Blockchain Characteristics and Acceptance

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A Thesis

In

The John Molson School of Business

Presented in Partial Fulfillment of the Requirements

For the Degree of

Doctor of Philosophy

Business Administration (Supply Chain & Business Technology Management) at

Concordia University

Montreal, Quebec, Canada

March 2019

CONCORDIA UNIVERSITY

SCHOOL OF GRADUATE STUDIES

This is to certify that the thesis prepared

By: Joe Abou Jaoude

Entitled: Blockchain Characteristics and Acceptance

and submitted in partial fulfillment of the requirements for the degree of

Doctor Of Philosophy (Business Administration - Supply Chain & Business Technology Mgmt)

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ABSTRACT

Blockchain Characteristics and Acceptance

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Originally conceived as a mechanism to enable a trust-less cryptocurrency – Bitcoin, blockchain has since unbound itself from its original purpose as an increasing number of industries and stakeholders eye the technology as an attractive alternative to solve today's complex business problems as well as disrupt mature industries. This dissertation explores the uses and application of blockchain in different domains and investigates empirically a theoretical model for its acceptance as the underlying technology for current and future information systems. The research is in three parts/essays: (1) a systematic literature review of blockchain technology to assess the body of research knowledge while also highlighting the major fields of study and areas of its application; (2) exploration of the relevant factors pertaining to blockchain-based information systems Acceptance in order to identify and develop their appropriate measurements; and (3)validation of a theoretical model from consumer decision making which includes trust, and risk but also includes important blockchain related antecedents in order to provide the needed insights for the blockchain consumer adoption/acceptance process. Findings suggest that the exploration of blockchain domains has only begun with Internet of Things, Energy, Finance, Healthcare, and Government as the most promising areas of implementation. Furthermore, perceived usefulness, risk, reputation, intention to transact, familiarity, comfortability, trust, perceived security as well as perceived privacy were identified as critical factors characterising blockchain, and measurements were developed, validated and modeled using a theoretical model. It was found that trust and perceived risk play a major role in driving consumer decisions regarding intention to transact. Furthermore, we find that perceived privacy protection, perceived security protection, reputation, and familiarity strongly influence consumer's trust and perceived risk in blockchain technology.

ACKNOWLEDGMENTS

This thesis is dedicated to my wife Melissa who has been a constant provider of encouragement and support throughout the challenges of my academic career.

I wish to express my very great appreciation to Professor Saade, my research supervisor whose patience, guidance, encouragement and support made this research work possible.

I would also like to thank Professor Tomiuk for his valuable feedback and expertise regarding the data analysis and methodology.

Finally, I wish to thank my parents for their continuous encouragement and teaching me to work hard for the goals I wish to achieve.

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Chapter 1: Introduction

I. Background

As it stands, most transactions are centralized through third-party organizations that need to be trusted. For example, when you graduate, your employer requests an official transcript as proof of completion of your studies. The university in this case is considered as a trusted intermediary between the student and the employer where its role is to ensure that the information contained within the transaction is accurate and truthful. Why doesn't the employer ask the student to provide a copy of their transcript directly? The reason is that of trust, as the candidate can modify the content. In short, the true service or commodity offered by a third-party is trust.

Launched in 2008 by Satoshi Nakamoto in his seminal paper titled "Bitcoin: A peer-to-peer Electronic Cash System", Bitcoin was the world's first fully digitally distributed currency. This innovation has sparked a wave of disruption and change in the finance industry, leading to the creation of FinTech and to a global discussion on the current state of the banking system as well as financial intermediaries including the future of the finance industry and monetary systems (Mackenzie, 2015).

Since the introduction of Bitcoin, cryptocurrencies have surges in popularity and by extension so has their underlying technology. As it stands, there are over 2100 cryptocurrencies running on over 800 blockchains with an overall market capitalization of 135 billion dollars and 30 billion dollars in daily trading led by the top 4 cryptocurrencies (Bitcoin, Tether, Ethereum and Ripple) which constitute over 57% of the market capitalization.

Blockchain is increasingly showing more promise of its application in the areas of "Internet of Things", digital collaboration, artificial and business intelligence, organizational information systems, technostress, and the dark side of digital innovations. Blockchain is promising enhanced business processes and transactions and at the same time resolve issues of trust. However, although some industries such as the financial sector might see it as a disruptive technology that cannot be avoided, it seems that they are facing the challenge and understanding the need for blockchain to be managed.

II. Blockchain Characteristics

While Bitcoin offered many unique features and innovations that lead to the acceleration of its adoption such as proof of work and digitally limited supply, it is blockchain that stands to be the key innovation whose applications seem to spin off away from Bitcoin and the financial services sector in general and into mainstream use across the various industries and technology applications (Underwood, 2016) as it offers three characteristics that render it an attractive and valuable tool for the current digital age: immutability, decentralization, asymmetric encryption and smart contracts (Wang et al., 2018).

Using cryptography and hash functions, blockchain can encrypt a grouping of transactions into what are called blocks to which specific has functions are automatically generated as a result of the content in the block. Any alteration to the block itself would lead to a change in the hash function and since all blocks are linked together through the inclusion of the current and previous hash key in each block, a change to one block would require decrypting and changing all the previous blocks on the chain. This feature allows for several advantages such as the ability to ensure that all information is kept secure and transparent while significantly reducing the risk of an attack thereby making the system capable of existing and operating without the help of trusted third parties and intermediaries (Savirimuthu, 2017).

Blockchain decentralization means that is does not have to rely on a single company or point of service in order to provide and diffuse information. This is done using hash functions and encryption which render the ability to hide sensitive information within a particular transaction only to the relevant stakeholders who possess the proper key to access it. This in turn makes possible the ability to store and simultaneously manage multiple copies and instances of the blockchain on several devices, who act to maintain the ledger and serve as guards to ensure that the future transactions undertaken on the blockchain are legitimate and do not undermine the integrity of the information in the system. This procedure is known as mining and is the primary basis of compensation for the blockchain business model; in this instance the community or "miners" receive tokens in relation to the amount of effort or computing power required to process the transactions and ensure the integrity of the information (Savirimuthu, 2017).

Blockchain allows for user privacy through the use of asymmetric encryption, which generates a public / private key allowing the user to transact publicly with information while retaining their identity private from the network. This can best be explained through the example of a regular mailbox, which is tied to a regular address known as the public key that is publicly available and can be used to send information directly to the user without direct knowledge of that user's private information; the mailbox is also tied a physical key which is held and controlled by the individual themselves which render the mailbox unable to be opened by anyone other than the holder of the key. This pairing allows the user to retain their privacy while transacting fully on the blockchain (Savirimuthu, 2017).

Of all features however, perhaps the most versatile and adaptable innovation tied to blockchain technology is the prevalence and use of smart contracts. Smart contracts are computer programs capable of executing and implementing complex instructions without the need for intermediates and human intervention. As it stands, contracts that are made between various parties must be executed either personally by the relevant stakeholder or using an intermediary. Smart contracts remove the obstacle by allowing parameters to be set which automate the execution of certain tasks and functions.

III. Purpose of the Research

In this research, blockchain was studied by first assessing the body of knowledge published in scientific journals and conferences. More specifically, this assessment focused on the application of blockchain. Blockchain is considered as a new paradigm disrupting the way business is done, and as such, it has serious implications to organizational and societal change. We therefore, seek to identify the factors for its acceptance. Finally, we proposed and tested a theoretical model to help us understand the interactions between those factors.

In our comprehensive literature review, we contextualize the initial application of Blockchain technology and trace its evolution into other fields of studies; identify and discuss our literature review methodology, and selection and mapping process. The results of the process are then elaborated followed by a discussion of the Blockchain application research landscape and the various fields covered as well as the respective Blockchain contributions suggested by the literature.

The findings then inform our study to identify the most relevant factors to the adoption and acceptance of blockchain technology by consumers within the previously identified domains. This identification culminates in the development and verification of items designed to measure the appropriate constructs of acceptance and more specifically development of measures for benefit, risk, reputation, intention to transact, familiarity, comfortability, trust, perceived security as well as perceived privacy – all of which are critical characteristics defining blockchain.

We then use measures developed, studied and validated in our previous work (Rossiter, 2002, Diamantopoulos, 2005 and Churchill, 1979) in order to apply a structural equation model to blockchain acceptance (Anderson & Gerbing, 1988). To that end we adopt the model established in (Kim et al., 2008) and integrate blockchain characteristics, in order to understand linkages for possible decision-making processes related to blockchain and propose a theoretical model for blockchain acceptance.

IV. Motivation

Blockchain technology has emerged as the central innovation of the Bitcoin system, allowing the decentralization of information through asymmetric encryption and immutability of the ledger while facilitating transactional capabilities within and across blockchains and systems using smart contracts. These features are proving to be valuable disruption components in various industries and domains relying on trusted third parties and intermediaries (Underwood, 2016).

While a few cryptocurrencies have facilitated indirectly, blockchain acceptance among consumers and its adoption into the mainstream especially through cryptocurrencies such as Bitcoin and Ethereum, the relatively small size of these platforms compared to the global financial markets and the national currencies managed by mature, sophisticated financial institutions means that the current integration of blockchain even within the area of FinTech is still not enough to constitute proper consumer acceptance of the blockchain (Folkinshteyn & Lennon, 2016).

Recent research has identified a surge in blockchain related research using bibliometric studies (Miau & Yang, 2018), indicating an increase in the user of blockchain related keywords in academic articles and research studies particularly pertaining to internet of things, smart contracts, payment systems and electronic commerce. Meanwhile, reviews of current research topics on blockchain qualitatively identify major applications of blockchain technology to fields such as internet of things, finance, healthcare (Lu, 2018). A systematic literature review of blockchain identified similar areas in academic research interests in addition to energy and government integration of blockchain.

Blockchain possesses several user advantages when compared to conventional centralized and intermediated systems, thereby opening the door for massive disruption and change in current business models and standards (Roman-Belmonte et al., 2018). However, aside from the technical challenges and limitations, there are several hurdles with regards to consumer acceptance and decision making that the technology needs to overcome (Kamble et al., 2018). These are issues related to reputation, familiarity, security, privacy, trust, risk, benefit and intention which have remained unaddressed in the domain of blockchain based information systems (BBIS) (Folkinshteyn & Lennon, 2016) (Kim et al., 2008).

Given the advent of blockchain as a supporting infrastructure and underlying mechanism enabling the Bitcoin network; blockchain has inherited notoriety due to its association with the cryptocurrency that serves to erode the trust and risk opinions formed by consumers regarding blockchain based information systems (BBIS) (Treleaven et al., 2017). Furthermore, while the hype cycle has served to increase overall public awareness of blockchain technology, it has also propagated misinformation that serves to decrease the overall user familiarity with the platform (Lu, 2018).

Security, privacy and trust are key issues in dealing with consumer perceptions of BBIS, given the novelty and unique nature of the technology and its infrastructure (Dorri et al., 2017). Specifically, blockchain offers a unique approach to these components whereby the decentralization of the information as well as the immutable nature of the ledger allows for greater security due to increased data integrity and a lower risk of theft and disruption. Meanwhile, BBIS provide greater privacy through asymmetric encryption and the advent of the private public key which allows for user anonymity within the system (Yli-Huumo et al., 2016). Finally, the nature of the ledger itself is to enable trust among participants without the use of an intermediary, hence the nature of the trust-less system.

Risk and benefit are especially relevant to the blockchain due to the relatively nascent nature of the technology (Folkinshteyn & Lennon, 2016). The proliferation and standardization of current banking systems and facilitated payment methods stand to offer a lower transaction risk than blockchain technology due to the lack of recourse with BBIS in cases of fraud and identity theft on the blockchain (Cocco et al., 2017). Furthermore, the novelty of the introduced platforms and the questions surrounding the viability, scalability and sustainability of BBIS business models stands to impede the general risk associated with the technology, further exacerbated by the traditional transaction risk (Giungato et al., 2017). Furthermore, the mature nature of the current banking system and the flexibility provided by innovative financial products such as direct bank transfers, automated check deposits and mobile payment systems serve to diminish the relative benefits of BBIS in the eyes of customers.

These factors greatly impact the potential for blockchain adoption, and even more so given the relative lack of research concerning their interaction within the consumer decision making and acceptance framework as most of the current literature focuses on the theoretical implications and applications of BBIS while empirical studies in general are limited (Kamble et al., 2018). For these reasons, there is a great need for the study of consumer decision making factors impacting blockchain acceptance in order to facilitate BBIS proliferation among consumers.

However, very few studies have focused on blockchain adoption. Kumpajaya & Dhewanto (2015), focused on the application of the TAM in an extended scope to the acceptance of Bitcoin in Indonesia; while Folkinshteyn & Lennon (2016), conducted a qualitative study to understand the TAM components of Bitcoin among various stakeholders. In relation to blockchain, Kamble, Gunasekaran & Arha (2018), studied the adoption of blockchain among supply chain stakeholders in India.

Luckily there is a strong history of literature pertaining to technology acceptance and consumer decision making models which started increasing exponentially since the late 1980s (Davis, 1993, Venkatesh et al., 2003, Davis et al., 1989). Specifically, the Technology Acceptance Model (Davis, 1989), Theory of Reasoned Action (TRA) (Hill et al., 1977) and the Theory of Planned Behavior (Ajzen, 1991) have been repeatedly combined through various constructs and factors in order to better understand the overall decision-making process of consumers (Kim, Ferrin & Rao, 2008).

From the perspective of consumer decision making research, fields such as ecommerce have received extensive study (Pavlou, 2003, and Ha & Stoel, 2009) with Kim et al. (2008) incorporating various constructs of decision making and technology acceptance models along with antecedents of privacy and security protection as well as familiarity and reputation in order to better understand the decision-making process of consumers.

Considering the above, this research was motivated by the fact that blockchain, and not Bitcoin or cryptocurrency, is the true paradigm shift. This shift is not only in the financial sector, but occurring across all layers of information infrastructure and supporting technologies (hardware, software, databases, business processes, organizational strategies, etc…) Blockchain has the promise to transform the way society thinks and believes. Considering this, blockchain is not equivalent to a new technology, and as such, research is relatively scarce, little, dispersed and unorganized. It is with that in mind this research was motivated to understand the state of body of knowledge in blockchain, and more specifically, blockchain applications. Then identifying factors and corresponding relationships that are critical for decision making and understanding behavior.

V. Findings

We find that blockchain research has increased substantially over the last 2 years and by around 32% as compared to 2015 and before. Furthermore, the outlets in blockchain publications have been through major publication sources primarily Elsevier and IEEE Xplore, which emerged as top publishers. The distribution of the articles has also shifted. Although the rate of publishing in conferences has remained the same, our study shows an important increase in journal publications. This we consider a sign of increased curiosity and demand for answers about the applicability of Blockchain. Relative to other domains of research, the Blockchain body of knowledge is still weak as it is at its infancy. The increase in research in the last two years is not impressive and it needs to be many folds more in order to reach an initial stage of maturity with possible theoretical proposals, models and designs. Expansion of the blockchain research landscape is of utmost importance, and the publication of Blockchain studies in high quality journals and outlets is necessary if we are to make sense out of its future. Another significant shift is the increase of application type publications. In 2015, Blockchain based applications represented 8 of 41 publications (Yli-Huumo et al., 2016). However, 7 of those publications were introduced in 2015 thereby signaling a potential shift in the publication landscape towards blockchain applications. Our study corroborates the existence of this trend with the identification of 151 blockchain application articles. We also identify six domains of blockchain applications (Finance, Insurance, Education, Supply Chain, Healthcare and Energy), one paradigm (IoT and Smart Cities) and six business fields (Transportation, Business Process Management, Fraud detection, Exchange, Resource Management and Rights Management).

Second, we identify relevant items pertaining to the top factors in technology acceptance models, namely familiarity, comfortability, trust, perceived security, perceived privacy, perceived usefulness, reputation, perceived transaction and technology risk as well as intention to use. These measures should make a study of technology acceptance with regards to blockchain technology a feasible endeavor with respect to generating representative and accurate models for blockchain uses and implementations.

Finally, we confirm the unique nature of blockchain technology and reveal special characteristics in relation to traditional information systems such as ecommerce. Specifically, the risk of blockchain technology is unaffected by security and privacy. We also find that familiarity is weakly significant to risk with a low path coefficient.

VI. Contributions

Blockchain as an area of research is relatively new and has many opportunities to make contributions to the body of knowledge. The research provides several contributions to the blockchain body of knowledge:

1. Provide a comprehensive literature review of recent advancement in blockchain research and its evolution, and more specifically and the interest of this study is blockchain applications.
2. The research is the first effort to identify the different domains of blockchain uses.
3. We reveal that high quality research in the area of blockchain is lacking.
4. Identification of factors for blockchain-based information systems' acceptance and success.
5. Empirical study of those factors and inter-relationships between them (note that only three empirical studies were found and all three are basic and superficial).
6. The research bridges the gap between acceptance and blockchain
7. The present study lays out the ground work for future research by:
    a. Providing blockchain-relevant acceptance measures
    b. Exploring empirically the relationship between those measures,
    c. Proposes an initial acceptance model for blockchain-based information systems use
8. Adapts a theoretical model from consumer studies, to blockchain acceptance.

9. Links the theoretical model to blockchain characteristics and includes cognitive and affective considerations.

The dissertation is organized as follows. Chapter Two presents the systematic literature review conducted regarding blockchain applications and their primary use cases in the popular domains, Chapter Three discusses the identification of factors affecting blockchain acceptance and consumer decision making including factor identification followed by the development of blockchain related measurements and their validation. Chapter Four leverages the established factors and measurements items to test an established theoretical framework for consumer decision making. Finally, Chapter Five concludes with a summary of the research conducted followed by the limitations of the dissertation and directions for future research.

Chapter 2: Blockchain Applications – Usage in Different Domains

I. Introduction

Blockchain can be considered as the newest technology stressing the paradigms of "Internet of Things", icollaboration, artificial intelligence, technostress, and the dark side of digital innovations. Blockchain seems to have stung all industries and created a buzz seeking opportunities for enhanced business processes and building trust. Yet, some industries such as the financial sector might see it as a disruptive technology that cannot be avoided and needs to be reshaped or managed.

Blockchain is a technology and a method that allows community users to validate, keep and synchronize the content of a transaction ledger which is replicated across multiple users. In other words, Blockchain is a decentralized transaction and data management technology which gained popularity in 2008 when an anonymous individual (or group) posted a white paper introducing Bitcoin – a Blockchain application of a digital currency (Yli-Huumo et al., 2016 and Aste et al., 2017).

As it stands, most transactions between individuals (financial, education, healthcare, etc.…) are centralized through trusted third-party organizations. For example, when you graduate, your employer requests an official transcript as proof of completion of your studies. This transcript is collected directly from the university, which acts as a trusted intermediary between the student and the employer in order to ensure that the information is accurate and truthful. Why doesn't the employer ask the student to provide a copy of their transcript? The reason is that of trust, as the candidate can modify the content to their advantage. In short, the true service or commodity offered by a third-party is trust, and that is precisely the Blockchain proposition.

More specifically, Blockchain offers a decentralized environment where no third-party is in control of the data and trust is not required between the stakeholders. This is achieved through a peer-maintained self-sovereign system where the transactions are time-stamped in a ledger chronologically. The transactions are broadcast to the people who participate in the system such that the ledger is publicly auditable (Aste et al., 2017). Since the transaction information is copied and maintained with the entire community, it cannot be altered or modified without the approval and update of the ledger. This prevents fraud and ensures a digital form of verification allowing for trust-less peer to peer transactions.

This proposition offers several advantages to the participants within the network. First, the transactions are transparent and publicly available for everyone to check and validate without needing to go through a central authority; Second, the transparency of the information allows for faster processing of transactions and information exchanges due to the elimination of the middle layer between the parties; Third, the information remains anonymous despite its public availability due to the existence of a set of public and private keys associated to an account. The public key is available to everyone, the private key is strictly known by the individual and the identity of that party remains anonymous.

However, while Blockchain technology does offer a promising future, it has likely suffered from the hype of its potential applications. This hype opened the door for questionable and fraudulent enterprises claiming Blockchain technology as their core business. While this may have eroded some trust and confidence particularly in the finance and technology sectors, it has offered the benefit of increasing public attention and interest in the topic. Consequently, it has in turn provided incentive for academic research, its technical aspects and applications.

In order to better understand the true potential of Blockchain as well as its various influences on industry, it is important to assess the current body of research. A systematic review on the current research on Blockchain technology was previously conducted to identify the technical perspective challenges and future directions. The study included works between 2013 and 2015 inclusive (Yli-Huumo et al., 2016).

A quick evaluation of the research output in Blockchain revealed that a spike occurred as of 2016. To that effect we decided to perform an updated literature review to include the research work after 2015 and analyze other than the technical perspective such as Blockchain applications.

More specifically, we address the gap with regards to (1) research work since 2015 (during which articles published on Blockchain have dramatically increased) and (2) focus on the business and management aspects of Blockchain - thereby mapping the existing literature around Blockchain applications and the pertaining fields of industry such as finance, healthcare, internet of things, energy, government, etc.…

In this paper, we contextualize the initial application of Blockchain technology and trace its subsequent evolution into other fields of studies; identify and discuss our literature review methodology, and selection and mapping process. The results of the process are then elaborated followed by a discussion of the Blockchain application research landscape and the various fields covered as well as the respective Blockchain contributions suggested by the literature.

We would like to stress that the use of Blockchain application in this article applies within the scope of the business and industry context and not the technical applications. Consequently, our literature review focuses on the following research questions:

RQ1: What business fields have been addressed in current research on blockchain applications and how has it evolved since 2015?

An important outcome of the present literature review is to compare the current state of research in Blockchain since 2015 while exploring, in addition to works with a technical perspective, other relevant areas such its applications and implementation. Collecting and consolidating a comprehensive body of literature will allow us to better understand the breadth and depth of related subject matter as we categorize and map the appropriate components while identifying the important areas that have been addressed.

RQ2: What solutions have been proposed for the major fields of blockchain applications?

Blockchain was created as the underlying technological solution for Bitcoin. However, as time has passed by and a better understanding of Blockchain technology has evolved, its potential application to different sectors of the industry has surfaced. We therefore aim to identify the current researched Blockchain solutions for various industries and business applications.

RQ3: What are current research gaps in blockchain business applications?

The study will help identify the appropriate research gaps either regarding overlooked fields and potential applications within the industry or problems that have yet to be addressed within the industry itself in relation to Blockchain implementation. These findings will also help pave the way and provide guidance and ideas for future research contributions.

RQ4: What are the future directions for blockchain business applications?

A direct result of answering the previous research questions should lead to the identification of important research topics and areas of interest for future research. This contribution will allow the academic community to better leverage the existing attention on Blockchain technology and address the important and needed research questions.

II. Background

Blockchain is the foundational technology behind Bitcoin (a crypto-currency). It is a decentralized transaction and data management technology allowing, in an ideal state for a low trust (or trust-less) exchange system. Information in this system does not rely on a third-party and instead leverages the economies of scale of the peer network to peer-validate the entries and disperse transaction details in a ledger. While Blockchain originated as a base for the financial services sector, and is revolutionizing the industry itself, its application has begun to spread to other sectors. The rate of Blockchain spread depends on the industry's potential to benefit from it as well as its sensitivity to the challenges that Blockchain brings into play (Aste et al., 2017).

The main driver to the adoption of Blockchain technology was the ability to solve the double spending problem while maintaining the anonymity and privacy of the transacting user's information. Double spending is a situation in which a user of a digital currency can spend several times the same amount of money before there has been a realization that the amount has already been spent / claimed.

Blockchain solves the double spending problem with the use of cryptography and having a shared ledger maintained simultaneously by the transacting community, the asymmetric encryption provides the user with a private and public key (similar to a public mailing address and a private key for the mailbox pertaining to that address). Using this combination, users can transact anonymously on the blockchain using their private keys while only being known to the community by their public keys. Through the public keys, the community verifies each transaction across the various copies of the ledger in order to ensure the funds or cryptocurrency has not been previously transferred from the same public address. In the case where two transactions are conducted simultaneously, the transaction that receives the greatest number of confirmations (note not necessarily the one that was conducted first) is the transaction that is validated whereas the other is rejected.

This method is currently the dominant form of blockchain transaction verification and is known as proof of work and suffers from an intensive need for resources and time to verify transactions, sometimes in excess of an hour. This stands in contrast to proof of stake whereby instead of splitting transaction processing relative to computing power, the transactions are split based on the wealth of the miners offered as collateral. Proof of stake offers a faster processing time but poses other risks such as agency issues. The discussion on the advantages and disadvantages of proof of work and proof of stake constitutes a research area and falls outside the scope of this study.

This allows for (relatively) rapid verification of the transaction's legitimacy by the network's nodes thereby clearing the double spending problem. User's private information is kept secure by using a public and private key combination attributed to each party on the network, the system allows the users to utilize the public key in order to conduct the transaction. These details pertaining to the transaction are stored within the block.

The block is then sent to the various nodes across the network to validate the transaction by ensuring that there was no double spending, the cryptographic properties of the blockchain allow a low trust system in which a small number of nodes is required to maintain the integrity of the blockchain and prevent an attack. Once the nodes clear the transaction, it is validated and added to the public ledger and details are stored thereafter. This entire process is conducted in complete anonymity, with neither of the parties and nodes involved having information concerning the identity of the participant.

Blockchain technology also lends itself well to transition into various industry and business applications due to the overall adoption of decentralized development and open source standards. While the above components are important characteristics of most blockchains and contribute significantly to defining their overall purpose, functionality and applicability within the businesses in which they operate; the most important component of the blockchain technology that cannot be modified or altered is the immutability of the ledger itself. When a transaction is processed and validated by the nodes in the network, the information is permanently recorded in the ledger and cannot be modified or erased from the system. In cases, where some modifications and action are required to be undertaken by an authority, smart contracts would come into play to alleviate the problems posed by the immutability of the Blockchain (Aste et al., 2017).

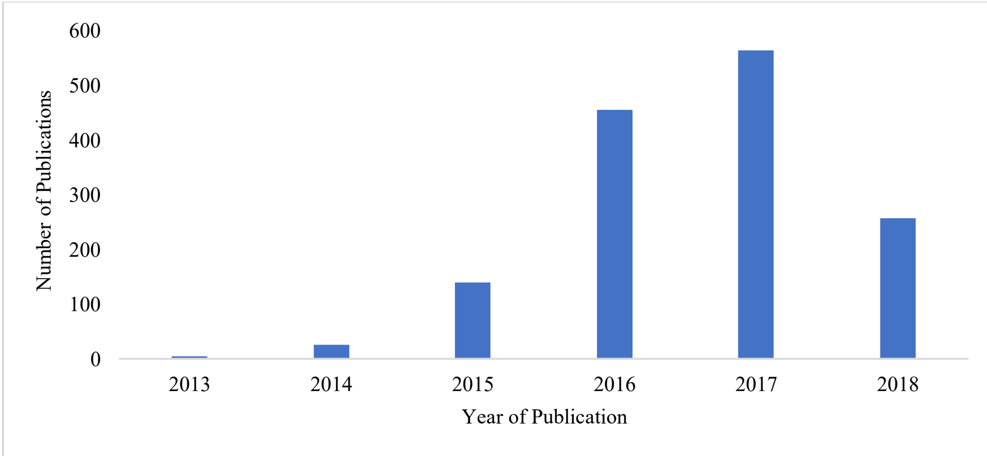

Figure 1: Publications with Blockchain in the title by year. The number of publications with Blockchain or its equivalent in the title has increased substantially since the 2015.

In the present study, we scoped our literature review to focus on the business management and application aspects (instead of the technical perspective only) of blockchain implementation. The motivation is threefold:

First, the explosion in Blockchain research starting 2016, with 2017 represents the most significant year thus far. This is illustrated in Fig. 1 showing the number of articles containing the term Blockchain in the title (using google scholar).

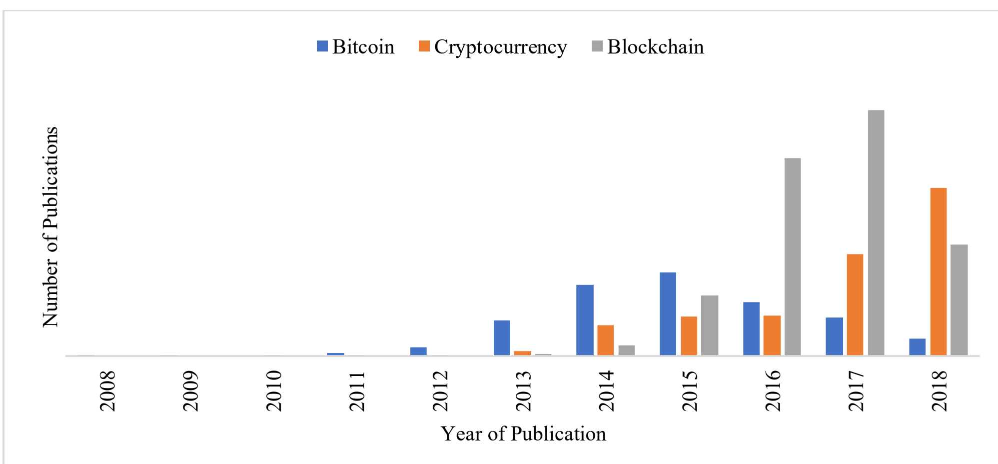

Figure 2: Number of publications with Cryptocurrency, Bitcoin or Blockchain in the title by year. In the first four years, Bitcoin publications were most of the group, however 2016 onwards saw Blockchain overtake Bitcoin in title occurrences with cryptocurrency on the rise and overtaking Blockchain as well in 2018.

Second, we believe a current study is warranted on the state of research into blockchain domains due to an apparent shift in research trends pertaining to blockchain, cryptocurrencies and Bitcoin within the last 2 years. While roughly 80% of all research articles prior to 2016 revolved around Bitcoin, Fig. 2 shows that the evolution of Blockchain research significantly surpassed those of Bitcoin, in 2016 and 2017. Furthermore, interest in cryptocurrency research has increased in 2018 and surpassed Blockchain research by about 30%, while research on Bitcoin has decreased gradually since 2015 to its original level in 2011-2012. This provides further justification for the timeliness of the research itself by indicating a relative slowdown in blockchain's research momentum and suggesting that the future direction of research within the field pertains to cryptocurrencies. However, it is important to note that our research focuses on blockchain research specifically and other keywords such as those included in Fig.2 fall outside the scope of this study.

Third, our classification framework focuses on Blockchain related applications and explores the associated fields that these applications address as well as the proposed benefits and contributions offered by blockchain to the major areas. This component of our work is the primary contribution as it was not evaluated before, and since practically every industry from aerospace to banking and the United Nations is presently considering its use in one way or another. Yet, the research to help these non-cryptocurrencies focused organizations make sense of blockchain technology while safely utilizing and taking advantage of the opportunities it brings is scarce.

III. Research Methodology

There are many approaches to literatures reviews that have been used in previous research. This includes the work of (Petersen et al., 2015) which outlines a systematic mapping process. Similarly, (Brereton et al., 2007) outlines a process to apply the review to the software engineering field. While there are many similarities and overlaps between the various methodologies, their evaluation and comparison fall outside the scope of this paper.

A systematic literature review approach based on the eight category coding steps established by was followed and presented schematically in Fig. 3. The literature review approach is made up of three sequential stages, namely criteria and coding, aggregation and consolidation (article reduction) and synthesis. The third stage includes synthesis of the final articles set, we identify the core and most relevant articles to our research questions (Carley, 1993 and Saade & Nijher, 2016). We elaborate on the phases and steps taken below.

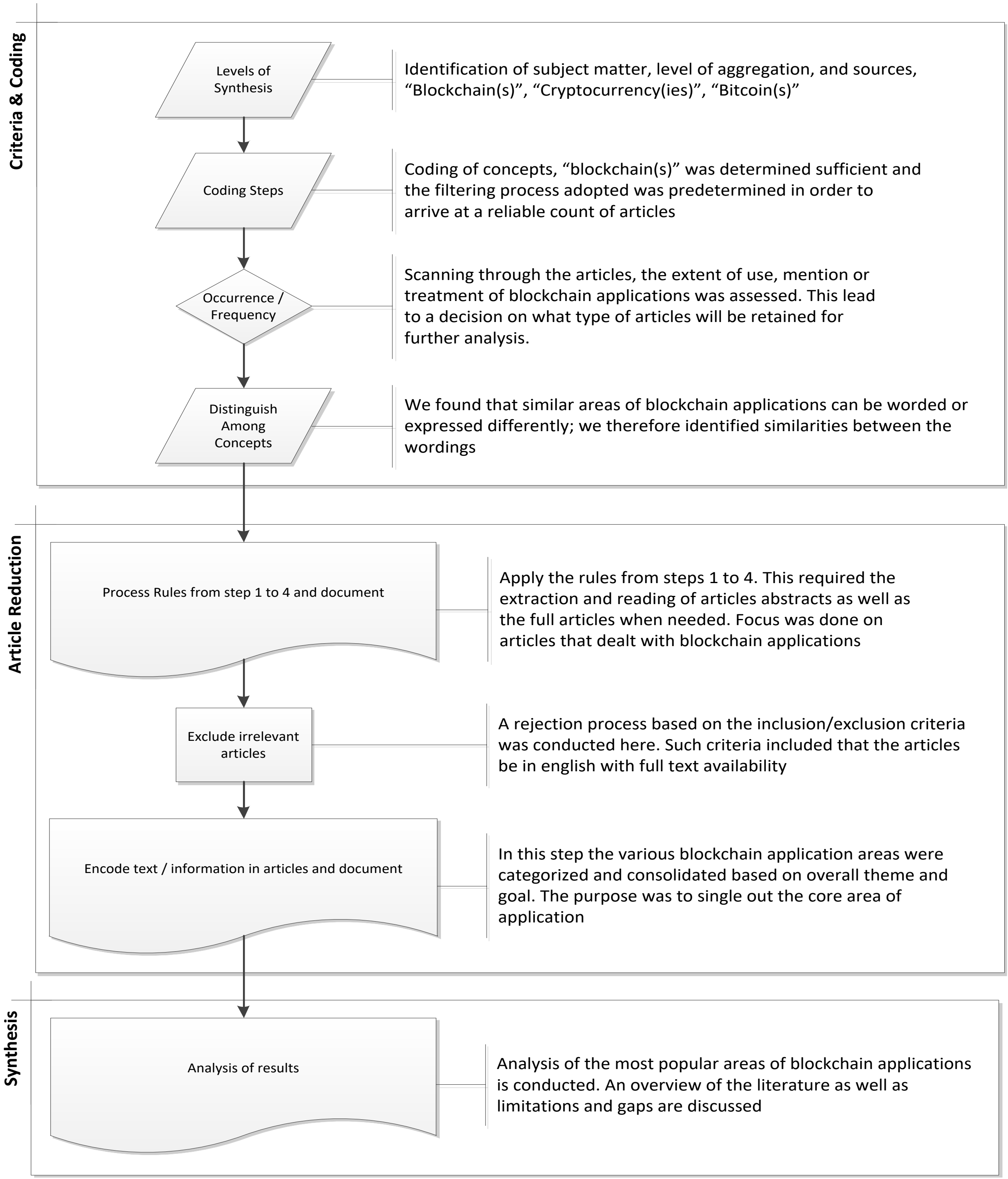

Figure 3: The Literature Review Process. The three stages of the process: Criteria and coding, article reduction and synthesis categorize the 8 steps of the process.

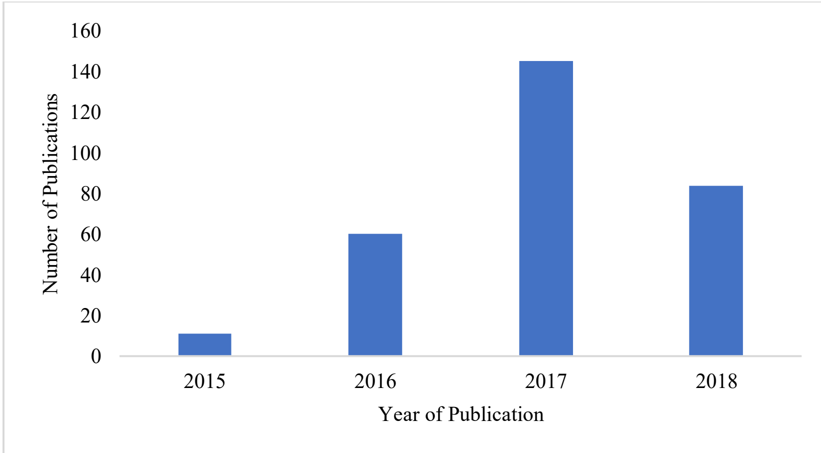

Figure 4: Publications from top 4 publishers with Blockchain in the title by year. The number of publications matches the overall trend seen in Fig. 1. However, there is a 2-year lag between the first Blockchain titled publication occurrence in 2013 and those of 2015 for the top publishers.

A. Stage 1: Criteria and Coding

1) Levels of Synthesis

We mined google scholar for all articles with the word “Blockchain” in the title, variations such as “Blockchains” were also allowed provided they were included in the title as well. The search yielded 1512 articles. We attempted to expand the search to include cryptocurrency and Bitcoin in the article title but that lead to an unmanageable number of returned articles. Furthermore, the inclusion of Bitcoin or cryptocurrency would incorporate a bias into the finance industry and introduce articles related to the marketing and financing of blockchain technology (i.e. discussing the economic and financial aspects) rather than the application of blockchain within the industry. Since the focus of our research is Blockchain and its applications, we decided to drop the pursuit after cryptocurrency and Bitcoin as they fall outside the scope. We then identified the top publishers in order to retain high quality articles. The resulting publishers/databases are: IEEE Xplore, ACM digital Library, Springer, and Elsevier.

2) Coding Steps

We screened the articles title and abstract to ensure that the topics fit the scope and research questions. Whenever needed, the full paper text was consulted. Articles not written in English, full text not available, posters, or articles addressing different fields or research were excluded.

3) Occurrence / Frequency

This step involves the decision of whether the inclusion should be due to the mere occurrence of the criteria (i.e. blockchain or its equivalent) or due to the frequency by which it occurs. Given that the criteria established in this paper require the occurrence of blockchain in the title, we believe the likelihood of frequency is relatively low and that occurrence relative to its significance to the subject of the publication is enough to merit the inclusion of the work.

4) Distinguish Among Concepts

In order to distinguish among the various concepts regarding the fields of blockchain application literature; we read through the abstracts in order to identify the appropriate classification and field of study. Once this phase was completed, we identified common keywords and concepts across the literature and did a second pass to map the articles to the appropriate categories based on derived classifications and fields. The resulting research resulted in a list of 300 articles.

B. Stage 2: Article Reduction:

5) Process Rules from Steps 1-4 And Document

Table 1: Distribution of articles with blockchain in the title by publisher

Publisher	# of Articles
dl.acm.org	58
Elsevier	29
ieeexplore.ieee.org	139
Springer	74
Total	300

Table I represents the breakdown of the 300 publications by the appropriate publishers. We then categorized the fields of those articles that qualified under blockchain business applications. The information in Table I shows that IEEE has emerged since 2015 as the leading source for blockchain publication research with springer as second and the inclusion of Elsevier as a significant knowledge source.

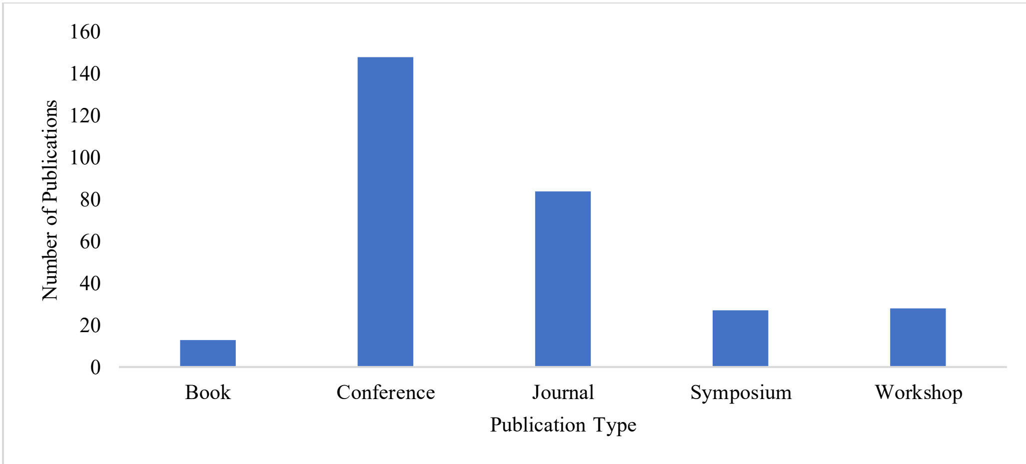

Figure 5: Publications from top 4 publishers with Blockchain in the title by type. The number of conference publications is the most significant followed by journal publications. This might indicate a shortage in the number of journal submissions pertaining to Blockchain technology.

6) Exclude Irrelevant Articles

While the original number of articles by the top 4 publishers yielded 320, several articles were excluded due to irrelevance, particularly with regards to their fit within the standard classifications by publication type as well as the field of study to which they are attributed. This led to a final number of 300 articles that meet the relevance criteria.

7) Encode Text / Information in Articles and Document

Table II highlights the data items (D…) which were extracted from the papers in question once the screening criteria were completed. D1 to D12 were collected using the information from google scholar whereas D13 to D18 were inputted after reading and reviewing the articles.

Table 2: Data Items

#	Data Item	Description
D0	Study Identifier	Study Id (1,2,3, etc.…)
D1	Cites	# of citations
D2	Authors	Name of the author(s)
D3	Title	Title of the paper
D4	Year	Year of the publication

D5	Source	The event / journal / … from where this originates
D6	Publisher	Source dataset for the article
D7	Article URL	Article link URL
D8	Cites URL	Article URL in google scholar
D9	GS Rank	Articles rank in google scholar
D10	DOI	Citation source where possible
D11	ISSN	Identification number where possible
D12	Query Date	date the information was collected
D13	Type	Type of publication (conference / journal / etc.…)
D14	Abstract	The abstract of the paper
D15	Research Question	The research questions of the paper
D16	Findings	The findings of the paper
D17	Classification	The type of paper (improvement, report, application)
D18	Field of study	In the case of application, which field (finance, energy, etc.…)

C. Stage 3: Synthesis:

8) Analysis of Results:

Considering the 320 articles from the previous step, Fig. 5 and Fig. 6 present the number of articles the year and type respectively. While our broader search does show articles containing the term blockchain as of 2013, the data sources selected did not contain such articles until 2015. This was expected as it would take time for Blockchain to build its own momentum as compared to Bitcoin. Indeed, as shown in Fig. 2, the prevalent keyword in the article titles until 2013 was "Bitcoin" with blockchain appearing with only 4 article titles in 2013 and 25 articles in 2014. In relation to our established databases, 2015 was the first year with such articles titles in 11 publications. This further highlights the significance of the current research as 2015 represents roughly 3% of all blockchain titles articles, indicating that much of the body of research took place from 2016 onwards.

Fig. 6 provides information concerning the publication type of the papers included in our study. While the percentage of conference articles up to 2015 remained the same since then at 50%, our findings reveal that the percentage of journal articles since 2015 is 28% as compared to 2.4% in 2015. This is indicative to the increased interest in the business of blockchain, and its gradual increase in its maturity as a research space.

We adapted the classification terms used in previous studies, namely “report”, “improvement” and “application”. Note that, an “improvement” article is one that defines a novel approach of protocol in order to address the shortcomings and technical limitations of blockchain technology. A “report” is a discussion, review or incorporation of previously suggested improvements within the context of a larger topic or area of interest pertaining to blockchain. An “applications” article in our study is interpreted differently and addresses the applicability of blockchain to business sector (Yli-Huumo et al., 2016). We note that the context of our initial scope incorporates both technical as well as business applications of blockchain.

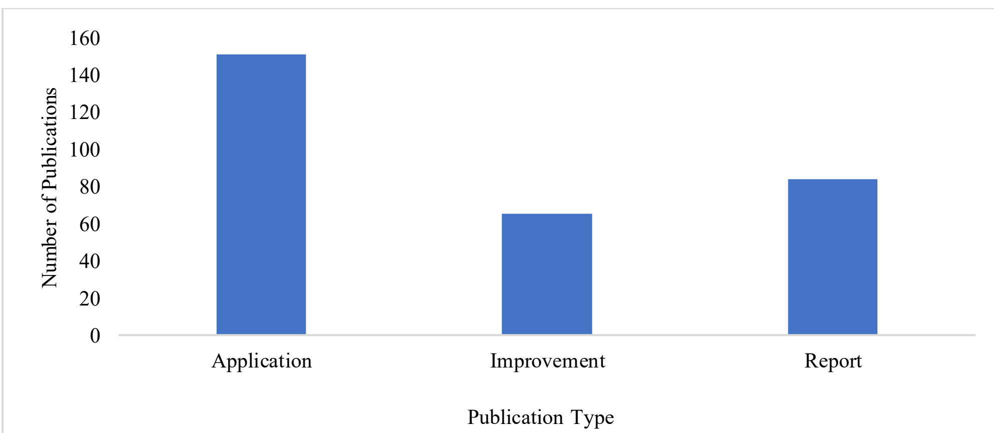

Figure 6: Publications from top 4 publishers with Blockchain in the title by classification. The number of applications is 151 out of a total of 300, constituting just over 50%. This is indicative of the overall potential for Blockchain applications in various industries.

Fig. 7 provides a breakdown of the publication classifications from our study. Business topics were 14 out of the top 15 application categories. With blockchain based privacy application constituting the exception among them.

After breaking down the publications by type, we focused on the Blockchain applications related class of articles and proceeded to leverage the 2-step mapping process described earlier in respect to categorizing the primary field covered by the articles. In cases where there were overlapping topics in the title and abstract with no clear preference to a specific area, we went to the article text in order to assess the prevalent theme of the paper and classify it accordingly.

Fig. 7 displays the classification by year of the articles in question. We can see in the graph the overall trend of significant increase in “application” articles since 2015. Another notable change is the decrease in the amount of “improvement” related publications and the rise of “reports” to overtake “improvements”.

These results were expected in the initial analysis, as the first stage of the research process is the proposal for improvements and modifications to an existing technology and given that reports are by nature dependent on the prevalence of improvements, it follows that they would first lag then overtake them.

Finally, as applications leverage the implementation of blockchain improvements as well as the reports needed to identify the core areas of competency where an application is efficient, it is expected that applications would be the last to spike and increase in significance as interest in the application and implementation of the technology increases.

Using the mapping process allowed us to identify the common areas of research on blockchain applications. 151 articles were identified for this analysis. Fig. 8 shows the distribution of these “application” articles by field. The Internet of Things (IoT) is the dominant blockchain business application topic. This is likely due to the high priority and concern raised by privacy and security problems in relation to the interconnectivity and data sharing of devices as well as exposing consumers and public infrastructure assets to security vulnerabilities. In fact, the findings corroborate the body of research, whereby the predominant application proposals for blockchain technology are security and privacy followed by trust (Yli-Huumo et al., 2016).

At this point, we needed to select the highest quality articles for final synthesis. We therefore chose to include only peer-reviewed journal-based Blockchain application. In our selection process we chose to include articles from IEEE based magazines with the other journals. Table II presents the final set of articles pertaining to Blockchain applications ready for final analysis and synthesis. The Table includes the authors, title, DOI, Journal, field of application and year.

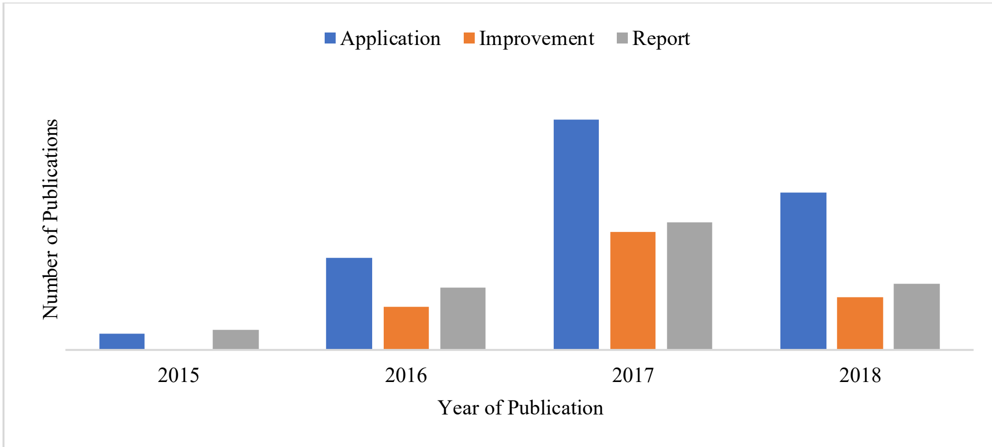

Figure 7: Publications from Top 4 Publishers with Blockchain In the Title by Classification by Year.

IV. Literature Review

We began with a total of 1512 publications containing the word blockchain(s) in the title. The top 4 publisher were identified with a combined article count of 320. An elimination via the selection criteria resulted in 309 articles. Removing articles with an NA publication nature yielded 301. An additional article was removed due to having an out of scope application parameter bringing the total to 300 articles. Of those articles, 151 were blockchain applications, 65 were improvements to the blockchain and 84 were reports regarding blockchain technology. Table III identifies the 53 journal articles published in peer refereed journals from the 4 top publishers and groups them by the appropriate field of study.

A discussion of the most studied Blockchain applications including those in Table III is elaborated in this section. After reading all those articles, we analyzed the top 5 clusters (see Fig. 8) which we consider as the primary areas/fields of Blockchain-related studies and extracted the areas of research in each, as presented in Table III.

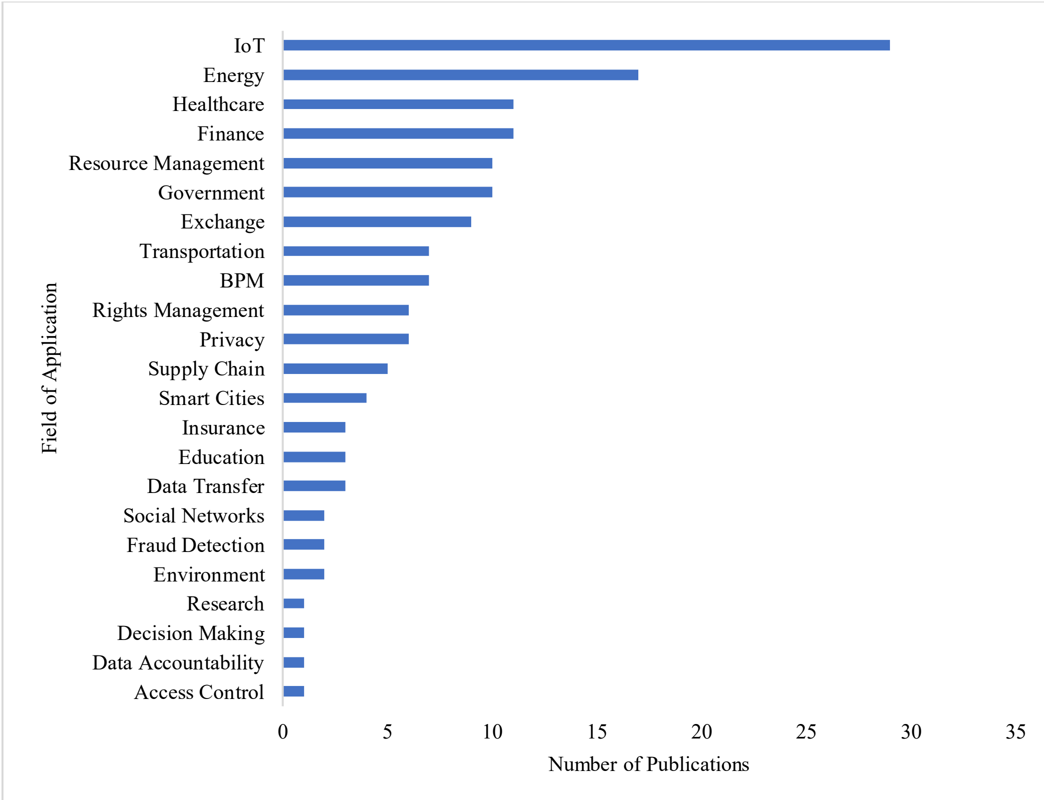

Figure 8: Number of Publications of Blockchain Applications from the Top 4 Publishers by Field. The Top 5 Fields Represent 78 Of The 151 Blockchain Application Literature.

We notice that the distribution of articles published in peer reviewed journals from the top 4 publishers follow the overall distribution of the 151 studies pertaining to blockchain applications and domains. Furthermore, the top 5 categories also constitute over 50% of the relevant body of research. However, we do note a key difference with regards to the fifth category; specifically, we find that research pertaining to the government domain of blockchain applications is absent with only one study pertaining to the topic itself. This implies a lag between government related blockchain application and those pertaining to the rest of the major domains of study and can therefore signal an upcoming area of interest and increase in relation to peer reviewed publications.

Furthermore, it is important to note the lack of clustering among the authors of the publications included, this indicates that most studies pertaining to the blockchain domain are authored by researchers within the domain to which it is being applied. This in turn signals a need for more centralized research around blockchain domains and its applications as well as the overall evolution of blockchain research thus far.

By far, it seems that most researchers today associate Blockchain application to the IoT. This is maybe due to the fact the IoT paradigm is integrative in nature and not only encompasses all advantages of the highly networked digital world, but also its bias and challenges. It seems that Blockchain in this case holds great promise and researchers are exploring how and to what extent Blockchain can address and solve these challenges.

Although still few, research efforts of Blockchain application in Energy, Finance, Healthcare and Government has been relatively equal. As shown in Table II, there are other dispersed Blockchain application research work (an article here or there) and include fields/areas in education, insurance, supply chain, rights management, transportation, business process management, fraud detection, exchange and resource management.

Overall, it seems that Blockchain applications research is still very young by any standard despite the recent spike in 2017.

A. Internet Of Things

The internet of things was by far the most popular "application" field. Twenty percent (29) of the 151 articles were related to Blockchain applications. All these articles were making the case for Blockchain's ability to improve and enhance the internet of things paradigm. In reviewing those IoT articles we were able to identify several dominant topics within the area: (1) enhanced security of interconnected devices; (2) maintaining anonymity; (3) smart contract provisions; (4) device management mechanisms and protocols; and (5) network security (Christidis & Devetsikiotis, 2016).

1) Enhanced Security of Interconnected Devices

A major problem with the interconnectivity of the millions of devices needed to propagate an IoT phenomenon is the exponential increase in security concerns presented by the various interfaces through which network devices communicate. This includes the various security problems pertaining to the IoT including but not limited to low-level concerns such as interlocking adversaries and insecure

Table 3: Journal Articles Published in Peer Refereed Journals from the 4 Top Publishers

Field	Authors	Title	Doi	Journal	Year	Reference
BPM	C. Prybila, et al.	Runtime verification for business processes utilizing the Bitcoin blockchain	10.1016/j.future.2017.08.024	Future Generation Computer Systems	2017	(Prybila et al., 2017)
	J. Mendling, et al.	Blockchains for Business Process Management - Challenges and Opportunities	10.1145/3183367	ACM Transactions on Management Information Systems (TMIS)	2018	(Mendling et al., 2018)
	Ž. Turka and R. Klinc	Potentials of Blockchain Technology for Construction Management	10.1016/j.proeng.2017.08.052	Procedia Engineering	2017	(Turk & Klinc, 2017)
Education	M. Turkanović, et al.	EduCTX: A Blockchain-Based Higher Education Credit Platform	10.1109/ACCESS.2018.2789929	IEEE Access	2018	(Turkanovic et al., 2018)
Energy	E. Mengelkamp, et al.	A blockchain-based smart grid: towards sustainable local energy markets	10.1007/s00450-017-0360-9	Computer Science - Research and Development	2017	(Mengelkamp et al., 2017)
	G. Liang, et al.	Distributed Blockchain-Based Data Protection Framework for Modern Power Systems against Cyber Attacks	10.1109/TSG.2018.2819663	IEEE Transactions on Smart Grid	2018	(Liang et al., 2018)
	J. Sikorskia, et al.	Blockchain technology in the chemical industry: Machine-to-machine electricity market	10.1016/j.apenergy.2017.03.039	Applied Energy	2017	(Sikorski et al., 2017)
	J. Kang, et al.	Enabling Localized Peer-to-Peer Electricity Trading Among Plug-in Hybrid Electric Vehicles Using Consortium Blockchains	10.1109/TII.2017.2709784	IEEE Transactions on Industrial Informatics	2017	(Kang et al., 2017)

	J. Hwang, et al.	Energy Prosumer Business Model Using Blockchain System to Ensure Transparency and Safety	10.1016/j.egypro.2017.11.037	Energy Procedia	2017	(Hwang et al., 2017)
Exchange	A. Pazaitis, et al.	Blockchain and value systems in the sharing economy: The illustrative case of Backfeed	10.1016/j.techfore.2017.05.025	Technological Forecasting and Social Change	2017	(Pazaitis et al., 2017)
	H. Subramanian	Decentralized blockchain-based electronic marketplaces	10.1145/3158333	Communications of the ACM	2018	(Subramanian, 2017)
	J. Lee, M. Pilkington	How the Blockchain Revolution Will Reshape the Consumer Electronics Industry [Future Directions]	10.1109/MCE.2017.2684916	IEEE Consumer Electronics Magazine	2017	(Lee & Pilkington, 2017)
	K. Khaqqi, et al.	Incorporating seller/buyer reputation-based system in blockchain-enabled emission trading application	10.1016/j.apenergy.2017.10.070	Applied Energy	2018	(Khaqqi et al., 2018)
Finance	B. Egelund-Müller, et al.	Automated Execution of Financial Contracts on Blockchains	10.1007/s12599-017-0507-z	Business & Information Systems Engineering	2017	(Egelund-Müller et al., 2017)
	D. Viana	Two Technical Images: Blockchain and High-Frequency Trading	10.1007/s13347-016-0247-x	Philosophy & Technology	2016	(Viana, 2016)
	E. Morse	From Rai stones to Blockchains: The transformation of payments	10.1016/j.clsr.2018.05.035	Computer Law & Security Review	2018	(Morse, 2018)
	G. Jesús, L. Hernández	Blockchain entrepreneurship opportunity in the practices of the unbanked	10.1016/j.bushor.2017.07.012	Business Horizons	2017	(Larios-Hernández, 2017)

	Y. Guo, C. Liang	Blockchain application and outlook in the banking industry	10.1186/s40854-016-0034-9	Financial Innovation	2016	(Guo & Liang, 2016)
Fraud Detection	H. Hyvärinen, et al.	A Blockchain-Based Approach Towards Overcoming Financial Fraud in Public Sector Services	10.1007/s12599-017-0502-4	Business & Information Systems Engineering	2017	(Hyvärinen et al., 2017)
	Y. Cai, D. Zhu	Fraud detections for online businesses: a perspective from blockchain technology	10.1186/s40854-016-0039-4	Financial Innovation	2016	(Cai & Zhu, 2016)
Government	C. Sullivan, E. Burger	E-residency and blockchain	10.1016/j.clsr.2017.03.016	Computer Law & Security Review	2017	(Sullivan & Burger, 2017)
Healthcare	C. Esposito, et al.	Blockchain: A Panacea for Healthcare Cloud-Based Data Security and Privacy?	10.1109/MCC.2018.011791712	IEEE Cloud Computing	2018	(Esposito et al., 2018)
	H. Wu, C. Tsai	Toward Blockchains for Health-Care Systems: Applying the Bilinear Pairing Technology to Ensure Privacy Protection and Accuracy in Data Sharing	10.1109/MCE.2018.2816306	IEEE Consumer Electronics Magazine	2018	(Wu & Tsai, 2018)
	P. Zhanga, et al.	FHIRChain: Applying Blockchain to Securely and Scalably Share Clinical Data	10.1016/j.csbj.2018.07.004	Computational and Structural Biotechnology Journal	2018	(Zhang et al., 2018)
	Q. Xia, et al.	MeDShare: Trust-Less Medical Data Sharing Among Cloud Service Providers via Blockchain	10.1109/ACCESS.2017.2730843	IEEE Access	2017	(Xia et al., 2017)
	X. Yue, et al.	Healthcare Data Gateways: Found Healthcare Intelligence on Blockchain with Novel Privacy Risk Control	10.1007/s10916-016-0574-6	Journal of Medical Systems	2016	(Yue et al., 2016)

Insurance	F. Lamberti, et al.	Blockchain or not blockchain, that is the question of the insurance and other sectors	10.1109/MITP.2017.265110355	IT Professional	2017	(Lamberti et al., 2017)
	F. Lamberti, et al.	Blockchains Can Work for Car Insurance: Using Smart Contracts and Sensors to Provide On-Demand Coverage	10.1109/MCE.2018.2816247	IEEE Consumer Electronics Magazine	2018	(Lamberti et al., 2018)
IoT	B. Lee, J. Lee	Blockchain-based secure firmware update for embedded devices in an Internet of Things environment	10.1007/s11227-016-1870-0	The Journal of Supercomputing	2017	(Lee & Lee, 2016)
	K. Christidis, M. Devetsikiotis	Blockchains and Smart Contracts for the Internet of Things	10.1109/ACCESS.2016.2566339	IEEE Access	2016	(Christidis & Devetsikiotis, 2016)
	M. Banerjee, et al.	A blockchain future for internet of things security: a position paper	10.1016/j.dcan.2017.10.006	Digital Communications and Networks	2017	(Banerjee, Lee & Choo, 2018)
	M. Khan, K. Salah	IoT security: Review, blockchain solutions, and open challenges	10.1016/j.future.2017.11.022	Future Generation Computer Systems	2018	(Khan & Salah, 2018)
	M. Hammi, et al.	Bubbles of Trust: A decentralized blockchain-based authentication system for IoT	10.1016/j.cose.2018.06.004	Computers & Security	2018	(Hammi et al., 2018)
	N. Kshetri	Can Blockchain Strengthen the Internet of Things?	10.1109/MITP.2017.3051335	IT Professional	2017	(Kshetri, 2017)
	O. Novo	Blockchain Meets IoT: An Architecture for Scalable Access Management in IoT	10.1109/JIOT.2018.2812239	IEEE Internet of Things Journal	2018	(Novo, 2018)

	P. Sharma, et al.	A Software Defined Fog Node Based Distributed Blockchain Cloud Architecture for IoT	10.1109/ACCESS.2017.2757955	IEEE Access	2017	(Sharma et al., 2018)
	P. Sharma, et al.	DistBlockNet: A Distributed Blockchains-Based Secure SDN Architecture for IoT Networks	10.1109/MCOM.2017.1700041	IEEE Communications Magazine	2017	(Sharma et al., 2017)
	S. Huckle, et al.	Internet of Things, Blockchain and Shared Economy Applications	10.1016/j.procs.2016.09.074	Procedia Computer Science	2016	(Huckle et al., 2016)
	Y. Zhang, J. Wen	The IoT electric business model: Using blockchain technology for the internet of things	10.1007/s12083-016-0456-1	Peer-to-Peer Networking and Applications	2017	(Zhang & Wen, 2016)
Resource Management	C. Xu, et al.	Intelligent Resource Management in Blockchain-Based Cloud Datacenters	10.1109/MCC.2018.1081060	IEEE Cloud Computing	2017	(Xu et al., 2017)
	K. Kotobi, S. Bilen	Secure Blockchains for Dynamic Spectrum Access: A Decentralized Database in Moving Cognitive Radio Networks Enhances Security and User Access	10.1109/MVT.2017.2740458	IEEE Vehicular Technology Magazine	2018	(Kotobi & Bilen, 2018)
	Nicolas Herbaut, Nicolas Negru	A Model for Collaborative Blockchain-Based Video Delivery Relying on Advanced Network Services Chains	10.1109/MCOM.2017.1700117	IEEE Communications Magazine	2017	(Herbaut & Negru, 2017)
	Y. Zhang, et al.	Outsourcing Service Fair Payment based on Blockchain and its Applications in Cloud Computing	10.1109/TSC.2018.2864191	IEEE Transactions on Services Computing	2018	(Zhang et al., 2018)
Rights Management	M. Zeilinger	Digital Art as 'Monetised Graphics': Enforcing Intellectual Property on the Blockchain	10.1007/s13347-016-0243-1	Philosophy & Technology	2016	(Zeilinger, 2016)

Smart Cities	J. Sun, et al.	Blockchain-based sharing services: What blockchain technology can contribute to smart citie	10.1186/s40854-016-0040-y	Financial Innovation	2016	(Sun et al., 2016)
Supply Chain	K. Toyoda, et al.	A Novel Blockchain-Based Product Ownership Management System (POMS) for Anti-Counterfeits in the Post Supply Chain	10.1109/ACCESS.2017.2720760	IEEE Access	2017	(Toyoda et al., 2017)
	Q. Lu, X. Xu	Adaptable Blockchain-Based Systems: A Case Study for Product Traceability	10.1109/MS.2017.4121227	IEEE Software	2017	(Lu & Xu, 2017)
	R. Casado-Vara, et al.	How blockchain improves the supply chain: case study alimentary supply chain	10.1016/j.procs.2018.07.193	Procedia Computer Science	2018	(Casado-Vara et al., 2018)
Transportation	A. Dorri, et al.	BlockChain: A Distributed Solution to Automotive Security and Privacy	10.1109/MCOM.2017.1700879	IEEE Communications Magazine	2017	(Dorri et al., 2017)
	A. Lei, et al.	Blockchain-Based Dynamic Key Management for Heterogeneous Intelligent Transportation Systems	10.1109/JIOT.2017.2740569	IEEE Internet of Things Journa	2017	(Lei et al., 2017)
	F. Knirsch, et al.	Privacy-preserving blockchain-based electric vehicle charging with dynamic tariff decisions	10.1007/s00450-017-0348-5	Computer Science - Research and Developmen	2017	(Knirsch et al., 2017)
	V. Ortega, et al.	Trusted 5G Vehicular Networks: Blockchains and Content-Centric Networkin	10.1109/MVT.2018.2813422	IEEE Vehicular Technology Magazine	2018	(Ortega et al., 2018)
	X. Huang, et al.	An optimal scheduling algorithm for hybrid EV charging scenario using consortium blockchains	10.1016/j.future.2018.09.046	Future Generation Computer Systems	2018	(Huang et al., 2018)

physical interfaces, intermediate-level security concerns such as insecure neighbor discovery, authentication and communication to high-level security problems that include insecure interfaces, software/firmware and middleware security (Khan & Salah, 2018).

Various Blockchain related solutions pertaining to the problems described in relation to IoT security were tackled. Specifically, Blockchain can leverage its address space (160bit) which allows for a drastic reduction in address collision probability as well as eliminating the need for centralized authorities to manage internet assigned numbers while providing a more scalable solution with the option of having more addresses than with IPv6.

Furthermore, using blockchain's identity management and governance mechanisms, devices related to the IoT can be easily registered and identified in a unified ledger with the ability to tag them to specific user and the option to quickly and securely transfer rights and ownership of devices among the various parties in the system.

The integrity of the data is confirmed through the natural design of Blockchain technology and the immutability of its ledger, enabling all data transmitted across the network to be cryptographically proofed which will enable the secure tracking and integrity of the data. Meanwhile, the private / public key mechanism established through Blockchain would allow for drastic simplifications of the security protocols needed to enable security on the traditional communication protocols.

However, the research fails to address the issues pertaining to the adoption of blockchain among devices, specifically regarding the computing power needed to implement proof of work mechanisms of verification with small and low-cost devices.

2) Maintaining Anonymity

From the user perspective, there is an inherent lack of trust in having devices that communicate constantly with the companies that spawned them and send private consumer data in a targetable way to profit seeking entities. Such problems are assumed to be behind the delayed adoption of some home speaker and smart assistant devices for fear that companies would be spying on their customers. Blockchain helps address this problem by allowing "security through transparency" where secure transfer of data among users would occur while maintaining the anonymity of their specific identity (Christidis & Devetsikiotis, 2016).

Blockchain addresses the security dilemma currently faced by constrained devices in an IoT framework where organizations cannot implement current access control standards but at the same time do not want to include powerful centralized mechanisms (due to privacy and data sensitivity concerns). To that end, Blockchain enables the introduction of a decentralized authorization management framework that leverages the consistency of the Blockchain technology in addressing privacy and data sensitivity concerns (Hardjono & Smith, 2016 and Ouaddah et al., 2016).

However, the studies do not cover the dangers of identity exposure and loss of anonymity using the additional information in order to identify the individual associated with the public key indirectly.

3) Smart Contract Provisions

Smart contracts leverage blockchain technology in order to build contracts and agreements between various parties. These agreements are essentially computer programs with specific instructions allowing them to be executed within the context and applicability of precise parameters. Existing on the blockchain, these contracts are part of a decentralized environment and allow for the automation and execution of multi-step procedures thereby facilitating information and currency exchange on the blockchain.

An example of a smart contract can be found on the Ethereum platform, whereby issuers of new cryptocurrencies set certain exchange rates between a new cryptocurrency and that of Ethereum. These parameters depend on the issuer of the contract itself and can range from the volume of the transaction to the overall volume of currency distributed up to that point in time. Through the smart contract the issuer can automate the process of users sending their Ethereum tokens and receiving the appropriate and equivalent amounts of the cryptocurrency in question.

Smart contracts can also be leveraged for other uses such as content distribution, supply chain management and the IOT. Through smart contracts, content distribution can be managed by identifying specific metrics pertaining to media and content consumption and implementing the equivalent remuneration for that use, this allows for a disintermediated approach to remuneration for artists and content creators. Similarly, supply chain can leverage smart contracts to automate the steps needed to be taken when an item ships, arrives or is in transition; this can be augmented by the internet of things using sensors and RFID chips enabling a human less exchange of information and up to date tracking of items and food sources (Yli-Huumo et al., 2016).

While smart contracts do offer several advantages that serve to increase blockchain's attractiveness relative to other systems, issues such as diverse standards and limited functionality continue to be an issue. Specifically, as smart contracts are programs they can be written in several ways and with varying parameters and standards which makes it difficult for non-technical users to understand and apply or agree to the use of smart contracts in a transaction for fear of fraud. This issue is currently being resolved using platform implemented standards such as the EC20 token standard used in Ethereum which specifies the required components and structure needed for a smart contract.

The second issue revolves around the limited use of smart contracts specifically across cryptocurrencies. In the case of Ethereum, the contracts can automate the exchange between a given cryptocurrency and the Ethereum token but cannot create exchanges and transfers from any cryptocurrency to another, which is otherwise known as a sidechain. This issue is currently being resolved in the case of Ethereum by allowing such parameters to exist within smart contracts and enabling the blockchain to incorporate these transactions.

We can therefore conclude that smart contracts can offer the IOT several advantages especially in the way of device communication automation; however, there are several steps needed to attain a level of maturity needed for this potential to materialize.

4) Device Management

With the use of Blockchain technology, the full automation of device interactions through the network is expected. For multiple interacting devices. Blockchain can allow user-less exchanges of information between the different inputs such as the transmitter from one component and the receiver from another. For example, when a container gets on board a ship, a truck for delivery or to a home address, the interaction is automatically recorded in the Blockchain and removes the human error component and added labor of tracking items.

Research proposes the use of Blockchain as a mechanism to build and manage an IoT network as well as its devices in relation to their synchronization and communications systems. The Blockchain would allow the management of device configurations and associated keys (Hardjono & Smith, 2016, Huh et al., 2017, Samaniego & Deters, 2016a, Samaniego & Deters, 2016b and Samaniego & Deters, 2016c).

However, there is a lack of practical application or business model development regarding the use of device management and its implications, namely the cost and maintenance requirements of incorporating such advanced communication equipment into various devices.

5) Secure Updates

A shift towards a decentralized architecture would lead to a more sustainable ecosystem, the current centralized model requires too much maintenance costs, especially for something as simple as distributing a software update to millions of devices not just once, but on a continuous basis even after they are no longer manufactured.

The literature introduces the concept of an update framework in which the Blockchain based system allows for permission less and distributed checks on the validity of the current firmware maintained on various IoT devices while checking the integrity of the software version and allowing the update procedure through automated processes leveraging the nodes on the network itself (Lee & Lee, 2016, Boudguiga et al., 2017 and Liu et al., 2017).

An example can be used to demonstrate the application of anonymity using blockchain's private/public feature found in its hashing algorithm, by considering vehicle intelligence and communication. Specifically, blockchain would leverage asymmetric encryption in order to generate a public and private key which are then assigned to vehicles, thereby enabling them to transact among one another through the public key while retaining anonymity through the securing of the private key. In this case cars will be able to exchange data directly with each other using the blockchain peer network infrastructure (such as the one used today for car cryptocurrencies) in order to exchange traffic information and other sensitive data while maintaining the anonymity of the vehicle itself and by extension its driver.

B. Energy

The energy field ranked second in our list of Blockchain applications with 17 (roughly 11%) of 151 application articles. We have identified several categories within the area of Energy and energy management Blockchain based applications including: (1) electricity market control between machines, (2) Facilitating energy trade, (3) increasing the security of the energy grid, and (4) assisting in the proliferation of green energy.

1) Controlling the Electricity Market Between Machines

The traditional method of electricity consumption may not benefit significantly from Blockchain implementation as it relies on the framework of one supplier, all customers. However, recent advances in energy production and consumption have begun shifting habits and market interactions away from the traditional model. Specifically, the ability for household level electricity generation using renewable energy such as solar energy paves the way for a distributed energy market with customers becoming suppliers depending on the time and conditions. As such, a platform is needed allowing for the secure transaction of energy generation and consumption information across the different parties while optimizing human involvement and maintaining privacy.

Blockchain may be a solution as it offers the potential for a framework that operationalizes machine-to-machine interaction and establishes an electricity marketplace where a consumer can choose from various suppliers and select the appropriate offer autonomously (Sikorski et al., 2017). Another problem pertaining to energy transactions among machines is the seemingly continuous payment requirements among the nodes with regards to the electricity provided or withdrawn. Micropayments are transactions with minimal nominal amounts of currency and are used to pay on a continuous basis for various small items. The introduction of micropayments allows direct interaction between machines as the authentication of the various parties is automated and decentralized (Lundqvist et al., 2017).

However, we need to consider the complexity of the parameters involved in trading energy such as distance from source as well as the overall need for fast and efficient switching between energy sources in order to prevent power outages which may be difficult under certain blockchain clearing algorithms such as proof of work.

2) Facilitating Energy Trade

The shift in the energy market discussed earlier opens the door to various exchanges between the different stakeholders in an energy community. Blockchain has to potential to establish a space for the creation of local electricity markets leveraging user's various energy generation mechanisms towards the democratizing of the energy market. However, there are several barriers standing in the way of energy trade.

Energy consumption privacy concerns and sharing information in the market is another problem in decentralizing the energy grid as the energy generation and consumption information of various individuals would be publicly available. A Blockchain solution can solve this by creating and exchange of information where the identity of the individual involved is not exposed. Furthermore, the solution would allow for the creation of automated auction mechanisms as mentioned earlier which would streamline energy exchange, regulate energy levels while improving security (Kang et al., 2017). Meanwhile the introduction of payment processing mechanisms within the Blockchain would facilitate transactions across micro grids (Lundqvist et al., 2017 and Munsing et al., 2017).

Implementations of these models should consider the relative impact such markets may have on a government's ability to predict and control energy demand and markets thereby allowing mechanisms for government intervention and moderation.

3) Increasing Energy Grid Security

Regardless of the model used to deliver and leverage electricity production, energy markets face a constant threat of security which poses a modern digital dilemma. An increase in digitization can leave energy manufacturers / facilities vulnerable to attack while a lack thereof would reduce efficiency and service quality.

Blockchain is a potential solution to the energy digitization dilemma – namely the introduction of a Blockchain-based approach that leverages smart contracts for the management of energy exchanges between the various power consumer / providers would allow a sustainable and increasingly secure mechanism for energy exchange while leading to a more decentralized and resilient power grid (Mylrea & Gourisetti, 2017). Meanwhile, a framework for transaction anonymity within the Blockchain would allow for an increase in the security and privacy of the transacting parties in the micro grid (Bergquist et al., 2017), while also having the ability to protect the energy network from a cyberattack by laying out a protection framework based on the distributed ledger (Liang et al., 2018).

However, research should include the cost of increased security in the form of lack of recourse and alterations in the case of an error or fraud, whereby the anonymity and immutability of the ledger would increase the difficulty of pursuing the issue by authorities. Therefore, research on blockchain implementations should also incorporate an aspect of know your customer for government and official purposes.

4) Green Energy Assistance

As energy systems continue to evolve and renewable energy sources become more accessible to the individual consumer, the market will in turn transform into a decentralized model comprising various energy production and storage mechanisms. This poses the opportunity to reduce the environmental impact of energy production and consumption by increasing the overall efficiency and reducing waste.

Blockchain technology can be useful in an energy management framework. The introduction of green certificates via the Blockchain allowing for the authentication of the source of energy production (i.e. produced from renewable energy, simply stored traditional generated energy in a battery, or other storage mechanism) would allow greater government incentives and programs by enabling authorities to establish adequate reward and benefit mechanisms (Imbault et al., 2017).

Current research should also consider the required complexity needed to establish exchanges across markets for various energy sources.

We can consider the example of a household generating solar power and engaging in an active exchange in the energy market in order to supply excess power generated during peak times and offset shortages caused due to the unpredictable nature of renewable energy sources. However, there are several issues that stand in the way of such an ecosystem including the household's concerns regarding the maintenance and engagement required in order to participate as both supplier and consumer within the same market, specifically in reference to finding appropriate bids and offering ones in return at various points of time every day. Blockchain technology offers to solve the problem by decentralizing the exchange of information between households, assigning a public/private key to each household as well as leveraging smart contracts to set specific energy consumption and supply parameters. Using the smart contracts, households can set preferences regarding energy supply and demand prices and automate the exchange, which will in turn be protected by the decentralized and immutable nature of the blockchain and household identity will be remain private due to the use of asymmetric encryption.

C. Finance

Finance was another major category aggregated from the literature review, with 11 (around 7%) out of 151 articles studied the interaction between finance and blockchain applications: (1) Better transaction processing, (2) sustainable banking and finance, (3) enhance financial security and (4) privacy as well as automated financial contracts.

1) Better Transaction Processing

While banking institutions have helped the world move forward in ecommerce and trade, the rapid expansion in overall trade coupled with the digitization of financial currencies continue to apply pressures from limitations on the current system, where centralized databases hold highly sensitive information and require several days of processing for even simple payment transactions to clear banking institutions. This slows down the pace of trade and exchange and keeps it from fully replacing the traditional fiat currencies with regards to transactions.

There are many benefits posed by the Blockchain framework in relation to the banking industry with regards to improved transaction processing and performance. Specifically, the Blockchain framework can assist governments in setting up single account structure which would automate the processing and balancing of fund accounts thereby reducing idle cash balances, unnecessary borrowing costs as well as reducing costs on central banks through improved liquidity (Peters & Panayi, 2016).

Blockchain based systems can be established not merely as components within banking institutions but also as competitors to them, with increased integration and decentralization as the main drivers for improved operations and faster transaction processing (MacDonald et al., 2016).

However, studies should consider the disadvantage faced by blockchain and other novel systems with regards to proliferation and acceptance when compared to traditional methods. Furthermore, the increased transaction speed and capability to engage in instant transactions have increased dramatically in countries where technologies such as pay pass, apple pay, google pay as well as others have been implemented. This implies that absent the added anonymity and security, the main advantage of blockchain directly to consumers will be its implications to international transfers and trade.

2) Sustainable Banking and Financial Transactions

Despite the 2008 crash and the subsequent rebound of the financial market, traditional banking systems still suffer from a sustainability problem. A bankruptcy by a bank leads to severe financial implications to its customers as well as chain effects for the rest of the industry. This situation made possible the global implications that arose during the financial crisis and the subsequent terming of too big to fail for most financial institutions.

The overall role of Blockchain in the future of banking and financial transactions can be seen from the perspective of achieving a sustainable financial system in the global economy. Decentralizing the storage of wealth to the individuals holding it and decoupling the value of wealth from the economy (or financial condition of a specific country or region) will allow for a globally decentralized ledger, leading to theoretically more stable financial wealth values as well as a more robust economic system (Nguyen, 2016).

However, research covering this potential application must consider the business model implications to existing financial intermediaries and its impact on the lending market.

3) Enhanced Financial Security and Data Privacy

An inherent flaw in the existing data structure of the banking system is that of centralized datasets and information. Banks are vulnerable to hacking and security breaches. Whereas this can be problematic in the cases where the data are social and general demographic, the problem is much more severe when it touches on financial assets and financial identity. Another concern posed using third-party financial institutions is the lack of anonymity, with stringent ID requirements and a lack of freedom in financial transactions.

There are several advantages to the implementation of blockchain technology from the perspective of cybersecurity given the unique characteristics and potential that it offers. Specifically, the decentralization of the ledger information would render the information more secure and impervious to hacking attempts, and the increased privacy and anonymity resulting from leveraging the blockchain private / public key allows greater freedom and protection in financial transactions such as identity theft (Singh & Singh, 2016).

However, research should also focus on the costs associated with such anonymity and privacy whereby an identification of a user's private key would enable the attacker to commit fraud and steal information without recourse.

4) Automating Financial Contracts

Blockchain enables the automation of financial contracts thereby leveraging the protocol for faster and more economical financial operations; with the potential for annual savings of roughly 11 to

12 billion dollars. This is due to blockchain's ability to implement level 3 contracts which not only execute a specific action but also automate its execution (Egelund-Müller et al., 2017).

Consider an example where an individual is seeking to send money abroad to a country in the developing world. There are several issues that stand to complicate the transaction, first of which is the length of time (normally in days) required for the transfer to go through. This is exacerbated by the risks of instability for financial service providers and financial institutions in the developing world. Blockchain would allow each of the sender and receiver to have a public and private key while decentralizing and encrypting the exchange of information. As such, the individual would be able to send the required payment directly and have the transaction processed in a matter of minutes rather than days while maintaining the safety of the asset in a decentralized platform away from the financial institutions.

D. Healthcare

Healthcare is the 4th category in blockchain applications with 11 (approximately 7%) out of 151 articles. A review of healthcare applied articles resulted in the identification of the following advantages: (1) Easier access to medical data, and (2) facilitated sharing of medical records, and (3) unification and standardization of medical records.

1) Easier Access to Medical Data

Overall, medical records continue to suffer a lack of innovation. This may be due to the sensitivity of healthcare information, the costly overhaul of information technology systems, and the overall regulatory environment and privacy concerns.

Blockchain may offer a solution by helping patients get easy access to their data. Instead of having to navigate through multiple laws and processes of medical service providers in order to retrieve the information, this can be accomplished with the help of the distributed ledger and the ability to maintain privacy through the public and private key. Moreover, easy identification of the user and granting access to the appropriate medical records while keeping the overall data anonymous is made possible in the Blockchain. The decentralized aspect also removes the need to store the information with one provider, as the information is shared and will be accessible across all medical stakeholders upon request (Azaria et al., 2016 and Liu, 2016).

However, research promoting these uses needs to account for the difficulty of accessing patient medical records in cases of accidents, incapacitation, as well as other issues of consent and authorized sharing.

2) Medical Data Sharing

Aside from the initial problem of patients being able to easily and efficiently access their data, another problem in relation to healthcare and medical information stems from the privacy and anonymity concerns pertaining to medical information in patient files. The dilemma faced by the medical profession is that medical data are extremely valuable for research purposes and the improvement of overall medical conditions and operations, but at the same time this information is highly sensitive and faces massive legal hurdles with regards to sharing and aggregating the information from the various sources.

Blockchain solves this by allowing the anonymization of the patient's medical data while keeping intact all pertinent medical information and rendering it serviceable in the aggregate. Using the Blockchain, the patient would remain anonymous by keeping his/her private key secure and only sharing their information via their public key; meanwhile the information remains publicly available for research purposes without the risk of revealing the identity of the patient (Mettler, 2016).

However, researchers experimenting with such systems should evaluate the impact of governing bodies and regulatory agencies with respect to authorizing and acknowledging the use of data collected through blockchain systems. Furthermore, business models such as remuneration for participants and health care professionals need to be considered.

3) Unifying Medical Records

The decentralization of medical records through a common Blockchain ledger would also allow for the unification and standardization of medical record information. This in turn will allow easy transferability and follow-up across the spectrum of health service providers which would in turn lead to the improvement of overall health and patient services.

However, researchers exploring this implementation should consider the issue of having multiple blockchain based healthcare systems which would lead to a divergence in the format of information and therefore cause in issue with regards to record unification.

We take the example of a patient wishing to transfer to the services of another doctor or hospital in order to demonstrate the application of decentralizing medical information on the blockchain. Currently a transfer requires the release of information directly from the previous party which can take several days and complicate proceedings. Furthermore, the records themselves may be in a different format and may contain sensitive information that the patient does not wish to share with their physician. In the case of blockchain, the medical information would be decentralized thereby rendering it available directly to the patient, who can leverage the asymmetric encryption of the blockchain in order to share their medical data with their physician while maintaining personal identity anonymity. Furthermore, the blockchain system would allow for a standardized data format that would make it easier to share and communicate between different physicians. Finally, users can choose to participate anonymously in medical research by offering their data to studies without the risk of personal identification.

E. Government

With 10 (about 6.5%) out of 151 applications of overall Blockchain business literature, government is the fifth highest category of study interest. Upon review of articles pertaining to government and blockchain; we were able to identify the following advantages: (1) eGovernment, (2) Creating a true digital identity, (3) eVoting, (4) Improving measuring instruments regulation.

1) eGovernment

EGovernment refers to the leveraging of digital tools and technologies by government officials in order to improve the overall services and benefits while enhancing its interaction with its citizens.

The integration of Blockchain into government offers several advantages. First, the scalable nature of Blockchain technology coupled with the decentralized nature of the ledger requires minimal effort to maintain and administer (Hou, 2017 and Stanciu, 2017). Furthermore, the introduction of smart contracts would allow the completion and execution of complex government bureaucratic operations in a streamlined method. These advantages would allow governments to simultaneously increase the amount of services offered while improving the overall quality and processing times of existing services.

Second, the decentralization of the Blockchain database allows for a greater amount of transparency and accessibility between the government and its citizens, by anonymizing the data, overall government transactions can be audited and monitored for anomalies without identifying the direct party, thereby also improving overall justice services by assisting in the removal of bias (Ølnes & Jansen, 2017).

Third, leveraging a private / public key combination would allow the government to open the information sharing services across the different organizations as well as to the public and the decentralized nature of the ledger means the information will be more standardized and accessible in more areas and parts than before.

Finally, the immutable nature of the ledger and its integration of financial transactions allow users to build and maintain a reliable and shareable financial history which can improve the overall quality and reliability of the credit system (Ølnes, 2016).

However, research should consider the relative significance of the large transactions and the potential risk involved in the theft of an individual's private key in order to proceed with a transaction.

2) Creating A True Digital Identity

Current government systems rely heavily on paper based and traditional forms of document authenticity and identity requirements. In most countries in the world it is not possible to use a digital ID to receive sensitive or critical government services. This is due to the lack of adoption of digital identity frameworks and standards that can both ensure privacy and security while allowing unique identification of individuals within a society.

Blockchain is aptly able to solve this problem by allowing the creation of a public and private ID whereby the individual would be able to authenticate themselves at any point while allowing the sharing of public information to be anonymous. Furthermore, the immutability and decentralization aspects of its management ensure that the information shared with the appropriate authorities is accurate and authentic (Sullivan & Burger, 2017).

However, research in this area should consider the significant dangers and implications of identity theft in the case of loss or collection of an individual's private key thereby allowing illicit behavior such as identity theft without recourse.

3) E-Voting

As government attempt to transition from the traditional voting systems that leverage paper ballots and signatures to a more modern and digital solution, a common problem persists: the centralized nature of the system means that there is a unique supplier that possesses the ability to control and manipulate the data as needed and therefore can pose a risk to the fundamentals of a country's democracy (Noizat, 2015).

Blockchain can provide the solution with its open source nature and the decentralization of its ledger allowing governments to mitigate risks of data manipulation and fend off security attacks from foreign governments. Concurrently, the ability of Blockchain to allow for proper authentication while maintaining complete anonymity in the aggregate lends itself very well to the purposes and uses of voting mechanisms.

However, research should consider the computational demands of such a system especially given the nature of the election cycle under the proof of work protocol. Another consideration is the potential for identity theft through the exposure of user's private keys

4) Improving Measuring Instruments Regulation

Improving measuring instruments regulation: As science has progressed, so have the measuring instruments required to identify and quantify different aspects within their respective scientific communities; and with the increased adoption of standardized measuring instruments across the different countries in general, and the developing world, certain challenges begin to develop with the added complexity of new instruments. The challenges faced pertain specifically to the amount of data being measured as well as the security risks of manipulating and modifying the data.

With the increase in the amount of information captured and needed to quantify and compute measurements, required resources have proven to be prohibitive for certain governments and developing countries. Blockchain can overcome this problem using distributed computations and measurements. By allowing the decentralization of measurement computations and dispersing it across the world while maintaining the security and integrity of the data, Blockchain can help governments overcome the limitations and obstacles of increased resource requirements. Furthermore, the decentralization of the data will make data and security breaches much more difficult, whereas the immutability of the ledger will ensure that the consistency, accuracy and integrity of the data is maintained (Melo et al., 2017 and Melo et al., 2018).

Research should also consider issues regarding differences in international measurements of values and their implication on the sustainability and widespread adoption of such systems.

We can use an example to demonstrate the application of a true digital identity using blockchain. A patron ordering an alcoholic beverage at a bar is currently required to provide a form of personal ID upon request in order to satisfy the appropriate legal requirements. However, along with providing the needed information such as age, the patron is also providing a vast amount of personal information such as the exact date of birth, address, and various other personal information. Using the blockchain's asymmetric encryption and decentralization, users would always be given a private/ public key capable of being used and validated due to the decentralized nature of the data. In the case of the patron, the digital identity would allow the individual to disclose only the pertinent information such as age while maintaining the identity of the individual.

V. Discussion

RQ1: What Business Fields Have Been Addressed in Current Research on Blockchain Applications and How Has It Evolved Since 2015?

Our research revealed several insights into the Blockchain research landscape, particularly to Blockchain applications and improvements.

Blockchain research has increased substantially over the last 2 years and by around 32% as compared to 2015 and before. Furthermore, the outlets in blockchain publications have been through major publication sources primarily Elsevier and IEEE Xplore, which emerged as top publishers. The distribution of the articles has also shifted. Although the rate of publishing in conferences has remained the same, our study shows an important increase in journal publications. This we consider a sign of increase curiosity and demand for answers about the applicability of Blockchain. Relative to other domains of research, the Blockchain body of knowledge is still weak as it is at its infancy. The increase in research in the last two years is not impressive and it needs to be many folds more in order to reach an initial stage of maturity with possible theoretical proposals, models and designs. Expansion of the blockchain research landscape is of utmost importance, and the publication of Blockchain studies in high quality journals and outlets is necessary if we are to make sense out of its future.

Another significant shift is the increase of application type publications. In 2015, Blockchain based applications represented 8 of 41 publications (Yli-Huumo et al., 2016). However, 7 of those publications were introduced in 2015 thereby signaling a potential shift in the publication landscape towards blockchain applications. Our study corroborates the existence of this trend with the identification of 151 blockchain application articles.

Research findings from the studies presented in Table II reveal six Blockchain applications sectors (Finance, Insurance, Education, Supply Chain, Healthcare and Energy), one paradigm (IoT and Smart Cities) and six business fields (Transportation, Business Process Management, Fraud detection, Exchange, Resource Management and Rights Management). IoT seems to be treated as an all-encompassing paradigm. Many areas of business have not been addressed in Blockchain. This includes a long and not comprehensive list of: manufacturing, production, operations, purchasing, marketing, sales, customer relationships, information technology, adoption, anxiety, outsourcing, logistics, business development, human resources management, and risk management. Moreover, there are many other sectors (other than energy and healthcare) and bodies that need to consider Blockchain and which includes but is not limited to: aviation and aerospace, pharmaceuticals, not for profit organizations, the United Nations, hospitality and tourism, real estate, retail, politics, economic development, environment and sports.

We believe that Blockchain technology holds great promise as it puts forth a very courageous and ambitious proposal on the table of human evolution. It has the potential to change the human course. Relatively speaking, and considering the outcomes of this study, researchers have just begun to probe with their minds the form and function of the Blockchain technology. At the same time, it seems that businesses are very cautious and maybe scared (or lacking the understanding) to experiment with it. Are businesses waiting for researchers or the other way around? What is holding them back?

RQ2: What Solutions Have Been Proposed with The Major Fields of Blockchain Applications?

Of the 151 blockchain related applications classified in our study, publications related to Internet of Things, Energy, Finance, Healthcare and government were the most prominent, constituting over 53% of the total Blockchain application literature; similar to previous studies (Yli-Huumo et al., 2016). Furthermore, they elaborated in their research gap discussion section the ability for blockchain to benefit fields outside of the cryptocurrency and the Bitcoin space, including the use of blockchain application for improvements in the operation and governance of other related fields, among others. Table IV summarizes the solutions that Blockchain technology has promise to solve in the various businesses and sectors.

IoT was initially discussed, with blockchain's ability to leverage its user privacy protection through public key anonymization which was identified as a valuable resource for maintaining privacy in a future with millions of interconnected devices sharing data and engaging in constant communication. Furthermore, the decentralized and immutable nature of the blockchain ledger allows IoT based devices quick, easy and distributed access to the information while permitting constant contributions and additions to the data set from various parties due to the integral security of the information. Finally, smart contracts were found very valuable in allowing IoT devices to interact directly with one another, helping further push the boundaries of automation and remove steps of human intervention from the process of communications and processing.

Blockchain research on energy predominately focused on the usefulness of blockchain's decentralized nature in democratizing the energy supply and demand industry while accommodating a more scalable and flexible solution for the world with consumers alternating as providers on the energy grid. The blockchain's privacy and anonymity features allow for the induction of multiple consumers and providers in the market and the creation of microgrids within the energy sector while preserving the data consumption and pricing preferences of the individuals engaging in the transactions. Finally, smart contracts allow the energy sector to automate and self-execute transactions between the various participants, enabling machine to machine interactions and allowing government authorities to reliable identify green energy sources and provide the appropriate motivation incentives to their producers.

In Finance, blockchain's decentralized ledger allows for easy and convenient access to user's financial information from multiple locations while limiting the impact and loss of wealth and information due to the shutdown or bankruptcy of a central authority. The decentralization also allows global currencies tied to international market values rather than national banks and currency systems. Furthermore, the ability to anonymize transactions and maintain privacy allows a greater interaction between the various parties within the financial system and facilitates the exchange of good and services directly between individuals rather than through businesses as the private identity is kept confidential while allowing a secure exchange. Smart contracts allow the creation of level 3 ledgers capable of not only executing certain financial contracts and commitments but also automating the execution process and criteria given present conditions and values, thereby allowing a more sustainable and flexible financial system.

Blockchain is also suggested as a method to spur and grow innovation in the healthcare sector, with the decentralization of patient data allowing users immediate and quick access to their important medical information from anywhere in the world rather than having to go through the service provider, furthermore, the immutability of the ledger would allow patients and their health service providers to freely update the ledger without concerns over data integrity and any party modifying the information for nefarious purposes. This will also increase accountability in the medical field, as mistakes would not be hide able; in addition, the enhance privacy and anonymity of interaction within the blockchain will strengthen doctor patient confidentiality while also allowing medical professionals open access to massive amounts of medical data previously walled off for privacy concerns.

Whether through aspects of EGovernment, digital identity, voting or measuring instruments; governments stand to gain significantly from the potential of blockchain applications. Through the decentralization of the dataset, governments can expand and enhance the quality of their services by removing the need for database administration and maintenance. It will also allow for proper digital voting as it solved the important problem of entrusting the voting data of in the hands of a single company or database with the motivation to manipulate the information. Decentralization will also help better run measuring instruments and the data they capture and run by removing the obstacle of costly computing and storage equipment and securing the information from manipulation through the blockchain, the immutability will also allow for the creation of a proper digital identity capable of removing the obligation of physical proof documents as the ledger will be trustable enough to confirm the information. The enhance privacy through public / private keys will allow the government to more freely grant access to its data to other government agencies and research groups allowing for a better understanding of current problems and proposals of solutions as needed. The added privacy will also improve the voting process by providing regulators and the government access to all voting information but maintaining the private identity of the voters themselves. Smart contracts will help alleviate the bureaucratic process of government systems by simplifying multi step basic procedures thereby improving the overall efficiency and quality of services provided.

Table 4: Major Subjects of Study Within the Top 5 Fields of Blockchain Application Solution Research.

Field of application	Number of Articles	Solution suggested by body of knowledge
Internet of Things	29	1. Enhanced Security of Interconnected Devices
		2. Maintaining Anonymity
		3. Smart contract provisions
		4. Device management mechanisms and protocols
		5. Network security
Energy	17	1. Electricity Market Control Between machines
		2. Facilitating Energy Trade
		3. Increasing the Security of the Energy Grid
		4. Assisting in the positive reinforcement and proliferation of green energy
Finance	11	1. Better transaction processing
		2. sustainable banking and finance
		3. enhanced financial security
		4. automation of financial contracts
Healthcare	11	1. Easier access to medical records
		2. Facilitated sharing of medical information
Government	10	1. eGovernment
		2. Creating a true digital identity
		3. eVoting
		4. Improving measuring instruments regulation

RQ3: What Are Current Research Gaps in Blockchain Applications Research?

We were able to identify several gaps in the existing blockchain research landscape. First of which is the fact that the top 5 fields of blockchain research accounted for over 53% of the articles identified in the study. While blockchain does pose a significant advantage to these particular sectors, there are various other areas where these same advantages can prove to be useful such as the research sector, be it academic or industrial which can stand to benefit in much the same way as the healthcare industry by opening up data sources and eliminating the need for universities to maintain and administer databases while increasing the reliability of scientific findings and the integrity of the data used in the research itself. Other areas such as education, environment, insurance and supply chain are important areas that have collectively entailed only 13 articles.

The second was the broad discussion on the technical application of blockchain into the specific sectors and how the advantages of the technology can help assist these fields in improving the overall quality and scope of services offered. However, blockchain does not merely represent a new technology platform for the storage and communication of data; it also presents a new business model landscape whereby the supplier and the seller are often interchangeable. This new structure requires massive changes in the current way of doing business and research on different business models and processes to build a blockchain have been limited. Existing research on the energy market has begun to touch on this with references to energy market creation and price matching through the blockchain.

Third, whereas the literature has expanded to discuss the uses and advantages of blockchain within the various industries, there has been few or little discussion concerning the challenges of blockchain implementation and the materialization of those benefits within specific industries. Some literature does discuss the challenges and limitations of blockchain technology, but it is mostly from an overall perspective that considers the limitations rather than their application to that field.

Fourth, the literature discusses the applications of Blockchain in relation to specific industries and circumstances. While useful, they do not touch on the overarching use of the underlying innovations used to render the solution itself feasible. Table V highlights some of the general solutions proposed across the various industries as well as some of the spinoff innovations that can be applied to across the board. Smart contracts have the capacity to radically alter and accelerate the adoption timeline for Blockchain technology, whereas machine to machine interaction will have dramatic applications in relation to big data, machine learning and artificial intelligence. More research is needed to classify and categorize the various spinoff innovations and map their use and applicability across the industry sectors.

Finally, the blockchain applications surveyed tended to be descriptive in nature, proposing implementation of a technology to a sector with little guidelines on actual implementation or development of the application or concept needed to make the system work. Thus far such research has been limited to industry and the introduction of whitepapers around the various businesses and concepts involved in blockchain technology. However, more work is needed to push for higher quality studies and bring these efforts into the academic sector.

Table 5: Blockchain Solutions and Resulting Spinoff Innovations

Solutions	
1	Decentralizing data and information
2	Privacy protection
3	Security of information
4	Fast and easy access to data and information
5	Remove human intervention from processing
6	Remove intermediary Service providers
7	Democratization of data and information
8	Scalability
9	Financial losses due to time delays
10	Quality of service
Spinoff Innovations	
1	Smart Contracts
2	Machine to machine communication and processing

RQ4: What are the Future Directions for Blockchain Applications?

Despite the seemingly rapid acceleration and continuous increase of interest in Blockchain technology we feel that the momentum for exponential growth is not enough yet. This is evident from the body of literature as the breadth and depth of Blockchain-related studies are still lacking quality, substance, cohesion and direction. The literature does not provide any hints of direction.

Our preliminary exploration of the literature including the term cryptocurrency has shown that research output in cryptocurrency surpassed that of blockchain in 2018. After increasing dramatically over the past 2 years, see cryptocurrencies-Blockchain research to continue to increase as part of the evolution of blockchain research. However, cryptocurrency and Bitcoin are not part of the scope of research and therefore we shall not analyze this area, however, we do question the impact of cryptocurrency research on Blockchain research. Is cryptocurrency research preventing Blockchain application research, or Blockchain application research is waiting for cryptocurrency research to mature first? It seems to us that cryptocurrency is a new paradigm for the financial sector pushing the envelope for new financial models. But Blockchain itself, viewed beyond the cryptocurrency space, involves organizations at a level beyond the technical domain with significant impact on their strategies, processes and competitive advantage. It follows that when it comes to Blockchain research, a strong partnership between industry and researchers must be forged for it to grow significantly, otherwise it will remain sluggish.

During our study, we observed some research on user technology acceptance. As most research today introduced blockchain into various fields and in general terms, little has been done on the usability and perceptions of users with regards to the implementation of blockchain technology. Furthermore, we find that digital rights management and digital content distribution stands to gain disproportionately from blockchain implementation and that high-quality academic research is needed, since neither of them has improved since 2015 (Yli-Huumo et al., 2016).

Finally, we expect an increase on the environmental impact of blockchain and the inclusion of environmental factors within the business model solutions of blockchain research dur to the high amount of energy required to deploy and maintain the network system. While decentralized and shifted away from the enterprising, Blockchain poses concerns to regulatory bodies and society with regards to the sustainability of blockchain, and which constitutes an important area of future research.

VI. Limitations:

Being a systematic literature review, the paper suffers from the conventional limitations of such studies. Publication bias is a concurrent concern as there is a higher likelihood of publications with positive results to appear than negative results due to citation and publication time established in (Petersen et al., 2015 and Fernandez et al., 2011). This was addressed in our study by mining a collective research engine (google scholar) and drawing the largest possible number of articles available in the body of knowledge, then identifying the top sources of publication and incorporating them in our analysis. This focus on increasing the range of article searches is expected to increase the likelihood of yielding papers with negative results. Another potential solution to the problem is to expand the search even further to include SSRN sources drafts and industrial whitepapers. However, this poses problems of its own namely in the way of publication quality and the difficulty of obtaining an accurate and solid version of the publications in question.

Selection bias can stem from the criteria used to identify and collect the relevant publications in our survey which in turn can lead to statistical biases. Specifically, our core criteria of having blockchain or its equivalent in the article title might exclude other papers dealing with the general topic without the keyword. We attempted to solve for this by mining cryptocurrency and Bitcoin related keywords, however this posed its own set of problems, namely the increase of articles to over 3000 potential publications, the duplication of many articles with multiple keywords in the title and the divergence in the research topic is publications with cryptocurrency and Bitcoin keywords have had other focuses and applications. Regardless, our objective was to build on the existing literature while investigating the growth of blockchain application literature within the various industry fields, of which we were able to identify 151 articles relating to the topics covered.

Data extraction bias was addressed using well established and regarded search engine allowing for the collection of publications and articles across different publishers, and while there remains the chance of missed articles from the search, we are confident that the method used provides an increased reliability relative to other article data extraction methods.

VII. Conclusion

Blockchain technology possesses certain characteristics that render it a valuable tool for industrial applications and a potential source of disruption for established industries. These include the immutability of the ledger, the decentralization of the data, the preservation of privacy, the allowance of trust-less transactions, the efficiency and sustainability of processes as well as the ability to automate multi-step processes using smart contracts.

We use a systematic mapping process to understand the current state of blockchain research as well as contrast it to past literature reviews and discuss its future implications for academic and industry stakeholders. The study approached the review form the standpoint of blockchain applications and publications dealing with the integration of blockchain into specific sectors and industries. Our final output resulted in 151 blockchain application publications extracted from a pool of over 1500 academic works and sifted by including only the top publishers.

Blockchain applications have focused heavily on sectors of the industry, namely IoT, Energy, Finance, Healthcare and Government; this focused interest is likely due to the propensity for such industries to benefit by the unique combination of advantages that blockchain offers into the market.

Our study indicates that blockchain research is expanding rapidly with a distinct evolution pattern among the different layers and concepts of blockchain implementation, with initial research focusing on blockchain's first application Bitcoin, then progressing to study the underlying technology itself in the past 3 years while gradually shifting from blockchain improvement related works into application papers.

Furthermore, we identify the next wave of research to center around cryptocurrencies and related user centered acceptance and adoption research in order to create interfaces and business models capable of streamlining blockchain integration into the various specialties.

Chapter 3: Blockchain Factors for Consumer Acceptance

I. Introduction

The past decade has seen a tremendous growth in the world of digital commerce (Anderson, 1973). The introduction of the iPhone as well as a host of other devices capable of harnessing the advantages of the internet has led to a global proliferation of intelligent devices. This technological revolution further propelled by the expansion of the World Wide Web and the multitude of services available has opened the door for changes in the traditional structures of businesses and commerce. In particular, the introduction of ecommerce facilitated the exchange of good, information and financial services at a local, regional and global level, threatening the established structure of traditional brick and mortar stores as online sales increase.

The introduction of crowdfunding technologies as well as cryptocurrencies and other forms of decentralized transactions between users, coupled with innovations in mobile payment technology such as apple and android pay are helping to reduce the friction normally involved in transaction processing (Zheng et al., 2017). A natural evolution in the realm of digital transactions is the introduction of the internet of things. Under the new promised paradigm, users would be able to not only transact and fulfill exchanges, but to disintermediate themselves from the process by enabling the devices to transact on their behalf. Through the internet of things, a multitude of smart devices containing sensors and other data collection components would be able to transfer useful and real time information seamlessly throughout the network, allowing for more intuitive and intelligent decisions from their users. Furthermore, the interconnected nature of the technology is likely considered as the catalyst for the future evolution of technology including but not limited to the expansion of artificial intelligence by leveraging the various devices and sensors recording data, the introduction of autonomous driving through the use vehicle x to x communication and the streamlining of global supply chain mechanisms via the use of automated device information exchanges (Christidis & Devetsikiotis, 2016).

Another area standing to benefit from the improvement of information technology is the healthcare sector. Through the prevalence of wearable devices containing sensors able to record data ranging from step tracking to sleep to heart rates and possessing the needed technology to communicate data directly to other systems and information hubs, healthcare stands to amass a trove of health information that will better the quality of life for future generations. Furthermore, the digitization and standardization of information and medical records coupled with the reduction in the cost and increase in capability of computing power will allow patients greater access to medical records as well as the ability to share their medical information with other parties (Mettler, 2016).

In the energy sector, the introduction of green technology coupled with the move to more personalized and sustainable energy sources open the door for private households and individuals to become simultaneous energy producers and consumers. The ability to generate electricity in excess will open the door to resell power back into the grid and subsidize energy needs at various national levels, thereby creating energy micro grids. Furthermore, the user of green energy generation technology will allow for direct government subsidies in the repurchase and exchange of energy between citizens (Lundqvist et al., 2017 and Sikorski et al., 2017).

The world of financial services, already improved through the advent of credit cards and digital transactions as well as payment processing stands to gain through the replacement of cash and hard currencies by smart devices capable of conducting financial transactions directly and efficiently, thereby reducing friction and allowing for greater liquidity security among financial institutions. Finally, the digitization of commerce, securities and currencies will allow for more efficient markets and a greater access to wealth creation tools across the modern world (MacDonald et al., 2016).

Finally, government areas and services will be able to offer better services to their citizens and enable a greater level of decentralization from capital cities and government agencies through the use of online systems and portals of service. The introduction of digital ID will streamline government communication with citizens while digital voting systems will remove the hassle of traditional voting while adding a greater layer of security and accountability while reducing the risk of fraud and tampering (Ølnes & Jansen, 2017).

However, these technological enhancements to existing industries do not occur in a vacuum, benefits and improvements give way to concerns and issues, particularly pertaining to privacy, security and data centralization. With the increased proliferation of information, privacy risks becoming a thing of the past, personal data can be tagged to individuals and the need to share information can be offset by the loos of control over one’s information. Smart devices can share more about you than you may feel comfortable, your neighbors can spy on your energy consumption and production, every transaction and purchase you conducted can be made public to various institutions and a centralized medical record system can impede medical data privacy and doctor patient confidentiality (Lindman et al., 2017).

Meanwhile the spread of information and its presence in multiple locations will increase the risk and probability of data theft. Data breaches are not a rare occurrence in the modern age, and the increased expansion of information size, quality and breadth can increase the temptation and potential reward of breaching user's data. Smart device networks can be hacked to obtain sensitive information, while financial accounts lead to credit card and financial fraud. Compromises in government systems can open the door to identity fraud even in cases of traditional brick and mortar services, the risks are compounded in relation to online exchanges.

There also the inherent risk of centralizing the information in the hands of trusted third-party entities. To this day, the digital revolution has been led by third party organizations looking to offer enhanced products and services by leveraging the internet and technological innovations in order to interact remotely and virtually with their consumers. This movement has led to an improvement in the number and quality of services offered to customers across the world. From ecommerce to banking and social media and networking, technology companies have allowed a greater connection and an easier approach to accomplishing tasks than was possible. However, with the increased interaction between users and technology companies there was an equivalent increase in the amount of data held about consumers and users. This has led to new business models whereby the user themselves as well as their data and their interaction with the company is an enough justification of the company as an ongoing concern and a creation of value. This poses a risk of abuse as companies can leverage customer information not only to provide better products and services but also to identify user tolerances and price sensitivities thereby allowing for greater price customization.

Introduced to the masses in 2008 as the underpinning technological infrastructure to the first global cryptocurrency Bitcoin; Blockchain technology allows for the validation and synchronization of content among users directly without the intervention of intermediaries and trusted third parties. This is due to the allowance of trust-less mechanisms whereby all users can hold and maintain a copy of the information system for themselves and validate its authenticity against other versions to ensure all information is kept authentic and valid (Nakamoto, 2017).

The introduction of asymmetric encryption allows for the existence of both private and public keys whereby the user interacts with the community using the public key while the private key remains unknown to other users (Weber et al., 2016). This advent in turn enables user to transact in complete privacy by making the ability to locate the identity of a particular user within the network exceedingly difficult. This enhancement of privacy allows blockchain users to utilize internet of things devices free of the concern of losing privacy; while financial transactions can be conducted without concern over the nature of the transaction and its implications opening the door to repercussions on the part of the user. In the healthcare sector, the protection of privacy will allow greater access to medical records without concerns over privacy violations and maintaining the anonymity of the data.

The use of cryptography also allows the security of the information. While traditional databases suffer from the prospect of data proliferation as it renders the information more difficult to maintain securely, blockchain's distributed ledger ensures that there is no central repository of data that can prove attractive to a hacker in order to steal pertinent information, each user holds a part of the whole that is the blockchain (Anderson, 1973). Through the encryption of information as well as the immutable aspect of blockchain whereby transactions recorded in the ledger cannot be modified or removed, only added upon, internet of things can operate safe of the risk that information will be tampered with or stolen without user consent, healthcare practitioners and patients can share information without concern over data theft and unauthorized access to medical records. Local energy suppliers will be able to ensure that the micro grid energy exchange system can operate without the risk of shutdown and tampering. Furthermore, financial companies can ensure that user accounts containing sensitive financial and personal information cannot be easily accessed and subverted. Finally, government can rust in a robust IT infrastructure that can withhold manipulation.

Blockchain technology also allows the decentralization of information through the mechanisms described above, this ensures that central authorities and third-party companies do not own user's personal data but are instead privy to its content for the purposes of greater services, products and the greater good. Devices supporting internet of things can be used without adhering to a centralized structure where the data is held by a single company, furthermore, devices would be able to proliferate updates and needed software improvements without a mandated intermediary.

Financial accounts and transactions would be conducted directly between individuals thereby circumventing financial institution and democratizing the financial system rendering it similar to the cash and free exchange market. Hospitals and insurance providers will also lose any monopoly and hold over patient's medical records and information, allowing healthcare customers to seek out and capitalize on the best opportunities and services. Finally, government programs and services such as digital ID and voting systems can exist without concerns of a third-party company holding individual identity records and the removing the risk of voting manipulation and fraud.

Blockchain technology is not perfect, like all nascent systems, it suffers from several issues and constraints that threaten its viability from the perspective of sustainability and scalability (Lindman et al., 2017). However, these points will not be discussed as they fall outside the scope of the current study. While research on blockchain technology has increased significantly in the past two years, much is left to be said concerning the acceptance of blockchain and its place within the existing literature of technology acceptance. Blockchain technology's features and promised advancements will not translate to applicability if the technology itself is not accepted by its users. User acceptance or lack thereof is a constant impediment to the adoption and proliferation of new information systems. Blockchain systems aim to decentralize information and transactions by shifting the focus and power to the users themselves, thereby posing the issue that the system by design cannot subsist solely on the adoption of trusted third parties and organization but on the very end users it aims to serve.

While the technology acceptance model was initially designed to measure the usage of information technology at work, it has since been adapted and heavily used in various areas of ecommerce and remote transaction assessments in order to determine user's intention to use and recommend the technology. The technology acceptance model enables researchers to discern between the various internal and external motivations can lead to modifications in beliefs, behaviors as well as attitudes. By leveraging these aspects to account for a user's attitude towards a system in particular rather than a random object, the technology acceptance model (TAM) has proven to be of consistent value in determining the outlook and adoption of various technologies, its implementation within the context of blockchain is therefore a natural progression of the subject's study (Pavlou, 2003).

The lack of research on the topic of blockchain acceptance leaves much to be discovered. As it stands, there is an inherent dearth of supporting content to enable a proper analysis and research into the application of TAM to blockchain. This stems from two major causes; the first is the relative novelty of blockchain technology, particularly within the framework of an independent framework. While blockchain has existed within the context of Bitcoin since 2008, much has been to done to study its properties and strengths as it relates to the sustainability and scalability of cryptocurrencies in general, however only recently has blockchain started to be considered as an independent technology in its own right, therefore necessitating further study into user's perceptions of blockchain in isolation from their attitudes and acceptance of cryptocurrencies. The second factor is the lack of exploratory research pertaining to blockchain acceptance; this has led to a lack of identifiable constructs and reliable measurements that can be used to investigate the relationship between blockchain and overall user acceptance. This study aims to alleviate this deficit through the development and verification of items designed to measure the appropriate constructs of the TAM. Specifically, we deal with the development of measures for benefit, risk, reputation, intention to transact, familiarity, comfortability, trust, perceived security as well as perceived privacy.

In the case of blockchain, this contribution should prove significant to the technology's evolution due to blockchain's unique potential to interact with the various TAM constructs mentioned earlier. The elimination of intermediaries and methods of recourse coupled with a unique reliance solely on technology and cryptography as arbitrators for transactions between strangers generates uncertainty around the technology's use, this is further fueled by the relevant infancy of the field, the hype surrounding blockchain technology as well as its dynamic and constantly evolving nature. Furthermore, the abstract nature of such a system coupled with the anonymity of other parties and openness of the platform itself makes risk a notable component. Finally, the early association of blockchain with cryptocurrencies in general and Bitcoin will pose an interesting question in relation to user attitudes and acceptance.

II. Factors in Blockchain Acceptance

In this section we elaborate on the various constructs and discuss their significance to the overall literature of technology acceptance and to blockchain technology as well as the decision leading to the development of the items needed to leverage the technology acceptance model as well as other models of consumer acceptance.

Consumer do not make their decisions in a bubble, they are often confronted by choice situations that are far less than ideal with regards to risk and uncertainty (Pavlou, 2003). The introduction of trusted intermediaries in commerce serves to establish trust by building on the reputation of the transacting parties and leveraging the public aspect of the transaction. All else equal, consumer will tend to choose the less risky options. However, risk is not the sole motivation driving the personal decision-making process of the consumer as perceived usefulness contributes to the positive aspects of the choice and will work to offset the negative attributes of risk. The balance between the two will translate to the appropriate transaction intentions depending on the overall risk / usefulness structure as well as the personal risk aversion and usefulness functions of the consumer (Wilkie & Pessemier, 1973).

Furthermore, while the major factors affecting user's acceptance to technology, particularly with regards to intention to transact, are risk and perceived benefit with trust forming the third; there are several underlying factors both from an affect as well as a cognitive based perspective that serve to influence these forces commonly called antecedents (Kim et al., 2008). From the cognitive perspective, we take into consideration the perceived privacy protection as well as the perceived security protection as it relates to its impact on consumer decision making and user acceptance. These factors were considered due to the unique nature of blockchain technology and its value proposition to the consumer, whereby the primary motivator to switch and accept the use of blockchain is due to the added privacy resulting from asymmetric encryption as well as the added security due to the decentralized and immutable nature of the ledger itself. We also consider the impact of trust on the decision-making model due to the relative novelty of the technology as well as its initial association with cryptocurrencies such as Bitcoin and by extension to illicit activities. Finally, we integrate familiarity and comfortability to the equation in order to consider the impact of the relative novelty of blockchain technology and its distinction from cryptocurrencies and Bitcoin with regards to consumer decision making

2.1 Reputation

Reputation is considered an affect-based trust antecedent. In previous literature reputation was used as a moderator to trust and the other constructs of the technology acceptance model (Kim et al., 2008). Reputation measurements include items such as knowing a specific website as well as determining its perceived reputation along with that of the vendor that operates within it and the overall familiarity with the website itself. Unfortunately, given that blockchain is an underlying technology meant to support existing systems and brands, it is difficult for blockchain to establish a reputation for the technology on its own without a brand name or independent from the cryptocurrency or site that leverages its potential (Gainsbury & Blaszczynski, 2017). This is further reinforced by the overall discrepancy in awareness of cryptocurrencies vs blockchain, even though blockchain provided the underpinning to cryptocurrencies. As such, we set out to convert the items presented in previous reputation research into those that would apply to blockchain technology.

2.2 Risk

There are various types of risks associated with blockchain technology that can range from privacy, security, overall transaction risk as well as the overall risk of the system itself as a sustainable model for its users. Given that the main advantages and offerings of blockchain technology are the increased security and privacy offerings that it offers its users in relation to conventional transaction mechanisms. We believed it better to focus on items involving overall transaction risk of blockchain (BRI) as well as the risk of blockchain as a business model and system of daily use (BCPRB) (Folkinshteyn & Lennon, 2016). This is due to the premise that blockchain technology suffers from a lack of recourse in the case of fraudulent transactions or stolen account. Furthermore, the current issues plaguing blockchain relate heavily to government regulation and efficiency concerns regarding power consumption which jeopardize its standing as a long-term sustainable system. Unfortunately, the unique nature of blockchain meant that the types of risks presented to the user were unconventional and therefore were not represented in the current literature. As such new items were added to measure blockchain system risk (Kim et al., 2008).

2.3 Benefit

Little research has been conducted on the overall used and application of blockchain technology. a review of the literature indicates a focus of blockchain on key areas of energy, internet of things, finance, government and healthcare. These areas all stand to benefit from the technology due to the inherent advantages that its structure offers. These include greater control over your own information as well as a removal of intermediaries, high speed of information transfers, low costs of data transfer, high security, international scope and improved trust among stakeholders. While previous research has been conducted on perceived usefulness in relation to technology systems, the disintermediation and global effect of blockchain does not lend itself to conventional benefit characteristics. As such, new items were added in order to measure the construct based on previous surveys regarding blockchain and cryptocurrencies (Kim et al., 2008).

2.4 Intentions

Traditional research methods would incorporate an aspect of pre and post purchase or transaction of an item in order to identify the overall attitude in using the technology itself. However, due to the previously mentioned underlying nature of the technology in that it is currently inseparable from cryptocurrencies, the use and trade of which is likely subject to immense regulation and scrutiny; a measure of actual transactions and purchases is not possible, this is especially true given the decentralized and anonymous nature of cryptocurrencies and blockchain based systems. We therefor contented with the measurement of overall transactions intentions (Suh & Han, 2003)

2.5 Familiarity

Familiarity is considered an experience based antecedent. With regards to blockchain, we attempt to measure the user's overall experience and familiarity with blockchain in general and more specifically with blockchain's features such as immutability of the ledger, decentralization of data and asymmetric encryption while also being acquainted with the challenges of blockchain technology from the limitations of the consensus algorithm to the sustainability issues raised by power consumption needs. Furthermore, it is important to measure user's understanding of blockchain's uses and implications into various fields since it is an underlying technology and can therefore be misrepresented with regards to its main purpose. Finally, it is important to ensure that users understand the difference between cryptocurrencies (namely Bitcoin) and the underlying technology supporting them that is blockchain (Gefen, 2000).

2.6 Comfortability

While measuring experience factors and characteristics, it is important to consider the overall comfortability of a user to the use of a given technology (Hossain & Prybutok, 2008). While a consumer may believe that a given technology is safer, more secure and more private than a comparable approach, this perception may not translate directly to a feeling of security and privacy during the experience itself. This is especially true in relation to blockchain given the lack of formal authorization or approval of the platforms supporting the technology as well as the general anonymity of the users engaging in the various transactions within the system. This stands in stark contrast to existing web systems and ecommerce solutions where the reputation of the platform itself is certified and accredited and parties transacting are visible and discoverable in relation to their identity and previous transactions. Specifically, we measure the overall comfort experienced by a user during their interaction with blockchain in the areas of privacy, security and safety in relation to internet use.

2.7 Perceived Privacy Protection

Perceived privacy protection relates to the user's perception that the information used during their transaction within a system is kept private and that no specific details regarding their identity is revealed (Ming-Syan Chen et al., 1996). This is a common concern with regards to traditional web systems, as personal information is provided by the use to a centralized and trusted third party in order to allow the processing of a transaction. It is the user's understanding that their information and data would not be abused or divulged to outside parties without the express consent and approval of the user themselves. With regards to blockchain, this becomes critically important as the ability to engage in transactions and exchanges with others while retaining full control over personal information and retaining anonymity is a pivotal feature of blockchain technology. However, such an innovation might not directly translate to a perception of privacy, hence the importance in measuring it in order to understand its interaction with the various factors of consumer decision making.

As such, new items were added in order to measure the construct based on previous surveys regarding blockchain and cryptocurrencies (Kim et al., 2008).

2.8 Perceived Security Protection

Perceived security protection means that the transacting user trusts that the website or vendor in the case of traditional ecommerce would follow the proper standards for security which include encryption and authentication as well as data integrity (Ming-Syan Chen et al., 1996). In the case of blockchain, the innovation of the decentralized ledger and the immutable nature of the blockchain's data means that the issue of security is taken outside the hands of the individual use or vendor and is instead built into the underlying platform. In its ideal implementation, this would translate to a vastly increased security in relation to traditional systems as decentralization would deter threats of attacks and information theft while the immutability of the ledger would ensure data integrity. However, these innovations are relatively recent and hard to explain to users who are used to the traditional mechanisms.

2.9 Trust

When engaging in online or digital transactions in general, there is an inherent uncertainty that comes with the separation of the goods or services offered from the time of the transaction itself (Gefen, 2000). This creates trust issues as each party will need to confirm that the other is legitimate. Specifically, from the consumer's perspective, there is a hesitance to offer payment before a given item has been received or shipped by the vendor. In traditional ecommerce, this issue is resolved through the reputation and trust of the platform itself, offering securities and guarantees regarding both the vendor and the consumer's reputation through mechanisms of recourse such as return, exchange and refund policies. This interplay of trust between the various stakeholders and the technology in question acts as a factor in the overall perception of the relative risk and benefit as well as a user's overall intention to use. With regards to blockchain, the issue is exacerbated due to the inherent lack of a trusted third party, whereby blockchain creates a decentralized platform and allows a trust-less system of exchange through cryptography. This innovation of trust-less exchanges thus shifts a consumer's trust to the underlying technology itself as it is the sole recourse in the case of issues regarding transactions and exchanges. We therefore attempt to measure user's trust in blockchain technology, specifically with regards to overall transactions and whether the use of blockchain is in alignment with a user's self-interest.

III. Methodology

Past research has studied the impact of the various technology acceptance model measurements on consumer acceptance. Established constructs such as intention to transact, perceived usefulness, perceived ease of use and perceived risk have emerged as principal components the combination of which forms the basis for the technology acceptance model (TAM) (Saadé et al., 2007).

Various works have mapped out different items designed to measure the different constructs influencing users during their interactions with a given system. There have also been extensions to the basic TAM model using antecedents, namely affect and cognitive. Examples of these includes trust whose own antecedent is the affect-based reputation as well as cognitive antecedents such perceived privacy, security protection and information quality. These previous works when applied to systems such as ecommerce and credit card payments allow for a better understanding of the underlying motives behind user acceptance and open the door for improvement both to the methodology of identifying user acceptance as well as the system itself (Kim et al., 2008 and Pavlou, 2003).

Blockchain technology is an emerging innovation originally introduced as the underlying enabler to the first widely recognizable cryptocurrency known as Bitcoin. This initial exposure has resulted in both advantages and disadvantages to the evolution and recognition of blockchain as a technological platform. On one hand the increased exposure received by Bitcoin in the media as well as by financial institutions and regulatory organizations has shed light on the underlying engine that enable the encryption, anonymity and immutability of the distributed ledger thereby creating the avenues of research and development for blockchain current being explored. On the other hand, the association of blockchain with Bitcoin since its inception is likely to impact the reputation and trust experienced by consumers with regards to blockchain adoption (Anderson, 1973).

While research has begun to emerge focusing on blockchain technology, the emphasis has been on the strengths and weaknesses of blockchain as a solution as well as proposals to solve the various technical problems encountered by the technology. Far less has been studied however, concerning the implementation and application of blockchain within the various themes and uses to the economy (Yli-Huumo et al., 2016). In order to achieve this, work must be done in relation to not only the application of blockchain itself but also in relation to its acceptance by consumers. The integration of blockchain and its analysis within the context of the technology acceptance model will allow for a cross comparison of blockchain's perception in relation to other systems such as ecommerce and credit card processing. However, in order to achieve this, measurements must be developed pertaining to the appropriate constructs thereby rendering researchers able to quantify with validity, reliability and confidence the relationships discussed in the TAM.

In this paper we develop measurements allowing the study of consumer acceptance and attitudes towards blockchain technology. We leverage existing measurements where applicable and consult parallel and relevant studies of Bitcoin and blockchain in order to mine quantitatively measurable items from qualitative results. Specifically, we generate measurements for the core constructs of intention to transact, perceived usefulness, perceived risk as well as trust through its affect-based antecedent of reputation (Kim et al., 2008).

The measurements are aggregated in a survey which we pass through a three-stage process. The first stage involves a distribution of the survey to a committee of experts and academics for review and suggestions for modification and improvement. The second stage is a limited release of the survey to a group of 6 students during a personal Q&A session designed to elicit feedback and constructive criticism as well as suggested modifications to the measurements themselves. The third stage concludes with the wider release of the survey to an online classroom of business technology management students (Moore & Benbasat, 1991).

Following the receipt of the survey from the respondents, we follow an exploratory factor analysis approach in order to test the validity of the various factors in blockchain acceptance. We run each factor independently in order to determine the appropriate factor loadings of the relevant items as well as to ensure that all items load on one factor with eigenvalue greater than one and that all items are loading properly. We then run the analysis for Cronbach's alpha in order to determine the reliability of the data. Once complete, we use the EFA mathematical criteria in order to create a factor model from the dataset. This simplifies the structure of the data by allowing the various items to group together if more efficient under common factors.

In order to test the validity of the items and their relation to the relevant constructs, we examined the overall perceptions and attitudes of online university student course participants in relation to blockchain technology and its various uses, features, risks and intentions. The respondents were bachelor students who were offered to complete the survey for extra credit as part of a course on the fundamentals of business technology. This is appropriate as current university students and young adults are likely to contribute disproportionately to the target market of blockchain technology and cryptocurrencies. Previous studies have made use of students in research, acknowledging their participation and role as useful representatives of the population. This holds particularly true with regards to online behavior as education and age are important factors when determining the amount of engagement and interaction with online transactions. In our results, over 35% of respondents indicated having heard of blockchain beforehand and knowing what blockchain represents through various forms and mediums (Kim et al., 2008 and Houston & Taylor, 1999). This is in line with previous polls and studies by CoinDesk and Gizmodo placing the overall knowledge of people of blockchain between 27% and 41% (Zhao, 2019). While their average knowledge on a set of 11 blockchain related knowledge questions were 6.05.

The students were asked to visit a link to a webpage explaining the basic concepts of cryptocurrency and delving a little deeper into blockchain technology properties. They were then asked to answer the survey to the best of their abilities. The participants were then asked to go to the discussion section of the course website and input their thoughts on blockchain technology and its uses as well as to comment and engage with other student's impressions of the topic. A total of 505 respondents were received after eliminating partial completions and unanswered questions. These responses were then included in the construct validation and testing (Kim et al., 2008).

IV. Results and Discussion

Student feedback on reputation

Fig. 9 represents the student feedback on reputation. The reputation reported by the sample student population is not positive. While most of the responses from the students are neutral, this is likely due to the lack of familiarity and exposure with blockchain technology. Furthermore, there is a lack of a brand or solid seal available to assist in the building of identity and reputation for blockchain which likely dissociates users from overall trust and impressions. For those who responded in a given direction, the results skewed negatively for the questions, this is likely due to the lingering association between blockchain technology and the cryptocurrencies on which it was based. Given the results, it is unlikely that reputation will be a prominent factor in the EFA model (Kim et al., 2008).

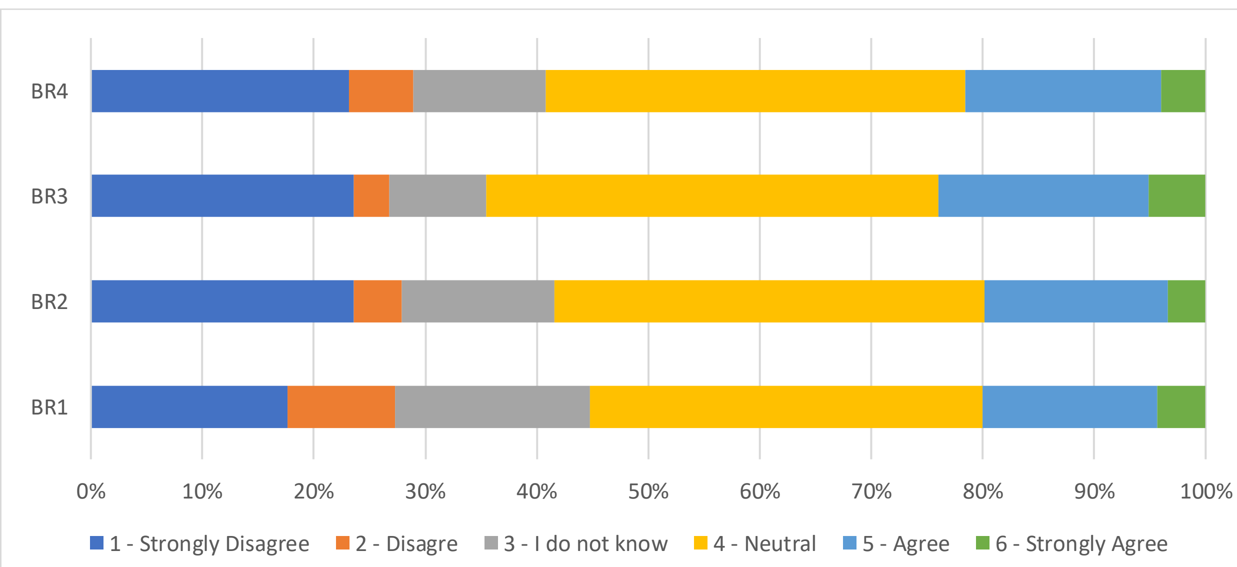

Figure 9: Student feedback on reputation

Student feedback on perceived transaction risk

Fig. 10 represents the student feedback on transaction risk; the overall response from students had been negative with roughly 30% disagreeing that blockchain technology posed less risk than conventional transactions in comparison to the roughly 20% of student who agreed with the statement. This response is likely due to several factors, first of which is blockchain's lack of familiarity among students which increased the levels of perceived risk. Furthermore, blockchain's relative infancy and lack of widespread acceptance and adoption further transaction risk considerations. Finally, the association with cryptocurrencies and those of Bitcoin could lead to negative perceptions of transaction risk (Wu & Wang, 2005). Finally, BRI3 runs counter to the rest of the items in the list, with more students agreeing that the rating of their risk from blockchain technology is low. This response is likely due to the measure asking about blockchain in general rather than transactions in particular, thereby associating the component with the overall risk of blockchain

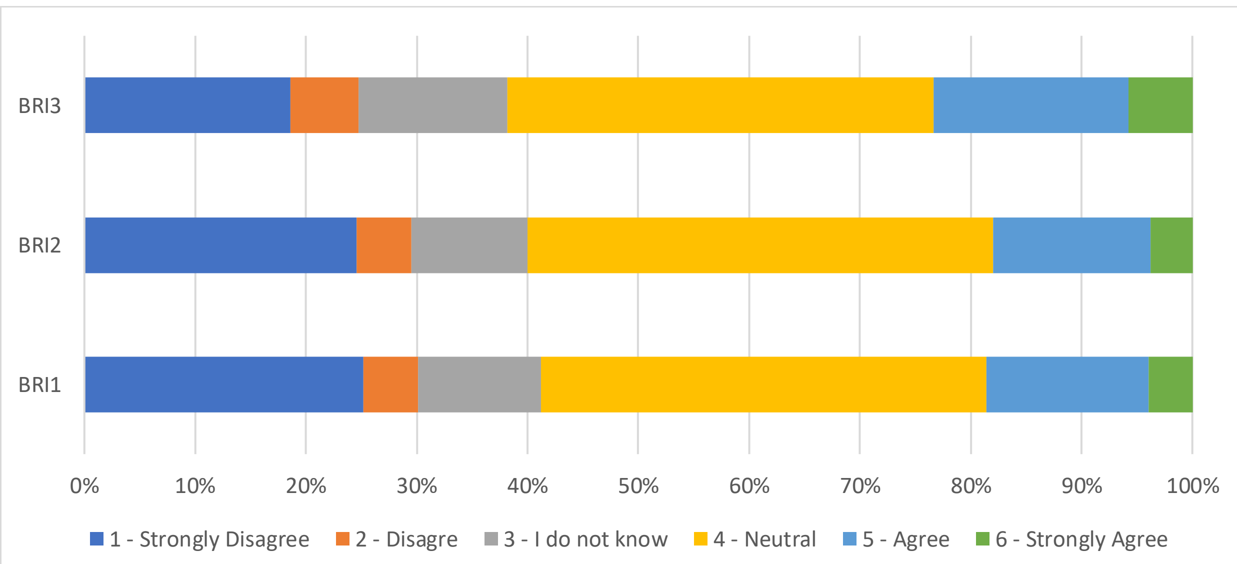

Figure 10: Student feedback on perceived transaction risk

Student feedback on perceived risk

Fig. 11 represents the student feedback concerning technology risk. Of the factors measured in our study, technology risk is the most negative of the group with of students responding to the survey disagreeing that blockchain technology is a safe and secure platform for use and transactions, this stands in high contrast to the 20% of student who responded positively. Questions regarding association with illicit activity, fraud and privacy loss were more negatively weighted than the rest of the questions. The representation is likely due to the association between blockchain and cryptocurrencies, specifically to the negative connotations of illicit activities and Bitcoin as well as the prevalent cases of account theft and fraud via cryptocurrency. We expect that measures identifying a student's ability to distinguish between Bitcoin and cryptocurrencies and their underlying technology of blockchain will likely impact the distribution of the answers (Wu & Wang, 2005).

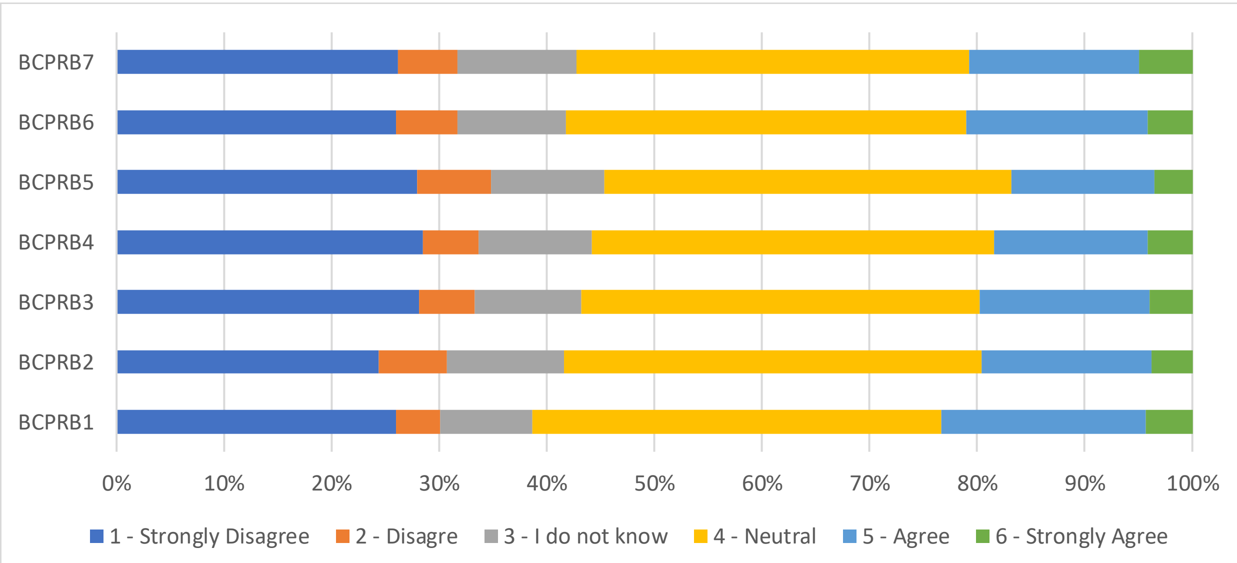

Figure 11: Student feedback on perceived technology risk

Student feedback on perceived benefit

Fig. 12 represents student feedback regarding perceived usefulness. While the overall impressions regarding blockchain usefulness are negative, it stands out from the rest of the factors as being with one of the least discrepancies between positive and negative survey respondent attitudes towards blockchain technology. Roughly 33% of respondents disagreed on the overall usefulness of blockchain in relation to 25% who agreed. This might be due to the lack of implementation and adoption of blockchain technology within the industry and the inability of students to experience its advantages. Furthermore, the current proliferation of modern and advanced services and systems indicates that the relative usefulness that blockchain can provide at the present level is unsubstantial when compared with that of established companies and systems.

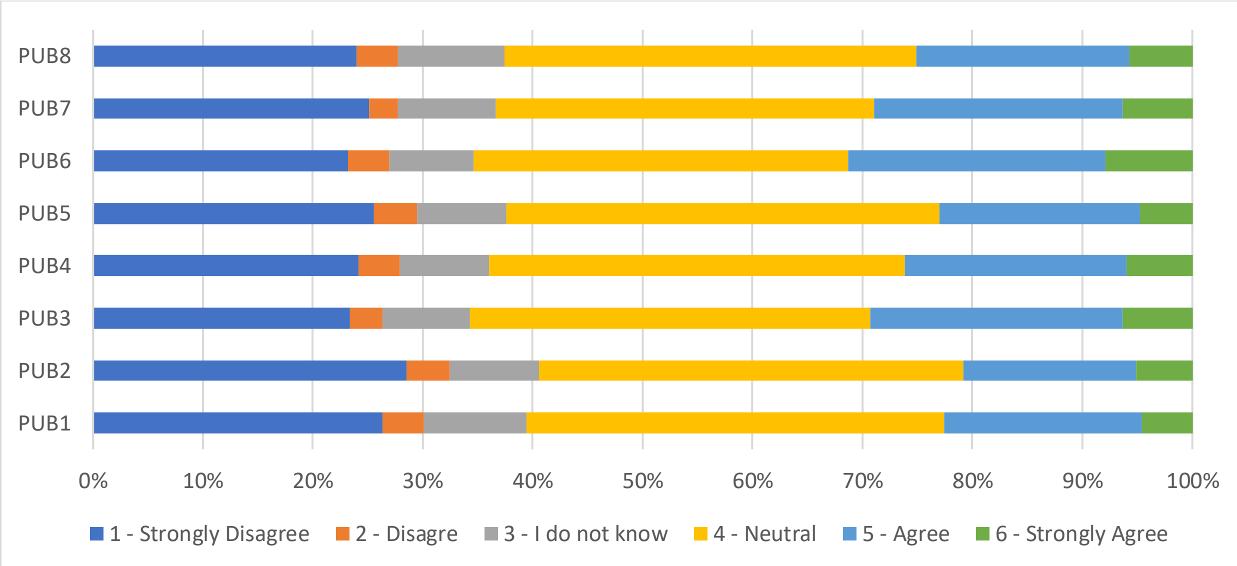

Figure 12: Student feedback on perceived usefulness

Student feedback on intention

Fig. 13 represents the student feedback on intention to transact and the response from the students was largely negative. As we know from previous research regarding consumer acceptance models, perceived risk is negatively related to intention to transact, with reputation and perceived usefulness being positively related to overall consumer intentions. Given that the survey results have shown a perception of both higher transaction and technology risk of blockchain technology as well as a lower reputation and perceived usefulness in relation to traditional technology platforms, it is understandable to see an overall negative intention to use.

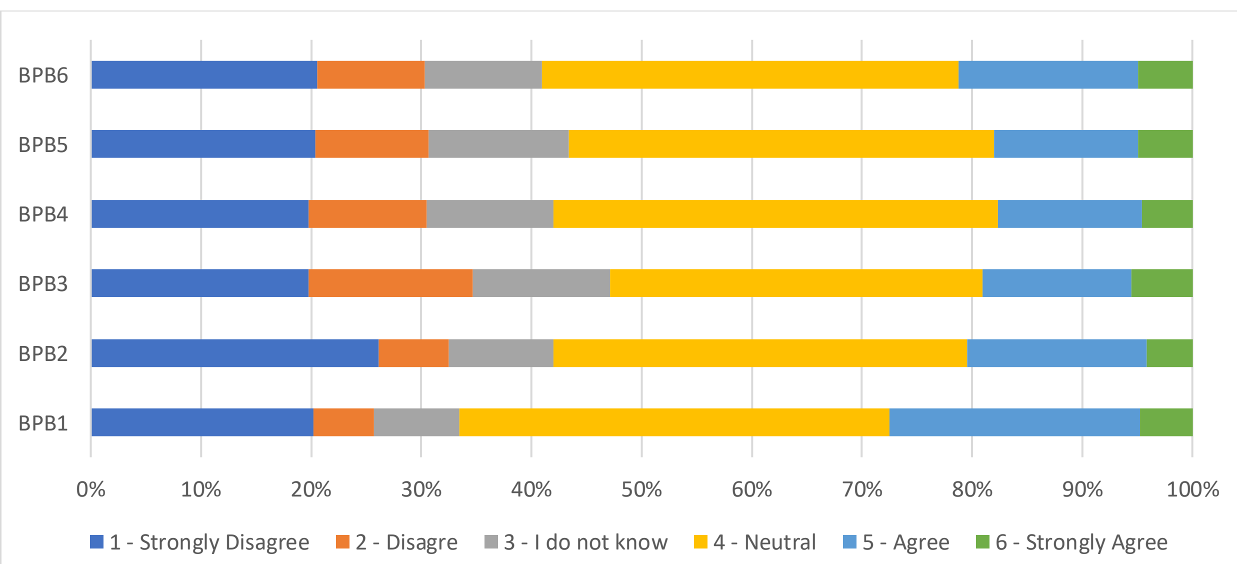

Figure 13: Student feedback on intention to transact

Student feedback on familiarity

Fig. 14 represents the student feedback on familiarity. The overall response from students regarding familiarity was negative, and while the largest response was neutral, the ratio of disagree to agree was roughly 2 to 1. This indicates that despite the presence of learning materials pertaining to blockchain technology and its presence in the consumer space for roughly a decade. The relative novelty of the technology as well as its limited implementation in various sectors and industries may have led to a lack of familiarity. It is important to note however, that FB7 through FB9 show the lowest ratio of disagree to agree among the group of items, indeed there are more who agree than disagree regarding FB8 and FB9. Upon closer examination we see that these items measure the ability of users to distinguish between blockchain technology and the associated cryptocurrencies and Bitcoin related to it (Kim et al., 2008).

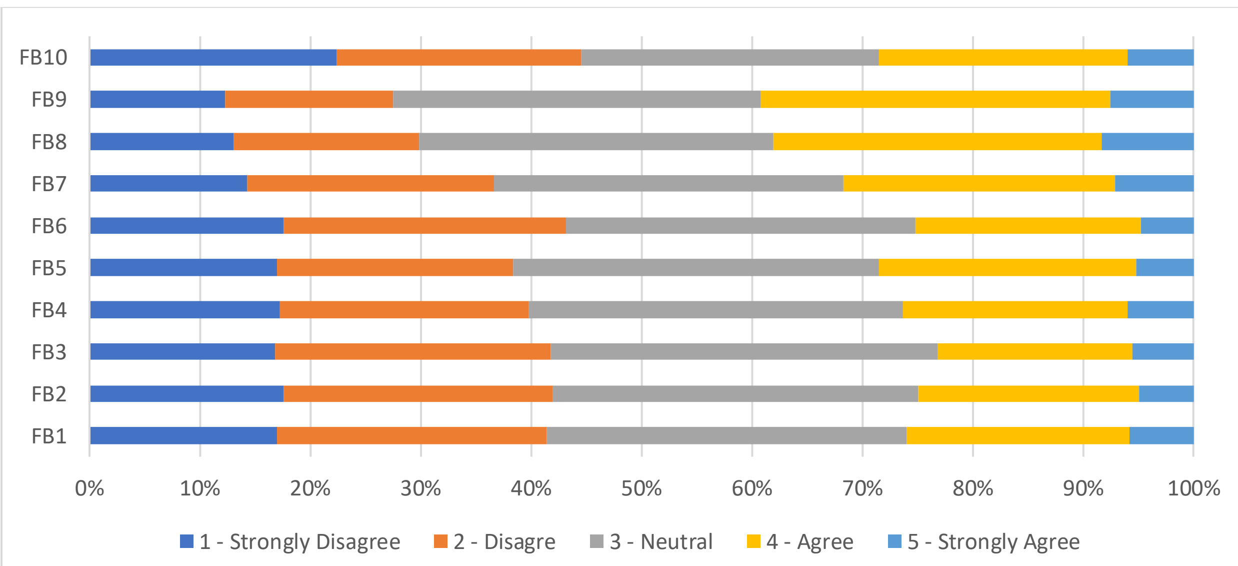

Figure 14: Student feedback on familiarity

Student feedback on comfortability

Fig. 15 represents the student feedback on comfortability; the overall response from students had been negative with roughly 50% more students disagreeing that they felt comfortable using blockchain technology than those who did. These results held for all items related to the construct with a similar response distribution. This lack of comfort is likely due to the nature of blockchain as an underlying technology thereby limiting the extent of comfortability that users can experience when utilizing its innovations in relation with more traditional ecommerce platforms that set standards for the overall interfaces and aim to provide comfort to the user. Furthermore, the lack of familiarity shown in Fig. 1 could relate to overall comfortability since users have indicated that they are not quite familiar with the overall features and capabilities offered by blockchain (Wu & Wang, 2005).

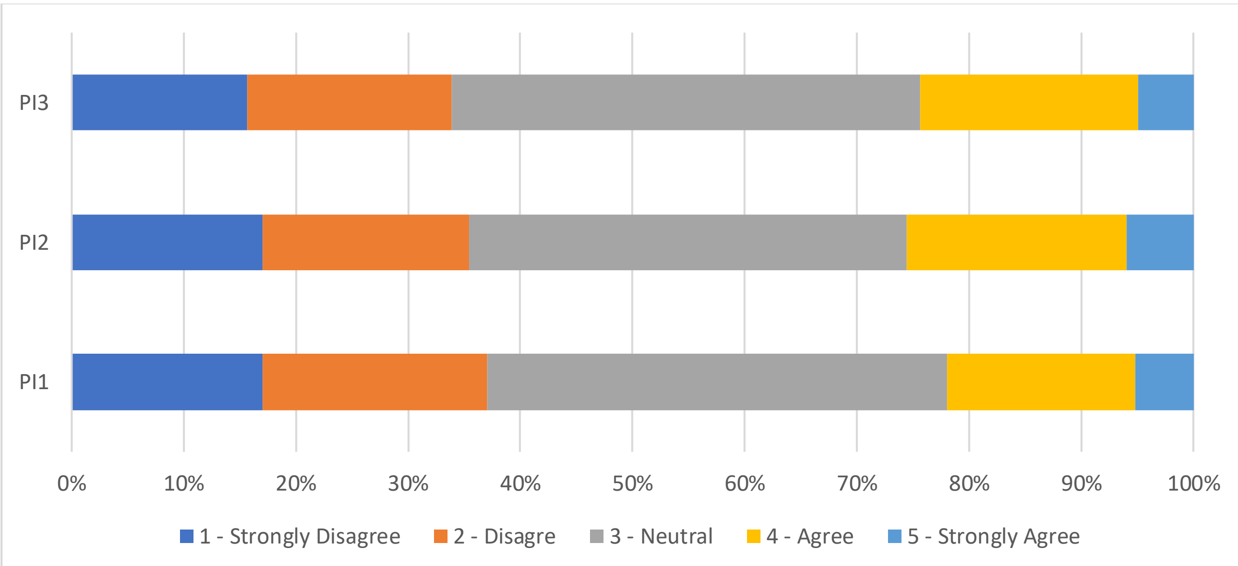

Figure 15: Student feedback on comfortability

Student feedback on perceived privacy protection

Fig. 16 represents the student feedback concerning perceived privacy protection. Overall there is an agreement regarding overall concerns of privacy protection for blockchain with 50% more of respondents agreeing on these concerns than disagreeing. Specifically, users were concerned that blockchain technology would allow the collection of too much personal information and would allow that information to be divulged without their permission. This is particularly interesting given the initial promise and value contribution of blockchain to allow for greater privacy through anonymity with the use of asymmetric encryption. This concern is likely due to the lack of student's familiarity with blockchain technology and the various features / innovations that it offers with regards to privacy. Another possible explanation is confusion between the blockchain and the third-party websites which allow users faster transactions across different blockchain platforms in exchange for storing their information ironically in a traditional database environment. Of note however is that respondents did not express concern regarding the selling of their information through the blockchain without their consent which indicates that while users may lack familiarity with the overall functions of blockchain, they are aware of the public and decentralized nature of the ledger which would make such a transaction impossible (Wu & Wang, 2005).

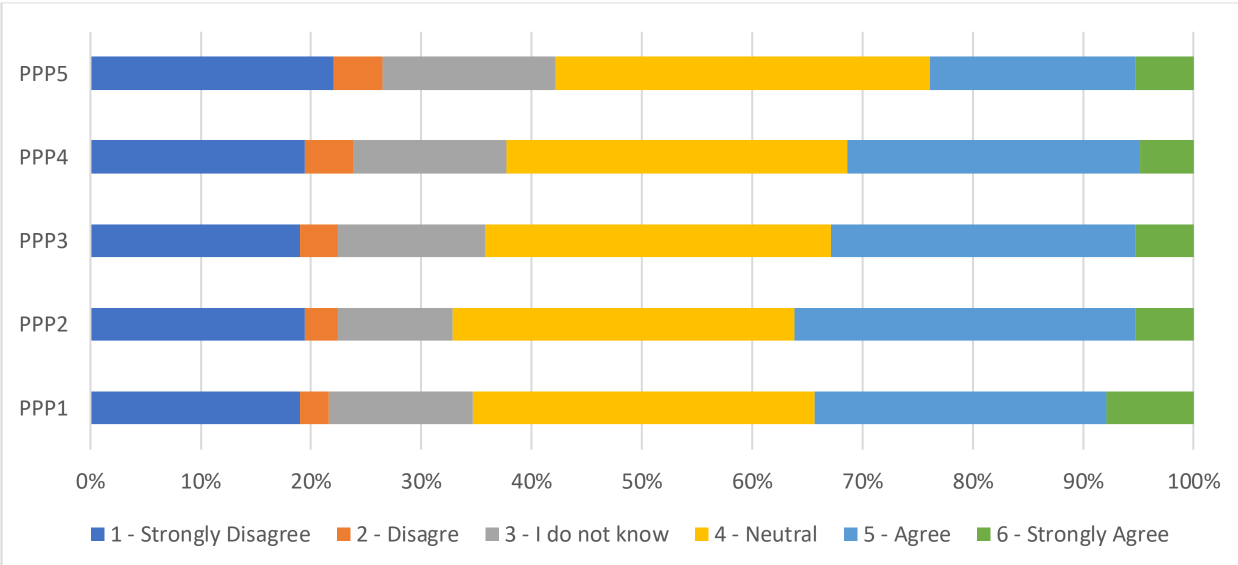

Figure 16: Student feedback on perceived privacy protection

Student feedback on perceived security protection

Fig. 17 represents student feedback regarding perceived security protection. We can see an overall negative response regarding the perceived security protection of blockchain technology. Specifically, users felt that blockchain did not allow for an implementation of security measures designed to help users. This correlates with the overall negative scores of familiarity and is further corroborated with negative responses regarding blockchain ability to protect transaction information from being altered and an overall consensus that using credit card information via blockchain is a greater risk than processing them through a traditional database, whereas the immutability of the ledger is a central component of blockchain technology.

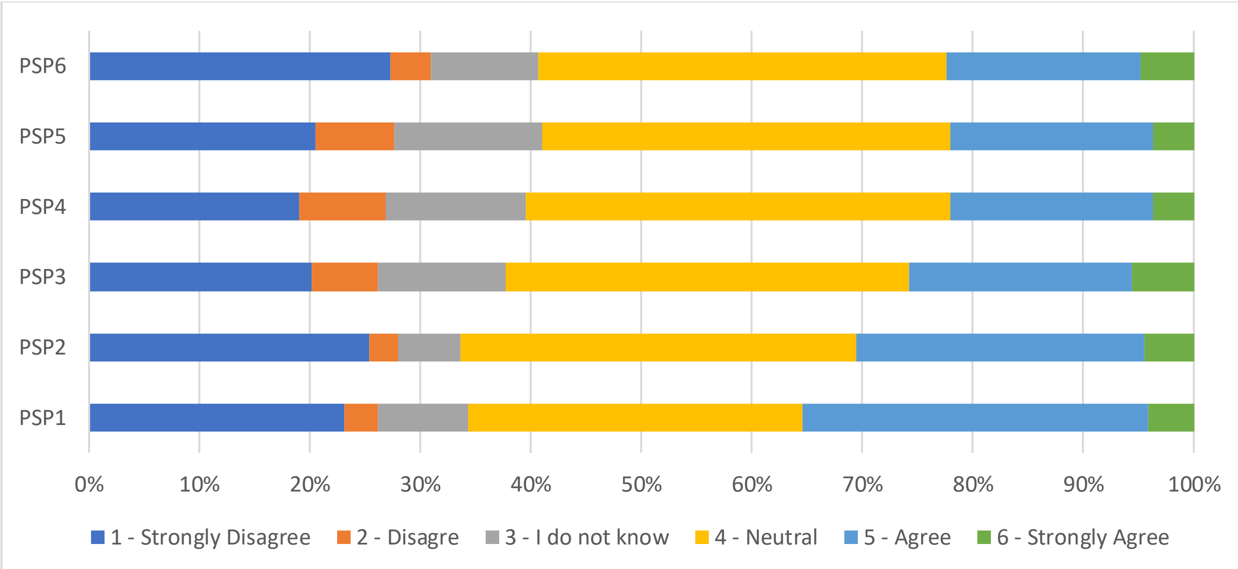

Figure 17: Student feedback on perceived security protection

However, responses were neutral overall regarding perceived security of blockchain technology-based payment systems. Indicating that the association with cryptocurrencies and Bitcoin might have acted to normalize the concept of a blockchain based payment system. Furthermore, users expressed some forms of security by indicating favorably regarding their willingness to use their credit card in blockchain based transactions as well as the feeling of safety when making transactions on the blockchain. Finally, respondents disagree that providing credit card information via blockchain technology is riskier that providing it via a centralized traditional database system.

Student feedback on trust

Fig. 18 represents the student feedback on trust and the response from the students was relatively positive. Namely, respondents responded positively when asked whether they trust blockchain technology in general, as well as their belief that blockchain will deliver on its promises while considering that it is in their best interest to transact in blockchain. This can be corroborated through certain positive sentiments regarding perceived blockchain security where respondents felt safe using and transacting on the blockchain despite their belief that it does not offer the same security as traditional databases.

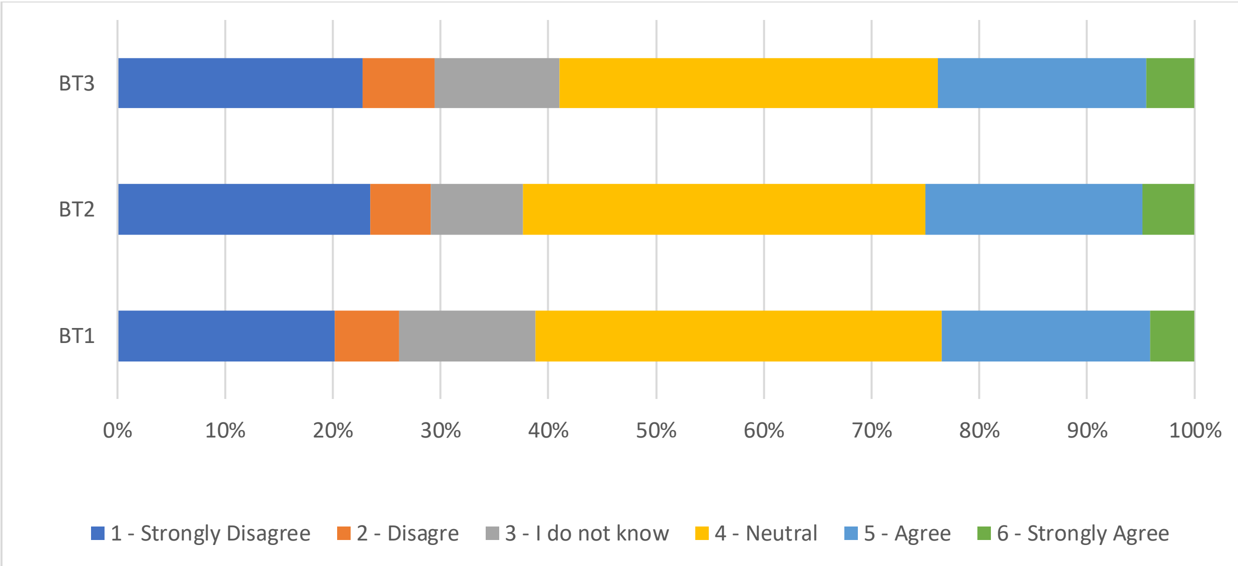

Figure 18: Student feedback on trust

Reliability and validity of the factor analysis

Table 6 shows Cronbach's Alpha and Eigenvalue for each Construct. The Cronbach reliability coefficients proved to be consistently higher than the established cut-off score in the literature (Fornell & Larcker, 1981). In the case of Cronbach's alpha, the assumption is that each item carries an equivalent weight in relation to the other which is suitable for the purposes of this study. Furthermore, we can see that the lowest Cronbach's alpha observed was that pertaining to transaction risk with 0.87 which would still be considered a significant value.

In order to test the construct validity, there are two major components to consider, the first is the eigenvalue of the factor itself, and the second are the factor loadings. Table 6 shows the Eigenvalues of each construct as measured individually against its items. As expected, the factors performed very well with all items loading on one factor which had a high significance. Of note is the is the eigenvalue and Cronbach's alpha of transaction risk, while the items do load on one factor with an eigenvalue of 2.21, the Cronbach's Alpha with all 3 items was found to be -0.51 specifically due to the negative correlation of BRI3 with the two other items (BRI1 at -0.64 and BRI2 at -0.62), this further confirms that the impression of overall perceived from blockchain is low despite the fact that respondents felt that blockchain based transactions were riskier than those of a traditional system.. As such we exclude the BRI3 item when estimating the BRI factor which yields a Cronbach's alpha of 0.94 and an eigenvalue of 2.13. Furthermore PSP6, is found to load negatively on the facto due to the opposing direction of the item with a Cronbach's alpha of 0.70. removing PSP6 leads to a Cronbach's alpha of 0.94

Table 6: Construct Cronbach's Alpha and Eigenvalue

Construct	Eigenvalue	Cronbach's Alpha
Reputation	2.92	0.92
Transaction Risk	2.13	0.94
Intention	4.53	0.95
Risk	5.51	0.96
Benefit	6.17	0.96
Security	4.34	0.94
Trust	2.26	0.92
Familiarity	7.40	0.96
Privacy	4.14	0.96
Comfortability	2.45	0.94

Table 7 shows the individually run factor loadings for all items and their respective factors. In order to examine convergent validity, all items pertaining to a construct should load with a factor greater than 0.5 and they must load on only one factor whose eigenvalue is greater than one (Wixom & Watson, 2001). Table 6 confirms the eigenvalues of the relevant factors, whereas table 7 highlights the factor loadings for the individual factor item models. All items are represented with a factor loading greater than 0.5. Here again we find that BRI3 presents a factor loading of -0.67, indicating that while the item does converge on the same factor, it is in a different relationship due to the general nature of the question which would categorize it more with blockchain risk in general.

Table 7: Individual factor loadings for measurement items and constructs

Construct	**Variable**	**Measurement Item**	**Loading**	**Source**
Reputation	BR1	Blockchain technology is well known	0.87159	(Jarvenpaa et al., 2000)

	BR2	Blockchain technology has a good reputation	0.92628	(Jarvenpaa et al., 2000)
	BR3	Blockchain technology has a reputation for transparency	0.85494	New item
	BR4	I am aware of the transactions that I make which use the blockchain technology	0.79463	New item
Transaction Risk	BRI1	Blockchain technology transactions would involve more risk than transactions on a centralized system	0.95341	(Jarvenpaa et al., 2000)
	BRI2	Blockchain technology transaction would involve more financial risk than those made on a centralized system	0.92273	(Kim et al., 2008)
	BRI3	Overall, I would rate my perception of risk from blockchain technology as very low	-0.67249	(Kohli, 1989)
Intention	BPB1	I think transacting via blockchain-based systems is convenient	0.77949	(Swaminathan et al., 2006)
	BPB2	I can save money by using blockchain-based payment systems	0.80677	(Kim et al., 2008)
	BPB3	I have done transactions that use systems based on blockchain technology	0.86131	New item
	BPB4	I am likely to recommend the use of blockchain-based transaction systems to a friend	0.93462	(Jarvenpaa et al., 2000)
	BPB5	I am likely to recommend the use of blockchain-based transaction systems to a family member	0.92641	(Jarvenpaa et al., 2000)
	BPB6	I am likely to conduct further transactions based on blockchain technology in the future	0.89103	(Jarvenpaa et al., 2000)
Risk	BCPRB1	Blockchain technology is a viable long-term solution	0.88205	(Folkinshteyn & Lennon, 2016)

	BCPRB2	Blockchain technology poses little security risk	0.90292	(Folkinshteyn & Lennon, 2016)
	BCPRB3	Blockchain technology has limited third party service failure risk	0.89671	(Folkinshteyn & Lennon, 2016)
	BCPRB4	Blockchain technology has limited user error	0.90062	(Folkinshteyn & Lennon, 2016)
	BCPRB5	Blockchain technology has little association with illicit activity	0.85248	(Folkinshteyn & Lennon, 2016)
	BCPRB6	Blockchain technology has little risk of privacy loss	0.89372	(Folkinshteyn & Lennon, 2016)
	BCPRB7	Blockchain technology has limited risk of counterparty fraud	0.88029	(Folkinshteyn & Lennon, 2016)
Benefit	PUB1	Blockchain technology allows me control over my own information	0.84457	(Folkinshteyn & Lennon, 2016)
	PUB2	Blockchain technology allows for disintermediation	0.83382	(Folkinshteyn & Lennon, 2016)
	PUB3	Blockchain technology allows for high speeds of information transfer	0.89363	(Folkinshteyn & Lennon, 2016)
	PUB4	Blockchain technology allows for a lows cost of data transfer	0.89806	(Folkinshteyn & Lennon, 2016)

	PUB5	Blockchain technology allows for high security in information transfers	0.89271	(Folkinshteyn & Lennon, 2016)
	PUB6	Blockchain technology has an international scope	0.8503	(Folkinshteyn & Lennon, 2016)
	PUB7	Blockchain technology lowers overall data transfer costs	0.90213	(Folkinshteyn & Lennon, 2016)
	PUB8	Blockchain technology increases user trust requirements	0.90445	(Folkinshteyn & Lennon, 2016)
Familiarity	FB1	In general, I am familiar with blockchain technology	0.88309	(Gefen, 2000)
	FB2	Overall, I am familiar with the features of blockchain technology	0.89131	(Gefen, 2000)
	FB3	I am familiar with the challenges of Blockchain technology	0.91901	New Item
	FB4	I am familiar with the innovations of Blockchain technology	0.91433	New Item
	FB5	I am familiar with the uses of Blockchain technology	0.93495	New Item
	FB6	I am familiar with the problems of Blockchain technology	0.9073	New Item
	FB7	I can distinguish between blockchain technologies and cryptocurrencies	0.81102	New Item
	FB8	I understand the relationship between blockchain technologies and cryptocurrencies	0.795	New Item
	FB9	I understand the relationship between Bitcoin and blockchain	0.76913	New Item
	FB10	I have had discussions with friends and relatives about Blockchain technology	0.71351	New Item

Comfortability	PI1	Blockchain-based transactions make me feel more comfortable in using the internet	0.90483	(Folkinshteyn & Lennon, 2016)
	PI2	Transactions based on blockchain technology makes me feel more secure in terms of privacy	0.92222	(Folkinshteyn & Lennon, 2016)
	PI3	Blockchain technology makes me feel safer in terms of doing transactions on the internet	0.92232	(Folkinshteyn et al., 2016)
Privacy	PPP1	I am concerned that blockchain technology transactions will allow the collection of too much personal information about me	0.90702	(Ming et al., 1996)
	PPP2	I am concerned that blockchain technology transactions will allow my personal information to be used for other purposes without my authorization	0.9495	(Ming-Syan Chen et al., 1996)
	PPP3	I am concerned that blockchain technology transactions will allow my personal information to be shared with other entities without my authorization	0.94981	(Ming-Syan Chen et al., 1996)
	PPP4	I am concerned that blockchain technology transactions will allow unauthorized persons to have access to my personal information	0.94849	(Kim et al., 2008)
	PPP5	Blockchain technology transactions will allow the selling of my personal information to others without my permission	0.7954	(Ming-Syan Chen et al., 1996)
Security	PSP1	Blockchain technology transactions allow the implementation of security measures to protect users	0.79248	(Ming-Syan Chen et al., 1996)
	PSP2	Blockchain technology transactions usually allow ensuring that transactional information is protected from accidentally being altered or destroyed during a transmission on the internet	0.85472	(Ming-Syan Chen et al., 1996)

	PSP3	I feel secure about electronic payment systems using the blockchain technology	0.90352	(Ming-Syan Chen, et al., 1996)
	PSP4	I am willing to use my credit card in blockchain-based transactions	0.89289	(Gefen, 2000)
	PSP5	I feel safe making transactions that use blockchain technology	0.89639	(Gefen, 2000)
	PSP6	In general, providing credit card information via blockchain technology is riskier than providing it via a centralized traditional database system	-0.74627	(Swaminathan et al., 2006)
Trust	BT1	I trust transacting on blockchain technology	0.90455	(Jarvenpaa et al., 2006)
	BT2	Blockchain technology gives the impression that it will deliver on its promises and potential	0.87954	(Jarvenpaa, et al., 2006)
	BT3	I believe that transacting in blockchain technology is in my best interest	0.87507	(Jarvenpaa, et al., 2006)

Exploratory factor analysis model

In order to ensure that we arrive at the proper results, it is important to select the proper factor analysis method. We implemented an exploratory factor analysis using the iterated PAF extraction method and Oblique rotation when needed for the multiple factor models. The individual factor tests are run without rotation as the total number of factors is 1. We also use the squared multiple correlation matrix for estimation of the initial communalities in order to be able to conduct the EFA. Once each factor was assessed and the appropriate items kept / removed, we combine all items and factors into a singular EFA assessment in order to assess the correlations and commonalities among the various factors and their impact on our ability to measure the construct appropriately (Saadé et al., 2007).

Our first iteration was run with all items pertaining to the 10 factors, to reflect the different constructs established throughout the study. The results indicate several issues regarding the implementation of EFA on all factors, with 19 items showing cross loadings greater than 0.2 and

17 items with no factor loadings greater that 0.4. Furthermore, we find that while risk related measurement items grouped on the 10th factor, there were no significant loadings pertaining to risk. We also find that trust has been dispersed as a factor with trust items loading across the different factors with no grouping. Finally, we find that FB7 to FB9 items from familiarity have grouped as one factor with significant loadings. Examining the items in question, we find they are the same items that indicated positive responses in familiarity whereas the other responses were largely negative. Specifically, the items pertained to the ability of the respondent to recognize and distinguish between cryptocurrencies and their underlying blockchain technology, to which users responded favorably, indicating recognition of the differences between blockchain and cryptocurrencies.

These results are likely due to the limited sample size and number of items which generates many free parameters that make model convergence difficult (Tanaka, 1987 and Bentler & Chou, 1987). As such, we proceed to implement item reduction by retaining three items per proposed factor. The items were selected based on the individual factor loadings whereby the three items with the highest individual factor loadings were retained.

Table 8: Initial EFA factor model

	Famili arity	Privac y	Inten t	Benefi t	Comfortabilit y	Securit y	Transactio n Risk	Reputation	Recogni tion	Risk
FB1	**0.78**	0.00	0.08	-0.02	-0.01	0.05	0.00	0.02	0.09	-0.02
FB2	**0.81**	0.00	0.07	-0.07	0.04	0.10	0.00	-0.03	0.06	-0.02
FB3	**0.88**	0.02	0.01	0.09	0.04	0.02	0.02	-0.06	-0.01	0.01
FB4	**0.78**	0.04	-0.05	0.07	0.05	0.00	-0.08	0.12	0.09	0.04
FB5	**0.79**	0.01	-0.07	0.01	0.04	0.04	-0.01	0.07	0.15	-0.02
FB6	**0.80**	-0.01	0.00	0.05	0.03	-0.04	0.06	0.02	0.09	0.02
FB7	0.26	0.00	0.08	-0.03	0.02	-0.02	0.06	-0.01	**0.64**	0.01
FB8	0.11	-0.01	0.03	0.07	0.05	-0.02	0.02	0.00	**0.79**	-0.02
FB9	0.04	0.02	0.03	-0.02	0.18	0.02	0.03	-0.01	**0.71**	0.00
FB10	**0.48**	0.05	0.05	-0.14	0.27	-0.07	0.15	0.06	-0.03	0.00
PI1	0.12	0.00	-0.01	-0.01	**0.83**	-0.07	-0.02	0.05	0.04	-0.02
PI2	0.06	0.02	-0.04	0.00	**0.86**	0.04	0.00	-0.06	0.05	0.01
PI3	-0.08	-0.02	0.01	0.01	**0.95**	0.04	-0.03	0.00	0.04	0.00
PPP1	0.01	**0.88**	0.03	0.03	-0.03	-0.04	0.02	0.02	0.04	-0.05
PPP2	0.03	**0.96**	0.00	0.02	0.02	-0.02	-0.07	0.06	-0.05	-0.02
PPP3	-0.03	**0.94**	0.07	0.01	0.03	-0.01	0.01	-0.04	0.00	-0.03
PPP4	-0.02	**0.95**	0.00	-0.02	-0.03	0.04	0.05	-0.05	0.01	-0.01

PPP5	0.02	**0.61**	-0.04	-0.03	0.03	0.10	0.10	0.09	-0.03	0.17
PSP1	-0.02	0.25	-0.08	0.09	0.04	0.32	-0.04	0.24	0.18	0.20
PSP2	0.06	0.17	-0.10	0.09	0.03	**0.47**	0.02	0.13	0.14	0.19
PSP3	0.09	0.07	0.10	0.06	0.10	**0.70**	0.04	0.00	-0.01	-0.06
PSP4	0.08	0.10	0.14	0.01	0.07	**0.63**	0.11	-0.02	-0.03	-0.01
PSP5	0.07	0.02	0.06	0.03	0.04	**0.62**	0.11	0.10	0.05	0.02
PSP6	-0.06	-0.08	-0.04	0.18	-0.03	-0.22	-0.49	-0.18	0.02	-0.14
BR1	0.02	0.14	0.07	-0.10	0.02	0.10	0.15	**0.53**	0.04	0.06
BR2	0.07	0.05	0.04	-0.03	0.03	0.03	0.11	**0.69**	-0.01	0.10
BR3	0.06	0.11	0.04	0.11	0.04	-0.01	-0.03	**0.65**	0.07	0.01
BR4	0.15	0.01	0.23	0.13	0.04	0.12	0.20	0.35	-0.07	-0.16
BRI1	0.03	0.03	0.02	0.09	0.05	0.04	**0.83**	-0.02	0.02	-0.04
BRI2	-0.02	0.10	-0.02	0.03	-0.04	0.01	**0.79**	0.04	0.10	0.03
BRI3	0.02	-0.13	-0.22	-0.14	-0.09	-0.15	-0.11	-0.16	-0.07	0.00
BT1	0.08	0.02	0.18	0.19	0.12	0.25	0.04	0.38	-0.02	-0.20
BT2	0.06	0.01	0.15	0.28	0.12	0.18	0.14	0.28	-0.03	-0.20
BT3	-0.04	0.04	0.23	0.19	0.14	0.20	0.19	0.19	0.04	-0.12
BPB1	-0.05	0.00	0.24	0.26	-0.02	0.25	0.14	0.11	0.19	0.01
BPB2	-0.04	0.02	0.31	0.11	0.10	0.14	0.09	0.12	0.05	0.25
BPB3	0.12	0.09	**0.60**	0.01	0.02	-0.05	0.16	0.10	0.00	-0.04
BPB4	0.02	0.09	**0.78**	0.03	0.04	-0.01	0.01	0.03	0.08	0.01
BPB5	0.03	0.09	**0.77**	-0.01	0.02	0.08	-0.04	0.03	0.07	0.06
BPB6	0.02	0.07	**0.65**	0.01	0.04	0.18	0.01	0.01	0.06	0.05
BCPRB1	-0.03	-0.01	0.29	0.13	0.03	0.18	0.04	0.12	0.17	0.36
BCPRB2	-0.07	0.02	0.22	0.15	0.12	0.12	0.14	0.11	0.13	0.34
BCPRB3	0.02	-0.01	0.20	0.13	0.11	-0.03	0.22	0.20	-0.01	0.37
BCPRB4	0.08	-0.01	0.17	0.23	0.12	-0.05	0.16	0.18	-0.01	0.35
BCPRB5	0.08	0.05	0.25	0.12	0.08	-0.10	0.19	0.19	-0.02	0.31
BCPRB6	0.14	0.07	0.13	0.32	0.08	0.06	0.10	0.08	-0.07	0.32
BCPRB7	0.13	0.07	0.24	0.30	0.08	0.05	0.10	0.07	-0.06	0.25
PUB1	0.22	0.11	0.12	0.30	0.08	0.10	0.10	0.02	-0.10	0.26
PUB2	0.28	0.03	0.19	0.32	-0.05	0.04	0.14	0.06	-0.05	0.21
PUB3	0.08	0.15	0.10	**0.55**	0.01	0.11	0.01	0.02	0.08	0.06
PUB4	0.08	0.16	0.02	**0.60**	0.10	0.07	0.07	-0.03	0.03	0.09
PUB5	0.17	0.02	0.07	0.39	0.08	0.16	0.14	0.05	-0.06	0.22
PUB6	0.01	0.10	-0.04	**0.57**	0.04	0.05	0.16	0.12	0.14	-0.02
PUB7	-0.01	0.03	0.01	**0.59**	0.09	0.05	0.12	0.10	0.12	0.06
PUB8	0.04	0.10	0.14	**0.55**	0.08	0.06	0.00	0.09	0.07	0.04

The results are displayed in table 9, there are several observations to be made. First, we find that all factors possess significant loadings of 2 or more with only BRI3 and BT3 presenting no significant factor loadings. Second, all cross loadings from the items were eliminated, with no items possessing two or more loading exceeding 0.2. BRI3's greatest factor loading is on general risk, this is understandable given that BRI3 measure the overall perception of blockchain transactions without the relativity of traditional systems. BT3 did not present a factor loading greater than 0.4, however its greatest loading was on the same factor as BT1 and BT2 with a value of 0.364 indicating that given a larger sample size this likely to be significant; furthermore, the second largest loading for the item was 0.18 indicating that the grouping is valid. We also removed BRI3 and ran the EFA again to find the existing structure and relationships remained intact.

Table 9: Final EFA factor model with reduced items

	Privacy	Familiarity	Comfortability	Intent	Security	Transaction Risk	Risk	Benefit	Reputation	Trust
FB3	-0.03	**0.88**	0.01	0.07	0.03	0.05	-0.01	0.05	-0.04	-0.05
FB4	0.03	**0.94**	-0.01	-0.01	-0.01	-0.05	0.03	0.02	0.06	-0.01
FB5	0.00	**0.89**	0.06	-0.03	0.03	0.03	0.00	-0.05	0.00	0.05
PI1	0.00	0.11	**0.83**	0.04	-0.09	0.03	-0.04	-0.01	0.03	0.05
PI2	0.04	0.05	**0.88**	-0.03	0.03	0.02	0.02	-0.02	-0.04	-0.01
PI3	-0.02	-0.08	**0.95**	0.01	0.06	-0.04	0.02	0.04	0.02	-0.03
PPP2	**0.91**	0.03	0.00	-0.02	0.01	-0.06	0.03	0.02	0.06	-0.01
PPP3	**0.97**	-0.02	0.03	0.04	-0.02	0.02	-0.01	0.00	-0.02	-0.01
PPP4	**0.93**	-0.01	-0.03	-0.01	0.03	0.06	-0.02	-0.01	-0.02	0.00
PSP3	0.05	0.06	0.04	0.04	**0.76**	0.00	-0.04	0.07	-0.02	0.09
PSP4	0.05	0.02	0.01	0.10	**0.75**	0.06	-0.03	0.05	0.04	-0.04
PSP5	0.00	0.04	0.02	-0.04	**0.76**	0.03	0.11	0.01	0.08	0.03
BR1	0.12	0.00	0.04	0.08	0.15	0.12	0.07	-0.05	**0.53**	-0.01
BR2	0.00	0.02	0.03	0.05	0.06	0.08	0.07	0.05	**0.73**	0.00
BR3	0.10	0.12	0.03	0.06	-0.03	-0.01	0.06	0.13	**0.49**	0.16
BRI1	-0.02	0.02	0.03	0.01	0.04	**0.87**	0.03	0.03	0.00	0.00
BRI2	0.06	0.00	-0.02	0.01	-0.02	**0.86**	0.02	0.00	0.04	0.01
BRI3	-0.16	-0.04	-0.06	-0.08	-0.11	-0.09	-0.25	-0.04	-0.01	-0.23
BT1	0.04	0.07	0.07	0.07	0.18	0.04	0.04	0.06	0.17	**0.46**
BT2	0.02	0.04	0.06	0.10	0.08	0.15	-0.05	0.20	0.11	**0.42**
BT3	0.05	0.00	0.08	0.12	0.13	0.18	0.17	0.05	0.00	**0.37**
BPB4	0.03	0.03	0.03	**0.80**	-0.04	0.05	0.02	0.06	0.03	0.03
BPB5	0.00	0.01	0.01	**0.98**	0.01	0.01	-0.02	0.00	0.04	-0.03
BPB6	0.05	0.03	0.01	**0.56**	0.18	-0.02	0.20	-0.04	-0.05	0.10
BCPRB2	0.05	0.00	0.06	0.06	0.11	0.05	**0.65**	0.07	-0.02	0.03
BCPRB3	0.01	0.02	0.02	0.04	-0.01	0.08	**0.76**	0.01	0.09	0.01
BCPRB4	0.00	0.10	0.03	0.04	-0.01	0.03	**0.63**	0.15	0.08	-0.01

PUB4	0.12	0.07	0.04	0.02	0.03	0.06	0.11	**0.57**	-0.04	0.03
PUB7	-0.03	-0.01	0.03	0.00	0.05	0.06	0.00	**0.88**	0.06	-0.02
PUB8	0.08	0.05	0.02	0.10	0.03	-0.04	0.11	**0.61**	0.01	0.11

V. Conclusion

Technology has evolved and grown considerably over the past decade, the latest iteration of which is the introduction of cryptocurrencies and the advent of blockchain technology. Blockchain's unique characteristics of enhanced security through the immutability of the ledger, privacy through asymmetric encryption and democratization of data from third party companies through the distributed ledger opens the door for major changes in existing business models as well as fortifications and improvements to existing technologies and platforms (Zheng et al., 2017).

These uses can range across industries, impacting particularly government through the decentralization of databases and computing power; finance through security and anonymity for financial transactions; energy by creating efficient anonymous micro power grids capable of withstanding security attacks; healthcare through the democratization of data and promotion of medical research and innovation and finally internet of things through the security and anonymization of private information while enabling quick communication and updates across devices.

Blockchain however poses a new challenge due to the lack of consumer awareness as well as the overall barriers surrounding its use coupled with the overall hype built around its dependent system of cryptocurrencies isolates the user from directly experiencing the technology itself. Furthermore, the decentralized nature of blockchain poses a radically different advantage / disadvantage combination from previous electronic commerce implementations. The increased anonymity and security at the expense of reputation and trust through an intermediary is likely to reverse the traditional value proposition of most systems.

Given the nature of blockchain technology and its unique characteristics of asymmetric encryption, immutability and decentralization; it is important to establish measurements of perceived privacy protection and perceived security protection. Furthermore, blockchain poses an interesting dilemma with regards to trust, familiarity and comfortability. Specifically, the initial implementation of blockchain was as an underlying technology powering the Bitcoin trust-less payment network, and while the cryptocurrency itself has gained widespread attention with regards to its characteristics, features and uses; the question remains on whether that familiarity with Bitcoin has trickled down to its underlying technology, especially with regards to the ability to distinguish between the former and the latter. This also raises the second question of trust, as the association of blockchain with cryptocurrencies in general and Bitcoin may have established an illicit reputation thereby impacting the overall trust in the technology in the absence of a central and trusted licensing or certification authority

Therefore, there is a need to establish measurements of perceived usefulness, risk, reputation, intention to transact, familiarity, comfortability, trust, perceived security as well as perceived privacy in order to allow research on blockchain technology acceptance to continue. This is especially pertinent due to the inability to conduct studies pertaining to blockchain acceptance without the prevalence of such measures. In this study, we set out to develop the items needed to quantitatively evaluate and identify user perceptions and attitudes towards a factor.

We develop the measures by consulting the literature and proceed through a rigorous process to ensure the clarity and consistency of the proposed items. The survey is then run across an online classroom of students and the results are assessed through exploratory factor analysis. Our study was able to successfully identify relevant items pertaining to the top factors in technology acceptance models, namely familiarity, comfortability, trust, perceived security, perceived privacy, perceived usefulness, reputation, perceived transaction and technology risk as well as intention to use. These measures should make a study of technology acceptance with regards to blockchain technology a feasible endeavor. We offer these measurements in the hope that they will serve to generate representative and accurate models for blockchain uses and implementations.

Chapter 4: Modeling Blockchain-Based Information Systems

I. Introduction

Blockchain technology has emerged as a central innovation of the Bitcoin system, allowing the decentralization of information through asymmetric encryption and immutability of the ledger while facilitating transactional capabilities within and across blockchains and systems using smart contracts. These features are proving to be valuable disruption components in various industries and domains relying on trusted third parties and intermediaries (Underwood, 2016).

While a few cryptocurrencies have facilitated indirectly blockchain acceptance among consumers and its adoption into the mainstream especially through cryptocurrencies such as Bitcoin and Ethereum, the relatively small size of these platforms compared to the global financial markets and the national currencies managed by mature, sophisticated financial institutions means that the current integration of blockchain even within the area of FinTech is still not enough to constitute proper consumer acceptance of the blockchain (Folkinshteyn & Lennon, 2016).

Recent research has identified a surge in blockchain related research using bibliometric studies (Miau & Yang, 2018), indicating an increase in the user of blockchain related keywords in academic articles and research studies particularly pertaining to internet of things, smart contracts, payment systems and electronic commerce. Meanwhile, reviews of current research topics on blockchain qualitatively identify major applications of blockchain technology to fields such as internet of things, finance, healthcare (Lu, 2018). A systematic literature review of blockchain identified similar areas in academic research interests in addition to energy and government integration of blockchain.

Blockchain possesses several user advantages when compared to conventional centralized and intermediated systems, thereby opening the door for massive disruption and change in current business models and standards (Roman-Belmonte at al., 2018). However, aside from the technical challenges and limitations, there are several hurdles with regards to consumer acceptance and decision making that the technology needs to overcome (Kamble et al., 2018). These are issues related to reputation, familiarity, security, privacy, trust, risk, benefit and intention which have remained unaddressed in the domain of Blockchain-Based Information Systems (BBIS) (Folkinshteyn & Lennon, 2016 and Kim et al., 2008).

Given the advent of blockchain as a supporting infrastructure and underlying mechanism enabling the Bitcoin network; blockchain has inherited a notoriety due to its association with the cryptocurrency that serves to erode the trust and risk opinions formed by consumers regarding the BBIS (Treleaven et al., 2017). Furthermore, while the hype cycle has served to increase overall public awareness of blockchain technology, it has also propagated misinformation that serves to decrease the overall user familiarity with the platform (Lu, 2018).

Security, privacy and trust are key issues in dealing with consumer perceptions of BBIS, given the novelty and unique nature of the technology and its infrastructure (Dorri et al., 2017). Specifically, blockchain offers a unique approach to these components whereby the decentralization of the information as well as the immutable nature of the ledger allows for greater security due to increased data integrity and a lower risk of theft and disruption. Meanwhile, BBIS provide greater privacy through asymmetric encryption and the advent of the private public key which allows for user anonymity within the system (Yli-Huumo et al., 2016). Finally, the nature of the ledger itself is to enable trust among participants without the use of an intermediary, hence the nature of the trust-less system.

Risk and benefit are especially relevant to the blockchain due to the relatively nascent nature of the technology (Folkinshteyn & Lennon, 2016). the proliferation and standardization of current banking systems and facilitated payment methods stand to offer a lower risk than blockchain technology due to the lack of recourse with BBIS in cases of fraud and identity theft on the blockchain (Cocco et al., 2017). Furthermore, the novelty of the introduced platforms and the questions surrounding the viability, scalability and sustainability of BBIS business models stands to impede the general risk associated with the technology, further exacerbated by the traditional risk (Giungato et al., 2017). Furthermore, the mature nature of the current banking system and the flexibility provided by innovative financial products such as direct bank transfers, automated check deposits and mobile payment systems serve to diminish the relative benefits of BBIS in the eyes of customers.

These factors greatly impact the potential for blockchain adoption, and even more so given the relative lack of research concerning their interaction as most of the current literature descriptive and elaborating on challenges and ideas, empirical studies are few and limited (Kamble et al., 2018). For these reasons, there is a great need for the study of consumer acceptance factors impacting blockchain implementation of BBIS.

However, very few studies have focused on blockchain acceptance. Kumpajaya & Dhewanto (2015), focused on the application of the TAM in an extended scope to the acceptance of Bitcoin in indonesia; while Folkinshteyn & Lennon (2016), conducted a qualitative study to understand the TAM components of Bitcoin among various stakeholders. In relation to blockchain, Kamble et al. (2018), studied the adoption of blockchain among supply chain stakeholders in India.

Luckily there is a strong history of literature pertaining to technology acceptance and consumer decision making models which started increasing exponentially since the late 1980s (Davis, 1993, Venkatesh et al., 2003, Davis et al., 1989). Specifically, the Technology Acceptance Model (Davis, 1989), Theory of Reasoned Action (TRA) (Hill et al., 1977) and the Theory of Planned Behavior (Ajzen, 1991) have been repeatedly combined through various constructs and factors in order to better understand the overall decision-making process of consumers (Kim et al., 2008).

From the perspective of consumer acceptance research, fields such as ecommerce have received extensive study (Pavlou, 2003, and Ha & Stoel, 2009) with Kim et al. (2008) incorporating various constructs of decision making and technology acceptance models along with antecedents of privacy and security protection as well as familiarity and reputation in order to better understand the decision-making process of consumers.

As such, this paper aims to contribute to the literature in the following ways: First, we leverage an adaption of the model established by Kim et al. (2008) in order to assess the consumer decision making process. Second, we use measures developed, studied and validated in Chapter 2 in order to apply a structural equation model to blockchain decision making (Rossiter, 2002, Diamantopoulos, 2005, Churchill, 1979 and Anderson & Gerbing, 1988). The results should also help establish a framework for blockchain acceptance and consumer decision making.

II. Background

Launched in 2008 by Satoshi Nakamoto in his seminal paper titled “Bitcoin: A peer-to-peer Electronic Cash System”, Bitcoin was the world’s first fully digitally distributed currency. This innovation has sparked a wave of disruption and change in the finance industry, leading to the creation of the term FinTech and to a global discussion on the current state of the banking system as well as financial intermediaries including the future of the finance industry and monetary systems (Mackenzie, 2015).

While Bitcoin offered many unique features and innovations that lead to the acceleration of its adoption such as proof of work and digitally limited supply, it is blockchain that stands to be the key innovation whose applications seem to spin off away from Bitcoin and the financial services sector in general and into mainstream use across the various industries and technology applications (Underwood, 2016) as it offers three characteristics that render it an attractive and valuable tool for the current digital age: immutability, decentralization, asymmetric encryption and smart contracts (Wang et al., 2018).

Using cryptography and hash functions, blockchain can encrypt a grouping of transactions into what are called blocks to which specific has functions are automatically generated as a result of the content in the block. Any alteration to the block itself would lead to a change in the hash function and since all blocks are linked together through the inclusion of the current and previous hash key in each block, a change to one block would require decrypting and changing all the previous blocks on the chain. This feature allows for several advantages such as the ability to ensure that all information is kept secure and transparent while significantly reducing the risk of an attack thereby making the system capable of existing and operating without the help of trusted third parties and intermediaries (Savirimuthu, 2017).

An example of a trusted third party or intermediary is a financial institution that steps in to mediate, confirm and authorize transactions between two or more clients. The institution is needed due to the lack of trust between the different parties and the inability of each stakeholder to ensure fairness and conformity to the outcome. However, the issue becomes problematic in scale and scope as the intermediary is constantly required to broker all transactions between all parties, leading to inefficiencies and reductions in processing times.

Furthermore, the introduction of a multitude of intermediaries such as in the case of clients with different financial institutions further exacerbates the problem by requiring further authorization and shifting the trust problem from between clients to between the financial institutions themselves. This is especially true in the case of international financial transfers whereby a simple transaction takes days to complete despite the proliferation and presence of advanced technologies to facilitate the process (Savirimuthu, 2017).

Blockchain decentralization means that is does not have to rely on a single company or point of service in order to provide information. This is done using hash functions and encryption which render the ability to hide sensitive information within a particular transaction only to the relevant stakeholders who possess the proper key to access it. This in turn makes possible the ability to store and simultaneously manage multiple copies and instances of the blockchain on several devices, who act to maintain the ledger and serve as guards to ensure that the future transactions undertaken on the blockchain are legitimate and do not undermine the integrity of the information in the system. This procedure is known as mining and is the primary basis of compensation for the blockchain business model; in this instance the community or "miners" receive tokens in relation to the amount of effort or computing power required to process the transactions and ensure the integrity of the information (Savirimuthu, 2017).

As it stands, most information systems are centralized databases relying on a central point of control. This is needed to ensure the integrity of the data and protect against mismanagement and misuse through unauthorized parties. Data protection and user information privacy laws are also paramount in the decision to hide data in a central location. Taking an example within the healthcare sector, a centralized system means that a given hospital or healthcare provider possesses all the information pertaining to their clients within a specific location and it is controlled via known points.

This poses several issues from a usability perspective to the rest of the stakeholders, first of which is the inability for patients to access their information when needed or to share and transfer the data to other medical service providers upon demand. Furthermore, the centralization of the information serves as a tempting prize for hackers and other parties who seek to benefit from the theft and sale of the information. Furthermore, the issue increases in complication when taking into consideration the integration of government related services such as the energy network and social insurance information into a central location that can be disrupted or hacked.

User privacy is a constant issue in recent times, from the Facebook scandal to various leaks of information from social media platforms and concerns over the use of personal information by private companies, users are becoming more suspicious of the information they provide and the way it is being used by the trusted intermediaries. Blockchain allows for user privacy through the use asymmetric encryption, which generates a public / private key allowing the user to transact publicly with information while retaining their identity private from the network. This can best be explained through the example of a regular mailbox, which is tied to a regular address known as the public key that is publicly available and can be used to send information directly to the user without direct knowledge of that user's private information; the mailbox is also tied a physical key which is held and controlled by the individual themselves which render the mailbox unable to be opened by anyone other than the holder of the key. This pairing allows the user to retain their privacy while transacting fully on the blockchain (Savirimuthu, 2017).

We can take the example of patient information in a hospital, where the need for specific and certain information related to health can lead to the disclosure of other private and unrelated information such as the identity and name of the individual. As it stands this is required due to the lack of a standardized digital identity capable of providing the asymmetric encryption needed to retain the user's privacy. In the case where such an identity was available, the user would be able to share the specifics of their health information without the need to disclose any unrelated data to health or other practitioners. This issue becomes more problematic when dealing with private companies such as financial institutions who have requirements to know their customer, thereby forcing users to disclose all pertinent information in order to access vital services in a modern economy.

Of all features however, perhaps the most versatile and adaptable innovation tied to blockchain technology is the prevalence and use of smart contracts. Smart contracts are computer programs capable of executing and implementing complex instructions without the need for intermediates and human intervention. As it stands, contracts that are made between various parties must be executed either personally by the relevant stakeholder or using an intermediary. Smart contracts remove the obstacle by allowing parameters to be set which automate the execution of certain tasks and functions.

We take the example of parcel delivery where the current supply chain systems require the personal management of the package tracking details which drains time and resources from stakeholders and reduces the overall reliability of the information provided. Furthermore, the system lends itself to fraud and misuse through human intervention and manipulation of the information provided. In the example of the parcel delivery service, the use of smart contracts and smart devices such as sensors and RFID chips can allow for the automated tracking and updating of information regarding a parcel's location and status in the supply chain through the direct communication between the technology platforms coordinated and executed via smart contracts.

III. Factors for Blockchain Decision Making

When deciding, consumers incorporate a multitude of factors into their decision-making process. These various constructs serve to mitigate the lack of information and uncertainty surrounding the decision in question. Of these components there are three major influences on decision making: Trust, Risk and Benefit.

Risk is an unavoidable part of technology acceptance and is part of the decision-making process. By definition the consumer has yet to try or experience the technology and therefore is concerned with the various potential outcomes that can occur as a result. In isolation, consumers would shy away from additional risk by preferring to remain with more traditional options and solutions. However, these decisions are not made in a bubble and the perceived benefit serves to motivate consumers throughout the decision-making process (Kim et al., 2008 and Bilkey, 1953).In order to understand to decision making process involved in consumer's acceptance of blockchain based information systems leading up to their decision to interact with the system, we incorporate the principal decision making factors of Risk (BCPRB), Trust (BT), Benefit (PUB) and Intention (BPB). We also expand the analysis to include especially relevant antecedents to the previously mentioned factors within the context of blockchain. These include cognitive antecedents such as Familiarity (FB), Perceived Privacy Protection (PPP), and Perceived Safety Protection (PSP) as well as affect the affect based antecedent Reputation (BR).

Familiarity (FB)

Initially introduced as an underlying technological framework to Bitcoin, blockchain suffers from both too little as well as too much familiarity (Yarbrough & Smith, 2007). While its association with the world's first cryptocurrency has increased awareness and led to a proliferation of research and development into the limitations, challenges and opportunities of the platform, that same association has led to confusion in the consumer decision making mindset regarding the properties and characteristics of blockchain.

In order to understand the relationship between familiarity and blockchain, we need to consider not only a general sense of understanding of the technology but also a consumer's knowledge of its various facets. Specifically, knowledge of blockchain related challenges such as the power consumption and scalability limitations of the proof of work algorithm; the recent blockchain innovations as they relate to proof of stake, smart contracts and side chains; the potential uses of blockchain as a force of disruption and improved services in fields such as IoT, energy, finance, healthcare and government. Finally, a key component in the understanding of user familiarity with blockchain is their ability to differentiate between cryptocurrencies and the underlying technology that allows them to function. This is of importance due to the notoriety of Bitcoin and its association with fraudulent activity and illicit behavior.

We expect familiarity to affect Trust, Risk, and Intention. As consumers gain familiarity with blockchain's features, and innovations they will then have the appropriate mindset to trust and understand BBIS especially with regards of trusting that customer's information will be kept safe and secure from any breaches or identity theft. With the increase in familiarity also comes a reduction in the perceived risk. Therefore, as user's understanding regarding the security measures of the technology becomes apparent the perceived general risk regarding the technology's viability and continuity is retained (Geffen, 2000).

Due to the unique nature of the relationship between familiarity and the topic covered, particularly in the case of blockchain, where familiarity with the underlying innovation behind Bitcoin and the ability to distinguish the features and characteristics of blockchain from those of cryptocurrencies, it was not possible to use the items included in Kim et al. (2008). We therefore follow the steps outlined for measurement development by Geffen (2000) and incorporate findings regarding the important aspects of blockchain from Folkinshteyn & Lennon, (2016) in order to arrive at the new familiarity item measurements.

Perceived Privacy Protection (PPP)

In the current digital age, privacy protection is key consideration in consumer mindsets. Blockchain offers a solution to this issue using asymmetric encryption thereby allowing the maintenance of anonymity while enabling users to transact on the network. However, the presence of such a feature does not indicate that consumers are aware of its existent or that they believe in its applicability. Specifically, it is important to measure consumer's perceptions regarding the collection of data on a blockchain system, particularly as it related to immutability (i.e. it can never be deleted), the collection of personal information which is often not required in BBIS. Of interest is consumer perceptions considering news concerning "blockchain" data breaches where the hack is conducted on a centralized system managing blockchain accounts (called blockchain digital wallets) rather than the blockchain itself. However, this might lead some users to perceive blockchain as less private than others (Chen et al., 2004).

The greater the perception of consumers that BBIS offer less privacy protection relative to a traditional decentralized database, the greater the perceived risk of the system itself. Specifically, blockchain risk is expected to be affected as this aspect of BBIS use contains the greatest potential for sensitive information to be collected and misused in line with ecommerce systems. Furthermore, a low perception of privacy protection would also affect trust negatively, as the lack of interest in blockchain's ability to maintain the user's information private would translate to an overall lack of trust in BBIS.

Perceived Security Protection (PSP)

Blockchain also offers a new model for security protection by decentralizing and encrypting the information contained in BBIS. Specifically, the decentralization allows various copies to be kept of the ledger thereby reducing the risk of data integrity and increasing the trust that user's information will be retained and kept safe. Furthermore, the use of encryption in the blockchain links sets of transactions together into a "block" that contains a continuously generated hash function that is in turn included as a reference in the next block of transactions. This framework creates the ability to form a blockchain (hence the name) which ensure the security of the information, thereby decreasing the perceived risk that the security of the system will be compromised and increasing trust that information will be properly protected from alteration or modification.

When relating perceived security perception to blockchain, it is important to measure BBIS' overall ability to implement appropriate security measures as needed in order to protect users. Perceived security can also be measured through the willingness of participants to use and present their credit card information in BBIS in order to perform transactions. Finally, we measure a comparative assessment of the perceived safety of BBIS systems in contrast to traditionally centralized information systems (Gefen, 2000).

Reputation (BR)

Blockchain's inception as a framework for cryptocurrencies, particularly Bitcoin has led to an inevitable association with the infamous cryptocurrency. Indeed, this association was further propagated by Bitcoin supporters in their promotion of blockchain, indicating that blockchain technology could not exist without the cryptocurrency framework, more specifically Bitcoin, as a mechanism of transaction. Current research and implementations have helped to move away from that mindset by promoting BBIS as innovations (Yermack, 2013 and Doney & Cannon, 1997). However, the absence of proper branding and information dissemination and education regarding blockchain to mass market consumer may mean that the association persists in the mindset of consumers.

As such, it is important to measure the overall reputation of blockchain on its own merit removed from any transaction related components. Specifically, consumer's perception whether blockchain is well known, as well as the overall reputation of BBIS and their transparency. Given the sensitivity and importance of reputation, we expect a positive impact on risk and trust. Specifically, as users perceive blockchain to have a better reputation, the perceived risk of transacting on BBIS will be negatively affected, furthermore the overall perceived risk of BBIS will be reduced as users will perceive blockchain to be well know and of good reputation. Finally, with reputation comes an increase in trust that blockchain will maintain transparency and uphold the good reputation imparted on it.

Trust (BT)

Trust is an important parameter of blockchain technology as the innovation introduced a new method to create trust in information systems. Specifically, the integration of the previously mentioned technologies of decentralization, encryption and cryptography through hash functions was designed to enable the disposal of intermediaries and trusted third parties, thereby allowing a self-governing trust-less system. However, this still means that users must place their trust in the blockchain itself rather than the private institutions that came before it. This trust is needed at three levels of interaction between consumers and BBIS: Transactions, Systems and Self Interest. Specifically, users should trust that transacting on the blockchain will not lead to a compromise in the security of their information or in a loss of privacy or fraud. Furthermore, consumers should trust in viability and sustainability of blockchain as a technology in general (Underwood, 2016). Lastly, consumer should believe that the use of blockchain based information systems is in their best interest due to the increased privacy and security offered relative to traditional mechanisms.

We therefore expect trust to interact with risk and intention. As users increase their trust of transacting on the blockchain, the perceived risk that their information will be stolen during the transaction or that fraud will occur will also decrease. Similarly, an increase in trust in the future of BBIS and its ability to sustain and scale will decrease the perceived risk of the systems failing and falling out of adoption and use. Lastly, a trust in a user's self-interest with regards to blockchain use will increase their willingness and intention to transact (Gefen, 2000).

Risk (BCPRB)

As blockchain is a nascent technology with several challenges and flaw which includes issues of sustainability due to the predominance of the proof of work mechanism necessitating massive amounts of energy and computational capacity in order to maintain and update the ledger, there is are inherent risk pertaining to the viability and continuity of the technology in the mainstream market. This is further exacerbated by the lack of proliferation of blockchain based system. As it stands there are few uses and avenues for users to interact with blockchain technology which limits the its overall acceptance and increases the risk perception among users. Furthermore, the radical business model espoused by blockchain proponents involves the removal of the traditional profit-based system into a decentralized market where users are both suppliers and consumers of information and services while eliminating intermediate profits and fees. This model has yet to be validated and serves to add to the overall risk of blockchain technology particularly with regards to consumer perceptions that the business will remain as an ongoing concern without a central vision and guiding force to sustain it. As consumer perception of blockchain's general riskiness increases, we expect a diminished intention to use as consumers steer away from using a system that risks being decommissioned resulting in the loss of information and value. Specifically, general risk measures consumer perception that BBIS are a viable long-term solution and that they pose little security risk to their users (Pavlou, 2003).

Benefit (PUB)

Blockchain offers several benefits to its users; as such it is important to measure user's perception of blockchain benefits. Specifically, blockchain allows increased control over user information through the decentralization of the database from the hands of intermediaries and trusted third parties thereby allowing for disintermediation of information and the expansion of BBIS into an international scope. In turn, the disintermediation results in a higher speed of information transfer as transactions are conducted directly between interested parties and reducing the costs of data transfer. Adding the immutability of the ledger also allows for an increase in information security.

We therefore expect benefit to positively affect intention, as the increased perceived benefits of blockchain will lead to an increasingly positive intention to leverage the benefits in comparison to the traditional solution and counter to the perceived risks (Folkinshteyn & Lennon, 2016).

Intention to Transact (BPB)

While most consumer decision making systems measure user's actual purchase decision in studies related to technology acceptance, the relative nature of BBIS and its dissociation from a platform removed from the use of cryptocurrencies such as Bitcoin renders such a measurement very difficult as it combines the decision to use cryptocurrencies with that of using BBIS. Furthermore, current legal restrictions regarding the use of most blockchain based platforms with regards to their cryptocurrencies exacerbate the problem by putting out of reach an egalitarian testing environment of consumer decision making.

As such we leverage the research established by incorporating the intention to transact into our measurement instruments. Specifically, we assess consumer intentions through the likelihood that they would recommend blockchain to friends and family. We also measure whether consumers are likely to conduct further transactions on BBIS (Kim et al., 2008).

IV. Proposed Hypotheses

Following the discussion in the previous section, the expected relationships between the various constructs, and adapting from consumer behavior theory, we posit the following 19 hypotheses, and theoretical model:

H1a: A consumer's perceived familiarity of blockchain positively affects their intention to transact in BBIS

H1b: A consumer's perceived familiarity of blockchain negatively affects their perceived risk in blockchain

H1c: A consumer's perceived familiarity of blockchain positively affects their trust in blockchain

H2a: A consumer's perceived privacy protection of blockchain negatively affects their perceived risk in blockchain

H2b: A consumer's perceived privacy protection of blockchain positively affects their trust in blockchain

H3a: A consumer's perceived security protection of blockchain negatively affects their perceived risk in blockchain

H3b: A consumer's perceived security protection of blockchain positively affects their trust in blockchain

H4a: A consumer's perception of blockchain reputation negatively affects their perceived general risk of blockchain

H4b: A consumer's perception of blockchain reputation positively affects their trust in blockchain

H5a: A consumer's trust in blockchain negatively affects their perceived risk of blockchain

H5b: A consumer's trust in blockchain positively affects their intention to transact in BBIS

H6: A consumer's perceived risk of blockchain negatively affects a consumer's intention to transact in BBIS

H7: A consumer's perceived benefit of blockchain positively affects their intent to transact in BBIS

Combining the above hypotheses, we propose the following theoretical model shown in Fig. 19 below.

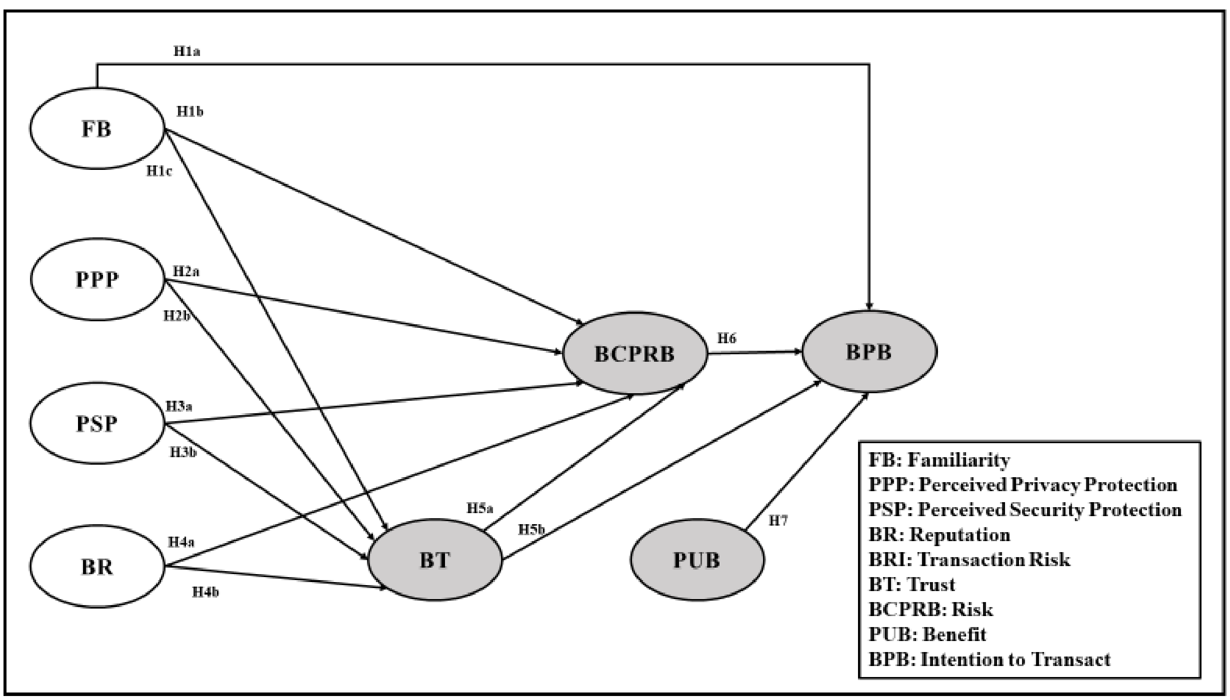

Figure 19. The proposed Consumer Decision Making Model

V. Methodology

In order to assess the framework established among the constructs through the hypothesis, we leverage the measurements that were developed, analyzed and validated in our previous research from Chapter 2 in order to meet the requirements outlined for the constructs in blockchain acceptance.

Context of Study

The study was conducted in a basic information technology course of which blockchain was a learning component. The course was conducted entirely online through an interactive learning platform with 1946 students enrolled. Course assignments were completed online and included quizzes, assignments involving building a computer and learning to measure its performance as well as informative tasks such as case discussions where students are given a reference material such as a link or article and asked to engage with other students by posting their comment on the proposed topic and replying to other student's comments.

The blockchain learning component was offered as an iteration of the case discussions, where we created a section in the learning management system that contained a link (Lantz, 2019) as the provided material, which students were requested to view and study before proceedings to comment and discuss. The task was followed by a post survey containing the items developed and discussed in Chapter 2. The assignment was worth one percent of the final grade and students were offered and extra credit of 0.5 percent of the final grade in exchange for completing the survey.

While university students may not be representative of the overall population, they do pose as useful representative in the case of blockchain technology given the relatively younger demographic associated with the adoption and implementation of the technology (Park et al., 2011). Furthermore, research has previously made use of students' survey responses in research especially in the case of online behavior and ecommerce. In the case of blockchain technology, student's overall responses were in line with overall estimates pertaining to familiarity and exposure to blockchain technology and cryptocurrencies in general (Sexton et al., 2002).

Survey & Process

A survey methodology approach was followed in this study. The survey was accessible online and conducted remotely as part of an online course. Students were provided a link to an online resource explaining the basic concepts of blockchain with a stronger emphasis on blockchain technology properties.

We then requested that student fill out the survey to the best of their abilities. Upon completion of the survey, students then proceeded to an online discussion forum where they were asked to provide their thoughts and reactions regarding BBIS and its possible implementations in the various domains. A total of 505 students responded to the survey after all invalid submissions were removed.

VI. Psychometric Analysis of Results

Content Validity

Content validity for the survey was assessed as discussed in the previous chapter: the proposed survey was subjected to a three-stage process in line with (Moore & Benbasat, 1991). The first version of the survey was delivered to academics for review and assessment of the quality of the measurements. This was followed by a limited release to a collection of 6 students in an equivalent in-class course on computer basics where they were asked to complete the survey and provide feedback on issues of inconsistency and clarity among the measurements. The survey was then released to a smaller subset of students in order to conduct an in-depth assessment of measurement model analysis with a total number of 268 respondents before its final release for the purposes of this study.

Construct Validity

Following receipt of the survey responses, we proceeded to analyze the measurement model using construct validity in order to ensure that the requirements of convergent validity and discriminant validity were met (Bagozzi et al., 1991 and Cunningham et al., 2001).

Convergent validity was assessed by ensuring that all items contained in the survey loaded onto only 1 factor with factor loadings of 0.5 or greater (O'Leary-Kelly & J. Vokurka, 1998). Furthermore, the loading factor must have and eigenvalue greater than 1. Table 10 displays the relevant eigenvalues of the factors as well as the item loadings, the results confirm that the all items possess a factor loading greater than 0.5 and that the relevant factors' eigenvalues are greater than 1.

Table 10. Individual factor loadings for measurement items and constructs with Eigenvalues

Factor	Eigenvalue	Item	Measurement Item	Loadings	Source
Familiarity (FB)	7.40	FB1	In general, I am familiar with blockchain technology	0.88	(Gefen, 2000)
		FB2	Overall, I am familiar with the features of blockchain technology	0.89	(Gefen, 2000)
		FB3	I am familiar with the challenges of Blockchain technology	0.92	New Item
		FB4	I am familiar with the innovations of Blockchain technology	0.91	New Item
		FB5	I am familiar with the uses of Blockchain technology	0.93	New Item
		FB6	I am familiar with the problems of Blockchain technology	0.91	New Item
		FB7	I can distinguish between blockchain technologies and cryptocurrencies	0.81	New Item
		FB8	I understand the relationship between blockchain technologies and cryptocurrencies	0.80	New Item
		FB9	I understand the relationship between Bitcoin and blockchain	0.77	New Item
		FB10	I have had discussions with friends and relatives about Blockchain technology	0.71	New Item
Perceived Privacy Protection (PPP)	4.14	PPP1	I am concerned that blockchain technology transactions will allow the collection of too much personal information about me	0.91	(Ming-Syan Chen et al., 1996)
		PPP2	I am concerned that blockchain technology transactions will allow my personal information to be used for other purposes without my authorization	0.95	(Ming-Syan Chen et al., 1996)
		PPP3	I am concerned that blockchain technology transactions will allow my personal information to be shared with other entities without my authorization	0.95	(Ming-Syan Chen et al., 1996)
		PPP4	I am concerned that blockchain technology transactions will allow unauthorized persons to have access to my personal information	0.95	(Kim et al., 2008)
		PPP5	Blockchain technology transactions will allow the selling of my personal information to others without my permission	0.80	(Ming-Syan Chen et al., 1996)
Perceived Security Protection (PSP)	4.34	PSP1	Blockchain technology transactions allow the implementation of security measures to protect users	0.79	(Ming-Syan Chen, Jiawei Han & Yu, 1996)
		PSP2	Blockchain technology transactions usually allow ensuring that transactional information is protected from accidentally being altered or destroyed during a transmission on the internet	0.85	(Ming-Syan Chen et al., 1996)
		PSP3	I feel secure about electronic payment systems using the blockchain technology	0.90	(Ming-Syan Chen et al., 1996)
		PSP4	I am willing to use my credit card in blockchain-based transactions	0.89	(Gefen, 2000)

		PSP5	I feel safe making transactions that use blockchain technology	0.90	(Gefen, 2000)
		PSP6	In general, providing credit card information via blockchain technology is riskier than providing it via a centralized traditional database system	-0.75	(Swaminathan et al., 2006)
Reputation (BR)	2.92	BR1	Blockchain technology is well known	0.87	(Jarvenpaa et al., 2000)
		BR2	Blockchain technology has a good reputation	0.93	(Jarvenpaa et al., 2000)
		BR3	Blockchain technology has a reputation for transparency	0.85	New item
		BR4	I am aware of the transactions that I make which use the blockchain technology	0.79	New item
Trust (BT)	2.26	BT1	I trust transacting on blockchain technology	0.90	(Jarvenpaa et al., 2006)
		BT2	Blockchain technology gives the impression that it will deliver on its promises and potential	0.88	(Jarvenpaa et al., 2006)
		BT3	I believe that transacting in blockchain technology is in my best interest	0.88	(Jarvenpaa et al., 2006)
Intention (BPB)	4.53	BPB1	I think transacting via blockchain-based systems is convenient	0.78	(Swaminathan et al., 2006)
		BPB2	I can save money by using blockchain-based payment systems	0.81	(Kim et al., 2008)
		BPB3	I have done transactions that use systems based on blockchain technology	0.86	New item
		BPB4	I am likely to recommend the use of blockchain-based transaction systems to a friend	0.93	(Jarvenpaa et al., 2000)
		BPB5	I am likely to recommend the use of blockchain-based transaction systems to a family member	0.93	(Jarvenpaa et al., 2000)
		BPB6	I am likely to conduct further transactions based on blockchain technology in the future	0.89	(Jarvenpaa et al., 2000)
Risk (BCPRB)	5.51	BCPRB1	Blockchain technology is a viable long-term solution	0.88	(Folkinshteyn & Lennon, 2016)
		BCPRB2	Blockchain technology poses little security risk	0.90	(Folkinshteyn & Lennon, 2016)
		BCPRB3	Blockchain technology has limited third party service failure risk	0.90	(Folkinshteyn & Lennon, 2016)
		BCPRB4	Blockchain technology has limited user error	0.90	(Folkinshteyn & Lennon, 2016)
		BCPRB5	Blockchain technology has little association with illicit activity	0.85	(Folkinshteyn & Lennon, 2016)
		BCPRB6	Blockchain technology has little risk of privacy loss	0.89	(Folkinshteyn & Lennon, 2016)

		BCPRB7	Blockchain technology has limited risk of counterparty fraud	0.88	(Folkinshteyn & Lennon, 2016)
Benefit (PUB)	6.17	PUB1	Blockchain technology allows me control over my own information	0.84	(Folkinshteyn & Lennon, 2016)
		PUB2	Blockchain technology allows for disintermediation	0.83	(Folkinshteyn & Lennon, 2016)
		PUB3	Blockchain technology allows for high speeds of information transfer	0.89	(Folkinshteyn & Lennon, 2016)
		PUB4	Blockchain technology allows for a lows cost of data transfer	0.90	(Folkinshteyn & Lennon, 2016)
		PUB5	Blockchain technology allows for high security in information transfers	0.89	(Folkinshteyn & Lennon, 2016)
		PUB6	Blockchain technology has an international scope	0.85	(Folkinshteyn & Lennon, 2016)
		PUB7	Blockchain technology lowers overall data transfer costs	0.90	(Folkinshteyn & Lennon, 2016)
		PUB8	Blockchain technology increases user trust requirements	0.90	(Folkinshteyn & Lennon, 2016)

After the loadings and eigenvalues were assessed, we kept only the highest 3 loading items per factor for the remainder of the analysis in order to ensure convergence of the structural equation model and reduce the number of free parameters relative to the sample size (Tanaka, 1987) (Bentler & Chou, 1987).

Table 11 below highlights the individual factor loadings following item reduction, the results show than once again all items load with the appropriate factor loadings and eigenvalues.

Table 11. Individual factor loadings for reduced measurement items and constructs with Eigenvalues

Factor	Eigen value	Item	Measurement Item	Factor Loading s
Familiarity (FB)	2.62	FB3	I am familiar with the challenges of Blockchain technology	0.93
		FB4	I am familiar with the innovations of Blockchain technology	0.96
		FB5	I am familiar with the uses of Blockchain technology	0.94
Perceived Privacy	2.66	PPP2	I am concerned that blockchain technology transactions will allow my personal information to be used for other purposes without my authorization	0.93

Protection (PPP)		PPP3	I am concerned that blockchain technology transactions will allow my personal information to be shared with other entities without my authorization	0.97
		PPP4	I am concerned that blockchain technology transactions will allow unauthorized persons to have access to my personal information	0.95
Perceived Security Protection (PSP)	2.47	PSP3	I feel secure about electronic payment systems using the blockchain technology	0.92
		PSP4	I am willing to use my credit card in blockchain-based transactions	0.92
		PSP5	I feel safe making transactions that use blockchain technology	0.92
Reputation (BR)	2.27	BR1	Blockchain technology is well known	0.86
		BR2	Blockchain technology has a good reputation	0.95
		BR3	Blockchain technology has a reputation for transparency	0.84
Trust (BT)	2.26	BT1	I trust transacting on blockchain technology	0.90
		BT2	Blockchain technology gives the impression that it will deliver on its promises and potential	0.88
		BT3	I believe that transacting in blockchain technology is in my best interest	0.88
Intention (BPB)	2.55	BPB4	I am likely to recommend the use of blockchain-based transaction systems to a friend	0.94
		BPB5	I am likely to recommend the use of blockchain-based transaction systems to a family member	0.98
		BPB6	I am likely to conduct further transactions based on blockchain technology in the future	0.86
Risk (BCPRB)	2.39	BCPRB2	Blockchain technology poses little security risk	0.89
		BCPRB3	Blockchain technology has limited third party service failure risk	0.93
		BCPRB4	Blockchain technology has limited user error	0.90
Benefit (PUB)	2.39	PUB4	Blockchain technology allows for a lows cost of data transfer	0.87
		PUB7	Blockchain technology lowers overall data transfer costs	0.95
		PUB8	Blockchain technology increases user trust requirements	0.90

At this point, it is important to examine discriminant validity using Average Variance Extracted (AVE). To establish validity, the square root of the AVE should be greater than any correlation shared between that construct and the others (Bagozzi et al., 1991). Table 12 provides the factor correlations with the square root of the AVE on the diagonal axis.

We can see from table 3 that the discriminant validity is satisfied, with AVE for each construct greater than any of its correlations with the other variables.

Reliability

We determine the internal consistency using Cronbach's alpha and Composite reliability (Fornell & Larcker, 1981 and Bagozzi, 1981). Table 13 contains the relevant information for the constructs including the mean, standard deviation, alpha, composite reliability as well as average variance extracted.

Table 12. Correlations of Latent Variables

	FB	PPP	PSP	BR	BT	BPB	BCPRB	PUB
FB	0.95							
PPP	0.39	0.95						
PSP	0.57	0.67	0.92					
BR	0.60	0.65	0.78	0.89				
BT	0.63	0.66	0.87	0.86	0.89			
BPB	0.57	0.61	0.77	0.77	0.82	0.93		
BCPRB	0.60	0.58	0.75	0.83	0.82	0.79	0.91	
PUB	0.57	0.61	0.78	0.78	0.85	0.77	0.86	0.91

Table 13. Descriptive Statistics and reliability criteria

Construct	Alpha	AVE	CR
Familiarity	0.96	0.89	0.96
Perceived Privacy Protection	0.96	0.90	0.96
Perceived Security Protection	0.94	0.85	0.94
Reputation	0.91	0.78	0.92
Trust	0.92	0.79	0.92
Intention	0.95	0.86	0.95
Risk	0.93	0.82	0.93
Benefit	0.93	0.82	0.93

As we can see from the table above, the Cronbach's alpha reliability coefficients were higher than 0.6 or 0.7 (Sullivan & Artino, 2013). While alpha assumes the same weight per item, composite reliability leverages the factor loadings in order to construct the weights. All numbers exceed the required threshold of 0.7 for CR and are therefore considered to be in conformance. Furthermore, AVE was consistently above 0.5 indicating that more than 50% of the measurement item variance has been accounted for by the constructs.

Structural Model Assessment

We use structural equation modeling in order to study the relationship between the factors. The methodology allows us to exceed the limitations of regression analysis through the development and testing of multi predictor-outcome equations between the constructs (Joreskog, 1970, Cheng, 2001, and Hatcher, 1996). We use the PROC CALIS Path modelling language in SAS in order to conduct the covariance analysis of linear structural equations of 8 latent factors and 24 observed variables. Table 14 displays the model fit statistics of the measurement model; while chi-Chi-Square is significant, this is expected due to the large sample size as discussed in, furthermore using the chi-square / df results in a ratio of 3.72 which is below the threshold suggested by (Bollen & Long, 1992). We also find that CFI, NFI and RMSEA as well as GFI are within the acceptable thresholds (Hu & Bentler, 1999)

Table 14. Model fit statistics of the measurement model

Chi-Square	852
Chi-Square DF	229
Pr > Chi-Square	<.0001
Bentler Comparative Fit Index	0.959
Bentler-Bonett NFI	0.9446
RMSEA Estimate	0.0735
Adjusted GFI (AGFI)	0.8452

VII. Results of SEM

Fig. 20 displays the results of the structural equation model. There are several interesting points of discussion from the findings.

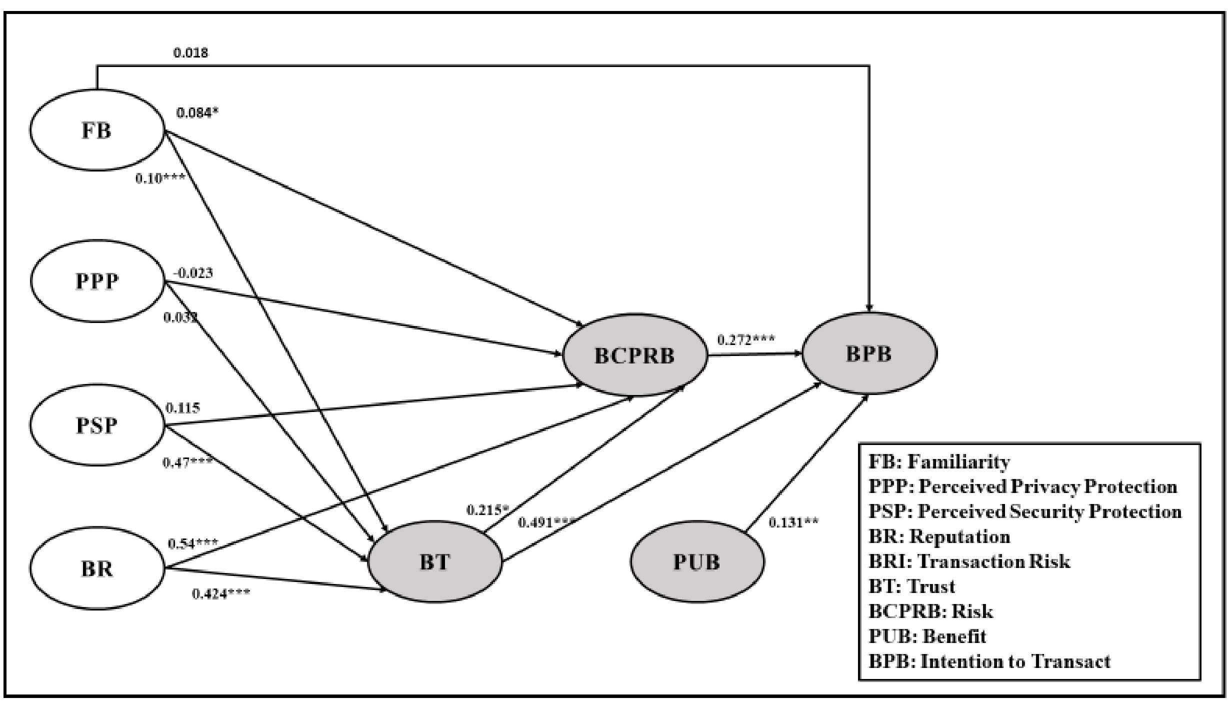

Figure 20. Results of the structural equation model

First, familiarity (FB) does not affect intention to transact (BPB) (H1a), this is likely because most consumers who are familiar with blockchain technology collected the necessary information regarding the innovation but did not necessarily translate into an intention to use (BPB) due to inherent challenges in the system. Furthermore, we find that the path coefficient relating to general risk (BCPRB) (H1b) is weak with a value of 0.084; the result is corroborated with the relatively low level of significance of 0.05. this is likely due to the inherent uncertainty and risk associated with blockchain which would not abate with a greater level of familiarity.

Second, perceived privacy protection (PPP) does not affect risk (BCPRB) (H2a) or trust (BT) (H2b); this can perhaps be explained in that perceived privacy protection (PPP) deals with primarily with the risk of being exposed and having information stolen during the process of a transaction rather than a longer-term concern regarding the information stored in the system. Similarly, perceived privacy protection's (PPP) interaction with trust (BT) would be explained in that the primary concern is from a loss of privacy due to abuse and fraud by the other transacting party rather than due to a lack of trust in the functionality and soundness of the system itself.

Third, perceived security protection (PSP) does not affect risk (BCPRB) (H3a). This can be explained by blockchain's unique security structure of decentralization and encryption, whereby a user's positive perception of blockchain's security mechanisms does not necessarily relate to the overall perception of the risks and challenges faced by the technology coupled with the lack of recourse and fraud within the blockchain network.

VIII. Discussion of Results

To facilitate the interpretation of the results, we remove both insignificant and weak paths from the proposed model and highlight the results in Fig. 20 for the significantly strong path coefficients.

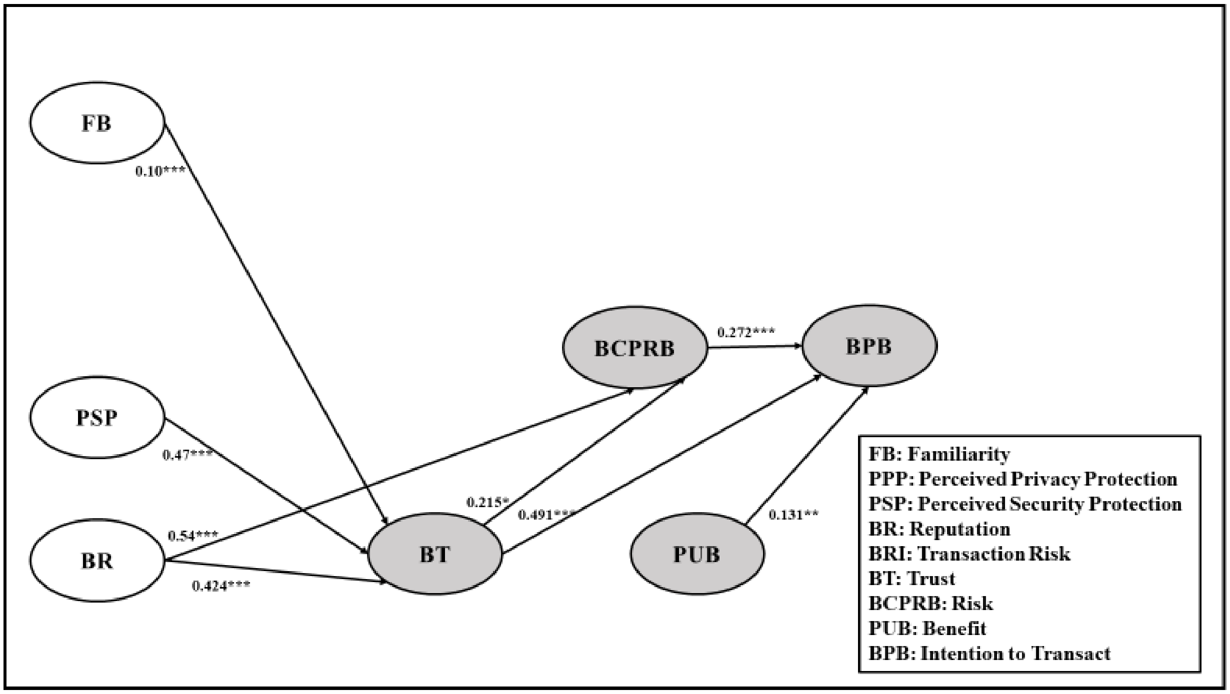

Figure 21. Reduced results of the structural equation model

Our findings confirm the unique nature of blockchain technology and reveals common characteristics to those of traditional transactional information systems such as ecommerce. First, we find that risk (BCPRB) of blockchain technology is unaffected by security (PSP), privacy (PPP) and familiarity. This implies that the inherent risks pertaining to blockchain technology whether due to its novelty, infancy or its unorthodox business model are unaffected by the traditional cognitive antecedents of decision making. However, reputation (BR) and trust (BT) affect risk (BCPRB) (H4a & H5a) with a path coefficient of 0.424 with high significance and 0.215 at 0.05 significance respectively, which is likely due to the impact of reputation on system viability and risk as users who deem blockchain to be of a high reputation would deem the risks associated with blockchain in general to have less merit.

Second, we find that perceived security (PSP) only affects trust (BT) (H3b). Perceived security protection of BBIS would increase the overall trust in the system's ability to store information due to the decentralized and encrypted nature of the platform, which would improve the trust but would not change the overall perception of blockchain's inherent risk.

Finally, we find that benefit (PUB) positively affects intention (BPB) (H7) and risk (BCPRB) affects intention (BPB) (H6) thereby confirming that a higher perception of benefit and a lower perception or risk lead to a higher intention to transact. To summarize, table 15 highlights the proposed hypotheses and their outcomes.

Table 15. Hypothesis Status, Coefficient and Significance

Hypothesis	Status	Coefficient	Significance
H1a:	Rejected	0.01752	0.6292
H1b:	Weak	0.0836	0.02
H1c:	Accepted	0.10147	0.0008
H2a:	Rejected	-0.02285	0.5559
H2b:	Rejected	0.03163	0.3404
H3a:	Rejected	0.11491	0.0986
H3b:	Accepted	0.46829	<.0001
H4a:	Accepted	0.54002	<.0001
H4b:	Accepted	0.42413	<.0001
H5a:	Accepted	0.21476	0.0284
H5b:	Accepted	0.49056	<.0001
H6:	Accepted	0.27173	<.0001
H7:	Accepted	0.13146	0.0091

IX. Contributions to the literature

The study provides several contributions to the literature. First, the study represents one of the first efforts to establish a consumer decision making model for blockchain acceptance. Second, the model provides a multifaceted perspective into the various constructs that interplay in the mind of consumers as they consider blockchain adoption and form their intention to transact in such systems. Third, the study highlights the unique nature of blockchain technology with regards to the existing research regarding the relationship between trust, risk, privacy and security as it differs from traditional technology systems such as ecommerce and payment solutions.

X. Limitations and Future Research

This study constitutes one of the first steps in the study of blockchain consumer acceptance, and future research is needed to address the limitation inherent in the exploratory nature of the research and to capitalize on the potential directions offered through the research. Specifically, the current measurements were developed and adapted from the existing literature of technology acceptance and suffered from a dearth of constructs and measurement items needed to conduct a more robust research into the topic. Furthermore, while the study integrates various constructs into the decision-making model, there are a multitude of model variations and components to integrate in order to better understand the dynamics of consumer decision making. Finally, the study discusses the general applicability and acceptance of BBIS in relation to consumers irrespective of the domain in which it is being applied; future research should consider a more directed study of blockchain acceptance among users as it relates to a specific domain such as IoT, Energy, FinTech, Healthcare and Government.

Today, blockchain research has just scratched the surface. There is still a multitude of issues and considerations to be studied rigorously, ranging from technical to social impact. Blockchain is a true paradigm shift for all researchers and practitioners alike. Most importantly it is foundational to the global society at large in its transformation promise. We discuss briefly some of the issues that need to be studied:

- Computing Power: In order to clear transactions and ensure the validity of the ledger, blockchain used the proof of work mechanism which relies on computing power to verify the legitimacy of the transaction and prevent attacks. This computing power is exceedingly expense, leading to a polarized system where a small number of stakeholders possess the majority of the computing power and are therefore capable of performing an attack on the system (Mishra, 2017).
- Energy Consumption: The proof of work mechanism also poses a sustainability risk due to the relatively large energy requirements of BBIS due to the computing power required combined with large volumes transactions. This raises questions concerning the future of blockchain and its related applications (Mishra, 2017).
- Proof of Stake vs Proof of Work: Steps are currently under way to address these limitations on computing power including the development of alternative methods of peer validations, the most notable of which is the proof of stake mechanism. Under this method, the validation of transactions shifts from computing power to trusted stakeholders who offer a portion of their holdings in the blockchain as collateral against fraud and abuse (Saleh, 2018).
- Hybrid Blockchains: Another approach to the problem of computing power is the development of new types of systems such as the hybrid blockchain where the network is split between core and edge components, thereby increasing efficiency while retaining full information transparency and allowing for alerts in cases of emergency such as attacks, abuse, or fraud (Jo et al., 2018).

The proposed solutions have the potential to solve the major issues faced by blockchain technology; however, they suffer from their own deficiencies and implementation constraints. Therefore, future research discussing solution to issues of energy consumption, computing power as well as alternative mechanisms is needed, particularly within the context of a specific domain such as Government and FinTech.

Chapter 5: Conclusion

I. Summary

Blockchain technology possesses certain characteristics that render it a valuable tool for industrial applications and a potential source of disruption for established industries. These include the immutability of the ledger, the decentralization of the data, the preservation of privacy, the allowance of trust-less transactions, the efficiency and sustainability of processes as well as the ability to automate multi-step processes using smart contracts.

We use a systematic mapping process to understand the current state of blockchain research as well as contrast it to past literature reviews and discuss its future implications for academic and industry stakeholders. The study approached the review form the standpoint of blockchain applications and publications dealing with the integration of blockchain into specific sectors and industries. Our final output resulted in 151 blockchain application publications extracted from a pool of over 1500 academic works and sifted by including only the top publishers.

Blockchain applications vary in the their use across domains, impacting particularly government through the decentralization of databases and computing power; finance through security and anonymity for financial transactions; energy by creating efficient anonymous micro power grids capable of withstanding security attacks; healthcare through the democratization of data and promotion of medical research and innovation and finally internet of things through the security and anonymization of private information while enabling quick communication and updates across devices. This focused interest is likely due to the propensity for such industries to benefit by the unique combination of advantages that blockchain offers into the market.

Our study indicates that blockchain research is expanding rapidly with a distinct evolution pattern among the different layers and concepts of blockchain implementation, with initial research focusing on blockchain's first application Bitcoin, then progressing to study the underlying technology itself in the past 3 years while gradually shifting from blockchain improvement related works into application papers. Furthermore, we identify the next wave of research to center around cryptocurrencies and related user centered acceptance and adoption research in order to create interfaces and business models capable of streamlining blockchain integration into the various specialties.

Blockchain poses a new challenge due to the lack of consumer awareness as well as the overall barriers surrounding its use coupled with the overall hype built around its dependent system of cryptocurrencies isolates the user from directly experiencing the technology itself. Furthermore, the decentralized nature of blockchain poses a radically different advantage / disadvantage combination from previous electronic commerce implementations. The increased anonymity and security at the expense of reputation and trust through an intermediary is likely to reverse the traditional value proposition of most systems.

Therefore, there is a need to establish measurements of perceived usefulness, risk, reputation, intention to transact, familiarity, comfortability, trust, perceived security as well as perceived privacy in order to allow research on blockchain technology acceptance to continue. This is especially pertinent due to the inability to conduct studies pertaining to blockchain acceptance without the prevalence of such measures.

We develop the measures by consulting the literature and proceed through a rigorous process to ensure the clarity and consistency of the proposed items. The survey is then run across an online classroom of students and the results are assessed through exploratory factor analysis. Our study was able to successfully identify relevant items pertaining to the top factors in technology acceptance models, namely familiarity, comfortability, trust, perceived security, perceived privacy, perceived usefulness, reputation, risk as well as intention to use. These results are then used to further our understanding of the consumer decision making process regarding blockchain through the use of structural equation modelling and the integration of several theories of technology acceptance and decision making.

We find that the general or systematic risk of blockchain technology whether due to its novelty, infancy or its unorthodox business model is unaffected by the traditional constructs of decision making except for reputation and trust.

II. Future Research

In this Chapter, we summarize the future research possibilities with regards to blockchain applications and consumer acceptance as discussed in the previous chapters, particularly with regards to research regarding blockchain applications in various domains, factor identification and measurement development as well as structural equation modeling and design.

Despite the seemingly rapid acceleration and continuous increase of interest in Blockchain technology we feel that the momentum for exponential growth is not enough yet. This is evident from the body of literature as the breadth and depth of Blockchain-related studies are still lacking quality, substance, cohesion and direction. The literature does not provide any hints of direction.

Our preliminary exploration of the literature including the term cryptocurrency has shown that research output in cryptocurrency surpassed that of blockchain in 2018. After increasing dramatically over the past 2 years, we expect cryptocurrencies-Blockchain research to continue to increase as part of the evolution of blockchain research. However, cryptocurrency and Bitcoin are not part of the scope of research and therefore we shall not analyze this area, however, we do question the impact of cryptocurrency research on Blockchain research. Is cryptocurrency research preventing Blockchain application research, or Blockchain application research is waiting for cryptocurrency research to mature first? It seems to us that cryptocurrency is a new paradigm for the financial sector pushing the envelope for new financial models. But Blockchain itself, viewed beyond the cryptocurrency space, involves organizations at a level beyond the technical domain with significant impact on their strategies, processes and competitive advantage. It follows that when it comes to Blockchain research, a strong partnership between industry and researchers must be forged for it to grow significantly, otherwise it will remain sluggish.

We also expect an increase of studies on the environmental impact of blockchain and the inclusion of environmental factors within the business model solutions of blockchain research due to the high amount of energy required to deploy and maintain the network system. While decentralized and shifted away from the enterprising, Blockchain poses concerns to regulatory bodies and society with regards to the sustainability of blockchain, and which constitutes an important area of future research.

III. Limitations:

This research constitutes one of the first steps in the study of blockchain applications and consumer acceptance, and future research is needed to address the inherent limitations of its exploratory nature and to capitalize on the potential directions offered through the research. Specifically, the current measurements developed and adapted from the existing literature of technology acceptance suffered from a dearth of constructs and measurement items needed to conduct a more robust research into the topic. Second, there is a lack of prevalent data necessary to conduct the appropriate robustness checks as the data set used in this study was limited to 505 observations which future research involving larger data collections could alleviate.

Furthermore, while the study integrates various constructs into the decision-making model, there are a multitude of model variations and additional constructs that can help us better understand the dynamics of consumer decision making. Similarly, the sample respondents were university students who are able to provide insight from a user perspective but do not represent the totality of blockchain stakeholders such as developers and industry professionals.

Additionally, student impressions were collected following a video presentation on blockchain technology thereby limiting the ability to distinguish between respondents who have had previous knowledge and experience with blockchain and those whose perceptions were formed following the video presentation. Finally, future research could move away from the general applicability and acceptance of BBIS in relation to consumers irrespective of the domain in which it is being applied and establish more directed studies of blockchain acceptance among users as they relate to a specific domain such as IoT, Energy, FinTech, Healthcare and Government which were identified in the current research.

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