information security, with seven studies each. Studies on the individual level have examined trust, social influence, performance expectancy, effort expectancy, and information security. In contrast, those focusing on the organizational level studied mainly the organizational perspective's factors in delivering Blockchain-based services, such as trust, perceived cost, and facilitating conditions. Still, there is abundant room for other factors to be investigated from the perspective of other technology sustainability theories/models and Blockchain-related specific characteristics. On

the other side, we have also analyzed the existing literature on Blockchain to determine the barriers affecting its sustainability. Being aware of these barriers and considering them when implementing Blockchains would improve their sustainability rate. Security risks and privacy risks were among the main risks that negatively affect the use of Blockchain technologies. High energy and investment costs represent the main costs of using Blockchain technologies. Organizations also impose some barriers to using Blockchain technologies, such as organizational policies, organizational culture, lack of knowledge and management support, and lack of collaboration and coordination. It is also imperative to mention that adopting Blockchain is hindered by some technological barriers, such as technological immaturity, reluctance to change, interoperability issues, and scalability issues. Cultural differences are also considered a barrier to Blockchain sustainability. This is mainly because users rely on themselves when seeking advice related to using Blockchains in individualistic societies, while they rely on others in collectivistic cultures.

To understand the primary purpose of the analyzed studies, the results showed that 80% of those studies concentrated on measuring Blockchain sustainability, followed by 10% for both acceptance and continuous intention. These results clearly indicate that the majority of existing studies have examined the sustainability stage of Blockchain technologies, the step that precedes the actual use of the technology. The results provided evidence that there is inadequate exposure to studying the actual use of Blockchain technologies and their sustainability, which furnishes a good space for further research.

The results reported that 50% of the analyzed studies relied on the top management to evaluate the use of Blockchain technologies, followed by experts and consultants (28%), academics

(13%), and students (5%). This shows that most of the existing studies have examined the sustainability of Blockchain technologies from the lens of the organizational level, with little attention paid to the individual level.

This systematic review differs from previous reviews in several ways. This review did not limit the data collection to a specific domain, while most of the earlier reviews did. Most of the earlier reviews concentrated on using Blockchain applications in healthcare (Hölbl *et al.*, 2018; Agbo, Mahmoud and Eklund, 2019; Chukwu and Garg, 2019; Tandon *et al.*, 2020) and supply chain and logistics (Wang, Han and Beynon-Davies, 2018; Kummer *et al.*, 2020; Queiroz, Ivanov, *et al.*, 2020; Dujak and Sajter, 2021). While some of the previously conducted reviews were general in the domain, their aims and scope were entirely different from the current study. For instance, Lu (Lu, 2019) investigated the Blockchain and its essential features, concerns (IoT, security, and data management), and industrial applications. Karger (Karger, 2020) offered the most recent research on the potential combination of AI and Blockchain technologies and discussed the possible advantages of such a combination. Besides, Namasudra *et al.* (Namasudra *et al.*, 2021) discussed the fundamentals of Blockchain technologies and their technical details. To make it distinct, this systematic review provided a thorough review of Blockchain sustainability by examining the main research methods, domains, influential factors, research objectives, and target participants through the lenses of technology acceptance models/theories.

2.3.11. Summary and Research Gaps

Despite the immense opportunities of Blockchain technologies, their sustainability across many domains is still in short supply (Agi and Jha, 2022). This is one of the main reasons behind

conducting studies related to users' satisfaction and sustainability. Determining what impacts the use and sustainability of Blockchain technologies can efficiently address their sustainability challenges. Therefore, we have reviewed the Blockchain sustainability studies from the perspective of technology adoption theories/models to identify the most influential factors, main research methods, domains/sectors, research objectives, and target participants. It is believed that this systematic review would be a valuable guide for scholars and practitioners seeking to understand the challenges and opportunities related to the sustainability of Blockchain technologies across various sectors.

This review shed light on several gaps in research. First, the TAM and TOE were the most common models for understanding the factors affecting the use and sustainability of Blockchain technologies. Little attention has been paid to the role of technical, social, and psychological elements in understanding the sustainability of Blockchain applications. This gap requires further research by considering other sustainability theories/models such as UTAUT2, ECM, PMT, etc. Second, although Blockchain sustainability is still in short supply, the findings showed that supply chain management was the dominating sector among others in the examined studies. We found a dearth of empirical research in the other domains, which necessitates the need for future research to look at how Blockchain technologies are adopted. Third, trust, perceived cost, and social influence were the most common factors affecting the sustainability of Blockchain technologies. The other factors were mainly adapted from the most common theories, such as TAM and TOE. By involving other theories/models, understanding what impacts the use and sustainability of Blockchain technologies would be enlightened, specifically when the factors are related to Blockchain-specific characteristics.

Fourth, 77% of the analyzed Blockchain sustainability studies relied on questionnaire surveys for data collection. Hence, it is suggested that further research would consider the mixed-

research approach by involving interviews or focus groups besides using questionnaire surveys. This is because qualitative methods can explain the interrelationships among the factors affecting the sustainability of Blockchain. Fifth, unlike the previous systematic reviews that analyzed conceptual and empirical studies, it is imperative to mention that this review has concentrated only on empirical Blockchain studies. Since there is still a limited number of studies across the world, more empirical research is required to examine the users' maturity levels and capabilities of adopting Blockchain applications across many collectivistic and individualistic societies. The implications of Blockchain applications, with their negative or positive sides, in certain cultural environments would assist in developing these applications both socially and economically.

Sixth, the findings showed that 80% of the examined studies concentrated on measuring Blockchain sustainability, with a limited number of studies focusing on the acceptance and continuous intention perspectives. There is insufficient knowledge of what impacts the actual use of Blockchain technologies and their continued use, which opens the door for further research trials. Seventh, 50% of the analyzed studies relied on the top management, experts, and consultants to evaluate the use of Blockchain technologies. This shows that most of the existing studies have examined the sustainability of Blockchain technologies from the organizational level perspective, with little attention paid to the individual level.

This review is limited in two ways. First, we focused on specific online databases to collect articles, such as Emerald, IEEE, ScienceDirect, Springer, MDPI, and Google Scholar. However, these online databases do not represent the entire literature published on Blockchain sustainability. Further reviews might thus extend this review by involving studies indexed in other databases, such as Scopus and Web of Science. Second, this systematic review involved

analyzing only empirical quantitative studies. Considering qualitative studies in future reviews would add more insights into the observed results.

CHAPTER 3

RESEARCH MODEL AND HYPOTHESES DEVELOPMENT

3. Research Model and Hypotheses development

3.1.Overview

In this research, the proposed model was developed by the integration of two different theoretical models, namely protection motivation theory (PMT), which is a special case of a more general category of theories that uses “expectancy” and “value” constructs (Rogers and Prentice-Dunn, 1997) and expectation confirmation model (ECM) (Bhattacharjee, 2001), which is characterized for continuous intention. This research aims to examine the impact of security factors on the sustainability of blockchain technology in higher education through the integration of PMT and ECM. The reason behind the selection of these two theories stems from the fact that PMT is concerned with measuring the impact of security factors, whereas ECM is basically used for post-acceptance research.

3.2.Protection Motivation Theory

Generally, PMT mainly seeks to elucidate the cognitive processes to mediate behaviour in response to any specific threat (Hassandoust and Techatassanasoontorn, 2019). It indicates that after facing a certain type of threatening event, an individual usually performs two processes of appraisal: one focusing on the threat itself while the other on an individual’s capability to act against a certain threat (threat appraisal and coping appraisal, correspondingly) (Rogers and Prentice-Dunn, 1997). Such aspects often influence an individual’s intention to take precautionary actions ensuing in a threat or maladaptive behaviour. In such a threat appraisal,

people will consider in what ways the consequence of the threat (perceived severity) is negative and the likelihood of the threat materializing in an aspect that will directly impact them (perceived vulnerability). Such a threat results in maladaptive behaviours, for example, avoidance or denial (Witte and Allen, 2000). In a coping appraisal process, individuals will examine whether performing a recommended course of action will eliminate the threat (response efficacy) along with their confidence levels in being capable of carrying that specific action out (self-efficacy). This appraisal may result in adaptive behaviours, considering the fact that the cost of making an adaptive response (response costs) is not on the higher side.

This theory has been previously applied to cybersecurity, precisely to virus protection behaviour (Lee, Larose and Rifon, 2008), security behavioural intentions of PC users (Anderson and Agarwal, 2010), security behaviour among individuals who are well aware of the ways to protect their systems but often fail to do so (Workman, Bommer and Straub, 2008) the role of personal responsibility in the protective behaviour of students studying in a college (Boehmer *et al.*, 2015) convincing internet users to guard themselves (Shillair *et al.*, 2015), the willingness of the young population to offer online information (Youn, 2005), security behaviour in regards to the fear appeals by employers (Allen C. Johnston and Warkentin, 2010), and adherence of employees' to information security policies (Siponen, Adam Mahmood and Pahnla, 2014). An analysis of effect sizes of such constructs in the previously published literature was undertaken by (Mayer, Kunz and Volkamer, 2017), who suggested that all PMT constructs aside from 'response cost' were known to have consistent positive albeit weak to medium effect sizes. Conversely, response costs had weak to strong negative influences on cybersecurity.

3.3. Expectation Confirmation Model

With regards to the continuance intention research, the expectation-confirmation model (ECM) is proved to be a valuable framework (Bhattacharjee, 2001) and has been broadly adapted to study continuance use and technology sustainability (Chen, Meservy and Gillenson, 2012; Lin *et al.*, 2012; Joo, Park and Shin, 2017). In the field of IT, (Bhattacharjee, 2001) proposed and ECM of IT continuance founded on the congruence between a person's continued IT utilization decisions and consumers' repeat purchase decisions. ECM posits that a person's intention to continue the usage of IT is mainly dependent on three variables: the degree of user's confirmation of expectations, the level of satisfaction of the users with the IT, and post-sustainability expectations in terms of perceived usefulness.

Furthermore, (Bhattacharjee, 2001) demanded that a student's continuous intent to use an information system is mainly associated with the reasoning behind an individual's reuse intention in expectation confirmation theory (ECT). (Lu, Wu and Hsiao, 2019) Highlighted that the ECM had been most commonly implemented to examine the use of online platforms for the purpose of managing the design structures. Specifically, the ECM recommends the two important influencers of confirmation and PU that are associated mutually with the satisfaction and continuous intent of students to use an online platform. In addition, confirmation equally proposes a link to PU. Confirmation addresses an association between the anticipated as well as the perceived performance of using online platforms, for example, in the case of students' course navigation and description (Halilovic and Cicic, 2013). In specific, students recognize it as an essential inspiration for online platforms. Conversely, PU is associated with the helpfulness of an object in fulfilling a specific task. The students studying online may enhance their levels of performance to confirm the usefulness of online learning platforms (Elwalda, Lü and Ali, 2016).

3.4.Theoretical Research model

The proposed model was developed by the integration of two different theoretical models, namely protection motivation theory (PMT), which is a special case of a more general category of theories that uses “expectancy” and “value” constructs (Rogers and Prentice-Dunn, 1997) and expectation confirmation model (ECM) (Bhattacharjee, 2001), which is characterized for continuous intention. This research aims to examine the impact of security factors on the sustainability of blockchain technology in higher education through the integration of PMT and ECM. Protection motivation theory describes behavioural change in terms of psychological perception. It can be seen as an account of how behaviour changes over time. The process by which individuals create behaviour changes involves considering both threat appraisal and coping appraisal comprehensively in order to establish behavioural intentions. An individual who is undergoing coping appraisals evaluates their ability to cope with risk factors, including the effectiveness of their responses, their self-efficacy, and the cost of their responses, based on their perception of their vulnerability and severity of the risk factors (Ge *et al.*, 2022).

In addition to environmental exposures, PMT considers a number of factors, such as personal factors, that can combine to pose a potential threat. As a result of the threat, two cognitive processes are initiated: threat appraisal and coping appraisal. During the threat appraisal process, the factors associated with the behaviour that may be dangerous are evaluated, including the intrinsic and extrinsic rewards that someone receives for taking action, the severity of the danger, and the individual's vulnerability to that danger. The coping appraisal process assesses the level of self-efficacy and response efficacy associated with maintaining a level of self-awareness in the face of threats and averting them (self-efficacy and response efficacy) in relation to the costs associated with protective behaviour (response cost). The perspective of

PMT can be used to explain the role of security concerns in affecting continued intentions to use blockchain technology in the future by examining the impact of security concerns. PMT suggests that the continued intention to use blockchain technology is influenced by the perception of severity and the perception of vulnerability and is considered a threat assessment component. In contrast to this, Self-efficacy, Response efficacy, and Response costs can also be interpreted as coping appraisals. A broad interpretation of ECM holds that it can be used as a tool for evaluating the sustainability of users rather than just a means of explaining satisfaction levels. In this model, expectations remain; however, the pre-consumption expectation is replaced by post-consumption expectations, namely perceived usefulness. In the context of ECM, it has been presumed that expectation confirmation has a significant impact on perceived usefulness and satisfaction.

3.5.Relationships Between Technology Acceptance Constructs

PMT is a process that focuses on identifying and evaluating environmental and personal factors that pose a threat. As a result of the threat, two cognitive processes are initiated: threat appraisal and coping appraisal. Consequently, this model has become one of the most useful tools for understanding future human behaviour regarding the acceptance and rejection of technology. During the threat appraisal process, the factors associated with the behaviour that may be dangerous are evaluated, including the intrinsic and extrinsic rewards that someone receives for taking action, the severity of the danger, and the individual's vulnerability to that danger. A coping appraisal procedure assesses the level of self-efficacy and response efficacy associated with maintaining a level of self-awareness in the face of threats and averting them (self-efficacy and response efficacy) in relation to the costs associated with protective behaviour

(response cost). The perspective of PMT can be used to explain the role of security concerns in affecting continued intentions to use blockchain technology in the future by examining the impact of security concerns. PMT believes that the sustainability of the use of blockchain technology as a threat appraisal will be influenced by the perceived severity and perceived vulnerability of the threat. Conversely, a coping appraisal, on the other hand, is strengthened by factors such as Self-efficacy, Response efficacy, and Response costs. Accordingly, a number of empirical findings suggest that protection motivation theory (PMT) may provide a new avenue to encouraging the adoption of new technologies in the future (Gurung, Luo and Liao, 2009). ECM examines the relationship between the expectations and confirmations of individuals before adoption and their satisfaction and intent to continue their relationship after adoption. In addition to considering factors like the perceived quality of the interface, the perceived level of security, and the level of self-efficacy, the model also explores the role played by factors such as psychological benefits post-adoption. To conclude, the findings indicate that pre-adoption performance expectations can play an important role in consumption-driven confirmation, which, in turn, can influence post-adoption perceived usefulness, post-adoption perceived security and the level of user satisfaction. A huge contribution is made by the framework's integration of concepts related to pre- and post-adoption, as well as how the two are related (Gupta, Yousaf and Mishra, 2020a). The expectation confirmation dimension in ECM has been assumed to have a significant impact on perceived usefulness and satisfaction.

3.6. Research hypotheses

3.6.1. Perceived Severity (PS)

Perceived severity refers to “the degree of physical harm, psychological harm, social threats, economic harm, dangers to others rather than oneself, and even threats to other species” (Rogers,

1975). Additionally, in numerous studies, perceived severity has been found to positively affect an individual's intentions of adopting a new behaviour, such as smart watches (Mostafa Al-Emran *et al.*, 2020), cyberspace (Wu, 2020) and Phishing (Shahbaznezhad, Kolini and Rashidirad, 2021). The PMT theory indicates that individuals' behaviour can be influenced by a number of factors, including their threat appraisals, which are based on their assumptions about the severity of an incident and the consequences that will follow, as well as their coping appraisals, which are based on their psychological strength and defence mechanisms in order to deal with, manage, or cope with risk (Rogers and Maddux, 1983). Specifically, this model contends that in order to assess threats and cope, cognitive processes are triggered by fear. Thus, when fear occurs, a prognosis is made, and protective behaviour is triggered. Appraisals of threats and coping mechanisms can generate adaptive or maladaptive responses depending on the threat assessment (Rogers and Rippetoe, 1987). PMT demonstrates that fear appeals influence voluntary behavior in a systematic manner (Sommestad, Karlzén and Hallberg, 2015).

The sustainability of blockchain technology depends on the perception of the severity of the problem among the participants (perceived severity). Therefore, if the perceived severity is high, here emerges the situation that creates a stronger motivation for engagement in block chain sustainability. Blockchain is widely and commonly known as the technology that can bring value by captivating digital verifications, such as cryptocurrencies (Haferkorn and Diaz, 2015). It is now emerging into more fields by creating innovative blockchain approaches. Transparency, trust, and traceability are key factors for blockchain sustainability. There have been several use cases where Blockchain technology is used to improve Higher Education (HE), as well as for the development of an educational infrastructure to support learning (Raimundo, 2021). Individual inquiry, intensive social connection with interest groups, and expert mentoring

are common features of relationships among creative scientific learners (Bucea-Manea-țoniș *et al.*, 2021). With blockchain technology, people with less knowledge can interact with mentors and colleagues with more knowledge (Fenichel, M.; Schweingruber, 2010). Furthermore, blockchain technology provides the basis for the acquisition of skills in the area of content and structure, as well as the implementation of educational tools as part of the process (Kuleto *et al.*, 2022). Perceived severity negatively influenced the usage of block chain technology. New technologies are often difficult to adopt because of psychological anxiety, which is a common factor that makes adopting them difficult. This can be addressed through PMT effectively.

(Rogers, 1975) designed the initial model of PMT with perceived severity (severity of the incident) and perceived vulnerability (the assumed consequences), and the potency of the measures to be taken (response efficacy). As a result of the cognitive variables that are associated with the perception of probability and severity of an event, the model holds that the perception of probability doesn't matter if the perceived severity of the event is low (Karlzén *et al.*, 2015). In PMT, perceived severity is one of two major cognitive components, which represents the user's assessment of the perceived threat's severity (Rogers, 1975).

The PMT provides a methodology that addresses the emotional state of fear arousal, which indirectly influences behaviour change through the assessment of the severity of the threat perceived when block chain technology is utilized in higher education. Hence, the following hypothesis is formulated:

H1: Perceived severity has a significant positive effect on blockchain technology sustainability.

3.6.2. Perceived Vulnerability (PV)

Perceived vulnerability refers to “the conditional probability that the threatening event will occur provided that no adaptive behaviour is performed or there is no modification of an existing behavioural disposition” (Rogers and Prentice-Dunn, 1997). In order to understand how new technology interacts and mitigates threats, it is essential to understand how one perceives his or her own vulnerability to it. Human interaction and risk mitigation are heavily dependent on humans, despite the increased reliance on digital technologies, which are able to be used proactively and in real-time but are still impacted by human behaviour. A lot of studies showed that Perceived vulnerability positively impacts individuals’ behavioural intentions to adopt many technologies such as smartwatches (Mostafa Al-Emran *et al.*, 2020), cyberspace (Wu, 2020) and Phishing (Shahbaznezhad, Kolini and Rashidirad, 2021). In higher education, adopting new technology is largely considered a matter of concern with regard to sensitive data such as educational records and other personal records. This can be addressed by establishing seamless communication of the systems involved by eliminating any gaps. Interoperability is defined as the ability to execute correspondence between peer models among different systems. The communication and coordination among these models enable flawless and accurate exchange and communication (Amalarethnam, 2012)

PMT prompts that perceived vulnerability positively influences maladaptive coping and behavioural intention. All the major research done on Protection Motivation Theory regularly engages measures that involve perceived vulnerability. In the context of protecting against security threats, a perceived security vulnerability is the probability that a person will experience a computer attack due to a failure to perform a security countermeasure. The perceived security vulnerability is one of the most utilized processes to comprehend a perceived risk of a threat.

Also, researchers examined the effect that perceived risk has on individual behaviour. Perceived vulnerability is known for its framework propounding uncertainty and consequences (Dowling and Staelin, 1994; Jia, Dyer and Butler, 1999; Conchar *et al.*, 2004; Pavlou and Gefen, 2004; Nicolaou and McKnight, 2006). When a person perceives that there are higher chances of being vulnerable to a security-related threat, they often examine how the threat can be mitigated. On the other hand, if they notice minimal threat vulnerability or lack thereof, the outcomes of the response become negative (Herath and Rao, 2009). (Dang-Pham and Pittayachawan, 2015) argued that users are motivated to protect themselves if they notice susceptibility to threats. On the other hand, (Posey, Roberts and Lowry, 2015) suggested that threat susceptibility is a “main constituent in the threat appraisal procedure and overall development of insiders’ protection motivation”. (Workman, Bommer and Straub, 2008) Stated the perception of being vulnerable to threat leads to an examination of coping appraisals that tends to encourage users to shield themselves. (Gutteling, Terpstra and Kerstholt, 2018) Supported this assertion indicating that when users perceive high threat susceptibility, they often become motivated to perform adaptive responses to protect their assets from a certain threat. (Vance, Siponen and Pahlila, 2012) highlighted adaptive response in the direction of threat is found to be positive. Hence, hypothesize formulated is the following:

H2: Perceived vulnerability has a significant positive effect on blockchain technology sustainability.

3.6.3. Self-efficacy (SE)

During the 1950s, (Rotter, 1954) implemented the hypothesis that a predicament of control might exist, which refers to a point in time where reinforcement for behaviour is exerted in order to induce the behaviour. An individual under internal control can control their behaviour within

themselves, while someone under external control can control their behaviour outside themselves, such as under the authority of a powerful individual. It is also relatively common for individuals who hold firm self-efficacy beliefs to feel well-being and enjoy high levels of self-esteem (Flammer, 1990; Bandura, 1997). The initiative is willingly taken in related domains, and effort is applied if required, persistence maintained as long as they believe in the efficacy of their efforts. Self-Efficacy can be defined as “the degree to which an individual has confidence that he or she will be able to carry out the coping behaviour” (Sergueeva and Shaw, 2017). (Keith *et al.*, 2015) suggested that self-efficacy has been researched in the context of the utilization of computers and contextualized as computer self-efficacy. Self-efficacy needs to be developed as a construct within the context of the computing aspects within which it is being used (Hardin, Chang and Fuller, 2008) so that it corresponds with the computing environment. (Allen C Johnston and Warkentin, 2010b) also, contend that fear appeals resolutely to self-efficacy. The self-efficacy of individuals is also considered to have a significant impact on their intent. In the fintech domain, self-efficacy and its effects are well-documented, both online (Alalwan *et al.*, 2015; Marakarkandy, Yajnik and Dasgupta, 2017) and in mobile banking (Luarn and Lin, 2005; Zhou, 2012; Jeong and Yoon, 2013). (Gao, Clark and Lindqvist, 2016) found that non-users perceived that they lacked the skills necessary to use bitcoin and cited this as their main reasoning as reason not to participate. In addition to blockchain technology, the study (Voskobochnikov *et al.*, 2020) encompassed a broader range of subjects. The self-efficacy of individuals was examined through a number of research studies and interviews. As a result of the study and its findings, a determination was made that self-efficacy refers to an individual's belief in their own ability to execute behaviours that are required to deliver specific performance outcomes, as stated (Bandura, 1977, 1986, 1997). Self-efficacy and PMT encourage the continued use of blockchain technology. Furthermore, influence the behavioural intention of

users to adopt various technologies (Hooper and Blunt, 2020; Mostafa Al-Emran *et al.*, 2020; Wu, 2020). Therefore, the following hypothesis is put forward:

H3: Self-efficacy has a significant positive effect on blockchain technology sustainability.

3.6.4. Response Efficacy (RE)

Response efficacy refers to the effectiveness of emotion-based appeals in conjunction with negative, fear-based appeals as well as positive appeals. It can be defined as “the beliefs to which a recommended response would significantly protect individuals from a threat” (Allen C Johnston and Warkentin, 2010a). This is a measure of the effectiveness of the recommended behaviour in removing or preventing the possibility of harm from occurring. As a cognitive construct, response efficacy influences not only the effectiveness of fear-based messages but also the positive emotional messages since it relates to how they are interpreted (Lewis, Watson and White, 2010). The Protection Motivation Theory analyses how to predict the sustainability of protective technologies, unlike most technology sustainability models. The framework of the model formulates that perceptions of the severity of the threat indirectly affect attitudes and behaviours through the emotional state of fear arousal, which is induced by perceptions of the severity of the threat (Plotnikoff and Trinh, 2010).

Response efficacy is the effectiveness of the recommended behaviour in removing or preventing possible harm. Unlike most technology sustainability models, the Protection Motivation Theory looks at how to predict the sustainability of protective technologies. In this way, Users have the opportunity to protect their systems against an exponential number of negative technologies, such as malware and phishing attacks (Chenoweth, Minch and Chenoweth, 2014). A certain level of resistance comes into play which, consequently, is the first response to a threat and gives the user a sense of protection which gauges and leads the user to respond effectively. Response

efficacy was found to have a significant positive influence on individuals' behavioural intentions to adopt smartwatches (Mostafa Al-Emran *et al.*, 2020), cyberspace (Wu, 2020) and Phishing (Shahbaznezhad, Kolini and Rashidirad, 2021).

Hence, the following hypothesis is formulated:

H4: Response efficacy has a significant positive effect on blockchain technology sustainability.

3.6.5. Response Costs (RC)

(Rogers and Prentice-Dunn, 1997) define response costs as "any costs (e.g. effort, time, difficulty, and side effects) associated with the recommended behaviour. There are a number of considerations when it comes to the cost, including time, effort, distance, and financial impact. Response cost is very commonly considered a negative factor for any subject being evaluated. The combination of response costs and protection motivation theory has been found to be one of the most comprehensive and extensively explored combinations. With the protection motivation theory as a groundwork, we were able to derive a relationship between threat and coping appraisals and response costs based on the protection motivation theory. A consistent approach to PMT suggests that threat and coping appraisals can positively influence users' protection motivations, which affect their actual mindset (Behavior *et al.*, 2021). Furthermore, it is important to keep in mind that responsive cost interpretations are negative for coping assessments. A responsive cost is defined as the least common denominator for the PMT. PMT Coping Appraisal Pathway consists of three constructs in two groups, Perceived Efficacy and Perceived Response Costs. One of the major constructs of the Perceived Costs is Response Costs, which measure the perceived social, monetary, personal, time, and effort costs associated with adapting PMT (Rogers and Prentice-Dunn, 1997). Blockchain is an open-source technology that offers an alternative to traditional intermediaries when transferring crypto-

currencies. It has been suggested by (Crossler and Belanger, 2015) that security countermeasures can be avoided when they are more costly than the threat they are meant to address. Likewise, (Post and Kagan, 2007) Post and studied that users do not adopt certain strong information security measures because the response costs involved were detrimental to creativity in an organization and restrictive to process flexibility. Response cost was found to negatively affect the sustainability of many technologies like smartwatches (Mostafa Al-Emran *et al.*, 2020), cyberspace (Wu, 2020) and Phishing (Shahbaznezhad, Kolini and Rashidirad, 2021). We, therefore, propose the following:

H5: Response costs has a significant negative effect on blockchain technology sustainability.

3.6.6. Expectation Confirmation (EC)

Expectation confirmation (EC) refers to “users’ perceptions of the congruence between the expectation of information system usage and its actual performance” (Bhattacharjee, 2001). In order to achieve expectations, you need to anticipate them (Churchill and Surprenant, 1982), and as a result, they are predictive regarding product attributes in the future (Spreng, MacKenzie and Olshavsky, 1996). An individual's evaluation of performance is based on their perception of quality after an event. In the event that a product meets or exceeds expectations (confirmation), post-purchase satisfaction will follow (Jiang and Klein, 2009). An expectation is the psychological characteristics of a user when they associate with an entity such as a product, service, or technology. Expectations are directly proportional to both perceptions of performance and confirmation, and this leads to post-purchase or post-sustainability satisfaction by way of a mediational relationship through the expectation confirmation construct (Bhattacharjee, 2001). As part of pre-purchase or pre-sustainability expectations, we create an understanding of the criteria by which a product, service, or technology artifact is

ultimately evaluated. With the revolutionary rapid developments that are being made in blockchain, we arrived at a subversive and positive impact of all fields. The positive characteristics of decentralization, trust-free, and tampering established block chain technology as the face of the future(Zhao *et al.*, 2022). Block chain technology is wide spread and is a potential solution to many practical problems in multiple fields including higher education(Raimundo, 2021). As a result of physical issues such as the storage of student data, administration-related documents, and also the ease of access from anywhere without any compromise in data security, users have developed expectations. ECM integrated with Expected confirmation ensured block chain technology's continued use in education. ECM has been previously validated and extended in several contexts like online shopping and healthcare (Wang *et al.*, 2019; Gupta, Yousaf and Mishra, 2020b; Wu, 2020). As a result, ECM has been demonstrated to provide a solid theoretical framework for explaining the expectation-confirmation behaviours of information system users in organizations. Also, there is a significant impact of Expectation Confirmation on satisfaction (Al-Emran, Arpaci and Salloum, 2020; Alshurideh *et al.*, 2020; Park, 2020). Indeed, there is a significant relationship between EC and perceived usefulness. Hence, the following hypotheses are suggested:

H6: Expectation Confirmation has a positive effect on Satisfaction.

H7: Expectation Confirmation has a positive effect on Perceived usefulness.

3.6.7. Satisfaction (SA)

Satisfaction (SA) refers to “the affective attitude towards a particular computer application by an end user who interacts with the application directly” (Doll, Hendrickson and Deng, 1998). It has been found by (Joo, Kim and Kim, 2016)that learners with higher satisfaction reselect the same technology for their learning situations when utilizing new technologies such as

smartphones. Users have multiple layers of cognition in terms of satisfaction with any new technology adoption. Due to the user's experience with the threat/solution, by the time he reaches this phase, his expectations regarding the performance of a given product/solution are almost on the same level as reality and he has a high chance of achieving satisfaction with it. ECM posits that satisfaction is directly influenced by confirmation and perceived performance and is indirectly influenced by both expectations and perceived performance by means of a mediational (Yang *et al.*, 2022). This summarizes that satisfaction is an effective construct of ECM. Since a blockchain encrypts, validates, and permanently records transactions, it ensures the cryptocurrency's integrity (Shin and Hwang, 2020). The customer experience, also known as CX, gives you an insight into how customers perceive your brand from their perspective, boosting confidence in the users. Any threats related to the unfamiliarity of the technology, security threats, and adaptation blocks can be addressed by using ECM (Wamba, 2019). As ECM is a psychological approach to tackling a threat, it is capable of bridging the gaps and overcoming any threats effortlessly. Data shared across a business network can be traced using blockchain technology, increasing trust, security, transparency, and efficiency (Sumit *et al.*, 2022). These are the expectation of the users, and this prerequisite being met by block chain leads to the satisfaction that there aids to continued use. Several studies triggered that SA has a significant impact on CI (Alshurideh *et al.*, 2020; Dai *et al.*, 2020; Park, 2020). Hence, the following hypothesis is formulated:

H8: Satisfaction has a positive effect on blockchain technology sustainability.

3.6.8. Perceived usefulness (PU)

Perceived usefulness (PU) refers the “the degree to which a person believes that using a particular system would enhance his or her job performance” (Davis, 1989). The perceived

usefulness of information is a crucial construct in formulating management information systems. It has three dimensions distinguished, namely performance-related outcome expectations, personal-related outcome expectations, and intrinsic motivation (Saadé, 2007). Perceived usefulness can be defined as the subjective probability of increasing a user's ability to complete a given task. There is extensive evidence proving the significance of the effect of perceived usefulness on adaptation intention. (Venkatesh and Davis, 1996) Suggested that perceived usefulness is an important factor in arriving at conclusions that determine the continued usage, and this factor is directly linked and permeates with ECM. Concerns regarding security, values, and standards are essential to establish any new technology blockchain as a technology is still in its nascent stages, and this is one of the major factors that affect the perceived usefulness of the technology(Lu, 2019). Many fields made progress using blockchain technology, and the number of users has exponentially increased, and blockchain is the next big thing in the field of technology (Andrii Horiachko, 2022). Many researchers, such as (Koufaris, 2002), have validated PU and found that it affects users' intentions, establishing it as a construct that has tremendous support from many other technological applications. A study by (Horton *et al.*, 2001)asserted that PU positively affects intentions in intranet media. Additionally, (Agarwal and Prasad, 1999); (Chau and Hu, 2001); (Davis, 1989); (Hu *et al.*, 1999); (Igbaria, Guimaraes and Davis, 1995); (Igbaria, 1993); (Mathieson, 1991); (Mathieson, Peacock and Chin, 2001); (Moon and Kim, 2001); (Ramayah and Jantan, 2002); (Venkatesh, Davis and College, 2000) concluded that PU has a significant effect on behavioural intent. However, there is always a negative mindset and fear of security and privacy that follows technology that gains huge attention (Lu, 2019). Recent advancements in blockchain technology, however, are creating a sense of security and safety for users. After familiarizing ourselves with the technology, we can then use ECM, which is a psychological mechanism to deal with perceived threats, to establish

an expectation of the technology performance that can be met. Using ECM as a methodology can lead to a thorough belief of perceived usefulness in the users. This eventually leads the users to arrive at a confirmation to continue the usage of block chain technology(Andoni *et al.*, 2019). In the field of electronic banking, the importance of perceived usefulness has been widely recognized (Polatoglu and Ekin, 2001; Liao and Cheung, 2002; Laforet and Li, 2005; Guriting and Oly Ndubisi, 2006). Previous research such as (Al-Emran, Arpaci and Salloum, 2020; Park, 2020; Suzianti and Paramadini, 2021)indicated that PU has a significant relationship with Satisfaction (SA). Therefore, the following hypotheses are put forward:

H9: Perceived usefulness has positive effect on blockchain technology sustainability.

H10: Perceived usefulness has a positive effect on Satisfaction.

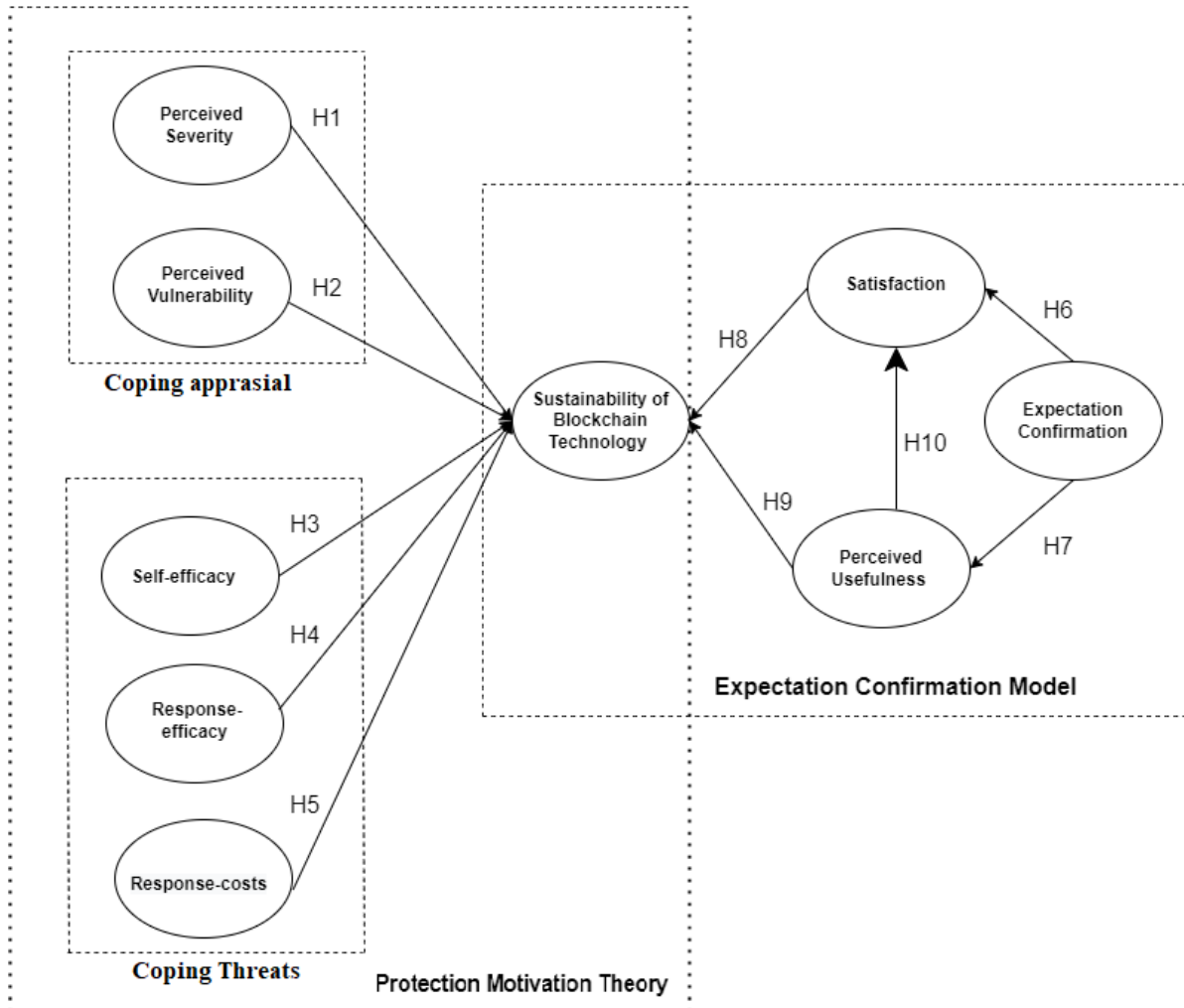


Figure 7.Proposed theoretical model

CHAPTER 4

RESEARCH METHODOLOGY SECOND EDITION

4. Overview

This research covers blockchain-technologies and the factors affecting the sustainability of blockchain technology in higher education using the SEM-ANN approach. An integrated research model by combining PMT and ECM is built to achieve a holistic understating of the system.

4.1.Research Design

In this research, the proposed work is adopted through a quantitative-based research approach for exploring the factors affecting the sustainability use of blockchain technology in higher education. Furthermore, questionnaire surveys are used in particular for data collection. (Huang, 2014) advised that the quantitative approach guides in analyzing the data of the survey as well as examining the factors that impact the acceptance of users for a specific technology. Compared to the qualitative research method, it can be deduced that quantitative data is considerably more effective as the research hypothesis can be evaluated and tested by applying several different statistical techniques. (Punch, 1998) indicated that surveys help researchers to determine the respondents' perceptions by means of a variety of inquiries for indicating their assessment for a measurement scale. Furthermore, a study undertaken by (Malhotra and Grover, 1998) suggested that surveys are considered the most suitable methods to determine the relationship among the factors being used in the study.

4.1.1. Instrument Development and Measurement

The data is collected by means of an online survey. The first part of the questionnaire includes the aim of this study, the consent form and questions about socio-demographic characteristics (such as gender, age, nationality, education level, and educational institute), blockchain technology usage patterns, experience and frequency see Figure 16 in Appendix E. Respondents who filled-in the online questionnaire are asked to tick a box indicating their willingness to participate in the study as seen in Appendix D. In the second part of the questionnaire; the respondents have given the scenario of the potential use case, security and services of a blockchain-based application in the context of its sustainability in higher education which includes conceptual model factors such as Perceived Severity (PS), Perceived Vulnerability (PV), Self-Efficacy (SE), Response Efficacy (RE), Response costs (RC), Expectation confirmation (EC), Perceived Usefulness (PU), sustainability (SUS), and Satisfaction (SA) see Table 6. Validated questions from previous research studies such as (Davis, 1989; Bhattacharjee, 2001; Allen C. Johnston and Warkentin, 2010; Ifinedo, 2012) are adapted to measure the applied model and theory in this study. In many of these researches, common questions are also used. Instruments that have been developed and empirically validated in previous research help to save time, costs and efforts required to develop new instruments. Most of the questions are in closed-ended form and based on (e.g., a five-point Likert scale ranging from “1 = strongly disagree” to “5 = strongly agree”). The participants took around 10-15 minutes to complete the questionnaire. The respondents will be asked to respond with their level of agreement on a five-point Likert scale constructed for each of the sections. A five-point scale is the most suitable and comprehensible, which enables respondents to express their perceptions and views. The constructs and their related items are presented in Table 5.

Table 5.Constructs and Their related Items as in the Research Instrument.

Constructs	Items	Content	Source
Perceived Severity	PS1	I believe that student records stored on blockchain is vulnerable to security incidents.	(Rogers and Prentice-Dunn, 1997)
	PS2	I believe that the productivity of blockchain is threatened by security incidents	
	PS3	I believe that the profitability of blockchain is threatened by data protection incidents	
	PS4	I believe that blockchain can allow remote access to student records.	
	PS5	I believe that blockchain can be used to download student records.	
Perceived Vulnerability	PV1	Blockchain could be vulnerable to security incidents.	(Rogers and Prentice-Dunn, 1997)
	PV2	Blockchain could be susceptible to security incidents.	
	PV3	A security problem to my personal data could occur if I do not comply with the institution's blockchain security policy.	
Self-Efficacy	SE1	It would be easy for me to use blockchain by myself.	(Sergueeva and Shaw, 2017)
	SE2	I could adopt blockchain even if there is no one around to tell me what to do.	
	SE3	I could adopt blockchain if I could contact someone when I got stuck.	
Response Efficacy	RE1	Blockchain can successfully prevent security incidents.	(Allen C Johnston and Warkentin, 2010a)
	RE2	Blockchain is the best solution for counteracting security problems.	
	RE3	If we use the blockchain in educational purposes, we can minimize the threat of security incidents.	
	RE4	Compliance with blockchain security policy reduces the security threat to my personal data.	
	RC1	Blockchain is expensive to purchase and operate.	(Rogers and Prentice-Dunn, 1997)

Response costs	RC2	We have to frequently upgrade our blockchain to download students' records.	
	RC3	Security incidents can slow down the blockchain performance.	
	RC4	Compliance with blockchain security policy would require a considerable investment of effort other than time.	
Expectation confirmation	EC1	My experience with using blockchain was better than what I expected.	(Bhattacharjee, 2001)
	EC2	The service provided by my university with respect to blockchain was better than what I expected.	
	EC3	Overall, most of my expectations from using blockchain in my institute were confirmed.	
Perceived Usefulness	PU1	Blockchain enhances my efficiency.	(Davis, 1989)
	PU2	Blockchain enables me to accomplish tasks more quickly.	
	PU3	Blockchain improves my performance.	
	PU4	Using blockchain increases my learning achievements.	
	PU5	Overall, blockchain is useful to me.	
Sustainability	SU1	I intend to continue using blockchain rather than discontinue its use.	(Bhattacharjee, 2001)
	SU2	I intend to continue using blockchain than other alternative means.	
	SU3	If I could, I would like to continue my use of blockchain.	
Satisfaction	SA1	I am satisfied with using blockchain as an assisted tool in my institution.	(Doll, Hendrickson and Deng, 1998)
	SA2	I am satisfied with using blockchain technology services.	
	SA3	My experience of using blockchain was very delightful.	

4.1.2. Instrument Validation

Before considering an instrument to be valid, it shall be reliable. Nevertheless, reliability must not rely on validity (Kimberlin and Winterstein, 2008). Validity mentions the notion of the degree to which it measures what it claims to measure. On the other hand, Reliability is referred

to as the consistency of a measure employed in certain research (Sekaran and Bougie, 2010). The reliability of a questionnaire is a way via which procedures for quality measures can be utilized for collecting the data. For considering a result to be valid, the measurement procedure must be reliable. Reliability often comprises the degree to which a measurement of a specific phenomenon provides consistent and stable outcomes. Generally, there are two consecutive stages of instrument validation; this comprises pre-testing and pilot study.

4.1.2.1. Pre-testing

In this phase, the researcher must select some academic experts as reviewers to examine the instrument constructed. Experts are often requested to assess the equivalent items to every factor with regard to the easiness of understanding, precision, and relevance to the objectives of the study. Founded on the feedback and comments of the experts, the instrument is then improved and modified respectively.

4.1.2.2. Pilot Study

This stage of the study represents the second phase for validating an instrument. The pilot study is often referred to as a trial run, such as a small-scale research study of a major research project. A pilot test is a crucial step that benefits researchers by figuring out potential difficulties and preventing them from growing. For the purpose of testing, it is best to choose a pilot group that is demographically like the target population. Feedback from the participants after applying the pilot test provides a glimpse into how respondents may respond to a specific question. Most meaningfully, a pilot study often confirms if the test is considered to be a good fit for the selected population and whether minor modifications in the survey questions are important or suitable.

Prior to conducting the final research study, this stage is considerably important (Sekaran and Bougie, 2010). The study must offer a brief detail regarding the study, who the participants are and how the survey can acquire the required sample size (such as, by self-administration, by email, or both). Based on the study conducted by (Hunt, Sparkman and Wilcox, 1982), the minimum number of respondents in any pilot study is usually 30. In this stage, the internal consistency of the items is measured using Cronbach's Alpha to ensure reliability. (Hair *et al.*, 2010) advised that the values of Cronbach's Alpha must be above 0.7 to be accepted. Hence, if the reliability of the specific scale is confirmed, this will lead to the final version of the instrument that would be ready for distribution. Otherwise, the researcher may need to manipulate the instrument and repeat these phases once again. In this study, the number of responses in the pilot study was 48 responded. Table 7. Show the result of Constructs Reliability and Validity of the pilot study.

Table 6.Constructs Reliability and Validity

Constructs	Number of Items	Cronbach's Alpha
Expectation confirmation	3	0.825
Perceived Severity	5	0.816
Perceived Usefulness	5	0.951
Perceived Vulnerability	3	0.763
Response-costs	4	0.768
Response-efficacy	4	0.937
Satisfaction	3	0.940
Self-efficacy	3	0.707
sustainability of blockchain technology	3	0.922

4.1.3. Population and Sample Size

The targeted population is the student enrolled in UAE universities using Blockchain technologies. In order to evaluate the research model, the survey method is used as a tool for collecting data from university students.

Following the ten times rules of Hair (Hair *et al.*, 2010), the minimum number of respondents should be at least 300. The G*Power tool was also employed to determine the minimum required sample size (Erdfelder *et al.*, 2009). The G*Power parameters include the values of 0.15 as the effect size, 0.01 as the error type (α), 0.8 as the power, and seven as the number of predictors. The minimum required sample size was found to be 142. Therefore, the collected sample size of 425 questionnaire surveys is considered satisfactory. In order to evaluate the research model, surveys are used as a tool for collecting data from the university students enrolled in different universities in the UAE. Due to the exploratory nature of this research, surveys are considered the best tools for such type of research.

Electronic mail surveys are sent out to the email addresses of the respective participants through organizational communicating channels. Unique codes are assigned to each participant. To obtain consent from the participants in the online survey, it is mentioned on the cover page to tick a box indicating their willingness to participate in the study. See Figure 15.

4.1.4. Sampling Technique and Units of Analysis

To the best of our knowledge, there are two types of sampling techniques: probability and non-probability sampling techniques. There are four kinds included in probability sampling such as sampling, stratified sampling, cluster sampling, and systematic sampling. In contrast, non-probability sampling comprises four types convenience sampling, quota sampling, judgment or purposive sampling, and snowball sampling. The selection of the technique primarily depends on the participant's availability and the nature of the study. Based on the analysis unit, the study must suggest the units of analysis employed to be obvious to the reader. Generally, there are two kinds of units; these include individual & organizational levels. In this study, the unit of

analysis is the individual level involving students using a purposive sampling technique to comply with the research objective of this study.

4.2.Data Collection and Ethical Procedures

Ethical approval from BUiD's Research Ethics Committee was acquired. Respondents are provided with suitable information about the purpose, methods and intended uses of the research in addition to their participation in the study. The privacy and confidentiality of the respondents are also maintained. The students are informed about the confidentiality and anonymity of all collected data. Information that can be used to identify students is often not collected. A consent form will be reviewed and signed by the respondents before completing the questionnaire assuring that the collected data will be used for scientific purposes only. Participants will be made evidently aware that they will not disclose their identity on the questionnaires. The names of the students will not be used in any reports. The participants will be well informed that the information provided on the questionnaire will remain strictly confidential.

The respondent's participation was voluntary. The subjects are free to withdraw at any time without giving any reason. If a respondent withdraws from the study, the data collected will be removed from the study and destroyed. The responses acquired through this survey will be stored, processed, and analyzed by authorized personnel involved in the study. Each subject was assigned a unique identifier that was used to identify the data. The collected electronic data is anonymous and is physically stored and pass-coded.

4.3.Data Analysis

Initially, the researcher ensures that the data is clean and ready to go into SPSS before conducting further statistical analysis. Data screening means checking data for errors and fixing or removing these errors, such as looking out for any missing data, outliers, normality, and

multicollinearity. The data gathered from the respondents is then entered into a computer software program called SPSS, where all the analysis is performed. Descriptive analysis is used to provide information about the demographics of the participants. It is in the form of frequency distribution for categorical items, and any issues that may negatively influence the analysis of the data are computed, including the standard deviation and the mean for the numeric variables. The analysis is presented graphically in the form of bar graphs for the items of each subscale of the survey. With regards to reliability, the internal consistency among the items within a similar construct is determined utilizing Cronbach's Alpha coefficient (α). (Hair *et al.*, 2010) stated that Cronbach's Alpha (α) values should be greater than 0.7 to be accepted.

4.3.1. Structural Equation Modelling (SEM)

Structural equation modelling (SEM) is one of the families of statistical methods which is most commonly used in research studies. Structural equation modelling (SEM) has considerably become extremely useful for a large number of research studies because of its capability to model the latent variables, consider a diversity of measurement errors, and test full theories. Furthermore, the SEM is also considered to be an example of multivariate analysis and a statistical method for testing and investigating a set of relationships between a certain hypothesis between several different independent and dependent factors (Gefen, Straub and Boudreau, 2000). Above and beyond, SEM permits scholars to answer a set of unified research questions in a single, systematic, and comprehensive analysis by investigating the association between the independent and dependent factors. Moreover, the SEM allows the joint analysis of both (structural models and measurement). Therefore, the measurement errors of the constructs detected can be examined as an integral part of the model. In addition, factor analysis is unified into a single process with the hypotheses testing. This study indicates using the SEM to examine

and test the hypothesized association between the factors in a specific conceptual model. There are two types of SEM: PLS-SEM and CB-SEM (Hair *et al.*, 2014; J. Hair *et al.*, 2016). CB-SEM is primarily utilized to confirm or reject theories (such as a set of systematic associations among different factors that can be inspected utilizing empirical procedures). PLS-SEM (i.e., PLS path modelling) is chiefly employed for constructing the theories in exploratory research. It is undertaken by focusing on understanding the variance in the dependent variables during the model examination. To answer the questions, such as when to utilize the CB-SEM or PLS-SEM, the researchers must focus on the objectives that differentiate the two methods.

4.3.2. Partial Least Squares (PLS)

One of the variance-based methods of SEM is PLS-SEM. PLS-SEM is normally utilized when the exploration objectives are construct prediction and development of the theory (Hair *et al.*, 2014; J. Hair *et al.*, 2016). PLS-SEM works proficiently with complex models and makes no suspicions about the information circulation (i.e., accepts that the information is non-regularly dispersed). Also, PLS-SEM can essentially deal with formative and reflective measurement models, as well as constructs with single and multi-item measures, without any recognizable identification issues. PLS-SEM has a higher statistical power compared to CB-SEM, in which PLS-SEM is more proficient in delivering a specific relationship as sure when it is, in fact, positive in the population. PLS-SEM is an engaging option in contrast to CB-SEM explicitly when there is a slight earlier information on the primary model connections or the estimation of the constructs or when the accentuation is more on investigation than declaration (Hair *et al.*, 2014; J. Hair *et al.*, 2016).

PLS-SEM is able to show the two elements and composites. This is valued by different researchers in different settings, which makes the PLS-SEM a promising strategy explicitly for

new innovation and data frameworks research (Henseler, Hubona and Ray, 2016). Along these lines, a review completed by (Urbach and Ahlemann, 2010) gave proof through an orderly writing audit that there is rising use of PLS in IS research studies. Likewise, a review led by (Hair *et al.*, 2017) demonstrated that PLS-SEM acceptance and continued usage in the IS research render the PLS-SEM an acknowledged strategy in the IS setting, explicitly when applied for the exploratory examination, model intricacy, and hypothesis development. Besides, PLS-SEM is viewed as a suitable methodology if the exploration objective is an expansion of a current structural theory (Hair, Ringle and Sarstedt, 2011).

4.4. Assessment of Measurement and Structural Models

The model assessments often provide empirical estimations of the measurement model (such as the association between the constructs and indicators) as well as the structural model (such as the association between constructs). This guides users to compare the theoretically formed structural models and measurement with reality, as categorized by means of the sample data. Hence, one can notice how adequately the theory fits the data. Here, a two steps strategy is recommended to examine a specific conceptual model. The primary one is associated with the measurement model assessment, whereas the second one is associated with the structural model assessment. The methods utilized to assess each step are verified in the sub-sections mentioned below.

4.4.1. Measurement Model Assessment

In this stage, the estimation model evaluation incorporates two fundamental methods: convergent validity and discriminant validity.

4.4.1.1. Convergent Validity

Concerning declaration (Hair *et al.*, 2014; J. Hair *et al.*, 2016), the principal standard to be evaluated is fundamentally the internal consistency reliability. The normal standard for internal consistency is Cronbach's Alpha (CA), which gives a proportion of the reliability as per the intercorrelations of the indicator variables that are being observed. Because of the impediments of Cronbach's Alpha, it is more reasonable to utilize one more measure of internal consistency reliability, which is known as composite reliability.

Composite reliability considers a diversity of external loadings of the indicator variables. For the most part, Cronbach's Alpha, as well as composite reliability values, are gone somewhere in the range of "0 and 1", where higher values are alluded to higher reliability levels. Explicitly, during an exploratory examination, values such as 0.60 to 0.70 can be viewed as acceptable, whereas in more advanced research, values of 0.70 to 0.90 are thought to be as satisfactory. Convergent validity alludes to "the degree to which a measure associates positively with elective proportions of a similar construct" declaration (Hair *et al.*, 2014; J. Hair *et al.*, 2016). To evaluate the convergent validity of reflective constructs, research studies ought to consider the external loadings (i.e., indicator reliability) of the actions (i.e., markers) and the Average Variance Extracted (AVE). Higher outer loadings on a specific construct uncover that the associated measures share a lot of commonalities, which is addressed by the construct. The outer loadings values ought to be ≥ 0.70 to be an acceptable declaration (Hair *et al.*, 2014; J. Hair *et al.*, 2016). The AVE alludes to "the grand mean value of the squared loadings of the indicators associated with the construct (i.e., the sum of the squared loadings divided by the number of indicators)" declaration (Hair *et al.*, 2014; J. Hair *et al.*, 2016). The values of AVE ought to be ≥ 0.50 to be accepted.

4.4.1.2. Discriminant Validity

Discriminant validity (DV) refers to "the degree to which a construct is truly distinct from different constructs by experimental principles" declaration (Hair *et al.*, 2014; J. Hair *et al.*, 2016). Hence, affirming the discriminant validity demonstrates that the variable is exceptional and addresses peculiarities that aren't caught by different factors in the model. As indicated by the declaration (Hair *et al.*, 2014; J. Hair *et al.*, 2016), research studies ought to rely upon two measures to survey the discriminant validity. Those actions are cross-loadings and the Fornell-Larcker criterion. As far as cross-loadings are concerned, an indicator's outer loading on the associated construct must be greater than all its cross-loadings (i.e., its correlation) on different constructs.

The Fornell-Larcker criterion looks at the square root of the AVE values with the connections of the latent variable. To be specific, the square root of each construct's AVE should be greater than its highest correlation with other constructs' declaration (Hair *et al.*, 2014; J. Hair *et al.*, 2016). Most current review led by (Henseler, Ringle and Sarstedt, 2015) has proposed another standard for surveying the discriminant validity, which is the supposed Heterotrait–Monotrait ratio (HTMT) of relationships. In straightforward words, HTMT is the mean of all relationships of indicators across constructs estimating various constructs. As per the proposed threshold level of HTMT by (Henseler, Ringle and Sarstedt, 2015), when constructs in the path model are thoughtfully particular, a <0.85 value is viewed as justified.

4.5. Structural Model Assessment

As soon as we confirm the results of the assessment for the measurement model, the next step would be to examine the structural model. The model's predictive capabilities and the associations among the constructs are typically examined. The primary assessment criteria for the structural model in PLS-SEM include the significance of the path coefficients, the R^2 values level, the f^2 effect size, and the predictive relevance Q^2 . The coefficient paths refer to the

hypothesized association between the constructs. Values of the path coefficients refer to the hypothesized association between constructs. These range between -1 and $+1$, where values close to $+1$ indicate strong positive relationships. Classically, most of the researchers use p values to evaluate the significance level. The p-value should be <0.05 when the assumption of the level of significance is 5% for the purpose of revealing the association being observed is significant. Hence, the interpretation of the results of the path model is founded on the significance assessment of all the structural model assessments using p and t values and the CI (confidence intervals).

Similarly, R^2 is also known as the most commonly used measure to examine the structural model. This type of coefficient is the measure of the predictive model's power. R^2 values often range between 0 and 1, where values on a higher side represent prediction determined at a higher accuracy level (Hair *et al.*, 2014; J. Hair *et al.*, 2016). (Chin, 1998) suggested that values of 0.67, 0.33, and 0.19 are categorized as substantial, moderate, and weak, respectively. The effect size (f^2) denotes the modification in the value of R^2 when a specific exogenous construct is detached from the model that can be utilized to examine whether the removed construct has a significant effect on the endogenous constructs. In regards to the effect size (f^2) assessment (Cohen, 1988), values of 0.02, 0.15, and 0.35 show small, medium, and large effects, respectively. The predictive relevance (Q^2) measure is one of the indicators of the model's out-of-sample predictive power.

4.6. Artificial Neural Network

As it's a known fact that PLS-SEM is predominantly utilized in examining linear models, there have been instances with a possibility of oversimplification of complications in the sustained use of blockchain technology in higher education. It was necessary to use an ANN approach

that was capable of identifying both linear and non-linear relationships as a result. Based on (Guresen, Kayakutlu and Daim, 2011), Artificial Neural Networks were selected as a prediction tool in addition to other methodologies because of the development of the multilayer concept. These techniques have a high potential for accurate predictions and are more precise in comparison to traditional regression procedures (Ooi *et al.*, 2018; Lee *et al.*, 2020; A. Sharma *et al.*, 2021; Alkawsi *et al.*, 2021; Kalinić *et al.*, 2021). In the case of the “BLACK-BOX” mode of operation, testing the hypothesis of casual relationships is impractical and derives no suitable results. This challenge was addressed by examining the causal relationships implementing the PLS-SEM method, followed by using the extract of the indicative factors as ANN precludes over-fitting of the model.

It is common for neural networks to contain an input layer, one or more hidden layers, and an output layer. The sigmoid function was used as the activation function for the hidden and output neurons. Model performance was improved by maintaining input and output neuron ranges within [0, 1] (Liu *et al.*, 2012; A. Sharma *et al.*, 2021; Kalinić *et al.*, 2021). An ANN model was trained using 90% of the data, and the remaining 10% was used for testing in order to avoid the issue of overfitting (Alshamaila, Papagiannidis and Li, 2013; Kalinić *et al.*, 2021).

CHAPTER 5

RESULTS AND DISCUSSION

5. Results and Discussion

5.1.Overview

In this chapter, I will examine the model by undertaking a thorough analysis of the data collected. Structural Equation Modelling (SEM) is successfully utilized (Ringle et al., 2015), and SPSS v.25 (SPSS® Statistics 25.0 - Overview | IBM, 2017) is used to obtain the demographic details of the respondents. The measurement and structural models (Inner and Outer, respectively) are also introduced along with the indicators and constructs, as the results show that seven hypotheses out of 10 were confirmed, and the proposed integrated theoretical model seemed to be valid for examining the factors affecting the sustainability use of blockchain technology in higher education in UAE.

5.2.Data Screening and Preliminary Analysis

5.2.1. Missing Data

Missing data are considerably the observations that are usually not recorded or are lost within the measuring instrument. One of the most relevant techniques utilized to reduce or prevent the chance of missing data is to ascertain a suitable design for the study (Smuk, 2015). Subsequently, one of the preventive strategies is used by means of Google forms (Google., 2021) for the purpose of eliminating the negative impacts of missing data. Google forms offer the ability to design all questions as compulsory to answer so that all the questionnaires returned are considered valid as there was no missing data.

5.2.2. Straight-lining Behavior

The Straight-lining behaviour often limits the data quality and associates the occurrence when any respondent provides similar answers for a list of Likert-scale survey questions (Kim *et al.*, 2019; Gogami *et al.*, 2021; VanDerSchaaf, Daim and Basoglu, 2021). Around 425 respondents were mentally disengaged from the survey; however, they still had to finish it. The respondents provided responses can be considered not practical as they did not answer the inquiries in a proper manner; therefore, the answers that were affected are coded as missing (Mirzaei *et al.*, 2021). In our case, 47 responses were dropped because of the straight-lining behaviour (having a variance of 0). These findings can be explained by means of having high levels of experience and education, as individuals with less education and experience are more likely to straight-line their answers (Kim *et al.*, 2019). Hence, the dataset after eliminating the straight-lined responses will be $N = 378$.

5.2.3. Analysis of Outliers

Outliers are observations which often break the patterns as exposed by other observations (Møller, Von Frese and Bro, 2005). There are some cases with extreme values that statistically misrepresent the data where the value on one variable as “univariate outlier” or odd values of 2 or more than two variables as “multivariate outliers” (Aguinis, Gottfredson and Joo, 2013). These researchers have classified the outliers into different categories, for example, interesting outliers, model fit outliers, and error outliers. Error outliers are introduced as data points within the most probable value range. The model fit outliers comprise the influential cases that impact the fit of the model. In this study, no error outliers were found because of the google forms functionality and strict Likert-scale to choose an answer with no specific need to enter a specific value. Conversely, 4 cases as influential outliers were considered using the Mahalanobis

Distance within the linear regression technique in SPSS as recommended by (Barbara G. Tabachnick and Linda S. Fidell, 2013) for the purpose of handling the multivariate outliers and followed by computing the value to calculate the probability of the outlier. For each variable, several critical χ^2 values, where the p value is $< .001$ and df is 1, less than the quant and df as the degree of freedom for the number of variables against the dependent variable. The 4 cases were removed as recommended handling method for the influential outlier (Aguinis *et al.*, 2010; Aguinis, Gottfredson and Joo, 2013; Mahapatra *et al.*, 2020). Hence, the dataset, without bearing in mind the outliers for investigation, will be $N = 374$.

5.2.4. Normality Testing

One of the critical processes is testing normality which depends on the normal distribution (Doornik and Hansen, 2008; Field, 2013). The PLS-SEM approach, on the other hand, does not need normality testing. (Rönkkö *et al.*, 2016; Joe F Hair *et al.*, 2019). Hence, the normality in this study was tested for the purpose of eradicating any doubt with respect to the normal distribution of the responses received. Two measures were demonstrated with respect to the normal distribution: Kurtosis (to measure the flatness or peakiness of a distribution) and Skewness (to measure the symmetry of a distribution) (Field, 2013). For both the measures, the acceptable ranges are (-2 and +2). (Kline Rex B, 2011) suggested that the acceptable range for kurtosis is (-3 and +3). Table 8 demonstrates that the data for every construct is normally distributed as all the kurtosis and skewness values are within the acceptable threshold. Negative kurtosis results demonstrate that the case distribution is considerably flat with thin tails (Platykurtic distributions), whereas the negative skewness results shows the distribution at the left side is long (Doornik and Hansen, 2008; Barbara G. Tabachnick and Linda S. Fidell, 2013).

Table 7.Summary of the Descriptive Statistics.

	Mean	Standard Deviation	Excess Kurtosis	Skewness
PS1	2.123	1.233	0.04	1.011
PS2	2.128	1.188	0.053	0.961
PS3	2.171	1.196	-0.06	0.909
PS4	2.433	1.37	-1.001	0.545
PS5	2.473	1.4	-1.081	0.513
PV1	2.326	1.184	-0.431	0.686
PV2	2.326	1.173	-0.55	0.622
PV3	2.586	1.319	-1.003	0.41
SE1	3.594	1.186	-0.516	-0.629
SE2	3.567	1.183	-0.632	-0.549
SE3	3.679	1.13	-0.202	-0.707
RE1	3.848	1.016	0.456	-0.918
RE2	3.834	1.047	0.338	-0.9
RE3	3.869	1.03	0.343	-0.886
RE4	3.888	1.046	0.587	-0.998
RC1	2.904	1.267	-1.037	0.205
RC2	2.971	1.235	-1.042	0.09
RC3	2.928	1.238	-0.995	0.18
RC4	2.973	1.249	-1.073	0.109
EC1	3.898	1.006	0.281	-0.856
EC2	3.888	0.994	0.008	-0.725
EC3	3.928	0.974	0.396	-0.847
PU1	3.968	0.983	0.504	-0.935
PU2	4	0.965	0.657	-0.987
PU3	3.963	0.978	0.213	-0.838
PU4	3.973	0.973	0.24	-0.839
PU5	4.051	0.976	0.908	-1.073
SU1	4.008	0.982	0.711	-1.001
SU2	4.019	0.943	0.61	-0.939
SU3	4.037	0.978	0.566	-0.989
SA1	4.043	0.933	0.582	-0.939
SA2	4.083	0.899	0.676	-0.939
SA3	4.032	0.964	0.519	-0.927

5.2.5. Analysis of Common Method Bias (CMB)

With reference to PLS-SEM, common method variance is a problem produced by the study's measurement design rather than the model being evaluated (Kock, 2015). The instructions given

before beginning the questionnaire, for example, might have an impact on the participants and how they reply to each question. The CMB may be analyzed using SmartPLS utilizing an automated process that considers the variance inflation factor computation (VIF). VIF is a metric for calculating multicollinearity for a collection of multiple regression variables (Kock and Lynn, 2012). The VIF for the latent variables in the model is lower than the prescribed threshold (3.3) in all of the values, as shown in Table 9, indicating that the model is not tainted by common method bias (Kock, 2015).

Table 8.Results of VIF (CMB).

	CI	EC	PS	PU	PV	RC	RE	SA	SE
CI									
EC				1.000				2.684	
PS	2.103								
PU	3.259							2.684	
PV	2.14								
RC	1.197								
RE	2.074								
SA	3.212								
SE	1.743								

5.3.Demographic Details for Participants

Our population is driven from the student studying in United Arab Emirates universities. The table below provides some descriptions of the population understudy in terms of:

- Age group
- Gender
- Nationality
- Educational Institute
- Educational level

Table 10 shows the demographic characteristics of the respondents, which were determined using the frequencies analysis in SPSS. As a result, in Table 10 and Figure 8 it considering the total responses received were males, 52.67% of respondents were females 47.32%. From the age perspective, most of the respondents, 50.53% were between the ages 18-22 years; meanwhile, 37.16% were between 23 to 28 years. About 57.48% were non-locals, while 42.51% were locals. As well as, almost 56.68% of the participants were undergraduate, while 43.31% were postgraduate. Around 35.56% of the students were studying at the British University in Dubai, followed by 32.88% from UAE University, 23.52% from Zayed University and 8% at the University of Dubai. In general, the participants are familiar with blockchain technology, with experience from 0 to 1 year 52.94% and from 2 to 3 years 44.91%.

Table 9. Sociodemographic characteristics of the respondents.

Item	Values	Frequency	Percentage
Gender	Male	177	47.32%
	Female	197	52.67%
Age	18-22	189	50.53%
	23-28	139	37.16%
	29-35	40	10.69%
	above 35	6	1.6%
Educational Institute	The British University in Dubai	133	35.56%
	UAE University, Al Ain, UAE	123	32.88%
	University of Dubai	30	8%
	Zayed University	88	23.52%
Educational level	Postgraduate	162	43.31%
	Undergraduate	212	56.68%
Nationality	Non-Local	215	57.48%
	Locals	159	42.51%

Experience	0 to 1	198	52.94%
	2 to 3	168	44.91%
	4 to 6	6	1.6%
	Above 5	2	0.53%

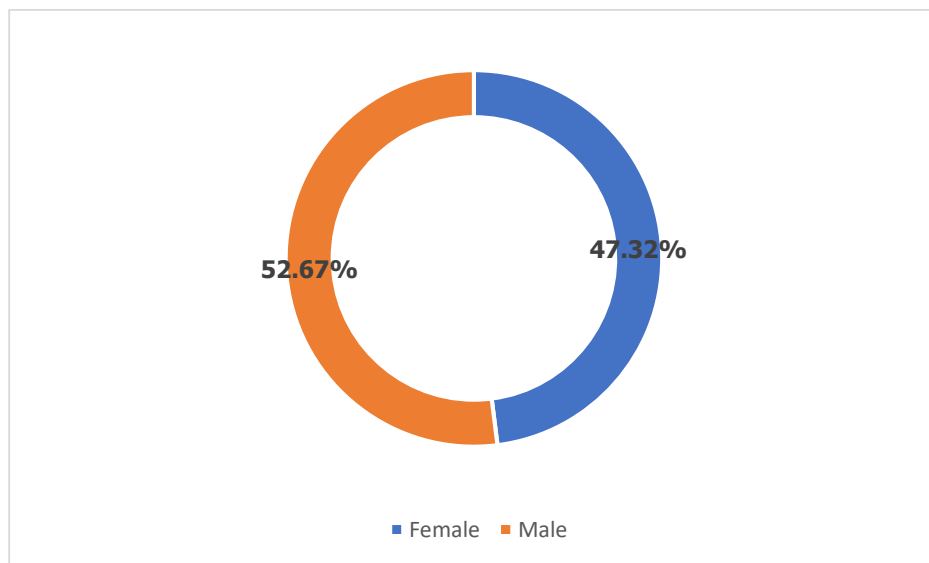


Figure 8. Gender Distribution.

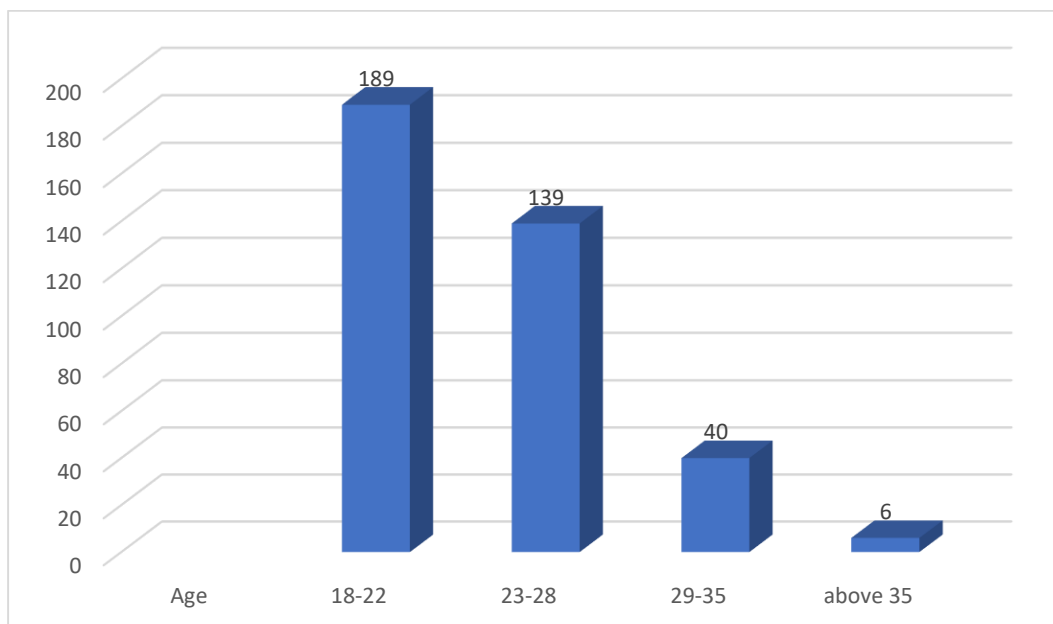


Figure 9.Age Distribution.

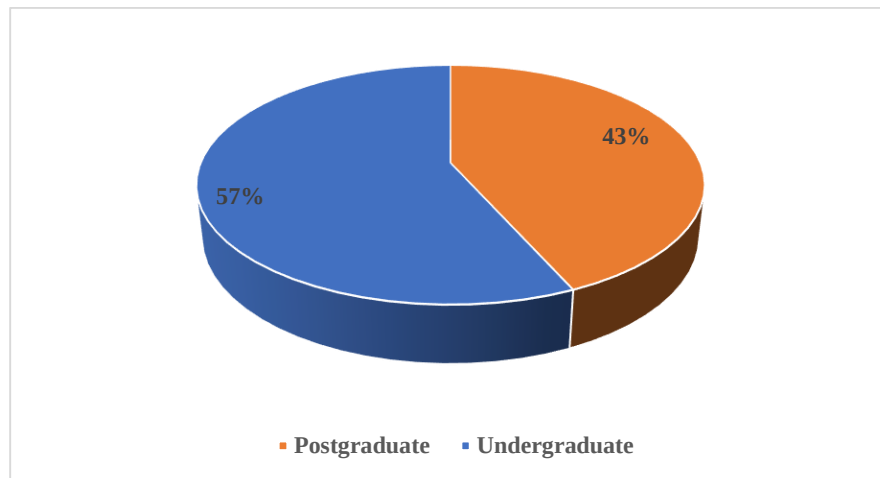


Figure 10.Educational level.

5.4.Partial Least Square Analysis Methodology

Partial least square (PLS) is considered to be a powerful analysis as it is not demanding when it comes to measuring scales: normality, residual distributions, measure type, and sample size (Chin W W, 1998; Hair, Ringle and Sarstedt, 2011). Besides its capability to confirm theories, PLS can be used to ascertain the existence of relationships, as well as propose propositions for testing at a later stage(Chin W W, 1998). SmartPLS was developed by (Ringle, C. M., Wende, S. & Will, 2005), and it is considered a distinguished application for the “Partial Least Squares Structural Equation Modelling (PLS-SEM).” It became famous because it is freely available and utilized by researchers, and its interface is user-friendly. It also offers advanced innovative reporting features (Wong, 2013).

5.4.1. Assessment of the Measurement Model

The Measurement Model often represent the association between latent constructs and indicators as a measure. (Hair *et al.*, 2017) mention that to assess the measurement model, the discriminant and convergent validity are important. The two validities offer the measurement

model with the needed indicator for “goodness of fit”(Joo, Lee and Ham, 2014). The convergent validity shows the degree to which there is a high relation between certain constructs which are identical theoretically. Whereas discriminant validity offers the degree to which a certain construct can be different from other constructs(Rahman *et al.*, 2013).

5.4.2. Convergent Validity

(J. Hair *et al.*, 2016) recommended that internal consistency reliability and validities (discriminant and convergent) are significant to be measured for the purpose of examining the measurement model. The reliability was measured by means of composite reliability (CR) and Cronbach’s alpha (Hair Jr *et al.*, 2016; Salloum *et al.*, 2019). Table 10 presents the composite reliability, factor loadings, values of average variance extracted (AVE) and Cronbach’s alpha. The findings for Cronbach’s alpha and composite reliability have been found larger than 0.70 as a suggested value (Hair Jr *et al.*, 2016; Sekaran & Bougie, 2016;Kundu & Gahlawat, 2018). Subsequently, all measures are satisfactory with regard to the reliability where the internal consistency reliability was confirmed.

Furthermore, the convergent validity (J. Hair *et al.*, 2016) was examined as a party of the validity for the measurement model (Roky and Meriouh, 2015). AVE values were examined in order to deduce the convergent validity (Hair *et al.*, 2017). The AVE values seen in table 10 for all constructs exceeded the recommended value of 0.5, so the construct can generate a minimum of 50% of the variance of its items (Fornell and Larcker, 1981; Joseph F. Hair *et al.*, 2019). For this reason, the convergent validity of the measurement model was established.

5.4.3. Discriminant Validity

Conversely, the cross-loadings, Heterotrait-Monotrait ratio (HTMT) and Fornell-Larcker criterion, were measured to ensure the discriminant validity existence (Fornell and Larcker,

1981; J. Hair *et al.*, 2016). With regards to the Fornell-Larcker scale, usually, the bold diagonal values demonstrate the square root of AVE scores which is larger as compared to the off-load diagonal values (its correlations amongst constructs) (Tsai *et al.*, 2019). Hence, the Fornell-Larcker criterion was established in table 12. Furthermore, the cross-loadings criterion in table 13 was also established as the findings of the cross-loadings for all items were larger compared to the loading of its corresponding items.

Hence, the Heterotrait-Monotrait ratio (HTMT) can also be calculated for ascertaining the discriminant validity. It demonstrates the average item value association within any construct, which can be compared with the mean associations for the items that intend to measure a similar construct (Joseph F. Hair *et al.*, 2019). Henseler proposed the HTMT (Henseler, Ringle and Sarstedt, 2015), as a method of replacement for the Fornell-Larcker criterion (Voorhees *et al.*, 2016; Joseph F. Hair *et al.*, 2019). It has been demonstrated that the Fornell-Larcker approach is not always correct, particularly when the loadings on various constructs are slightly varied (Henseler, Ringle and Sarstedt, 2015). Some concerns may appear if the HTMT values are at a peak. For example, if the HTMT value is above 0.90, then the discriminant validity (Joseph F. Hair *et al.*, 2019). is usually not presented. However, if the structural model constructs are conceptually identical, then the threshold value of the proposed, i.e. 0.90, is acceptable (Henseler, Ringle and Sarstedt, 2015). furthermore, if the constructs are more distinct, then the proposed threshold must be lower and more conservative, and the value is 0.85 (Joseph F. Hair *et al.*, 2019)

Table 10.Results of Convergent Validity and Internal Consistency Reliability.

Constructs	Items	Loading	Cronbach's Alpha	Composite Reliability	AVE
Sustainability	SUS1	0.938	0.938	0.960	0.890

	SUS2	0.939			
	SUS3	0.953			
Expectation Confirmation	EC1	0.922	0.938	0.960	0.890
	EC2	0.953			
	EC3	0.954			
Perceived Severity	PS1	0.893	0.948	0.960	0.827
	PS2	0.923			
	PS3	0.935			
	PS4	0.910			
	PS5	0.884			
Perceived Usefulness	PU1	0.917	0.971	0.977	0.896
	PU2	0.962			
	PU3	0.962			
	PU4	0.952			
	PU5	0.940			
Perceived vulnerability	PV1	0.955	0.938	0.961	0.891
	PV2	0.965			
	PV3	0.910			
Response Cost	RC1	0.930	0.96	0.971	0.893
	RC2	0.964			
	RC3	0.929			
	RC4	0.954			
Response Efficacy	RE1	0.959	0.976	0.982	0.933
	RE2	0.974			
	RE3	0.965			
	RE4	0.966			
Satisfaction	SA1	0.970	0.965	0.977	0.935
	SA2	0.969			
	SA3	0.962			
self-efficacy	SE1	0.945	0.937	0.96	0.889
	SE2	0.953			
	SE3	0.929			

Table 14 shows the Heterotrait-Monotrait ratio values of the correlations (HTMT). It can be noticed that all values of HTMT were less than the proposed threshold and the target met. Finally, the findings of cross-loadings, the Fornell-Larcker criterion, and the Heterotrait-Monotrait ratio could demonstrate the presence of discriminatory validity with no concerns.

Table 11.Fornell-Lacker Scale.

	SUS	EC	PS	PU	PV	RC	RE	SA	SE
SUS	0.943								
EC	0.722	0.943							
PS	-0.439	-0.462	0.909						
PU	0.805	0.792	-0.387	0.947					
PV	-0.416	-0.407	0.701	-0.4	0.944				
RC	-0.223	-0.191	0.359	-0.154	0.379	0.944			
RE	0.553	0.564	-0.300	0.57	-0.250	-0.087	0.966		
SA	0.867	0.740	-0.394	0.816	-0.392	-0.184	0.562	0.967	
SE	0.451	0.488	-0.238	0.459	-0.173	-0.082	0.638	0.456	0.943

Table 12.Cross-loading Results.

SUS1	0.938	0.658	-0.423	0.738	-0.367	-0.200	0.513	0.798	0.430
SUS2	0.939	0.716	-0.420	0.771	-0.407	-0.216	0.518	0.828	0.423
SUS3	0.953	0.670	-0.399	0.768	-0.403	-0.216	0.533	0.828	0.425
EC1	0.701	0.922	-0.448	0.753	-0.390	-0.210	0.539	0.679	0.447
EC2	0.668	0.953	-0.448	0.732	-0.397	-0.170	0.518	0.697	0.451
EC3	0.676	0.954	-0.411	0.756	-0.364	-0.161	0.538	0.718	0.482
PS1	-0.388	-0.404	0.893	-0.345	0.613	0.297	-0.263	-0.369	-0.212
PS2	-0.450	-0.430	0.923	-0.390	0.634	0.307	-0.340	-0.399	-0.259
PS3	-0.413	-0.404	0.935	-0.369	0.656	0.334	-0.302	-0.348	-0.231
PS4	-0.372	-0.435	0.910	-0.324	0.654	0.357	-0.228	-0.340	-0.186
PS5	-0.360	-0.429	0.884	-0.322	0.633	0.345	-0.215	-0.329	-0.183
PU1	0.749	0.781	-0.355	0.917	-0.349	-0.123	0.550	0.777	0.462
PU2	0.776	0.754	-0.363	0.962	-0.384	-0.144	0.530	0.790	0.433
PU3	0.768	0.746	-0.385	0.962	-0.393	-0.157	0.540	0.783	0.427
PU4	0.745	0.741	-0.395	0.952	-0.413	-0.173	0.536	0.771	0.423
PU5	0.771	0.726	-0.333	0.940	-0.355	-0.134	0.542	0.743	0.428
PV1	-0.395	-0.374	0.661	-0.383	0.955	0.322	-0.253	-0.381	-0.174
PV2	-0.395	-0.376	0.650	-0.374	0.965	0.339	-0.253	-0.364	-0.155
PV3	-0.388	-0.402	0.674	-0.376	0.910	0.413	-0.202	-0.364	-0.161
RC1	-0.221	-0.170	0.309	-0.156	0.334	0.930	-0.074	-0.166	-0.073
RC2	-0.203	-0.187	0.355	-0.151	0.382	0.964	-0.070	-0.157	-0.082
RC3	-0.217	-0.177	0.347	-0.153	0.359	0.929	-0.110	-0.197	-0.087
RC4	-0.201	-0.186	0.346	-0.119	0.357	0.954	-0.071	-0.173	-0.066
RE1	0.519	0.546	-0.312	0.537	-0.269	-0.098	0.959	0.515	0.635
RE2	0.544	0.560	-0.309	0.561	-0.246	-0.100	0.974	0.558	0.602
RE3	0.527	0.543	-0.286	0.541	-0.241	-0.091	0.965	0.539	0.604
RE4	0.545	0.530	-0.254	0.562	-0.212	-0.047	0.966	0.559	0.626
SA1	0.811	0.730	-0.366	0.780	-0.376	-0.180	0.524	0.970	0.419

SA2	0.856	0.707	-0.380	0.809	-0.372	-0.176	0.563	0.969	0.457
SA3	0.849	0.711	-0.397	0.780	-0.389	-0.177	0.543	0.962	0.448
SE1	0.412	0.458	-0.239	0.418	-0.172	-0.104	0.573	0.420	0.945
SE2	0.447	0.486	-0.256	0.449	-0.196	-0.094	0.607	0.450	0.953
SE3	0.415	0.435	-0.176	0.430	-0.120	-0.032	0.626	0.420	0.929

Table 13.Results of Heterotrait- Monotrait Ratio (HTMT).

	SUS	EC	PS	PU	PV	RC	RE	SA	SE
SUS									
EC	0.770								
PS	0.463	0.491							
PU	0.843	0.830	0.401						
PV	0.443	0.434	0.744	0.420					
RC	0.235	0.201	0.379	0.159	0.400				
RE	0.577	0.590	0.309	0.585	0.262	0.089			
SA	0.911	0.778	0.410	0.843	0.412	0.191	0.579		
SE	0.481	0.520	0.249	0.481	0.184	0.086	0.668	0.479	

5.5.Assessment of the structural Model

(J. F. Hair *et al.*, 2016) recommended that the path significance must be analysed and the coefficient of determination (R^2) shall be measured for the purpose of examining the structural model.

5.5.1. Coefficient of Determination – R^2

The R^2 value (coefficient of determination) is being utilized on a frequent basis for examining the structural model (Dreheeb, Basir and Fabil, 2016). It mainly guides in controlling the predictive accuracy of a model by means of computing the squared association of certain endogenous constructs predicted as well as actual values. Furthermore, the coefficient specifies the combined impact of exogenous latent-variables on the endogenous ones (Senapathi and Srinivasan, 2014; J. Hair *et al.*, 2016). Hence, it also aids to imply the degree of variances' in endogenous constructs evaluated by every exogenous construct which are connected. When we

talk about the R^2 Value the following is the basic to categorize the result of R^2 value, if the value is higher than 0.67, it is considered as high, whereas the value from “0.33 - 0.67” and from “0.19 - 0.33” are moderate and weak, respectively. When R^2 is less than 0.19, it is generally considered unacceptable. (Chin, 1998). (Falk and Miller, 1992) Conversely, indicated that 0.10 as the lowest acceptable value for the R^2 value, where a low R^2 value such as 0.10 is thought to be satisfactory based on the discipline as well as the context of the study.

The value of R for the constructs expect PU are more than 0.67. Thus, the constructs' predictive power values are high. For the Perceived Usefulness construct between (0.33 and 0.67), the value is moderate. The model has examined three endogenous variables: Perceived vulnerability, sustainability, and Satisfaction. The sustainability factor was anticipated by perceived severity, perceived vulnerability, self-efficacy, response efficacy, response costs, Satisfaction, and perceived usefulness resulting is a value of $R^2 = 0.791$, which indicate that those aforementioned constructs could explain 79.1% of the variance in the sustainability to accept the blockchain technology in higher education. The results of the other endogenous variables can be seen in Table 15.

Table 14. Coefficient of Determination (R^2) Results.

	R Square	Result
SUS	0.791	high
PU	0.627	Moderate
SA	0.690	high

5.5.2. Model Goodness of Fit

In PLS-SEM, goodness-of-fit measures are still in their nascent phases (J. F. Hair *et al.*, 2016); indeed, the suitability of goodness-of-fit measures is still being explored (Henseler, Hubona and Ray, 2016). As a result, no clear conclusions can be taken from the model's goodness of fit measurements. SmartPLS provides many goodness-of-fit measurements such as the standard

root-mean-square residual (SRMR), dULS, dG, Chi2, normed fit index (NFI), and RMSttheta, as seen in Table 16.

The responsibility of SRMR is to display the difference between observed associations and the model's implicit correlation matrix (J. F. Hair *et al.*, 2016), where a value less than 0.08 indicates a satisfactory fit measure (Hu and Bentler, 1998). Furthermore, the NFI measure expresses the Chi2 value as a ratio for the recommended and benchmark models (Lohmoller, 1989), where the bigger parameters indicate higher NFI and NFI values greater than 0.80 indicate strong model fit (Bentler and Bonett, 1980; J. Hair *et al.*, 2016). On the other hand, the squared Euclidean distance (dULS) and the geodesic distance (dG) are used to demonstrate the contradiction between the covariance matrix and the empirical one, as established by the composite-factor model(Dijkstra and Henseler, 2015; J. Hair *et al.*, 2016).

(Lohmoller, 1989) defined RMSttheta as the root mean squared residual covariance matrix of the outer model residuals. Because outer model residuals for formative measurement models are meaningless, this fit metric is only appropriate for evaluating purely reflective models. As presented by (Hair Jr *et al.*, 2016), a saturated model analyzes the connection between constructs, whereas an estimated model considers overall effects and model structure. In general, the model fits well because all of the variables are within the appropriate ranges.

Table 15.Summary of Model Fit.

	Saturated Model	Estimated Model
SRMR	0.032	0.053
d_ ULS	0.562	1.580
d_ G	1.015	1.029
Chi-Square	2337.095	2336.760
NFI	0.869	0.869

5.5.3. Test of the Hypotheses - Path Coefficient

In order to test the hypotheses that are related to the correlations between observed and latent variables, structural equation modelling is considered a comprehensive method (Hoyle, 1995). Therefore, all hypotheses have been evaluated simultaneously through the SEM technique. Figure 7 illustrates a construct model where each correlation hypothesized was evaluated in the analysis. To identify the significance levels among path coefficients, a PLS-SEM was conducted with 5000 re-samples utilizing a nonparametric test of significance -bootstrapping approach. Or A PLS-SEM with 5000 re-samples was performed utilizing a nonparametric test of significance -bootstrapping approach to determine the significance levels among route coefficients (Vinzi, Trinchera and Amato, 2010; Gil-Garcia, 2011; Hair, Ringle and Sarstedt, 2011; J. Hair *et al.*, 2016). The model's results presented in Figure 11 shows that the model can explain 79.1% of the total variance in the sustainability of using blockchain technology in higher education, along with 69% of the total variance of satisfaction and 62.7% of perceived usefulness. The results of the hypotheses testing can be seen in Table 17. The result shows that seven hypotheses out of ten were supported by the conducted experimental test, whereas H2, H3, and H4 were rejected. In detail, the findings indicated that satisfaction has a significant positive influence on sustainability ($\beta=0.590$, $P<0.001$) and perceived usefulness ($\beta= 0.258$, $P<0.001$). So, the results support H8 and H9. Also, H6 and H7 are supported because the results pointed out that expectation confirmation has a significant positive influence on satisfaction ($\beta= 0.251$, $P<0.001$) and perceived usefulness ($\beta= 0.792$, $P<0.001$). In addition, H10 is supported because it has a significant positive influence on Satisfaction ($\beta= 0.617$, $P<0.001$). In contrast with the proposed hypothesis in H2, there is no significant effect on the sustainability of blockchain technology in higher education ($\beta=0.000$, $P=0.988$). Therefore, H2 is rejected. Similarly, the analysis has

specified a lack of significant path in self-efficacy ($\beta=0.019$, $P=0.570$) and response efficacy ($\beta=0.035$, $P=0.296$) in the sustainability of blockchain technology. Thus, H3 and H4 are not supported.

In line with H1, the results revealed that the perceived severity construct has a significant positive effect on the sustainability of blockchain technology in higher education ($\beta=-0.076$, $P<0.001$), which supports hypothesis H1. Finally, the results could verify that the sustainability of using Blockchain technology in higher education is significantly influenced by response cost ($\beta=-0.044$, $P<0.001$).

Table 16.Path coefficient results.

Hypot thesis		Original Sample (O)	Sample Mean (M)	Standard Deviation (STDEV)	T Statistics (O/STDEV)	P Values	Direction	Decision
H7	EC -> PU	0.792	0.792	0.036	21.907	0.000	Positive	Supported
H6	EC -> SA	0.251	0.246	0.073	3.423	0.001	Positive	Supported
H1	PS - >SUS	-0.076	-0.076	0.038	2.004	0.045	Positive	Supported
H9	PU -> SUS	0.258	0.266	0.064	4.037	0.000	Positive	Supported
H10	PU -> SA	0.617	0.623	0.068	9.090	0.000	Positive	Supported
H2	PV -> SUS	0.000	0.002	0.035	0.014	0.989	Positive	Not Supported
H5	RC -> SUS	-0.044	-0.043	0.020	2.207	0.027	Negative	Supported
H4	RE -> SUS	0.035	0.035	0.034	1.045	0.296	Positive	Not Supported
H8	SA -> SUS	0.590	0.583	0.062	9.508	0.000	Positive	Supported
H3	SE -> SUS	0.019	0.020	0.033	0.574	0.566	Positive	Not Supported

Note: $p^{***}<0.001$, $p^{**}<0.01$, $p^{*}<0.05$

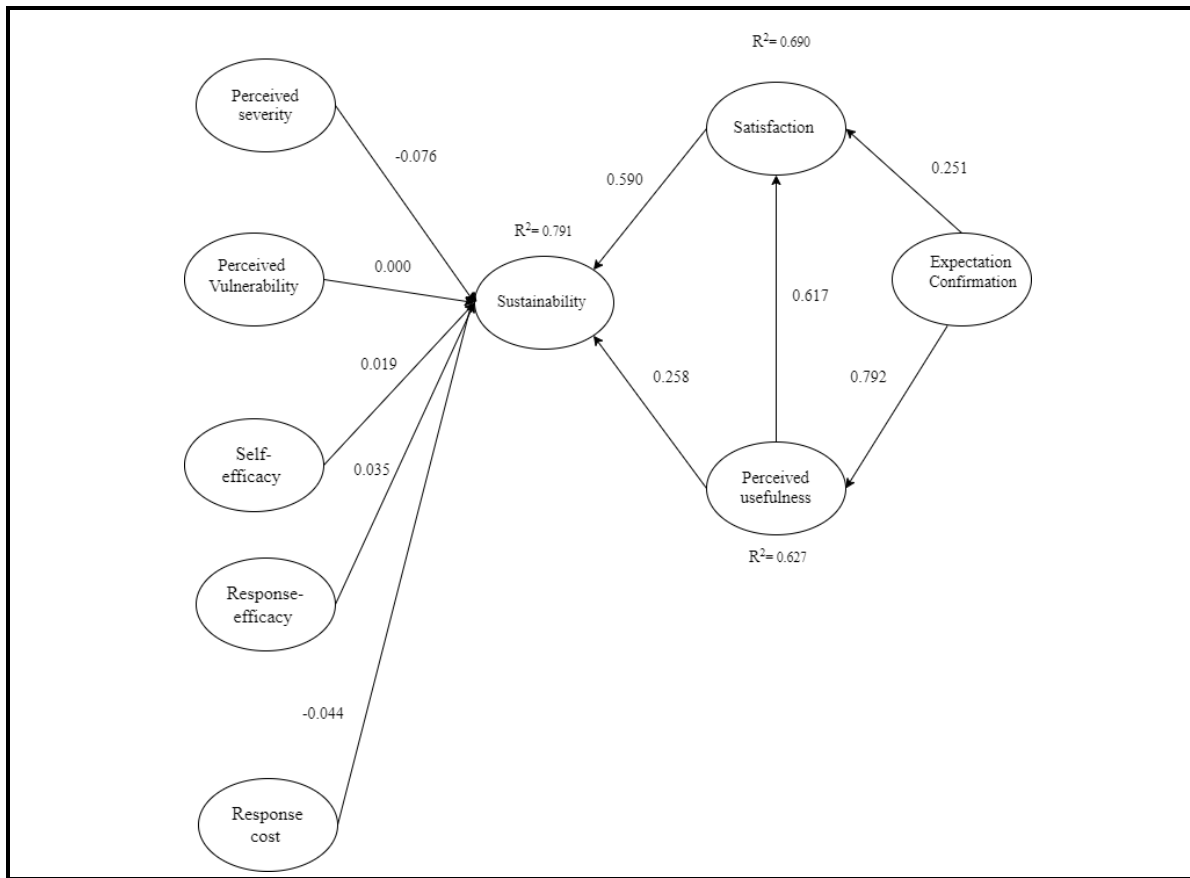


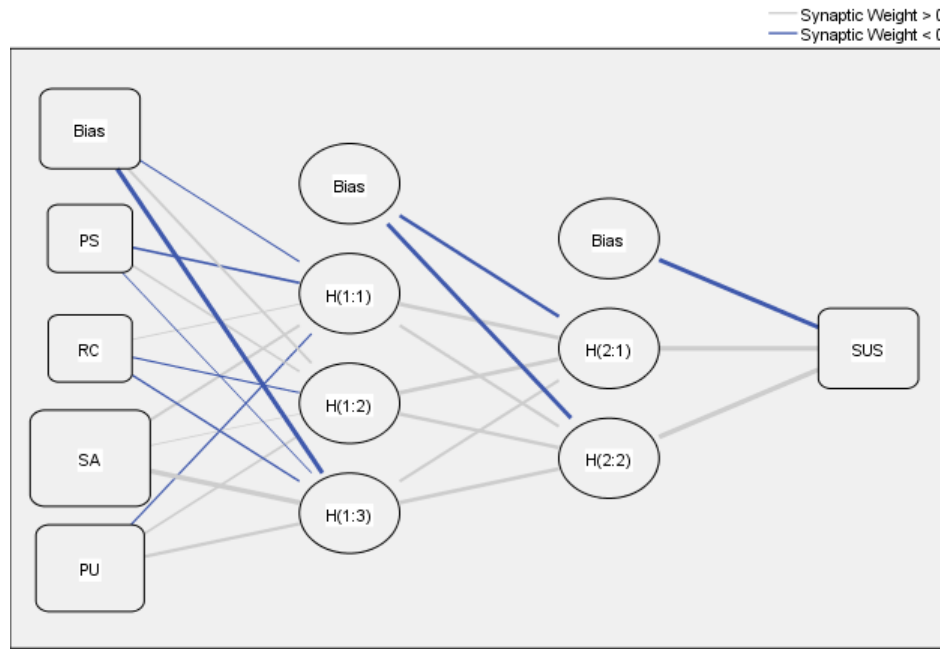
Figure 11.Proposed Model Result.

5.6.ANN Results

This study's constructed research model includes two endogenous components. As a result, the research model was decomposed into two ANN models, as seen in Figures 12-13. SPSS 26 was used to examine the two models utilizing the ANN multilayer perceptron network. ANN models have a single hidden layer that is used to generate the number of neurons in the hidden layer (Alkawsi *et al.*, 2021). The number of generated hidden neurons for the first model was 4, while the number of generated hidden neurons for the second model was 2, as shown in Figures 12 and 13. A six-fold cross-validation strategy was used to solve the issue of model overfitting. The data were divided into 90:10 partitions for training and testing, accordingly. This method

was also used to determine the predictors' relative relevance(Wang and Elhag, 2007; Alshamaila, Papagiannidis and Li, 2013; Khayer and Bao, 2020; Kalinić *et al.*, 2021).

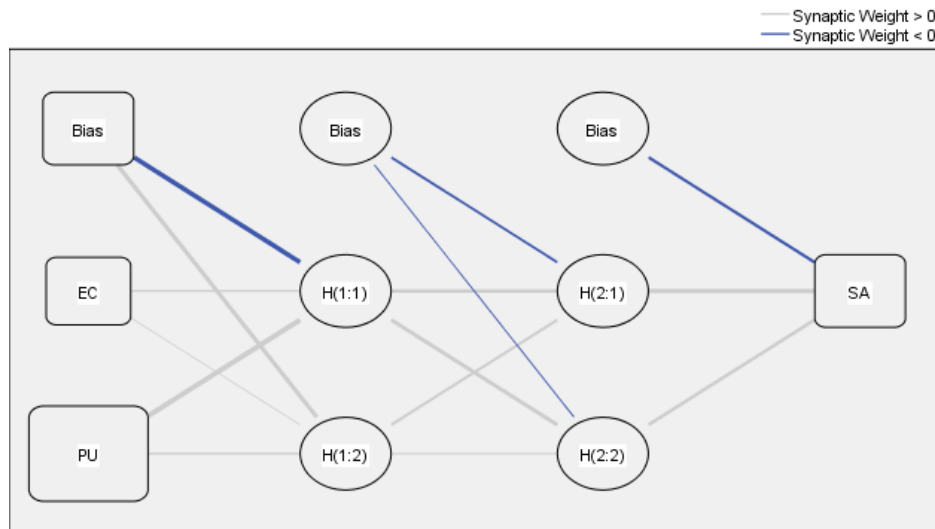
The sigmoid function was used as the activation function in the ANN model's hidden and output layers (Kalinić *et al.*, 2021). The first model, as shown in Figure 12, comprises four key exogenous constructs: perceived severity, response cost, satisfaction, and perceived usefulness. These four variables served as input layers, with the endogenous variable (sustainability) serving as the output layer. In the second model, as shown in Figure 13, the exogenous variables (expectation confirmation and PU) served as input layers, whereas the endogenous variable (satisfaction) served as the output layer. The root means square of error (RMSE) from the six networks is calculated to measure the prediction accuracy of the two ANN models (Morris *et al.*, 2004; Kalinić *et al.*, 2021). Table 18 indicates that the RMSE values for model 1 are in the 0.072–0.084 range for training and 0.047–0.0108 range for testing. The RMSE values for model 2 were from 0.088 to 0.094 for training and from 0.058 to 0.100 for testing. Efficiently as a result, the models achieved higher precision due to the implementation of ANN, judging by the slight differences in the RMSE values and the calculated standard deviation for both datasets (0.003107942 and 0.002706407 for the training dataset in the two models, respectively) and (0.019298351 and 0.01498682 for the testing dataset in the two models, respectively).



Hidden layer activation function: Sigmoid

Output layer activation function: Sigmoid

Figure 12.ANN model 1.



Hidden layer activation function: Sigmoid

Output layer activation function: Sigmoid

Figure 13.ANN model 2.

Table 17.RMSE values of ANN models

	Model 1		Model 2	
Network	RMSE (Training)	RMSE (Testing)	RMSE (Training)	RMSE (Testing)
1	0.075	0.108	0.093	0.088

2	0.078	0.068	0.094	0.098
3	0.076	0.049	0.091	0.069
4	0.076	0.082	0.093	0.082
5	0.076	0.085	0.090	0.088
6	0.084	0.067	0.092	0.071
7	0.072	0.073	0.098	0.062
8	0.077	0.053	0.094	0.058
9	0.074	0.087	0.093	0.075
10	0.077	0.047	0.088	0.100
Mean	0.077	0.072	0.093	0.079
Standard deviation	0.003107942	0.019298351	0.002706407	0.014498682

This discloses that ANN models can certainly constitute predictor-output relationships and also consists of the potential to exhibit enhanced prediction performance by inculcating the data adeptly.

5.6.1. Sensitivity analysis:

Sensitive analysis has been utilized in evaluating the contribution of each predictor to the sustainable usage of blockchain technology in higher education. This has been conducted by computation of established significance in the stipulation of percentage by segregating the relative significance of each input by the optimum relative importance (Morris *et al.*, 2004; Wang and Elhag, 2007; Chong, 2013; Al-Shihi, Sharma and Sarrab, 2018; Qasem *et al.*, 2020; Kalinić *et al.*, 2021) Based on the results from the studies conducted on model 1 using sensitive analysis in table 19 SA(RI=100) can be established as the most critical input that correlates with sustained use of block chain technology in higher education which is sustainability with PU and PS with the associated significance of 58.8 and 12.1, subsequently. Moreover, the RC is stated to have the least influence on the discussed sustainability of the usage of block chain in higher education. In parallel to this, model 2 in table 19 demonstrated and established PU(RI=100) as

a crucial input that is directly proportional to the sustained use of block chain technology in higher education, trailing ES with the associated significance of 29.2.

Table 18.Sensitivity analysis for model 1.

Neural Networks	PS	RC	SA	PU
1	0.039	0.061	0.559	0.342
2	0.076	0.053	0.482	0.389
3	0.077	0.052	0.522	0.349
4	0.053	0.057	0.527	0.362
5	0.051	0.083	0.566	0.299
6	0.067	0.075	0.728	0.130
7	0.600	0.200	0.570	0.349
8	0.103	0.032	0.563	0.302
9	0.086	0.034	0.570	0.310
10	0.060	0.048	0.523	0.369
Mean importance	0.121	0.070	0.561	0.320
Normalized importance (%)	12.1%	9.2%	100.0%	58.8%
Ranking	3	4	1	2
Note(s): PS: “perceived severity”, RC: “response cost”, SA: “satisfaction”, PU: “perceived usefulness”				

Table 19.Sensitivity analysis for model 2.

Neural Networks	ES	PU
1	0.129	0.871
2	0.114	0.886
3	0.328	0.672
4	0.226	0.774
5	0.369	0.631
6	0.222	0.778
7	0.142	0.858
8	0.180	0.820
9	0.179	0.821
10	0.280	0.720
Mean importance	0.217	0.783
Normalized importance (%)	29.2%	100.0%
Ranking	2	1
Note(s): ES: “expectation confirmation”, PU: “perceived usefulness”		

5.7.Discussion

Regardless of the criteria, it is critical to engage people and have them embrace the technology in order for it to succeed, for example, in fresh development or adding features (Taherdoost, 2019). In several areas, a variety of theoretical models and extensions have been presented and explored in order to actualize and assess technology acceptability and user behaviour (Rahimi *et al.*, 2018). Globally, the development of information technology has attracted the attention of the higher education field, and the research related to its acceptance has been increasingly motivated. In light of this, many studies have proposed hybrid models and integrated models by using multiple acceptance models in order to establish the elements that impact users' sustainability of various technologies in higher education. This research proposes an integrated theoretical model based on the integration of different constructs extracted from PMT and ECM. The findings signified that the proposed integrated model is relatively capable of explaining a high proportion of variation regarding the sustainability to use blockchain technology in higher education. In order to evaluate the suggested theoretical technology sustainable model, the following hypotheses were studied in depth.

5.7.1. The impact of Perceived Severity on the Sustainability of Blockchain technology

When an individual faces a threat, they cognitively examine the threat's severity and their ability to confront it. Hence, employing the Protection Motivation Theory makes it possible to determine the motivation for using the services based on blockchain representing a protective behaviour directed at guaranteeing the privacy and security of data used in the education sector. The construct of perceived severity is defined as the degree of economic harm, social threats, psychological harm, dangers to others rather than oneself, physical harm, and even threats to

other individuals, which refers to the severity of the outcome or event consequence. While managing any information system, the construct reflects the seriousness of the event consequence, for example, financial fraud and hacker attacks. Perceived threat severity considerably plays a crucial role in motivating practices such as the adoption of antiplagiarism software, compliance with IS security policies, and energy conservation (Ifinedo, 2012). In the previously conducted studies, the effect of this construct was not confirmed (Tsai *et al.*, 2016; Menard, Bott and Crossler, 2017), putting it down to the difference in settings (Vance, Siponen and Pahlila, 2012) and methodological limitations (Tsai *et al.*, 2016). Here in the individual context, the losses that may be a result of the technology use are borne by firms, compared to the employees (Tsai *et al.*, 2016). This is the reason why; individuals may experience mild consequences. Nevertheless, the negation to the utilization of privacy-preserving technology entails personal threats, for example, misuse of personal data and financial data exposure. Henceforth, the relationship between perceived threat severity and blockchain sustainability is significant. As a result, from the study, perceived severity was found to positively influence the sustainability using blockchain technology in higher education. Such a result proposes that the sustainability of students using blockchain technology can be enhanced if those students believe that blockchain technology can provide more benefits to them. The participating students are expecting better performance results while using blockchain technology in higher education. Similar findings were found in other studies conducted in Various settings (Al-Emran, Arpaci and Salloum, 2020; Deng *et al.*, 2020; Shahbaznezhad, Kolini and Rashidirad, 2021).

5.7.2. The impact of Perceived vulnerability on the Sustainability of Blockchain technology

The term perceived threat vulnerability refers to an individual evaluation of the likelihood that threatening events may occur. When this comes to technology utilization, the threat may refer to losses in financial terms, misuse of private data or identity exposure during any online transaction. The PMT posits that there must be a direct association between the behaviour of using blockchain technology and perceived vulnerability (Chenoweth, Minch and Chenoweth, 2009). In previous studies, such as association has been empirically confirmed while examining Blockchain Adoption to determine the IS security behaviour, for example, IS security policies compliance and the anti-spyware software adoption (Chenoweth, Minch and Chenoweth, 2009; Ifinedo, 2012). On the contrary, the significance of the effect was not consistent across different studies (Vance, Siponen and Pahlila, 2012; Tsai *et al.*, 2016).

Based on the study analysis, there is no significant relationship between perceived vulnerability and sustainability. The result suggests that the participating students do not motivate to take security measures to reduce security breaches. This contradicts what was found in previous studies regarding the significance of this factor (Mostafa Al-Emran *et al.*, 2020; Wu, 2020; Shahbaznezhad, Kolini and Rashidirad, 2021). A potential explanation for such contradictory results can be due to the context of this study. The users may perceive that specific types of threats are not likely to happen, although it exists potentially. Hence, given the seriousness of the potential threats which can be tackled by blockchain technology along with the evidence of the common cases pertaining to cyber-hacking, it can be assumed that perceived vulnerability tends to have a significant effect on blockchain technology-enabled services.

5.7.3. The impact of Self-efficacy on the Sustainability of Blockchain technology

Coping appraisal processes are primarily dependent on self-efficacy, response efficacy, and response cost. The term self-efficacy refers to the belief that individuals are able to commission operative measures envisioned to cope with the threat (Woon, Gek Woo and R T, 2005). Hence, confidence in personal abilities often upsurges the intention to embark on adaptive behaviour for example, with respect to the adoption of blockchain technology. Hence, the correlation between the change in behaviour and self-efficacy has also been researched and examined in different studies in the past (Tsai *et al.*, 2016; Menard, Bott and Crossler, 2017). Self-efficacy either directly or indirectly impacts the intention to engage in activities, for example, fake-website detection systems, software use, and email authentication.

Similarly, it was observed that self-efficacy has no substantial influence on the sustainability of Blockchain technology. The result suggests that Students' confidence in their use of blockchain technology for education and their ability to keep their blockchain safe is not an important determinant for their sustainable use of this technology for educational purposes, which is against what was claimed by (Hooper and Blunt, 2020; Mostafa Al-Emran *et al.*, 2020; Wu, 2020).

5.7.4. The impact of Response efficacy on the Sustainability of Blockchain technology

Response efficacy refers to the belief of an individual that adaptive behaviour will avert a threat (Lee, 2011). The previously conducted studies tend to confirm the response efficacy role in the use of technology along with the evidence about the utilization of the privacy and security

benefits of the blockchain (Janssen *et al.*, 2020). It is expected that people consider that technology can be useful in protecting the data personally from unauthorized use by other parties. Examining the potential threat, the individuals perform a cognitive examination of the opportunities available to deal with such a potential threat. If they believe that adaptive behaviour will boost their chance of confronting the threat, the intention to adopt will also intensify. Unpredictably, the response efficacy had no significant impact on the Sustainability of Blockchain technology. This shows that students do not believe in the power of the recommended behaviour to avoid security risks associated with the use of blockchain technology for educational purposes. This is not similar to the finding of (Hooper and Blunt, 2020; Mostafa Al-Emran *et al.*, 2020; Wu, 2020).

5.7.5. The impact of Response costs on the Sustainability of Blockchain technology

Response cost is also referred to as an individual's cost evaluation that they bear if indicated to engage in adaptive behaviours (Tsai *et al.*, 2016). Such a cost can either be mental efforts of financial investment that may be needed to put into operating the services which are enabled by blockchain. If the response cost is higher, there is less chance to engage in behaviours (Menard, Bott and Crossler, 2017). Inspire of supporting results of the previous studies and theoretical foundation, a negative impact of response cost on intention to use blockchain technology was not always the case (Menard, Bott and Crossler, 2017).

Furthermore, response cost has a significant negative effect on the sustainable use of Blockchain technology, demonstrating that students' efforts to implement the advised safe usage of blockchain technology have a big impact on how long they can continue to utilize this technology for learning. The amount of work required to adhere to the advised safe

usage of blockchain technology is seen by students as a deterrent to guaranteeing the security of this technology while utilizing it for educational purposes. This result confirms the findings reported by (Al-Emran, Arpaci and Salloum, 2020; Wu, 2020; Shahbaznezhad, Kolini and Rashidirad, 2021).

5.7.6. The impact of Expectation Confirmation on Satisfaction of Sustainability of Blockchain technology

When talking about the continued intention, the expectation-confirmation model (ECM) is proved to be a valuable framework (Bhattacharjee, 2001) and has been broadly adapted to study continued use and technology sustainability. ECM integrated with Expected confirmation achieved the continued usage of blockchain technology in the education sector. This suggests that there is a significant impact of Expectation Confirmation on satisfaction. The expectation confirmation could provide a significant impact on the satisfaction of the sustainability of Blockchain technology. A possible explanation for these results is the fact that when students' expectations of the blockchain technology advantages are confirmed, sustainable use of blockchain will definitely enhance their performance and satisfaction. Such finding is in congruence with what has been confirmed by (Al-Emran, Arpaci and Salloum, 2020; Alshurideh *et al.*, 2020; Park, 2020).

5.7.7. The impact of Expectation Confirmation on the Perceived usefulness of Sustainability of Blockchain technology

Perceived usefulness (PU) refers to the extent to which an individual believes that using a particular system may help in increasing his or her job performance. Using ECM as a methodology often leads to a thorough belief of perceived usefulness among the users. This

eventually leads the users to arrive at confirmation to continue the utilization of blockchain technology.

The analysis verified that the sustainability of Blockchain technology of students who use blockchain is significantly influenced by expectation confirmation on perceived usefulness. Sustainability use of blockchain would increase their usage performance in the university. This means that if the student feels and thinks that this technology is useful, they intend to use it; meanwhile, if they believe that it is less useful, they will not use it. The correlation between PU and the sustainable use of blockchain has been validated in many studies conducted in the past (Al-Emran, Arpaci and Salloum, 2020; Alshurideh *et al.*, 2020; Park, 2020).

5.7.8. The impact of Satisfaction of Sustainability of Blockchain technology

Satisfaction (SA) often refers to the affective attitude in the direction of a specific computer application by an end user who primarily interacts with a certain application directly. Satisfaction is the main prerequisite for ECM. Once any particular user gets familiar with the threat and understands how to face it, he/she enters into a thorough process of expecting the solution to accomplish in a certain way.

As well the results pointed out the significant positive of satisfaction with the sustainability of Blockchain technology. It refers to the reason that even though blockchain technology would enhance the performance and satisfaction of students in UAE, their expectations toward the use of block-chain advantages might be much more than what they have expected to leverage their sustainable use for the technology, which is compatible with what was stated by (Alshurideh *et al.*, 2020; Dai *et al.*, 2020; Park, 2020).

5.7.9. The impact of Perceived usefulness of Sustainability of Blockchain technology

In addition, the results exposed that the sustainability of blockchain technology is significantly influenced by the perceived usefulness results. These findings could be explained by the reason that when students perceive blockchain technology, their performance and sustainability to use of this technology would undoubtedly be improved. This result comes in line with what has been found in earlier studies (Al-Emran, Arpaci, et al., 2020; Park, 2020; Suzianti & Paramadini, 2021).

5.7.10. The impact of Perceived usefulness on Satisfaction of Sustainability of Blockchain technology

Perceived usefulness was a major factor in predicting the sustainable use of blockchain technology and satisfaction, and it is believed that the overall usefulness of the blockchain can ultimately govern acceptance and technology diffusion. Moreover, the result shows that perceived usefulness has a positive significance on the satisfaction of sustainability of blockchain technology. The experiential correlation between these two factors could be accredited to the fact that when blockchain technology enhances the students' performance, they would generally exhibit high levels of satisfaction. This correlation could be explained by the fact that when blockchain technology enhances student performance, they are more likely to be satisfied. This is harmonious with the reported findings by (Al-Emran, Arpaci, et al., 2020; Park, 2020; Suzianti & Paramadini, 2021).

CHAPTER 6

CONCLUSIONS

6. Conclusions

6.1.Overview

The aim of this chapter is to summarize the research findings, limitations, theoretical contributions, practical implications, and conclusions for the field of research. In addition, discusses the future work that can be accomplished in future studies, as well as the suggested recommendations.

6.1.1. Research Summary

In this study, a systematic literature review was conducted focusing on studies of technology acceptance in higher education during the past decade (2010-2021). A systematic review was conducted of technology acceptance literature to establish a comprehensive understanding of the current situation and to perform a classification analysis on the basis of a variety of characteristics coded into the literature.

A theoretical model for technology acceptance in higher education was also developed as part of the research. Based on the findings of the systematic literature review, the model was constructed. The developed integrated model included the integration of the key constructs of PMT and ECM factors. The novel model was applied to assess the acceptance of the technology as proposed in this research by 374 participants who study at different universities in the UAE. Empirical validation of the model was conducted using a questionnaire survey measuring five

points on the Likert scale. The results were analyzed using partial least squares-structural equation modelling (PLS-SEM).

6.1.2. Key Findings

There are three main research questions addressed by this study, and key findings will assist in answering those questions.

6.1.2.1. What are the most frequent factors affecting blockchain technology, studied domains, and leading theoretical models?

It is imperative to understand what impacts the sustainability of new technologies, such as blockchain. Suitable any technology relies on the determinants affecting its users (Al-Emran, Mezghuyev and Kamaludin, 2018; Al Shamsi, Al-Emran and Shaalan, 2022). A forecasting report illustrates the positive evolution of the Blockchain market between 2017 and 2024 (Chernov and Chernova, 2018). While this magnitude was USD 800 million in 2017, it is estimated to reach USD 20.550 million in 2024. Therefore, it is vital to gain more insights into what impacts the suitability of Blockchain technologies across many sectors to improve and sustain their usage.

For the influential factors affecting Blockchain sustainability, trust was seen to be the most common factor affecting the sustainability of Blockchain technologies (n = 17), as mentioned in chapter 2, figure 5. This was followed by the perceived cost and social influence, with 11 studies each, as well as facilitating conditions (n = 10) as mentioned in chapter 2 figure 5, performance expectancy, effort expectancy, and information security, with seven studies each. Studies on the individual level have examined trust, social influence, performance expectancy, effort expectancy, and information security. In contrast, those focusing on the organizational level studied mainly the organizational perspective's factors in delivering Blockchain-based

services, such as trust, perceived cost, and facilitating conditions. Still, there is abundant room for other factors to be investigated from the perspective of other technology sustainability theories/models and Blockchain-related specific characteristics. On the other side, we have also analyzed the existing literature on Blockchain to determine the barriers affecting its sustainability. Being aware of these barriers and considering them when implementing Blockchains would improve their sustainability rate. Security risks and privacy risks were among the main risks that negatively affect the use of Blockchain technologies. High energy and investment costs represent the main costs of using Blockchain technologies. Organizations also impose some barriers to using Blockchain technologies, such as organizational policies, organizational culture, lack of knowledge and management support, and lack of collaboration and coordination. It is also imperative to mention that sustainability Blockchain is hindered by some technological barriers, such as technological immaturity, reluctance to change, interoperability issues, and scalability issues. Cultural differences are also considered a barrier to Blockchain sustainability. Mainly this is because users rely on themselves when seeking advice related to using Blockchains in individualistic societies, while they rely on others in collectivistic cultures.

Regarding the main domains/sectors through which the analyzed studies were carried out, supply chain management dominates the list with 12 studies, followed by education and agriculture, with three studies each, as mentioned in chapter 2, figure 3. While our findings agree with (Taherdoost, 2022), who found that supply chain management is the dominating sector concerning studies related to Blockchain sustainability, it contradicts what is reported by (Frizzo-Barker *et al.*, 2020), who suggested that banking and finance was the primary sector. Regardless of the differences between this review and the previously conducted reviews,

understanding Blockchain sustainability across many domains is still in short supply due to the limited number of applications.

Concerning the prevailing technology sustainability theories/models, the results pointed out that the TAM is the most common model in studying Blockchain sustainability, with 14 studies as mentioned in chapter 2 figure 4. This is followed by the TOE ($n = 8$), UTAUT ($n = 7$), and IDT ($n = 5$). In the same vein, (Taherdoost, 2022) found that TAM and TOE were the most dominating models in studying Blockchain sustainability. TAM is still a valid model for evaluating large-scale emerging technologies (M. Al-Emran *et al.*, 2020; Al-Emran and Granić, 2021), where Blockchain is not an exception. These results indicate that studies focusing on the individual level have mainly relied on TAM, while those examining the organizational level have relied on TOE. Further research might consider other adoption Models that have yet to be used in the existing literature, such as UTAUT2, ECM, PMT, etc.

6.1.2.2. What is the suitable model to understand the factors affecting the sustainability of blockchain technology?

The factors such as risk, motivation, trust, innovativeness, perceived ease of use, and perceived usefulness are considered to be the most significant factors when one aims to investigate the behaviours of individuals toward adopting blockchain technology. The technology acceptance model can be extended with expert data and knowledge. Blockchain technology is considerably new and can be influenced by factors such as usefulness and ease of use. The technology acceptance model is considered the most suitable framework for understanding users' acceptance of Blockchain technology. Conversely, to understand the factors affecting the sustainability of blockchain technology, one may use the expectation confirmation model (ECM), which is characterized for sustainability. Hence, our model, including a diversity of factors from PMT and ECM, is suitable.

The integrated theoretical model developed, which was discussed in Chapter 3, incorporated factors influencing technology acceptance in the higher education domain. As mentioned above, the model includes the core factors of PMT, which are coping threat (perceived severity, perceived vulnerability) and coping appraisal (response efficacy, self-efficacy, and response costs), meanwhile ECM (satisfaction, expectation confirmation and perceived usefulness) as in Figure 7. Moreover, the ten hypotheses in the developed model were assumed based on the context and nature of this research and the most confirmed hypotheses, as in Figure 7 and Table 17. The result shows that seven hypotheses out of ten were supported by the conducted experimental test, which H1, H5, H6, H7, H8, H9, and H10, whereas H2, H3, and H4 were rejected

6.1.2.3. To what extent would the proposed model be able to predict the sustainable use of blockchain technology?

Based on the results in Chapter 5 shows that the proposed model is successful in exploring the acceptance of information technologies in higher education. The model has explained 79.1% of the variance in the sustainability of accepting blockchain technology in higher education.

As mentioned in Figure 12-13, the ANN models (model 1 and model 2) with using of SPSS 26 to examine the two models utilizing the ANN multilayer perceptron network. As (Alkawsi *et al.*, 2021) mention that ANN models consist of a single hidden layer which is used to generate the number of neurons in the hidden layer. The result showed that the first model was generated with four hidden neurons; meanwhile, the second model was generated with two hidden neurons, as mentioned in Figures 12 and 13. To solve the issues of model overfitting, a six-fold cross-validation strategy was used. For training and testing, the data were divided into 90:10 partitions. In order to determine the predictors' relative relevance, this method was used (Wang

and Elhag, 2007; Alshamaila, Papagiannidis and Li, 2013; Khayer and Bao, 2020; Kalinić *et al.*, 2021).

The sigmoid function was used as the activation function in the ANN model's hidden and output layers (Kalinić *et al.*, 2021). Figure 12 shows the first model comprises four key exogenous constructs: response cost, perceived severity, perceived usefulness, and satisfaction, which served as input layers, with the endogenous variable sustainability output layer. However, Figure 12 shows that model 2 and the exogenous variables expectation confirmation and perceived usefulness served as input layers, whereas the endogenous variable satisfaction served as the output layer. To measure the prediction accuracy of the two ANN models, the root means square of error (RMSE) from the six networks is calculated (Morris *et al.*, 2004; Kalinić *et al.*, 2021). The RMSE values for model 1 are in the 0.072–0.084 range for training and 0.047–0.0108 range for testing; however, for model 2, the RMSE values from 0.088 to 0.094 for training and from 0.058 to 0.100 for testing as shown in table 18. It illustrated that due to the implementation of ANN, the models achieved higher precision, judging by the slight differences in the RMSE values and the calculated standard deviation for both datasets (0.003107942 and 0.002706407 for the training dataset in the two models, respectively) and (0.019298351 and 0.01498682 for the testing dataset in the two models, respectively).

In general, the results showed that the sustainability of blockchain technology in higher education is positively influenced by some of the PMT factors (i.e. perceived severity, response cost) while it is negatively impacted by (perceived vulnerability, self-efficiency, and response efficiency). On the other hand, the sustainability of blockchain technology in higher education is positively influenced by ECM factors (i.e. satisfaction, expectation confirmation, and perceived usefulness).

6.2. Research Contributions and Implications

6.2.1. Theoretical Contributions

Multiple contributions to technology acceptance models and theories, particularly in higher education, were made by the performed systematic review, which included the classification analysis. There are various reasons why the systematic review adds a significant contribution to the existing literature. First, rather than focusing on two models or theories (e.g., PMT and ECM), it examined all technological acceptance models.

Second, the review included the extensions and integrations of the experimentally evaluated acceptance models. Third, rather than focusing on just one technology, the research has examined a variety of information technologies (e.g. students' electronic records). Fourth, the reviewed papers were all recently published (between 2010 and 2021), giving us a new perspective on the literature. As a result, our findings diverge from those of other evaluations that have been done previously. With regard to the enhancement of blockchain technology, the research could clarify the sustainability of using this technology to help improve accountability through smart contracts, incentivizing learning and increasing transparency. Several theoretical contributions are presented in the current study. This study is an early attempt to examine the determinants affecting the sustainable use of blockchain technology by university students. Through the lenses of the PMT and ECM, this study represents one of the early attempts to examine the factors affecting the sustainable use of blockchain technology by university students. Secondly, despite extensive research conducted in recent years regarding blockchain technology, no single study has been conducted that examines the key factors influencing sustainable usage, specifically for educational purposes. Therefore, the results of this study provide new insight into what factors contribute to the sustainability of users' use of blockchain

technology for learning activities, such as perceived vulnerability, perceived usefulness, perceived severity, response cost, response efficacy, self-efficacy, satisfaction, and expectation confirmation factors. In addition, contrary to the existing literature which examined the determinants affecting the sustainability of blockchain technology in education (Bhaskar, Tiwari and Joshi, 2020). As a result of this study, it will gain new insight into the sustainable use of blockchain technology in the United Arab Emirates.

6.2.2. Practical Implications

The insights obtained through the systematic review and empirical analysis provide several practical implications for practice. For the systematic review, the review considered different models, various users, disciplines, active countries, influential factors, and technology acceptance models, which makes it more generic than the existing reviews. These results are valuable for decision-makers and researchers interested in Blockchain sustainability. Second, the review found that there is a gap in the higher education's sector use of Blockchain. This finding would assist policymakers in reviewing the current data privacy policies and regulations. It is also necessary to announce and publish these regulations. To enhance end users' acceptance, they need to be educated and aware of their roles and responsibilities. Third, the findings from the influential factors can be used as a type of lessons learned by educational organizations, system analysts, and developers. Therefore, this review can contribute to improving the currently implemented solutions as well as anticipate future Blockchain enhancements to be more innovative and user-friendly.

For the empirical analysis, a number of practical implications can be offered for service providers, instructors, developers, and designers. First, this study examined factors that influence the sustainable use of blockchain technology in higher education. Developers and

designers should therefore test these factors before implementing them to ensure that students have an engaging experience that will enable them to sustain their use. To ensure that the technology can assist learning activities in a more practical, reliable, and reasonable manner, developers and designers must pay careful attention. In order to accomplish this, interactive functions should be improved in order to meet learners' needs and meet their expectations of casual, natural, and humanized interactions with these agents.

In addition, since perceived usefulness plays an influential role in the sustainable use of blockchain technology for education, providers should emphasize features that will provide users with reliable information to the fullest extent possible, including the ability to browse at "anytime, anywhere" settings, and provide personalized notifications about the latest information and updates. Students with low experience can master blockchain with this. Furthermore, we found that students are generally satisfied with this technology that is simple and relevant to their needs. Lastly, service providers should pay special attention to PMT and ECM variables and ensure that such variables are met for the demographic profile of the learners in order to increase the sustainable use of blockchain for learning. Concerning the context of the study, the results are useful for higher education institutions in the UAE and other countries that share the same cultural characteristics in the Mena region. Decision-makers and policymakers in these institutions need to consider the influential factors in developing policies and procedures related to the implementation of Blockchain in a more efficient manner.

6.2.3. Methodological contribution

In contrast to earlier empirical studies that relied mainly on SEM analysis, this research mainly applied a Hybrid SEM-ANN approach which is founded on deep learning for the purpose of validating the hypothesized association among the factors in any specific research model. Such

a method involves two kinds of phases. The primary thing is to analyse the proposed research model utilizing the partial least squares-structural equation modelling (PLS-SEM) by means of Smart-PLS. The basic purpose of using the PLS-SEM in this study routes from the exploratory nature of the theoretical model, along with the absence of studies published previously. This research follows the general guidelines to utilize the PLS-SEM in information systems research. As mentioned in past studies, a two-step approach (for example, measurement as well as structural model) must be followed to examine the model being researched. As an advanced method in PLS-SEM, this study also applied the importance of performance map analysis (IPMA) to recognise the significance and performance of every construct in the research model.

Second, the ANN is mainly adopted to authenticate, complement and investigate the PLS-SEM analysis and determine the efficiency of independent variables on the dependent variable. The ANN is considered a function approximation instrument that is mainly suitable in situations where the collaborative nature among output(s) and input(s) is nonlinear and complex. ANN entails three significant mechanisms, which comprise transfer function, learning rule, and network architecture, that primarily cascades into subcategories such as recurrent network, feed-forward multilayer perceptron (MLP) network, and radial basis. The MLP neural network is thought to be the most widely applied method, and it is composed of many layers, for example, output and input. Furthermore, the output and input layer are furthermore associated with each other by means of hidden nodes. The most commonly applied activation function is known as the sigmoidal function. Our study adopts the MLP neural network to train and test the proposed research model.

6.3. Research Limitations and Future Work

This study focused on particular digital libraries and databases in its systematic review (i.e., Springer, ACM, PubMed, Science Direct, IEEE Xplore, and Google Scholar). This means it may not be possible to provide a complete picture of higher education in these digital libraries. Researchers may extend this review by including studies sourced from various digital libraries, such as Scopus, Web of Science, Sage, CINAHL, Web of Science and Cochrane. Furthermore, only empirical quantitative studies have been reviewed. However, other types of technology acceptance studies can be conducted in the future, for example, Qualitative studies. Moreover, a thorough meta-analysis can also be constructed using the findings by combining the results of each reviewed study or even by adding additional studies. Furthermore, the findings of this study can serve as a foundation for the construction of a new acceptance model or an integration of existing acceptance models to explore the user's acceptance of technology in higher education. A number of limitations were in the empirical analysis, namely survey time, users' types, survey time, and factors studied. It is possible to increase the sample size to receive better results in the future. At present, there are only 374 participants in the sample. Due to the time of the survey, the sample size was impacted.

Surveys were distributed during COVID-19 outbreak stage 2 (September - December 2021), and the students were busy with registration for the course and determining whether to study online or on campus. A moderating factor, such as nationality, gender, age, level of experience, and education level, was not explored to determine if the independent variables influence the sustainability of blockchain technology in higher education. Future research on moderating factors may yield more interesting results since there is a lack of knowledge about their impact. Moreover, the research has only investigated the acceptance of higher education students.

Researchers might find it interesting to examine faculty members' behaviour toward accepting and using blockchain technology.

In spite of the important implications our study provides, it is also important to acknowledge some limitations. In order to gain a better understanding of what impacts the sustainable use of blockchain, we primarily collected data through questionnaires. First, student interviews may provide more insight into the correlations between the factors in future attempts. Second, since the study targeted only blockchain users, convenience sampling was used in selecting participants. In spite of this, the results cannot be generalized to others or other contexts using this technique. Therefore, generalizing the results should be treated with caution. Third, it is almost impossible to create a specific research model that incorporates all the variables. The sustainability of blockchain technology for higher education purposes is a relatively recent topic, which requires more empirical studies to understand what affects its sustainability.

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APPENDICES

Appendix A: The Results of Quality Assessment.

Table 20.Constructs and Their related Items as in the Research Instrument.

Study	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Total	Percentage
S1	1	1	1	0.5	1	1	1	1	1	8.5	94.44%
S2	1	1	1	1	1	1	1	1	1	9	100%
S3	1	0.5	1	1	1	1	1	0.5	0.5	7.5	83.33%
S4	1	1	1	1	1	1	1	1	1	9	100%
S5	1	0.5	1	1	1	1	1	0.5	0.5	7.5	83.33%
S6	1	1	1	1	1	1	1	1	1	9	100%
S7	1	1	1	1	0	1	0	1	0.5	6.5	72.22%
S8	1	0.5	1	0.5	1	0.5	1	0.5	0.5	6.5	72.22%
S9	1	1	1	1	1	1	1	1	1	9	100%
S10	1	1	1	1	1	1	1	1	0.5	8.5	94.44%
S11	1	1	0.5	0.5	0.5	0.5	0.5	1	0.5	6	66.66%
S12	1	1	1	1	1	1	1	1	1	9	100%
S13	1	1	1	1	1	1	1	1	1	9	100%
S14	1	1	1	1	0	0.5	0	1	0.5	6	66.66%
S15	1	1	1	1	1	1	1	1	1	9	100%
S16	1	1	1	1	1	1	0.5	1	1	8.5	94.44%
S17	1	1	1	1	1	1	1	1	1	9	100%
S18	1	1	1	1	1	1	1	1	1	9	100%
S19	1	1	1	1	1	0.5	0.5	1	1	8	88.88%
S20	1	1	1	1	1	1	1	1	1	9	100%
S21	1	0.5	1	1	1	0.5	1	0.5	1	7.5	83.33%
S22	1	1	1	1	1	1	1	1	1	9	100%
S23	1	1	1	1	0.5	1	0.5	1	1	8	88.88%
S24	1	1	1	1	1	1	1	1	1	9	100%
S25	1	1	1	1	0.5	1	1	1	1	8.5	94.44%
S26	1	1	1	1	1	1	1	1	1	9	100%
S27	1	1	1	1	1	1	0.5	1	0.5	8	88.88%
S28	1	1	1	1	0.5	1	1	1	1	8.5	94.44%
S29	1	1	1	1	1	1	0.5	1	1	8.5	94.44%
S30	1	1	1	1	0.5	1	1	1	1	8.5	94.44%

Appendix B: Full List of The Included Publications

Table 21.List of analyzed studies.

#	Source	Year	Method	Country	Domain	Theories/Models
S1	(Albayati, Kyoung and Jeung, 2020)	2020	Survey	Not specified	Finance	TAM
S2	(Kamble <i>et al.</i> , 2021)	2021	Survey	India	Supply chain management	TAM and TOE
S3	(L. W. Wong <i>et al.</i> , 2020)	2020	Survey	Malaysia	Supply chain management	TOE
S4	(Karamchandani, Srivastava and Srivastava, 2020)	2020	Survey	India	Supply chain management	TAM and IDT
S5	(Yadav <i>et al.</i> , 2020)	2020	Survey	India	Agriculture supply chain	ISM-DEMATEL
S6	(Yang, 2019)	2019	Survey and interviews	Taiwan	Maritime shipping	TAM
S7	(Wahab, Loo and Say, 2020)	2020	Not specified	Malaysia	Warehouse industry	UTAUT
S8	(Orji <i>et al.</i> , 2020)	2020	Survey	Nigeria	Logistics	TOE
S9	(Wamba and Queiroz, 2019)	2019	Survey	Brazil	Supply chain management	UTAUT
S10	(Pantouw and Aruan, 2019)	2019	Survey	Indonesia	Gaming	TAM
S11	(Lou and Li, 2017)	2017	Survey	Taiwan	Finance	IDT and TAM
S12	(Lee, Kriscenski and Lim, 2019)	2019	Survey	USA	Academia	UTAUT
S13	(Queiroz and Fosso Wamba, 2019)	2019	Survey	USA and India	Logistics and supply chain management	TAM and UTAUT
S14	(Francisco and Swanson, 2018)	2018	Not specified	Not specified	Supply chain management	UTAUT
S15	(Aketch, Mwambia and Baimwera, 2021)	2021	Survey	Kenya	Finance	TAM and IDT
S16	(Shrestha and Vassileva, 2019)	2019	Survey	Canada	Research community	TAM
S17	(Nuryyev <i>et al.</i> , 2019)	2019	Survey	Taiwan	Tourism and hospitality	TAM
S18	(Ullah <i>et al.</i> , 2020)	2020	Survey	Developed countries	Energy	TAM and DOI
S19	(Ullah <i>et al.</i> , 2021)	2021	Survey	Malaysia	Education	TAM and DOI
S20	(Muhamad <i>et al.</i> , 2020)	2020	Survey	Malaysia	Intelligence community	TAM 3 and TRI 2

S21	(Toufaily, Zalan and Dhaou, 2021)	2021	Semi-structured interviews	Middle East and North Africa	N/A	DOI and TOE
S22	(Saurabh and Dey, 2021)	2021	Survey	India	Agri-food supply chain	ISM and DEMATEL
S23	(Kouhizadeh, Saberi and Sarkis, 2021a)	2021	Survey	Not specified	Supply chain management	TOE
S24	(Fernando, Rozuar and Mergeresa, 2021)	2021	Survey	Malaysia	Manufacturing	TOE
S25	(Alazab <i>et al.</i> , 2021)	2021	Survey	Australia	Supply chain management	UTAUT, TTF, and ISS
S26	(Kamble, Gunasekaran and Arha, 2018)	2018	Survey	India	Supply chain management	TAM, TRI, and TPB
S27	(Clohessy and Acton, 2019)	2019	Interviews	Ireland	Mixed contexts	TOE
S28	(Singh <i>et al.</i> , 2020)	2020	Not specified	Not specified	Finance	TAM
S29	(Queiroz, Fosso Wamba, <i>et al.</i> , 2020)	2020	Survey	Brazil	Supply chain management	UTAUT
S30	(Rijanto, 2020)	2020	Case study	Indonesia	Agriculture	TOE and the theory of mindfulness of adoption

APPENDIX C: ETHICAL FORM



Examining the factors affecting the sustainability of blockchain technology in higher education

 20199983@student.buid.ac.ae (not shared) [Switch account](#)



* Required

My Name is Mohammed Salem AL Shamsi, and I am pursuing my PhD in Computer Science at The British University in Dubai under the supervision of Prof. Khaled Shaalan and Dr. Mostafa Al-Emran. The aim of this survey is to understand the factors affecting blockchain services and their continued use in higher educational environments from the perspectives of students.

There are no anticipated risks to participate in this study. Your participation is voluntary, and your identity will be kept as anonymous. Your entries will be strictly confidential and will be entirely used for scientific research purposes. I would like to thank you in advance for your kind agreement to participate in this survey.

For more details regarding this study, please contact me (Mohammed Salem Alshamsi, a PhD student, Faculty of Engineering & IT, The British University in Dubai, UAE) through the following:

E-mail address: mohammed.salem@hotmail.co.uk

Phone number: +971 50 5177732

Figure 14.Ethical Form.

APPENDIX D: CONSENT FORM

I have read and understand the above information and I agree to participate in this study. *

☐ Yes, I agree

Figure 15.Consent Form.

APPENDIX E: PERSONAL INFORMATION

Part A: Personal Information

- **Gender:** ☐ Male ☐ Female
- **Age:** ☐ 18-22 ☐ 23-28 ☐ 29-35 ☐ above 35
- **Nationality:** ☐ Local ☐ Non-local
- **Education level:** ☐ Undergraduate ☐ Postgraduate
- **Educational Institute:** ☐ Higher Colleges of Technology ☐ The British University in Dubai ☐ University of Dubai ☐ Zayed University ☐ others: please specify

Part B: Blockchain technology use

B1: Experience of using Blockchain:

[☐] 0-1 year. [☐] 2-3 years. [☐] 4-6 years [☐] Above 6 years.

B2: Frequency of using Blockchain in educational purposes:

[☐] Once a month. [☐] Several times a month. [☐] Once a year.
[☐] Several times a year.

B3: What is the most frequent blockchain service that you usually use?

- [☐] Record-keeping of certificates.
- [☐] Records of education achievements.
- [☐] Seamless payments.
- [☐] Teaching and storage space.
- [☐] Others, please specify: _____

Figure 16.Personal Information.

APPENDIX E: SURVEY QUESTION

Part C: Conceptual model factors

Please indicate your agreement to the following statements:

[1: Strongly Disagree; 2: Disagree; 3: Neutral; 4: Agree; 5: Strongly Agree]

Table 22.Study Survey.

No.	Items	1	2	3	4	5
Perceived Severity (PS)						
PS1	I believe that student records stored on blockchain is vulnerable to security incidents.					
PS2	I believe that the productivity of blockchain is threatened by security incidents					
PS3	I believe that the profitability of blockchain is threatened by data protection incidents					
PS4	I believe that blockchain can allow remote access to student records.					
PS5	I believe that blockchain can be used to download student records.					
Perceived Vulnerability (PV)						
PV1	Blockchain technology could be vulnerable to security incidents.					
PV2	Blockchain could be susceptible to security incidents.					
PV3	A security problem to my personal data could occur if I do not comply with the institution's blockchain security policy.					
Self-Efficacy (SE)						
SE1	It would be easy for me to use blockchain by myself.					
SE2	I could adopt blockchain even if there is no one around to tell me what to do.					
SE3	I could adopt blockchain if I could contact someone when I got stuck.					
Response Efficacy (RE)						
RE1	Blockchain can successfully prevent security incidents.					
RE2	Blockchain is the best solution for counteracting security problems.					
RE3	If we use the blockchain in educational purposes, we can minimize the threat of security incidents.					
RE4	Compliance with blockchain security policy reduces the security threat to my personal data.					

	Response costs (RC)				
RC1	Blockchain technology is expensive to purchase and operate.				
RC2	We have to frequently upgrade our Blockchain to download students' records.				
RC3	Security incidents can slow down the Blockchain performance.				
RC4	Compliance with Blockchain security policy would require a considerable investment of effort other than time.				
	Expectation confirmation (EC)				
EC1	My experience with using Blockchain technology was better than what I expected.				
EC2	The services provided by my university with respect to Blockchain technology was better than what I expected.				
EC3	Overall, most of my expectations from using Blockchain technology in my institute were confirmed.				
	Perceived Usefulness (PU)				
PU1	Blockchain enhances my efficiency.				
PU2	Blockchain enables me to accomplish tasks more quickly.				
PU3	Blockchain improves my performance.				
PU4	Using blockchain increases my learning achievements.				
PU5	Overall, blockchain is useful to me.				
	Sustainability (SU)				
CI1	I intend to use Blockchain technology rather than discontinue its use.				
CI2	I intend to continue using Blockchain than other alternative means.				
CI3	If I could, I would like to continue my use of Blockchain.				
	Satisfaction (SA)				
SA1	I am satisfied with using Blockchain as an assisted tool in my institution.				
SA2	I am satisfied with using Blockchain technology services.				
SA3	My experience of using Blockchain was very delightful.				

End of questionnaire

Thank you for your cooperation