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Critical Success Factors for Implementing Blockchain in the Supply Chain for Product Traceability

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CRITICAL SUCCESS FACTORS FOR IMPLEMENTING

BLOCKCHAIN IN THE SUPPLY CHAIN FOR

PRODUCT TRACEABILITY

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CURRICULUM VITAE

Gary Lee was born in Oklahoma but raised in Alaska. Gary did ROTC while pursuing his undergraduate degree. After completing a degree in Business Administration from College of the Ozarks in 1997, he accepted a commission as an Officer in the United States Army and served in a PATRIOT unit. Upon leaving the military, Gary took a position with GKN Sinter Metals (a tier I automotive company) in Wisconsin. While living in Wisconsin, he completed his Master of Business Administration degree from the University of Wisconsin at Milwaukee in 2004 and then moved to Missouri to take a Vice President of Quality position with Jakel Motors. The company was sold after 3 years and he moved to Reyco Granning Suspensions as their Quality Manager and later Supplier Quality Manager. After 10 years, he moved to American Products to serve as their Quality Manger where he completed his Ph.D. in Technology Management – Quality Systems Specialization from Indiana State University, Terre Haute, Indiana (2021).

Currently Mr. Lee works as the Director of Quality for AmProd Holdings overseeing the quality function for American Products, Ensight Solutions, Press Room Equipment, and Likwifier. He has published an article about the quality body of knowledge and has spoken nationally about quality culture. His research interests include cost of quality, quality culture, and product traceability.

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ABSTRACT

Satashi Nakamoto's introduction of blockchain in 2008 initially directed the technology for the use of Bitcoin and other cryptocurrencies (Nakamoto, 2008). In recent years the technology has been identified for other use cases. Businesses are currently developing this technology to reduce or eliminate transactional costs. Along with this anticipated use, businesses are using this technology to include traceability across the supply chain. This research looks at implementing blockchain technology in supply chain traceability.

Clohessy (2019) identified critical success factors for implementing blockchain, but what is not existing in the literature are the relative importance of each factor for implementation of blockchain in the supply chain. The problem for this study is that we do not know which factors have the greatest influence on implementation of blockchain in the supply chain. Blockchain is in the incipient stages of implementation and there are no developed guidelines for practitioners to follow for implementing blockchain technology in the supply chain. The purpose is to provide practitioners with a foundational model as a guideline for implementing blockchain in the supply chain for product traceability.

To do this, the researcher used the critical success factors identified by Clohessy in a survey instrument administered to Association of Supply Chain Management (ASCM) members. The survey had 88 respondents but only 58 that had useable data provided about the critical success factors. There were 9 respondents who had implemented blockchain. Using the 9 respondents who had implemented blockchain, a regression model was created to correlate the critical success factors to successful implementation. Other findings from the 58 respondents were that there is a significant difference on the critical success factors between small and large organizations for implementing blockchain in the supply chain, there is no significant difference on the critical success factors between low and high revenues for implementing blockchain in the supply chain, and there is a significant difference on the critical success factors between manufacturing and service industry for implementing blockchain in the supply chain.

This was a quantitative non-probabilistic study based on a convenience sample of ASCM members. After the data was collected, a stepwise regression was applied to the data, so that implementation factors are considered, to create the model. Three factors were found to create a regression model for implementing blockchain in the supply chain.

PREFACE

This dissertation is submitted for the degree of Doctor of Philosophy at Indiana State University. This research was conducted under the supervision of Dr. S. Rodchua, Ph.D. at the University of Central Missouri through a consortium agreement with the College of Technology, Indiana State University.

To the best of my knowledge, this work is original, except where cited and references are made to existing literature. No similar dissertation has been or is being submitted for any other degree, diploma, or other qualification at any other university.

ACKNOWLEDGMENTS

As I think about the people that have influenced me in this process, there are too many to name. As I consider all the people, I come to three groupings: personal, professional, and academic.

Enough cannot be said about the personal influence that a spouse has on a person. Mine has made me a better person. From being my inspiration to do better, to listening to my ad nauseum droning about this process. To my wife, Trinity, I love you and could not have done this without you.

Still in the personal category are my two sons and my extended family. This is specifically referencing my parents, and my sister. And I would be remiss if I didn't also give a thank you to Red Bull for all the caffeine. I thank each of you.

From a professional perspective I have so many influences. Phil Fridley and Ken Youker started me down the path of becoming a quality professional. They gave me a solid foundation upon which to build my career. I thank you both for the fast start and giving me more chances than I deserved.

In my more recent career, I have had influences that, again, gave me more chances than I deserved. Dave Compton, James Hoenshell, and Dale Richter. You each have given me inspiration in different ways.

Academically, there is something to be said for the special relationship a candidate has with their advisor. I have had the pleasure of having two during this process. Dr. Woolsey, you started as my advisor before retiring. You were so steady and calm, it helped me not panic at various stages of this process. Dr. Rodchua, you kept me calm by believing in me. Your faith in me has kept me going. I thank you both.

In addition to the advisors there are my committee members. Dr. Kluse and Dr. Schafer both have contributed in too many ways to enumerate. Your attention to detail along with encouragement are welcomed. I appreciate all of your gentle corrections and encouragement.

Beyond the committee there is an entire consortium of professors that have guided me on this journey. At the center of all of this is Marti Mix and her predecessor Mary (Mebby) Griffy. So many of us in the program cannot say enough good things about you both. Thank you for all that you do.

My classmates in the program helped in so many ways. Specifically, I want to thank Dr. Grant Short. Dr. Short has been with me through this entire process. He was ahead of me in the program and has partnered with me on projects, helped me as we published a paper together, and guided me through the steps of the proposal, etc. I consider you a great friend and will always cherish knowing you.

For this research specifically I would be remiss if I did not thank ASCM, my expert panel, and the survey respondents. Their help and knowledge are incalculable when it comes to conducting research of this nature. Last and certainly not least, Dr. Trevor Clohessy. You have been very supportive in allowing me to reproduce some of your work and expand upon your ideas. Your research is what mine is based upon. I hope that I have “added great value to the blockchain literature”.

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INTRODUCTION

Traceability is an ongoing question for the quality and the supply chain professional alike. In 2008 Satashi Nakamoto wrote his seminal paper introducing the idea of blockchain (Nakamoto, 2008). Initially the technology was used for Bitcoin and other cryptocurrencies. In recent years organizations have explored other use cases for the technology. This research looks at the use of blockchain technology in supply chain traceability.

Research about traceability has been ongoing for a number of years. While blockchain technology has less existing literature, it is still an area of academic research that is growing (Yli-Huumo, Ko, Choi, Park, & Smolander, 2016). What is not well explored in the literature is how to implement blockchain in supply chain for product traceability.

To give the reader context, this chapter starts with the background of traceability. A detailed summary of blockchain is also provided in order for the reader to understand the basics of blockchain and provide additional context. The statement of the problem and purpose for this research is also given.

Background

Traceability

Juran (1999, P. AIV.2) defines traceability as the “Ability to trace the history, application, or location of an entity by means of recorded identifications”. The beauty of Juran is that he simplified many concepts without losing the precision of the statement. There are, however, missing elements of this definition. For instance, while you can know the history of a product (or entity as he refers to it) this definition doesn't infer that you also know the history of the components and materials that make up that final product. If there is a failure on a vehicle frame, there is a need to know the batch of steel that was used to make the frame to identify potential failures in other products made from that batch of steel. The history of the product at various steps of production as well as the history of the product through distribution must both be included in the definition. Bechine, Cimino, Marcelloni, & Tomasi (2008) break traceability into track and trace. Tracking is following a product downstream in the supply chain and tracing is following a product upstream in the supply chain.

Within the context of track and trace, the elements of traceability can be broken down even further. Caplan (1989) provides five necessary elements of an effective traceability system.

1. Lot integrity control: Lot and part identification
2. Processing control: Unique identification of each item or group of items (lot) and process data (e.g. furnace temperature).
3. Build control: data showing which items were combined to make the product and the process data when it was built at each step of the process.
4. Inspection and test: records of test, rework, and other off standard work on a product.
5. Field activity and modification control: records of field installation, service, post delivery changes, etc.

This data can be gathered and stored in many different ways. Bar codes, Radio Frequency Identification (RFID) tags, and human readable are some of the more common ways of gathering the data (Steele, 1995). The ways to gather this data is beyond the scope of this review. How the data is stored is precisely in line with this review and will be discussed later.

Blockchain

Purchasing goods normally involves the exchange of currency. In modern supply chains this involves a third party such as a bank or broker. Satoshi Nakamoto wrote a paper in 2008 first proposing a distributed ledger that would eliminate the need for a trusted third-party payment system (Nakamoto, 2008). The idea allows for peer to peer payments using a digital currency across a public ledger system that is solved in blocks making it almost impossible to forge. These blocks could not be altered but only added to, thus it was titled block chain.

Before discussing how blockchain can be applied to the supply chain we need to understand the basics of how blockchain works. To understand the way that blockchain works let's use a simple example of exchanging money among friends. This example is taken from a 3Blue1Brown YouTube video (Sanderson, 2017).

Let's say that a group of friends frequently eat out and want to keep up with their portion of the ongoing food bill. Exchanging cash at each meal may become inconvenient. To simplify the process, they could use a communal ledger that records all of the transactions and who owes which portion of all of the bills. To keep the system trustworthy everyone would have access to the ledger, like on a web site. As bills are paid they are added to the ledger along with who owes what portion of the bill.

This would make it convenient to settle up at the end of every month. If someone owed more than they spent they would contribute money to the central pot and if you spent more than you received you would take money from the central pot.

The problem lies in that anyone can add to the ledger because everyone would have access to it. Nothing prevents one friend from adding false entries showing money due to them onto the ledger. The issue is trust. Solving this trust issue would be a simple matter of adding a signature line that the payer signs. In the case of an electronic ledger this is in the form of a digital signature. This creates the potential problem of a digital signature being copied and pasted easily. Cryptography is a logical solution. A simple private key/ public key could be the answer.

In simple terms, here is how that works. A public key and the private key combine with the message to make the digital signature. The private key could be a string of 256 ones and zeros. This private key would change depending upon the message. If the message is changed then the private key would have to change as well. If the message is different, then the signature won't work. In order for someone to guess the correct private key would require 2^{256} possible combinations. This gives extremely high confidence that the originator of the payment knew the private key.

This approach still has a weakness. Although someone could not forge a new entry into the ledger by copying and pasting the signature, they could still copy and paste a previous transaction in its entirety since that message and signature combination is known to work. The simple solution is that each transaction has a unique identifier that in essence changes the message and would thus require a new matching private key.

This solves the falsification issue but does not solve the trust issue completely. Nothing would prevent one of the friends from skipping out on settling up on their portion of the bill after running up a high tab. The solution to this is to initially place money into the central pot before any other transactions. Then the system can be set up to not allow over spending their balance. This requires a running balance which is predicated on knowing the entire transaction history. At this point no currency is ever needed to exchange.

The last bit of trust still exists in where the ledger is kept. If the ledger is on a web site, as in our example, who hosts the web site? Who is controlling the rules of adding transactions? The group of friends is trusting the web site host. To eliminate this, each of the friends would keep a copy of the ledger. When a transaction is performed it gets recorded on all of the ledgers.

But there is a problem with this. What assurance does each friend have that everyone else recorded the transaction? The solution is to trust the ledger that has the most amount of computational work put into it successfully. At regular intervals the ledger would be collected into a block of transactions and computational work put into it in the form of a cryptographic hash function. If one friend's ledger has 3 blocks and another friend has 30 blocks, the ledger with 30 blocks is accepted and becomes the new starting point. This is convenient if someone has had their computer off line but wants to get caught up.

A cryptographic hash function is essentially a series of 256 ones and zeros. It works in much the same way as the public and private key cryptographic example explained earlier. A list of transactions plus a unique number will create a hash using a cryptographic key. If the rules are that the hash that is output must start with 30 zeros then 2^{30} is roughly equal to a billion meaning that it would take a billion random guesses to get the correct answer. Keep in mind that 30 zeros is not what is always used, it is just as an example.

In order to verify that the list of transactions along with the unique number creates the hash starting with 30 zeros, is by simply inputting the unique number. This is known as the proof of work. Once the proof of work is established that set of transactions becomes a block.

Figure 1 is a visual way of thinking about how the blocks in a blockchain link together via the private key.

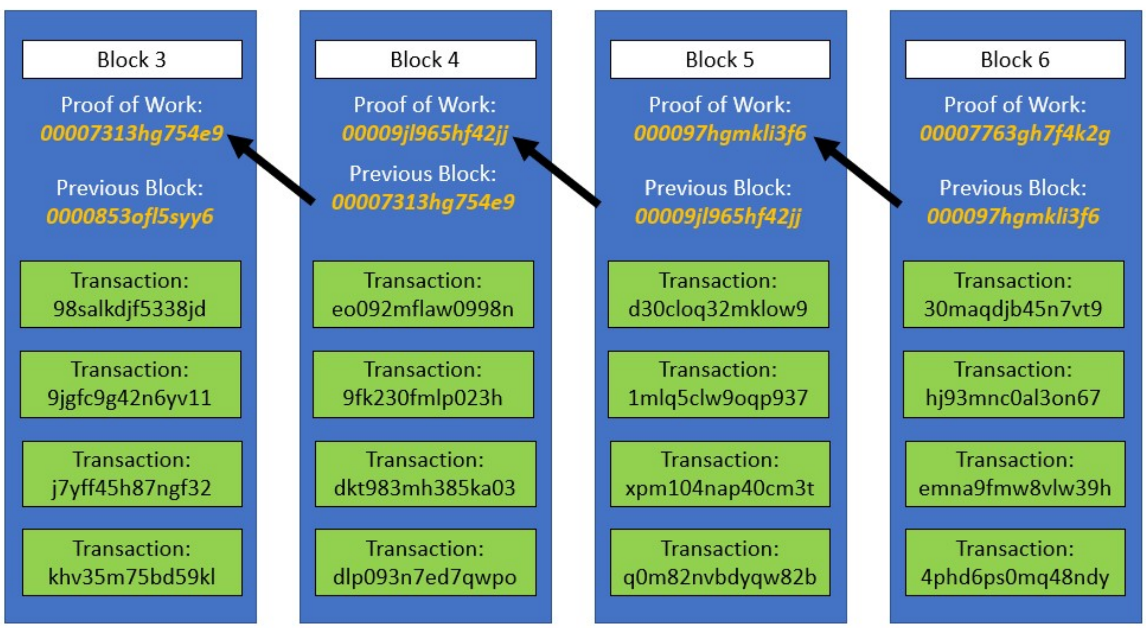

Figure 1. *Basics of Blockchain*

The next block (or set of transactions along with a unique number) uses the hash from the previous block in the header. This prevents someone from changing any previously blocked set of transactions. To do so would require changing (computing) the hash for every subsequent block before any new blocks are formed. The attempt would get further and further behind as the chain of blocks grows. This is why the longest set of blocks is accepted (Sanderson, 2017).

Using blockchain for traceability

The previous scenario illustrates the basic concepts of blockchain technology. The blockchain discussed in this scenario works well to eliminate the need for trust among friends exchanging money. The blockchain concept can also be applied to supply chain transactions.

Remember that supply chain transactions require a third party to facilitate the payments. This third party would normally be a bank. A bank would have record of funds available. When a transaction comes through for funds to be paid to a supplier, a bank would process the transaction to the supplier. This process naturally would incur a fee that is paid to the bank for performing the transaction. It is these seemingly small transaction fees that add up to large amounts of money when hundreds, thousands, or tens of thousands of transactions are processed by companies.

Large companies (and even small ones) can use block chain to avoid these fees or to collect fees for themselves. This is a big incentive for companies to reduce their transaction costs. Companies like IBM, Kodak, Wal-Mart, SAP, Oracle, and Maersk have all invested millions of dollars into researching and establishing blockchains for their supply chain or their customers (Bowles, 2018).

In addition to avoiding transactional fees as the reason to implement a blockchain in the supply chain, there are other use cases that make the implementation of distributed ledger technology a growing trend (Yli-Huumo, Ko, Choi, Park, & Smolander, 2016).

The use case of interest here is that of product traceability. Traceability is always a concern of quality professionals. Wal-Mart and IBM have been partnered since 2016 to develop blockchain uses (McKenzie, 2018). Frank Yiannas is Wal-Mart's VP of food safety. In 2017 he had his team trace the path of a package of sliced mangoes. To follow the trail using conventional recordkeeping methods from store back to farm it took 6 days, 18 hours, and 26 minutes of linear time. Using the blockchain software they built with IBM, the same traceability exercise took 2.2 seconds (McKenzie, 2018).

Based on these anecdotal tests, it appears that Blockchain may be suitable for traceability queries even though the development initially was transaction focused. The next step then is to look deeper and determine how these systems are implemented. There are two basic formats for the implementation of a block chain; public, and permissioned (sometimes called private).

Public blockchains are exactly as the name sounds. They are open to the public. Anyone with a way to access the network can become a node on the network. Once on the network, the node has full permissions to read, transact, and create blocks. In a permissioned blockchain someone with a way to access the network can receive permission from the "owner" of the blockchain network to have access to the network. The network "owner" can set permissions on who can read information on the blockchain, who can transact on the blockchain, and who can write new blocks to the chain (Bauerle, n.d.).

Permissioned blockchains are perfectly applicable to companies who would not want all of their supply chain transactions available to everyone. By having permissioned rather than public blockchains, there are some immediate benefits, but also some immediate questions.

The benefits of a permissioned blockchain network is in the control over who can see, transact, and create on the blockchain. There is an added layer of security by requiring permission to be on the blockchain network. Other benefits include increased performance of the network since the transactions are directed to one type of transaction (Monax, n.d.). Additional performance improvement is gained by not having to do full proof of work but rather proof of stake.

Proof of work asks that every node on the network make an attempt to hash the block and the first that accomplishes it is given a reward in the form of bitcoin or some other cryptocurrency. Proof of stake assigns one node to solve the hash. The node is assigned by the system and other nodes can later verify the solution to reach consensus. The node that is assigned to solve the hash is incentivized to perform the work by receiving a transaction fee (Blockgeeks. 2017). If this is done by the owner of the blockchain, they can not only avoid transaction fees to banks but collect fees for themselves.

Along with these benefits come some questions about the security of fewer nodes and reducing the proof of work requirement. The security question can be debated on the technical side, but it is argued that it is more secure because not only is the hash computation still completed and verified, it is done by only those with permissioned access to the blockchain (Monax, n.d.).

Another question is how is traceability on the blockchain better than current methods. This debate is not a part of this study. It is noted that companies are moving to blockchain to eliminate transactional costs and taking the opportunity to include traceability data.

Value of the Study

The need for traceability data to be gathered and maintained exists when products are not identical such as different production lots or dates (Töyrylä, 1999). Töyrylä also identifies 4 applications of traceability data.

1. Material flow management applications – where physically is a product. Applies primarily to shipping/logistics companies.
2. Legal verification applications – Warranty, fraud, proof of origin, and proof of quality fall within the legal applications for traceability.
3. Segregation applications – used to determine which customer ordered which items.
4. Measurement and analysis applications – used to gather data for analysis into marketing efforts, quality relationships to design changes, etc.

Based on Töyrylä's (1999) applications it can easily be seen that traceability data is not limited to recalls or legal requirements. Other uses for traceability data that Töyrylä points out are in logistics, quality, security, accounting, and after-sales applications. Based on his study of traceability, Töyrylä suggests that traceability is a separate discipline and not just a part of other disciplines like PDM or TQM, for instance.

Other authors have rightly pointed out that traceability data is not just within a single company but extends to the entire supply chain (Caplan, 1989; Abeyratne, & Monfared, 2016; Kim, & Laskowski, 2018; Limón, & Garbajosa, 2005).

The need for traceability exists and there is agreement on the need for it to exist throughout the entire supply chain. Blockchain is a technological enabler of traceability systems.

Clohessy (2019) has identified the critical success factors for implementing blockchain, but how to implement blockchain in the supply chain for product traceability has not been explored in the literature and there is a need for a model of implementation using the critical success factors. Having this model will be of value to academia and practitioners alike.

Terms

Blockchain – "a distributed transaction database in which different computers – called nodes – cooperate as a system to store sequences of bits that are encrypted as a single unit or block and then chained together" (Lemieux 2016, p. 118).

Product traceability – "the ability to track forward the movement through specified stage(s) of the extended supply chain and trace backward the history, application or location of that which is under consideration" GS1 (Ryu & Taillard, 2007, P. 13).

Supply Chain – A supply chain is a network of manufacturers and service providers that work together to create products or services needed by end users (Bozarth & Handfield, 2006).

Large Organizations – Organizations with 500 or more employees (Ghobadian & Gallear, 1997).

Small and Medium Enterprises (SMEs) – Organizations with fewer than 500 employees (Ghobadian & Gallear, 1997).

Statement of the Problem

Traceability has been explored in the literature and blockchain technology is a growing area of academic research (Yli-Huumo, Ko, Choi, Park, & Smolander, 2016). What is not well explored in the literature is how to implement blockchain in a supply chain for product traceability. Blockchain is in the incipient stages of implementation and there are no developed guidelines for practitioners to follow for implementing blockchain the supply chain (Queiroz, Telles, & Bonilla, 2019). The problem for this study is that we do not know which factors have the greatest influence on implementation of blockchain in the supply chain.

Research Questions

Research question 1: What factors most influence the implementation of blockchain in the supply chain for product traceability?

Research question 2: Does organization size, revenue, or type of industry have an impact on which critical success factors are considered most important for implementing blockchain in the supply chain?

Research Hypotheses

To answer research question 2, the following research hypotheses are set up

$H_0 1$: There is <u>no</u> significant difference on the critical success factors between small and large organizations for implementing blockchain in the supply chain.

$H_a 1$: There is a significant difference on the critical success factors between small and large organizations for implementing blockchain in the supply chain.

$H_0 2$: There is <u>no</u> significant difference on the critical success factors between low and high revenues for implementing blockchain in the supply chain.

$H_a 2$: There is a significant difference on the critical success factors between low and high revenues for implementing blockchain in the supply chain.

$H_0$3: There is <u>no</u> significant difference on the critical success factors between manufacturing and service industry for implementing blockchain in the supply chain.

H_a3: There is a significant difference on the critical success factors between manufacturing and service industry for implementing blockchain in the supply chain.

Statement of the Purpose

The purpose of this research is two-fold. The first purpose is to evaluate a relationship that might exist between the identified critical success factors and use those relationships to design a model for the successful implementation of blockchain in the supply chain as it relates to product traceability. The second purpose of the research is to determine if organization size, revenues, or type of industry have an impact on the ranking of critical success factors.

Statement of Assumptions

Using the Clohessy (2019) determined critical success factors, this research was conducted through a survey instrument administered to supply chain professionals during the 2020 Association for Supply Chain Management (ASCM) national conference. The 2020 ASCM national conference was conducted differently than previous years because of the COVID-19 pandemic. ASCM offered an in person and a virtual conference option for potential attendees with travel restrictions. For this reason, the survey instrument was posted in conference chat rooms, sent via conference message to attendees that had agreed to share their contact information, and posted in a Linked ASCM group. There are several assumptions in this approach. The first assumption is that the supply chain professionals surveyed were aware of blockchain. An underlying assumption to this is that the variation in the respondent's knowledge of blockchain did not have a significant skewing effect. The next assumption in this approach is that the supply chain professionals surveyed were aware of and familiar with the need for traceability.

Statement of Limitations

One major limitation is the possible lack of knowledge of blockchain among survey respondents.

Another limitation is the lack of prior research on this topic. The use case of traceability within blockchain in the supply chain is being developed currently in industry and there is little prior research on a framework for practitioners (Queiroz, Telles, & Bonilla, 2019).

Statement of Delimitations

The researcher has delimited this study to supply chain professionals and not information technology or quality professionals that have a hand in the implementation of blockchain in the supply chain for traceability.

The researcher has also delimited this study by selecting the ASCM members and not the entirety of supply chain professionals. This means that the data was not from a randomized sample.

The researcher has also delimited this study by choosing to not sub-divide respondents to the survey instrument by income, gender, race, organizational level, etc. The population is generalizable to supply chain professionals as a whole but populations within that group were not evaluated.

Scope of the Project

The research was conducted in four (4) phases. The first phase was the literature review.

The second phase of the research was to develop the survey instrument. A panel of experts in the fields of information technology, blockchain, and supply chain reviewed the questionnaire once it was drafted. The purpose of the expert panel was to develop the full questionnaire. Once the full questionnaire was developed, the IRB process was utilized to protect the rights and welfare of human subjects in the next phase of the research.

The next phase of the research (phase three) was to conduct a quantitative study using the survey instrument shown in Appendix A. The survey instrument used a 10-point Likert type scale. To ensure reliability and validity, Chronbach's alpha and expert evaluation of the survey instrument were used. Pilot testing of the survey instrument was also used.

The population for this study is of supply chain professionals. ASCM recently merged with APICS and APICS considered themselves to be the "largest non-profit association for supply chain" with over 45,000 members (APICS, 2018).

A correlational design was chosen using a convenience sample from the ASCM2020 conference attendees and ASCM members on LinkedIn.

The survey responses of the ASCM members to the relative importance of each critical success factor was used to develop the model in phase four of the study.

Chapter Summary

This chapter has given the background of both traceability and blockchain. The chapter then went on to explain the statement of the problem, purpose and need for this research. The assumptions and limitations were also shown and the methodology was briefly covered.

REVIEW OF LITERATURE

The purpose of this literature review is to investigate the current state of the literature related to implementation of blockchain in the supply chain for product traceability. The literature review is divided up into four sections. The first section looks at literature related to blockchain while the second section looks at literature related to traceability. Tying these together is the third section looking at literature focused on using blockchain for product traceability. The final section examines the critical success factors used in this study.

Blockchain

Blockchain was originally designed for the cryptocurrency of bitcoin. Since the initial inception of the technology it has been applied to many other uses. Primarily the uses have been transactional. Since it can be applied to any type of transaction, this opens up the possibilities for research on many blockchain applications. In the past few years, the supply chain has been advocated as a use case for blockchain (Clohessy, 2019).

When searching for literature about blockchain technology there is a significant amount of grey literature. Much of it in the form of white papers not peer reviewed. Even the Federal Reserve Board and the European Union have published papers about the use and effect of blockchain (Mills, Wang, Malone, Ravi, Marquardt, Chen, Badev, Brezinski, Fahy, Liao, Kargenian, Ellithorpe, Ng, Baird, 2016; Ganne, 2018). In fact, the original paper by Satoshi Nakamoto introducing the concept of bitcoin was not peer reviewed.

There is growing literature about blockchain (Yli-Huumo, Ko, Choi, Park, & Smolander, 2016). The peer reviewed literature about blockchain is heavily weighted toward bitcoin and other cryptocurrencies. A systematic literature review in 2016 noted that over 80% of the papers extracted focused on bitcoin systems (Yli-Huumo, Ko, Choi, Park, & Smolander, 2016). A common theme in the literature is the security of the system. This is mostly from the IT perspective and there is much discussion around the 51% attack (Firica, 2017).

Smart contracts are frequently discussed in the blockchain literature. Smart contracts are not "smart" in the IT sense but are automatically executed transactions when conditions are met. For example, when a product is received a smart contract would initiate payment for the product. They can be more sophisticated and require multiple conditions to be met at various stages of the supply chain. They can also have bearing on traceability systems in automating the process (Vukolić, 2017; Vukolić, 2015; Yli-Huumo, Ko, Choi, Park, & Smolander, 2016; Laurence, 2017; Crosby, Pattanayak, Verma, & Kalyanaraman, 2016; Swan, 2015).

Because blockchain technology is relatively new, there is a lot written about the potential for the technology and things that it "can" do, but they miss the mark on efficacy. Frequently blockchain technology is referred to as a "disruptive technology". Melanie Swan went so far as to title her book "Blockchain: Blueprint for a New Economy" (Swan, 2015). While many papers talk about what blockchain "can" do, there was one dissenting voice in the discussion around blockchain. Ammous (2016) gives an honest assessment of blockchain technology not by saying what it "can" do but what it is able to do while saying that in 8 years of availability on the market there have been no commercially available applications. He goes on to say that the technology cannot compete with the current best practices (Ammous, 2016). It should be noted that subsequent to his paper in 2016 there have been commercially available applications of blockchain.

Traceability

More has been written about traceability. ISO 8402:1994 is titled as *Quality management and quality assurance – Vocabulary* and defines traceability as, “The ability to trace the history, application or location of an entity by means of recorded identifications” (International Organization for Standardization, 1994). This is an older standard that has since been withdrawn and replaced with ISO 9000:2000 which has undergone several revisions. The most recent edition (2015) defines traceability a little more specifically as “the ability to trace the history, application, use and location of an item or its characteristics through recorded identification data”. (International Organization for Standardization, 2015). GS1 Global Traceability Standard uses the ISO 9000:2000 definition expanded, “The ability to track forward the movement through specified stage(s) of the extended supply chain and trace backward the history, application or location of that which is under consideration” (Ryu, & Taillard, 2007). Bechine, Cimino, Marcelloni, & Tomasi (2008) also define it as track and trace. Tracking is following a product downstream in the supply chain and tracing is following a product upstream in the supply chain. While there is still debate about the exact definition of the term and what data should be included, the concept is well understood (TÖYRYLÄ, 1999; Hobbs, 2003). Both the history of the product throughout the supply chain as well as the history of the product through distribution must be included in the definition.

Many authors have rightly pointed out that traceability data is not just within a single company but extends to the entire supply chain (Caplan, 1989; Abeyratne, & Monfared, 2016; Kim, & Laskowski, 2018; Limón, & Garbajosa, 2005).

Within the context of track and trace, the elements of traceability can be broken down even further. Caplan (1989) provides five necessary elements of an effective traceability system.

1. Lot integrity control
2. Processing control
3. Build control
4. Inspection and test
5. Field activity and modification control

Regatieri, Gamberi, and Manzini (2007) give four pillars for an effective traceability system.

1. Product identification
2. Data to trace
3. Product routing
4. Traceability tools

The need for traceability is written about in the literature (Hobbs, 2003; Limón, & Garbajosa, 2005), and most of the literature focuses on the food industry (Opara, 2003; Dabbene, Gay, & Tortia, 2014; Tian, 2016; Aung, & Chang, 2014; Kelepouris, Pramatari, & Doukidis, 2007). Regardless of the industry, traceability has an important role in assuring quality. Toyryla (1999) gives 4 basic applications of traceability:

1.Material flow management applications

2.Legal verification applications

3.Segregation applications

4.Measurement and analysis applications

Toyryla shows that traceability data is not limited to recalls or legal requirements. Other uses include logistics, quality, security, accounting, and after-sales applications (TÖYRYLÄ, 1999).

Improvement of current systems is also discussed in the literature. Improving the current systems is necessary because there are areas where the system needs exceed the current processes. The issues experience in traceability systems fit into the following categories:

1. Real time information (Feigenbaum, 1991).

2. Easy availability (Martin, 1983).

3. Long term storage (Steele, 1995)

4. Security (TÖYRYLÄ, 1999)

5. Accuracy (TÖYRYLÄ, 1999).

Improving the current systems through technological means appears in the literature with relative frequency. The most common means of improving current traceability is through the use of RFID (Dabbene, Gay, & Tortia, 2014; Opara, 2003; Tian, 2016; Kelepouris, Pramatari, & Doukidis, 2007). Still included in the literature is the assumption of a central database.

Another assumption is that there is a need for traceability systems. It is implied in some of the areas mentioned earlier about the role of traceability but is expressly addressed by Hobbs (2003) as well as by Limon and Garbajosa (2005). To fulfill this need GS1 has created a traceability standard. GS1 is a not-for-profit that creates standards for business communication (the bar code system is one of their standards). The GS1 standard is an attempt to standardize the minimum requirements for traceability systems (Ryu, & Taillard, 2007).

Traceability is also being researched in connection with current social issues. Recently there have also been literature about the role that traceability plays in sustainability (Germani, Mandolini, Marconi, Marilungo, & Papetti, 2015; Busse, Meinlschmidt, & Foerstl, 2017; Aarseth, Ahola, Aaltonen, Økland, & Andersen, 2017; Badzar, 2016). A measure is now in place that is used by the textile and clothing industry, called the Higg Index, that scores suppliers on traceability and sustainability (Agrawal, 2019).

Blockchain for Product Traceability

In conducting this search for literature on the implementation of blockchain technology in the supply chain for traceability, it is noted that the literature is truly scant. There is growing literature about blockchain in the supply chain but not focused on implementation.

The potential uses of blockchain appears to be the most widely discussed topic in the literature. This is to be expected. With the technology only recently having been developed and the use cases being explored, it is natural that as blockchain is beginning to be deployed in the supply chain that authors would explore the potential use of it which include product traceability.

The literature around the potential uses of blockchain in the supply chain seem to fall into four categories. The categories are; data transparency (Benton, Radziwill, Purritano, & Gerhart, 2018; Niforos, 2017; Francisco, & Swanson, 2018; Wu, 2017; Badzar, 2016; Eljazzar, Amr, Kassem, & Ezzat, 2018), proposed uses in the food industry (Biswas, Muthukkumarasamy, & Tan, 2017; Tian, 2017), smart contracts for payments and transaction tracking (Augusto, 2019), and product provenance (Alzahrani, & Bulusu, 2018; Lu, & Xu, 2017; Bjöntegaard, & Holmgren, 2019; Gammelgaard, Welling, & Nielsen, 2019). The product provenance discussions in this category of the literature revolves around using blockchain for traceability but do not discuss implementation.

The use of blockchain for traceability has also been indirectly discussed in the literature. DiCiccio et al looks at the use of blockchain for traceability of BPM tasks in the supply chain (Di Ciccio, Cecconi, Mendling, Felix, Haas, Lilek, & Uhlig, 2018). This is not tracing a product but tracing that tasks are completed in the supply chain and executed by smart contracts.

The World Trade Organization published a paper in 2018 discussing blockchain's potential effect on international trade. Many use cases were discussed but product traceability was not directly discussed. It did indirectly talk about provenance when discussing the potential for blockchain to protect intellectual property rights by being able to, "provide proof of creation, existence, ownership and/or first use, to register IP rights…" (Ganne, 2018, p. 58).

Some authors have written about the potential benefits of implementing blockchain in the supply chain (Abeyratne, & Monfared, 2016). Tian (2016) gives both advantages of blockchain as well as the disadvantages. Tian does this in the context of combining blockchain technology with RFID systems. The advantages enumerated are; better tracking and tracing, enhanced credibility of safety information, and fighting against fake products. The disadvantages listed are simply the high cost (of the RFID for every product), and the immaturity of blockchain. The example given is the number of transactions per second that can be handled through blockchain. Blockchain can perform up to 7 transactions per second compared to 47,000 transactions per second that Visa processes (Tian, 2016). It should be noted that since the writing of this article in 2016, the number of transactions per second on blockchain has been developed further. By 2018 (just 2 years later) Hyperledger Fabric, for example, can handle more than 3,500 transactions per second (Androulaki, Barger, Bortnikov, Cachin, Christidis, De Caro, & Muralidharan, 2018).

Rapalis and Hossain (2019) also write about the potential benefits of blockchain for product traceability in the supply chain. They enumerate much of what Tian (2016) list. What they also provide are some of the potential challenges to implementing blockchain in the supply chain for product traceability that they cite from the literature.

1. Lack of standardized format for information exchange in the supply chain
2. Differences in accuracy levels of traceability between links in the supply chain
3. Lack of integration and transparency within the supply chain
4. Data issues such as trust, privacy, security and reliability

Biggs, Hinish, Natale, & Patronick (2017), in contrast, assert that blockchain technology used in the supply chain will build trust and transparency. They see what Rapalis & Hossain call data issues as enablers and not potential challenges. They list their own challenges under the heading "Blockchain Barriers to Marketplace Acceptance" (Biggs, Hinish, Natale, & Patronick, 2017, P. 10).

1. Uncertain government regulatory status
2. Large energy consumption
3. Cross industry integration
4. Black market

Malyavkina, Savina, & Parshutina (2019) begins to get more specific about challenges to implementation. They list the challenges in categories of technology, organizational, normative, legal, economic, and psychological. Clohessy (2019) groups these into the categories of Technological, Organizational, and Environmental (TOE). He then divides each category out into factors affecting implementation of blockchain in the supply chain.

Critical Success Factors

Using the TOE framework, Clohessy derived 25 factors affecting implementation of blockchain in the supply chain. He conducted interviews with senior managers in 20 companies across both large and small organizations in Ireland along with guidance from the literature (Clohessy, 2019).

The 25 factors Clohessy identified are:

- Perceived Benefits
- Complexity
- Compatibility

- Data Security
- Smart Contract Coding
- Maturity
- Relative Advantage
- Disintermediation
- Permissions (public vs private)
- Architecture
- Organizational/Value Chain Readiness
- Top Management Support
- Organizational Size
- Business Model Readiness
- Technology Readiness
- Innovativeness
- Participation Incentives
- Blockchain Knowledge
- Regulatory Environment/Regulation
- Market Dynamics/Competitive Pressure
- Industry Pressure/Standards
- Government Support
- Business Use Cases
- Trading Partner Support
- Critical User Mass

Below is a summary table by Clohessy (2019) which groups the factors into categories of Technological, Organizational, and Environmental (TOE).

As defined by Clohessy, technological perspective is viewing those technologies that exist within and without the organization. Current infrastructure as well as future needs. Technological enablers are things that make traceability systems easier. Bar codes, RFID tags, internet connectivity, etc. The following are brief descriptions of each factor, identified by Clohessy, within the technological grouping.

Table 1

Summary of Significant Blockchain Adoption Factors

Summary of significant blockchain adoption factors		
Technological Factors	**Organizational Factors**	**Environmental Factors**
Perceived benefits	Organizational readiness[1]	Regulatory environment[2]
Complexity	Top management support	Market dynamics[3]
Compatibility	Organizational size	Industry pressure[4]
Data security	Business model readiness	Government support
Smart contract coding	Technology readiness	Business use cases
Maturity	Innovativeness	Trading partner support
Relative advantage	Participation incentives	Critical user mass
Disintermediation	Blockchain knowledge	
Permissions (public vs private)		
Architecture		

1: Includes value chain readiness; 2: Includes government regulation; 3: Includes competitive pressure; 4: Includes industry standards

Note. Reproduced with permission from the author (Appendix B)

Perceived Benefits are defined exactly as it sounds. Davis (1989) called it perceived usefulness when talking about acceptance or rejection of information technology. He defined perceived usefulness as, “the degree to which a person believes that using a particular system would enhance his or her job performance” (Davis, 1989).

Complexity is another term that is self-explanatory in this context. Although discussed as a decentralized network, blockchain is essentially an information technology (IT) (Swan, 2015). How complex an IT appears may have an effect on an organization’s willingness to implement it.

As organizations consider the IT factors of implementation such as throughput, latency, bandwidth, security, and resources it becomes a better-informed decision for implementation.

Compatibility as an implementation factor is referring to the technical compatibility with current infrastructure. Will it be a stand-alone system, or can it be integrated with current systems? Questions such as this are important considerations when determining to implement blockchain (Shrier, Sharma, & Pentland, 2016). This factor would not only take into consideration the current infrastructure of one company but of the supply chain as a whole.

Data Security – Blockchain by its nature has shared data among users. Beyond the normal concerns of transmitting data across a network, there is an added concern that data in the blockchain is secured. This will always be a consideration when dealing with an open network (Mendling, Weber, Aalst, Brocke, Cabanillas, Daniel, & Gal, 2018). This would naturally be a factor to be addressed when implementing blockchain in a supply chain – potentially with competitors.

Smart Contract Coding is the inclusion of code into the blockchain transaction that automatically executes when conditions are met. As a factor for consideration of implementation, smart contract coding can help, “facilitate contract negotiation, simplify contract terms, implement contract execution, and verify contract fulfillment state” (Chen, Xu, Lu, & Chen, 2018, P. 12).

Maturity is an important consideration when deciding to implement a technology. Blockchain is still a relatively new technology. In 2017 Morabito estimated that blockchain would need between 5 and 10 years for full adoption in live environments stating, “technological innovations don’t achieve success from the first versions” (Morabito, 2017, P. 35).

Relative Advantage begins to ask about company strategy and positioning. Michael Porter stated, “A company can outperform rivals only if it can establish a difference that it can preserve” (Porter, 2011, P. 2). In short, relative advantage is fleeting. Deciding to implement blockchain in the supply chain must include a consideration of relative advantage. Also note that if a company is a part of developing the use of a technology then they have an advantage of access to determine the manner in which it is used.

Disintermediation is not as intuitive as some of the other terms. Blockchain, by its nature, eliminates intermediaries. Eliminating transactional intermediaries, such as banks, would seem a positive financial incentive. On the other hand, if smart contracts execute transactions and contracts automatically then traditional firm structures like accountants and lawyers’ primary functions could be disrupted. These must be considered when determining to implement blockchain in the supply chain (Iansiti, & Lakhani, 2017).

Permissions (public vs private) is less a consideration of architecture than a consideration of identity. In a public blockchain the nodes existing on the chain are anonymous. In a private blockchain, all of the nodes represent identifiable members (Pilkington, 2016). In this instance it would be members of the supply chain. As many companies often buy from competitors these kinds of privacy matters come into consideration.

Architecture as a factor in implementing blockchain in the supply chain is dealing with how the blockchain is structured. Considerations within the architecture include who has read-write permissions, which nodes can perform validation, and how are various nodes connected (see figure 2).

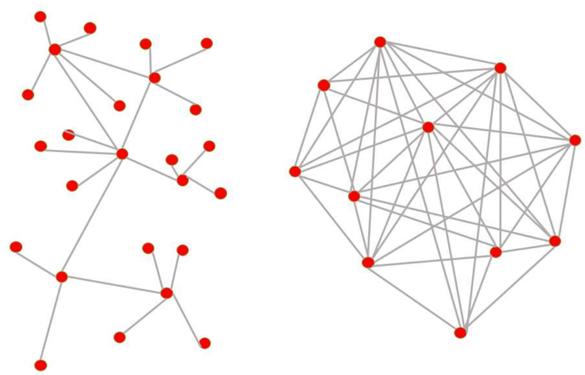

Figure 2. *Architecture Examples*

In addition to the technological factors briefly described above there are organizational factors. The organizational perspective is looking at internal factors to an organization such as knowledge, management support, and organizational readiness. Organizational enablers are harder to define. It is the organizational setting that supports the acceptance of the system

Organizational/Value Chain Readiness is separate from technologically being ready. This factor is about the human resources facet and the financial facet (Clohessy, 2019). It also becomes, to some extent, a matter of trust and partnership in the entire chain. As new suppliers are added to the supply chain there become added security risks. There have been hacks of the bitcoin blockchain. The hacks that have occurred to bitcoin were not of the blockchain itself but systems connecting to the blockchain (Iansiti, & Lakhani, 2017). Companies need to consider the ability of their supply chain partners to maintain system security.

Top Management Support, as defined by Clohessy (2019), is a key factor. Top management support is managerial participation and advocation of blockchain in the supply chain (Clohessy, 2019). How well does senior management participate in and advocate for technological advancement? The assumption here is that the higher the level of participation and advocation the greater the likelihood of success.

Organizational Size has been shown to correlate with a company's willingness to implement a new technology (Clohessy, 2019). This correlation will presumably translate to the implementation of blockchain in the supply chain. However, other research has also indicated that it depends upon the specific technological innovation (Clohessy, 2019). Companies need to consider if their large organizational size gives them the necessary IT budgets and resources to implement blockchain, or if their small organizational size gives them the flexibility to implement blockchain.

Business Model Readiness can be a slightly confusing phrase of the intended term. What it is meant to represent is the business model of the supply chain as a whole. For example, if smart contracts begin to automatically execute agreements, the function of attorneys will change. Perhaps the expertise of accountants and auditors will also have to change in order to audit transactions on the blockchain (Swan, 2015). As these, and other, roles change, how ready is the supply chain to support this implementation? These are the considerations that are termed business model readiness.

Technology Readiness, as defined as an organizational factor, is how well an organization (and extending into the supply chain) is prepared to implement and support a new technology like blockchain.

Innovativeness is similar to the technology readiness factor in that it, too, requires assessing the organization and the supply chain. Innovation is a difficult term to define. It touches upon the culture of the organization. Companies will need to assess their organization to determine if they believe they have the innovativeness necessary to implement blockchain in the supply chain.

Participation Incentives are of two categories. In traditional blockchain 'mining' there is an incentive to solve the hash by being awarded some sort of 'coin' (Pilkington, 2016). In a private blockchain (such as might be implemented in a supply chain) the chain owner can determine if this incentive is provided. The other category of incentives that may be offered is a business decision. If a large company moves their entire supply chain to blockchain, the requirement to implement blockchain may be necessitated for suppliers. In order to sell to a certain customer there is an incentive to implement blockchain. Both types of incentives may play into a company's decision to implement blockchain.

Blockchain Knowledge factor asks the question about the people in an organization. How well do the people in the organization know blockchain? This is a critical factor as it may defer implementation, initiate hiring of additional resources, or allow for full ahead implementation.

Beyond the technological and organizational factors of implementing there are the environmental factors. Environmental factors encompass all of the business operations dynamics. Factors in this category could be the industry requirements, regulatory requirements, or competitive pressures, etc.

Regulatory Environment/Regulation factors are the biggest unknown right now as it relates to blockchain (Iansiti, & Lakhani, 2017). Regulatory pressures can come from the FTC, SEC or others. The danger here, for blockchain, is that since it is not a mature technology, regulations are not settled for this technology (Crosby, Pattanayak, Verma, & Kalyanaraman, 2016). The US Federal Reserve Chair has stated that regulation will not be set for blockchain yet to allow for freedom of innovation (Guo, & Liang, 2016). While allowing for innovation it creates an unsure regulatory environment for the technology. This is confounded for multi-national companies who face not only an uncertain regulatory environment domestically, but also internationally with potentially conflicting or disparate requirements.

Market Dynamics/Competitive Pressure must also be considered as a factor of whether to implement blockchain or not. Some industries are further along the path of implementation of blockchain than others. The financial services industry is further along than manufacturing, for instance (Iansiti, & Lakhani, 2017). Companies in the financial services industry would feel more competitive pressure towards implementing blockchain than manufacturing companies.

Industry Pressure/Standards are distinguished from the regulatory environment. Regulations would stipulate what kind of oversite, where standards would stipulate how transactions are conducted. The International Organization for Standardization (ISO) has a newly formed Technical Committee (307) who met initially in Australia in 2017 to begin establishing standards for transactions using the technology (Naden, 2017). So far they have roughly 10 ISO standards under development ranging from terminology to guidelines for governance. ISO have already published ISO/TR 23455:2019 Blockchain Distributed Ledger Technologies-Overview of and Interactions Between Smart Contracts in Blockchain and Distributed Ledger Technology Systems. These kinds of standards give guidance for companies looking to implement blockchain in the supply chain.

Government Support is an interesting factor to consider for implementation. It can be easily confused with the regulation factor described earlier. Governmental support is more specific to acknowledging the transactions and being able to convert transactions on a blockchain to fiat currency (currency issued by governments).

Business Use Cases are an industry specific factor for companies to consider when determining to implement blockchain in the supply chain. As mentioned earlier some industries are further along in the development of blockchain applications. Using the example above, companies in the financial services sector would have more defined use cases for blockchain than manufacturing (Iansiti, & Lakhani, 2017).

Trading Partner Support as a factor of implementation can be highly important. A company looking to implement blockchain in the supply chain must know that their customers and suppliers alike have the same commitment to the technology. As mentioned earlier this could be in the areas from technology support to security of connected systems.

Critical User Mass as a factor to consider is a matter of timing. When to begin adopting the technology is a matter of consideration for any company. If a company adopts the technology too soon then they shoulder the risk for longer of developing the technology but also may have a hand in shaping its' use to create a competitive advantage. If a company adopts the technology later then they have less risk in developing the technology but do not have as much influence on how it is adopted by the industry.

The factors described above were divided into the three categories (technological, organizational, and environmental) by Clohessy (2019). Other enumerations of critical success factors were reviewed but not selected for this study.

An examination of the German logistics industry by Gottschlich (2018) identified the critical success factors as cost, transparency, speed, complexity, data security, and digitization. That analysis seems to not be concerned with human factors or the business environment and were thus not selected as the basis for this further study.

A master's thesis from Fredrik Jansson and Oskar Petersen at Lund University in the spring of 2017 used the research questions asking "what inputs are necessary to evaluate blockchain technology as a means for improved traceability" and "how can blockchain be used to improve traceability" (Petersen, & Jansson, 2017, p. 4). Their research generates the inputs to evaluate blockchain technology as a means for improved traceability but does not perform any study to actually evaluate blockchain as a means for improved traceability using those criteria.

Blockchain is a new tool that holds a lot of promise as a developing field. Traceability is a new use case for blockchain technology and companies are investing heavily in development. The lack of literature in this area is understandable with this being a new use case of a very new technology. It is also both encouraging and discouraging. This is encouraging because it is a wide-open field for research. This is discouraging because with not much research applied to it there is not a deep understanding of the topic from which to build.

One of the more interesting aspects of this potential area of research is the relative newness of the technology and its many possible application. Many quality topics have existed for decades. The conception of blockchain began in 2008 with Nakamoto's paper (Nakamoto, 2008). It is only in the last few years that traceability has been explored as a use of the technology. This research is necessary for the foundation of further uses of the technology.

Multiple global companies have invested heavily into this technology. There is a financial incentive for companies to invest. Blockchain has grown to the point where even the Federal Reserve Board have published white papers on the topic (Mills, Wang, Malone, Ravi, Marquardt, Chen, Badev, Brezinski, Fahy, Liao, Kargenian, Ellithorpe, Ng, Baird, 2016;

Brainard, 2016). Any disciplined research into this topic would be of great value to these companies and others waiting to enter the field.

As it relates to quality and the supply chain, there are obvious use cases for the technology. Traceability was shown earlier to have several known issues. The potential applications for using blockchain to improve traceability in these areas have not yet been fully defined. Research into this use case of blockchain technology will be of interest to quality professionals, companies, and regulatory agencies.

Chapter Summary

This literature review looked at the literature related to implementation of blockchain in the supply chain for product traceability. The literature review was divided up into four sections. Literature related to blockchain was examined first while the second section looked at literature related to traceability. The third section explored tying these together by examining literature focused on using blockchain for product traceability. The last section that was given examined the critical success factors used in this study.

RESEARCH METHOD

The intent of this study was to determine a model for implementation of blockchain in the supply chain for product traceability and to further determine if organization sizes, revenue, or type of industry have an impact on critical success factors for implementation. Two different types of analyses were used to complete the study with all of the data being collected from one survey instrument.

Restatement of the Problem

The problem for this study is that we do not know which factors have the greatest influence on implementation of blockchain in the supply chain. Blockchain is in the incipient stages of implementation and there are no developed guidelines for practitioners to follow for implementing blockchain the supply chain.

Restatement of the Research Questions

Research question 1: What factors most influence the implementation of blockchain in the supply chain for product traceability?

Research question 2: Does organization size, revenue, or type of industry have an impact on which critical success factors are considered most important for implementing blockchain in the supply chain?

Restatement of the Research Hypotheses

To answer research question 2, the following research hypotheses are set up

$H_0$1: There is no significant difference on the critical success factors between small and large organizations for implementing blockchain in the supply chain.

H_a1: There is a significant difference on the critical success factors between small and large organizations for implementing blockchain in the supply chain.

$H_0$2: There is no significant difference on the critical success factors between low and high revenues for implementing blockchain in the supply chain.

H_a2: There is a significant difference on the critical success factors between low and high revenues for implementing blockchain in the supply chain.

$H_0$3: There is no significant difference on the critical success factors between manufacturing and service industry for implementing blockchain in the supply chain.

H_a3: There is a significant difference on the critical success factors between manufacturing and service industry for implementing blockchain in the supply chain.

Research Design

The design of this research is a quantitative non-probabilistic study. It used a convenience sample of supply chain professionals at the 2020 ASCM national conference and LinkedIn ASCM group members.

The analysis for research question 1 was correlational using stepwise regression. The analysis for research question 2 is causal comparative using t-tests.

Data Gathering

Population

The population for this study was supply chain professionals. The Association of Supply Chain Management (ASCM) recently merged with the American Production and Inventory Control Society (APICS) and considers themselves to be the "largest non-profit association for supply chain" with over 45,000 members (APICS, 2018). The organizations are currently in transition and are sometimes referred to interchangeably but will eventually be known as ASCM exclusively. For the purposes of this research, they are referred to as ASCM.

ASCM members were the target population for this study.

Annually ASCM conducts conferences that supply chain professionals attend. The 2020 ASCM national conference was conducted differently than previous years because of the COVID-19 pandemic. ASCM 2020 national conference (held 13-15 September 2020) offered an in person and a virtual conference option for potential attendees with travel restrictions. For this reason, the survey instrument was posted in conference chat rooms, sent via conference message to attendees that had agreed to share their contact information, and posted in a LinkedIn ASCM group

The sample was a non-probability convenience sample taken of ASCM members and only representative of those members and not the larger population of supply chain professionals that are not ASCM members. Permission from ASCM shown in Appendix C.

Instrument

An online survey instrument was administered to ASCM members. A 10-point Likert-type scale was used. The survey instrument was developed based on the Clohessy (2019) identified factors influencing implementation. Higher numbers reflect a larger influence of that factor.

A panel of experts in the fields of information technology, blockchain, and supply chain reviewed the questionnaire once it was drafted. The purpose of the expert panel was to develop the full questionnaire. The final survey instrument was pilot tested and then administered to ASCM members. Appendix A shows the survey questionnaire.

The expert panel consisted of:

1) Information Technology - Robert Nordmark, Director of Service – NetFabric formerly Executive Director – Arkansas Research and Education Optical Network
2) Blockchain - Trevor Clohessy, Ph.D., Researcher – Galway-Mayo Institute of Technology
3) Supply Chain - James Hoenshell, Operations Manager – Play power, Inc.

The draft of the survey instrument was revised after each panel expert gave recommendations.

The first section of the survey instrument are grouping questions. The first three questions helped to answer research question 2. The first hypothesis was answered by using the responses to question 9 through 11 (the relative ranking of the critical success factors) and question 2 (organization size of the respondent).

The second hypothesis was answered by using the responses to question 9 through 11 (the relative ranking of the critical success factors) and question 3 (organizational revenue of the respondent).

The third hypothesis was answered by using the responses to question 9 through 11 (the relative ranking of the critical success factors) and question 1 (industry of the respondent).

Questions 4 through 8 are included in the survey as questions to ensure the correct population is responding to the survey, i.e. supply chain professionals that are familiar with blockchain.

The second section of the survey instrument are the critical success factors. These factors were grouped into technological, organizational, and environmental factors. These three questions were used to answer research question 1.

Ghobadain & Gallear (1997) cite the Eurostat and European Observatory to define Small to Medium Enterprises (SME) as those outside the agricultural sector with 500 or fewer employees. Conversely large organizations were defined as those with more than 500 employees. These criteria were be used in the survey and the analysis for research question two.

Also part of research question 2 was organization revenue. Revenue had four categories consisting of less than 50 million US dollars annually, between 50 million and 250 million US dollars annually, between 250 million and 1 Billion US dollars annually, and greater than 1 Billion US dollars annually.

The Standard Industrial Classification (SIC) system was established by the US Department of Labor (2019). The ten broad industry classifications they define are:

- Agriculture
- Mining
- Construction
- Manufacturing
- Transportation, Communications, Electric, Gas, and Sanitary Services

- Wholesale Trade
- Retail Trade
- Finance, Insurance, and Real Estate
- Services
- Public Administration

The SIC industry classifications were used as the industry sectors within the survey. Also included in the survey was self-reported levels of knowledge of blockchain. These criteria were selected to help answer research question 2.

The quantitative survey instrument used a Likert-type scale based on the research questions enumerated above and the critical success factors given by Clohessy (2019). The critical success factors from Clohessy (2019) under consideration were:

- Technological
  - Perceived Benefits
  - Complexity
  - Compatibility
  - Data Security
  - Smart Contract Coding
  - Maturity
  - Relative Advantage
  - Disintermediation
  - Permissions (public vs private)
  - Architecture
- Organizational
  - Organizational/Value Chain Readiness
  - Top Management Support
  - Organizational Size
  - Business Model Readiness
  - Technology Readiness
  - Innovativeness
  - Participation Incentives
  - Blockchain Knowledge
- Environmental
  - Regulatory Environment/Regulation
  - Market Dynamics/Competitive Pressure
  - Industry Pressure/Standards
  - Government Support

Business Use Cases
Trading Partner Support
Critical User Mass

The survey instrument was developed using Qualtrics (an online survey creation software). The survey instrument was administered during the annual ASCM conference. Each ASCM conference has a computer/telephone application for conference attendees. This includes a discussion board. A link to the survey was posted in the ASCM 2020 national conference application. Because not all supply chain professionals attend conferences, a link to the survey instrument was also posted in the ASCM LinkedIn group.

Statistical Analysis

The 25 factors identified by Clohessy (2019) can be categorized in two groups. The first category is factors that influence the decision to implement blockchain as compared to the second category which are those factors that influence how well blockchain is implemented.

The decision factors are those that a company would consider when deciding whether or not to implement blockchain. When deciding to implement blockchain, a company should consider the compatibility, complexity, data security, regulatory environment/regulation, participation incentives, maturity, business model readiness, critical user mass, technology readiness, government support, perceived benefits, trading partner support, organizational/value chain readiness, innovativeness, disintermediation, relative advantage, and market dynamics/competitive pressure. These factors are considerations for a company to determine if they are ready to implement blockchain.

The implementation factors are those that help determine how well blockchain is implemented. The factors that help determine how well blockchain is implemented include architecture, permissions (public vs private), industry pressure/standards, top management support, blockchain knowledge, organizational size, smart contract coding, and business use cases. These factors help predict successful implementation.

To answer research question 1, the implementation factors were analyzed using a stepwise regression in minitab to build the statistical model. This method helps to ensure that all the variables are considered.

There are three groups that were compared to answer research question 2. Comparisons of groups were the organization size, revenues, and industry.

This research looked at Small to Medium Enterprises (SME) as compared to large organizations. SMEs are defined as those with 500 or fewer employees. Large organizations are defined as those with more than 500 employees. (Ghobadian & Gallear, 1997).

The next comparison made was based on organizational revenue. For the purposes of this analysis, revenue has two categories consisting low and high revenue. The survey instrument had four categories consisting of:

<50 million US dollars annually
between 50 million and 250 million US dollars annually
between 250 million and 1 Billion US dollars annually
>1 Billion US dollars annually.

The cut off between low and high revenue was <250 million US dollars annually for low revenue and >250 million US dollars annually for high revenue. The analysis will use these two categories to answer the research question and the associated hypotheses.

The third comparison made was that of industry. For the purposes of this analysis, the industry categories were manufacturing and service. The survey instrument used ten categories consistent with the Standard Industrial Classification (SIC) system established by the US Department of Labor. The ten broad industry classifications they define are:

Agriculture
Mining
Construction
Manufacturing
Transportation, Communications, Electric, Gas, and Sanitary Services
Wholesale Trade
Retail Trade
Finance, Insurance, and Real Estate
Services
Public Administration

The analysis used the manufacturing and service categories to answer the research question and the associated hypotheses. There were only three categories of responses that were not strictly manufacturing or services. Agriculture and construction were grouped with manufacturing. Transportation, communications, electric, gas, and sanitary services was grouped with services.

Also included in the survey were self-reported levels of knowledge of blockchain. These criteria were selected to help check the initial assumptions.

The analysis for the second research question applied t-test to analyze the differences. Organization size was divided into two categories (those less than 500 employees and those with 500 employees and above). Having just two categories, this part of the research question used the t-test.

Hypotheses two and three (of research question 2) are stated as:

$H_0$2: There is no significant difference on the critical success factors between low and high revenues for implementing blockchain in the supply chain.

H_a2: There is a significant difference on the critical success factors between low and high revenues for implementing blockchain in the supply chain.

$H_0$3: There is no significant difference on the critical success factors between manufacturing and service industry for implementing blockchain in the supply chain.

H_a3: There is a significant difference on the critical success factors between manufacturing and service industry for implementing blockchain in the supply chain.

Revenue was distinguished using four categories (less than 50M, 50M-250M, 205M-1B, >1B), and type of industry was divided into ten categories (Agriculture, Mining, Construction, Manufacturing, Transportation, Communications Electric Gas and Sanitary Services, Wholesale Trade, Retail Trade, Finance Insurance and Real Estate, Services, Public Administration). Despite these divisions as stated on the survey instrument, the analysis remained a t-test in keeping with the hypotheses.

This is an exploratory situation; the outcome of this research is to be used for implementation of blockchain in the supply chain in real world situations. For this reason, an $\alpha = 0.05$ was selected.

ASCM anticipates ~2,000 people from more than 50 countries to attend their conference annually (APICS, 2018). The 2020 ASCM national conference was conducted differently than previous years because of the COVID-19 pandemic. ASCM offered an in person and a virtual conference option for potential attendees with travel restrictions. For this reason, the online questionnaire was posted in conference chat rooms, sent via conference message to attendees that had agreed to share their contact information, and posted in a Linked ASCM group. A non-probability snowball sampling method was used by sending the survey to supply chain professionals and asking that they forward the survey link to others supply chain professionals as well as posting it as described.

Survey response rates are generally around 30% (Hayden, 2017). Response rates being unpredictable, there were other methods used to try to ensure a large enough return rate. The survey instrument was distributed on the ASCM LinkedIn page to bolster the number of respondents.

A National Institutes of Health (NIH) study found that responses were twice as high when monetary incentives were offered (Edwards, Roberts, Clarke, DiGuiseppi, Pratap, Wentz, & Kwan, 2002). Monetary incentives could not be offered for a potential of 2000+ surveys distributed (budgetary consideration), so a drawing for a $50.00 monetary incentive was offered.

Validity and Reliability

There are three ways to check validity of an instrument. Content validity, criterion validity, and construct validity. The most appropriate evaluation of the survey instrument for this study is content validity. Content validity is defined as, “the extent to which an instrument covers the whole concept” (Van Saane, Sluiter, Verbeek, & Frings-Dresen, 2003). An exert panel was used to evaluate if the survey instrument was valid, readable, understandable, and covers the entire concept. This review panel consisted of an expert in each of information technology, blockchain, and supply chain.

Mohajan (2017) identifies four methods of assessing the reliability of a survey instrument: 1) test-retest reliability, 2) parallel-forms reliability, 3) inter-rater reliability, and 4) split-half reliability. This questionnaire was evaluated by using the test-retest method.

Test-retest method of assessing reliability is conducted by administering the survey instrument to the same group of people more than once (at least twice). The two (or more) scores can then be correlated to assess the errors of measurement (Mohajan, 2017). Mohajan (2017) cautions that the interval between tests should be minimized to not allow for external changes which could affect the reliability measure. This survey instrument used the test-retest method administered to the local chapter of ASCM. The chapter normally would meet monthly and the test was to be administered in successive months. Due to the COVID-19 restrictions, the local ASCM chapter was not conducting scheduled meetings at the time of this research. The test-retest of the survey instrument was conducted with two consecutive rounds of e-mail requests.

Table 2 below shows the reliability coefficient for each critical success factor calculated from the test-retest conducted. Coefficients vary between 0 and 1 with a correlation above 0.7 generally accepted as a good value.

Table 2

Test-retest by Critical Success Factor

Critical Success Factor	Reliability Coefficient
Perceived Benefits	.929
Complexity	.958
Compatibility	.929
Data Security	.919
Smart Contract Coding	.968
Maturity	.929
Relative Advantage	.978
Disintermediation	.978
Permissions (public vs private)	.928
Architecture	.984
Organizational /Value Chain Readiness	.987
Top Management Support	.927
Organizational Size	.958
Business Model Readiness	.958
Technology Readiness	.978
Innovativeness	.908
Participation Incentives	.928
Blockchain Knowledge	.918
Regulatory environment /Regulation	.958
Market Dynamics /Competitive Pressure	.918
Industry Pressure /Standards	.968
Government Support	.989
Business Use Cases	.926
Trading Partner Support	.965
Critical User Mass	.947

Each of the scores rated above 0.9 and therefore the survey instrument was considered reliable. When a post-hoc reliability analysis was performed, the Cronbach's Alpha for the technological factors was 0.9677, organizational factors was 0.8984 and environmental factors was 0.8059. When all factors were considered together the Cronbach's Alpha was 0.9472. A Cronbach's Alpha is a single number that indicates how well items measure a characteristic. A score of 0.00 indicates no relationship and thus no reliability, while a 1.00 is a perfect relationship and perfect reliability. Generally values above 0.7 are considered acceptable (Griffith, 2015).

Chapter Summary

The intent of this study was to determine a model for implementation of blockchain in the supply chain for product traceability and to further determine if organization sizes, revenue, or type of industry have an impact on critical success factors for implementation. This study analyzed the critical success factors as presented by Clohessy (2019). This study gathered data with a survey instrument administered supply chain professionals (members of ASCM).

The design of this research is a quantitative non-probabilistic study. Two different types of analyses were needed to complete the study. Stepwise regression was used to generate a model and t-tests were used for comparisons of organizational size, revenue, and type of industry on each critical success factor.

An expert panel was used to develop the full questionnaire and to check validity. Reliability was confirmed using the test-retest method administered to local ASCM members and a post-hoc Cronbach's Alpha was performed. In all cases the results were acceptable.

FINDINGS AND ANALYSIS

Overview

This chapter presents the results of the data collected from the survey instrument used to collect data from supply chain professionals. The problem for this study was that it was not known which factors have the greatest influence on implementation of blockchain in the supply chain, and whether organization size, revenue, or type of industry have an impact on which critical success factors are considered most important for implementing blockchain in the supply chain.

The chapter is organized into four parts. First there is a discussion of survey response data. The second part presents survey responses to answer research question 1 – which factors most influence the implementation of blockchain in the supply chain for product traceability. The third part presents comparisons of organization size, revenue, and type of industry, by critical success factor, in order to answer research question 2 – does organization size, revenue, or type of industry have an impact on which critical success factors are considered most important for implementing blockchain in the supply chain. The fourth part provides additional information gathered from the survey such as other factors recommended for consideration by participants, and reported issues experienced during implementation by survey respondents.

Survey response data

The 2020 ASCM national conference was conducted differently than in previous years because of the COVID-19 pandemic. Both in-person, and a virtual conference option was offered. For this reason, the data was gathered by posting a link to the survey instrument in conference chat rooms, sent via conference message to attendees that had agreed to share their contact information, and posted in a Linked ASCM group during the calendar month of September 2020.

There were 88 survey responses. Two responses were completely blank. Of the remaining 86 there were two that stated they do not consent to participate and were thus blank as well. Of the remaining 84, there were 25 that completed only the parts about company size, industry, etc., but did not rate the relative importance of any critical success factors in the survey. There were three participants that rated some of the critical success factors, but not all of them. Their data were included where possible. This leaves 56 participants that completed the full study. Of the 56 that completed the full study, one participant rated every critical success factor at a 10. This does not provide for any analysis of relative importance and, thus, these data were removed from the analysis. For the purposes of this discussion only the 55 respondents are considered (sometimes 58 for the partial respondents).

Survey participants were asked some qualifying questions beyond ranking of the critical success factors. Participants were asked what type of position they hold. The options were Buyer level, with some decision-making authority, Manager level, with decision making authority, and Upper Management, with strategic level decision authority. There were 17, 24, and 17 respondents by category, respectively.

Participants were also asked if they were familiar with blockchain. This was a categorical yes or no question with 42 respondents stating yes, they were familiar with blockchain and 16 stating no, they were not familiar with blockchain

Another categorical question asked of survey participants is if their company has product traceability requirements for their suppliers. Forty respondents stated yes, they have product traceability requirements for their suppliers. Eighteen respondents stated no, they do not have product traceability requirements for their suppliers.

There were two questions that were dependent up on an initial question. The first question was if their company has adopted blockchain. There were 49 respondents that stated their company had not implemented blockchain, and 9 stating their company had adopted blockchain. The 49 respondents who had not adopted blockchain were asked if their company was considering adopting blockchain. The result was that 19 of the 49 respondents stated their company was considering adopting blockchain, leaving 30 who stated their company was not considering adopting blockchain. The 9 respondents who stated their company had adopted blockchain were asked if the blockchain implementation was successful. Seven respondents stated the implementation was successful, and two respondents stated the implementation was unsuccessful. Of the two that responded that the implementation was not successful, one was in a manufacturing industry and one was in a service industry.

Research Question 1

The survey instrument asked the respondents to rank to what extent the critical success factors influence implementation of blockchain in the supply chain. They were asked to rate how much the listed factor will influence the implementation of blockchain in the supply chain. A rating of 1 is no influence on implementation and a rating of 10 is extremely high influence on implementation. These rankings were averaged across all responses and the following bar chart was created.

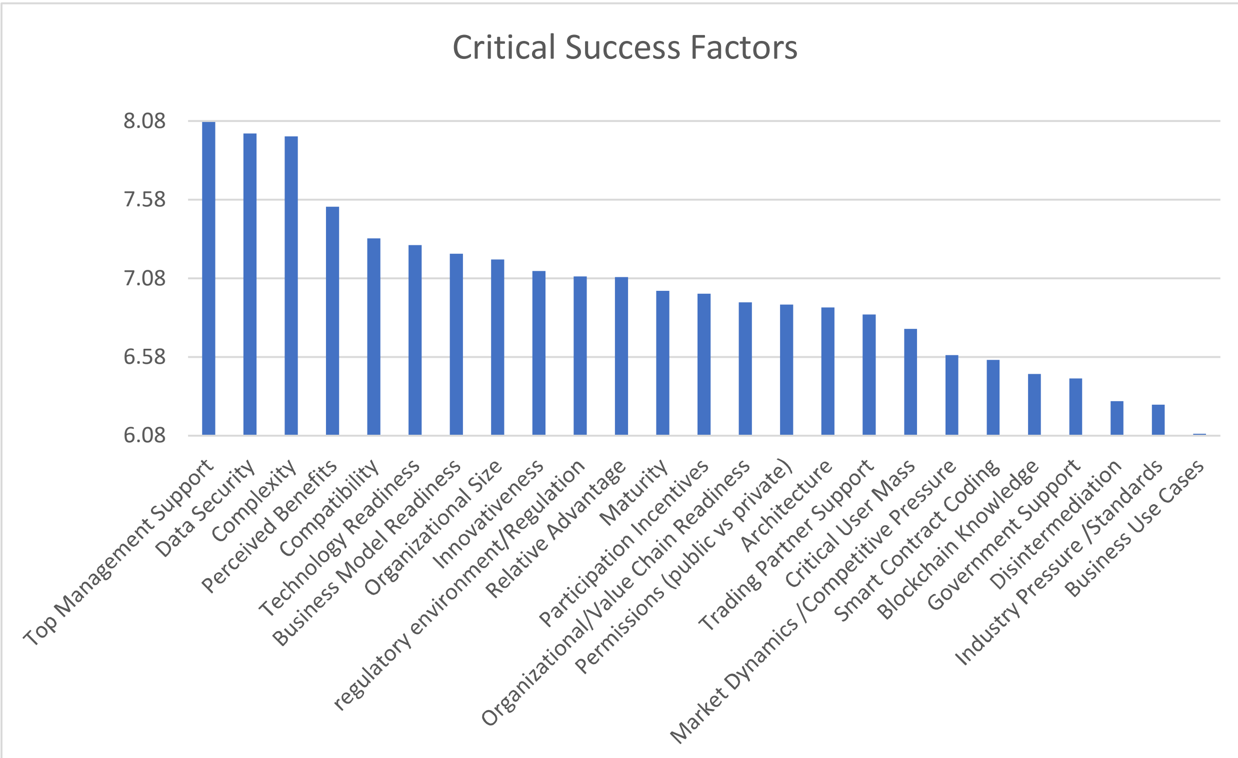

Figure 3. *Bar Chart of Critical Success Factor Rankings*

Top management support, data security, and complexity (how complicated blockchain will be to implement) became the top three factors with average rankings of 8.07, 8.00, and 7.98 respectively. It is worth noting that there are large drops in relative rankings after complexity and again after perceived benefits. A relatively even drop in rankings begins again at compatibility, then continues until it gets to Market Dynamics/Competitive Pressures which has the third largest drop. With only a 1.98 difference between the average ranking of the top critical success factor and the lowest average ranked critical success factor, a drop of 0.446 from complexity to perceived benefits and another drop of 0.202 to compatibility represents 22.5% and 10.2% of the total difference. Roughly one-third of the difference.

Research question 1 asked which factors most influence the implementation of blockchain in the supply chain for product traceability. Simplistically this can be answered by the bar chart shown in figure 3. A more complete answer includes evaluating a relationship that might exist between the identified critical success factors and using those relationships to design a model for the successful implementation of blockchain in the supply chain as it relates to product traceability. The key term is "successful implementation".

For this portion of the analysis only the respondents who had implemented blockchain were considered. Also for this portion of the analysis, only the implementation factors were considered. The successful implementations and the unsuccessful implementations were compared using stepwise regression to generate a model. Stepwise regression enters and removes predictors, in a stepwise manner, until there is no more to enter or remove. The regression model for implementing blockchain in the supply chain is written as:

Success = 0.286 + 0.1512 Permissions + 0.0745 Organizational Size + 0.1589 Blockchain Knowledge.

It is interesting to note that in the simple bar chart, the top 3 factors are Top Management Support, Data Security, and Complexity, while in the model none of these factors are represented.

Research Question 2

In addition to ranking the critical success factors by relative importance, the survey instrument also asked respondents to provide their organization size (in terms of the number of employees), the revenue of their organization, and what type of industry they were in. Research question 2 asked if organization size, revenue, or type of industry has an impact on which critical success factors are considered most important for implementing blockchain in the supply chain. There were three research hypotheses associated with research question 2.

$H_0 1$: There is <u>no</u> significant difference on the critical success factors between small and large organizations for implementing blockchain in the supply chain.

$H_a 1$: There is a significant difference on the critical success factors between small and large organizations for implementing blockchain in the supply chain.

$H_0 2$: There is <u>no</u> significant difference on the critical success factors between low and high revenues for implementing blockchain in the supply chain.

$H_a 2$: There is a significant difference on the critical success factors between low and high revenues for implementing blockchain in the supply chain.

$H_0 3$: There is <u>no</u> significant difference on the critical success factors between manufacturing and service industry for implementing blockchain in the supply chain.

$H_a 3$: There is a significant difference between the critical success factors between manufacturing and service industry for implementing blockchain in the supply chain.

To answer these hypotheses, the data were organized by organizations size, organization revenue, and industry and then t-tests were conducted for each critical success factor.

The first division of the data was by size. There were 27 survey respondents who reported that their company had less than 500 employees and 31 respondents reporting that their company had more than 500 employees. 47% and 53 % respectively.

Based on the a priori $\alpha = 0.05$, there are two critical success factors that have a statistically significant difference. Trading Partner Support, with a p value of 0.036, shows a clear difference in responses from Small to Medium Enterprises (SME) as compared to large organizations (SMEs are defined as those with 500 or fewer employees and large organizations are defined as those with more than 500 employees). Participation Incentives is also statistically significant with a p value of 0.05. Each t-test with t values, degrees of freedom, p values and the decisions are shown in appendix F. A summary of the t values and significance levels for organizational size is shown in table 3.

The null hypothesis for organizational size is that there is <u>no</u> significant difference between the critical success factors between small and large organizations for implementing blockchain in the supply chain. With two critical success factors having a statistically significant differences between small and large organizations, this study rejects the null hypothesis at the .05 significance level for those two factors. There is a significant difference between the critical success factors among small and large organizations for implementing blockchain in the supply chain. The means of the critical success factors are not the same between small and large organizations. This can be interpreted that the organization size may affect the level of influence of critical success factors.

Table 3

Organizational Size t-tests

Organizational Size		
	t	Sig
Perceived Benefits	-.104	.917
Complexity	-.577	.566
Compatibility	-.309	.758
Data Security	-1.574	.121
Smart Contract Coding	-.246	.806
Maturity	-.186	.853
Relative Advantage	-1.762	.084
Disintermediation	-1.619	.111
Permissions (public vs private)	-.377	.707
Architecture	-.597	.553
Organizational /Value Chain Readiness	-1.038	.304
Top Management Support	-1.441	.155
Organizational Size	-1.370	.176
Business Model Readiness	-.751	.456
Technology Readiness	-.530	.599
Innovativeness	.084	.934
Participation Incentives	**-2.002**	**.050**
Blockchain Knowledge	-1.024	.310
Regulatory environment /Regulation	.705	.484
Market Dynamics /Competitive Pressure	-.872	.387
Industry Pressure /Standards	-.770	.445
Government Support	1.170	.247
Business Use Cases	-.271	.787
Trading Partner Support	**-2.147**	**.036**
Critical User Mass	-.380	.705

The next division of the data was by revenue. There were 24 survey respondents who reported that their company had less than \$250 Million in revenue 34 respondents reporting that their company had more than \$250 Million in revenue. 41% and 59 % respectively.

Based on the $\alpha = 0.05$, there are no critical success factors that have a statistically significant difference. Each t-test with t values, degrees of freedom, p values and the decisions are shown in appendix F. A summary of the t values and significance levels for revenue is shown in table 4.

The null hypothesis for organizational revenue is that there is no significant difference between the critical success factors between low and high revenues for implementing blockchain in the supply chain. With no critical success factors having a statistically significant difference between low and high revenues, this study fails to reject the null hypothesis at the .05 significance level for those two factors. This can be interpreted that the organization revenue does not affect the level of influence of critical success factors.

It is worth noting that a Levene's test found that the assumption of homogeneity of variance was not met, $p = .040$ for smart contract coding.

Table 4

Organizational Revenue t-tests

	Organizational Revenue	
	t	Sig
Perceived Benefits	-.011	.991
Complexity	.078	.938
Compatibility	.077	.939
Data Security	1.886	.065
Smart Contract Coding	-.202	.841
Maturity	-.547	.587
Relative Advantage	.669	.506
Disintermediation	.259	.797
Permissions (public vs private)	.163	.871
Architecture	1.303	.198
Organizational /Value Chain Readiness	1.198	.236
Top Management Support	1.030	.308
Organizational Size	1.150	.255
Business Model Readiness	-.193	.848
Technology Readiness	-.026	.979
Innovativeness	-1.192	.239
Participation Incentives	.928	.357
Blockchain Knowledge	.553	.582
Regulatory environment /Regulation	-.582	.563
Market Dynamics /Competitive Pressure	1.021	.312
Industry Pressure /Standards	.651	.518
Government Support	-.572	.569
Business Use Cases	-.333	.741
Trading Partner Support	1.983	.053
Critical User Mass	-.326	.745

The final division of the data was by industry. There were 21 survey respondents who reported that their industry was service-related, and 37 respondents reported that their industry was manufacturing. 36% and 64% respectively.

Based on the a priori $\alpha = 0.05$, there is one critical success factor that has a statistically significant difference. Organizational/Value Chain Readiness, with a p value of 0.014, shows a clear difference in responses from manufacturing and service. Each t-test with t values, degrees of freedom, p values and the decisions are shown in appendix F. A summary of the t values and significance levels for industry is shown in table 5.

The null hypothesis for industry is that there is no significant difference between the critical success factors between manufacturing and service industry for implementing blockchain in the supply chain. With one critical success factor having a statistically significant difference between manufacturing and service industry, this study rejects the null hypothesis at the .05 significance level for those two factors. There is a significant difference between the critical success factors among industries for implementing blockchain in the supply chain. The means of the critical success factors are not the same between industries. This can be interpreted that type of industry affects the level of influence of critical success factors.

It is worth noting that a Levene test found that the assumption of homogeneity of variance was not met, p = .011 for regulatory environment/regulation.

Table 5

Industry t-tests

	Industry	
	t	Sig
Perceived Benefits	.667	.508
Complexity	.709	.482
Compatibility	.963	.340
Data Security	1.359	.180
Smart Contract Coding	.395	.694
Maturity	.491	.625
Relative Advantage	.742	.462
Disintermediation	-.916	.364
Permissions (public vs private)	-.506	.615
Architecture	-.176	.861
Organizational /Value Chain Readiness	**2.543**	**.014**
Top Management Support	1.630	.109
Organizational Size	.481	.633
Business Model Readiness	.224	.823
Technology Readiness	-.050	.961
Innovativeness	.203	.840
Participation Incentives	1.250	.217
Blockchain Knowledge	-.143	.886
Regulatory environment /Regulation	-1.543	.129
Market Dynamics /Competitive Pressure	.281	.780
Industry Pressure /Standards	-.034	.973
Government Support	-1.325	.191
Business Use Cases	-.732	.468
Trading Partner Support	-.979	.332
Critical User Mass	-1.431	.159

Additional Survey Data

Along with the survey questions already discussed, there were three short-answer questions for the respondents.

1) Are there any other factors for implementing blockchain in the supply chain that were not covered? Please list them.
2) Are there any problems or issues you have experienced in implementing blockchain in your organization or in the supply chain? Please describe them here.
3) Feel free to add any comments/suggestions.

The first question was asking for any additional factors not covered in the survey instrument. One item that was mentioned more than once is tariffs and laws. One respondent stated, “different country/laws/regulations [sic] involved for Global companies”. As discussed earlier, the Regulatory Environment/Regulation factors are the biggest unknown right now as it relates to blockchain (Iansiti, & Lakhani, 2017). The danger here, for blockchain, is that since it is not a mature technology, regulations are not settled for this technology (Crosby, Pattanayak, Verma, & Kalyanaraman, 2016). This creates an unsure regulatory environment for the technology. This is confounded for multi-national companies who face not only an uncertain regulatory environment domestically, but also internationally with potentially conflicting or disparate requirements.

The second question was asking what problems have been experienced in the implementation of blockchain. One respondent stated it this way, “limited awareness within senior management”. Other respondents cited culture or a specific department (IT). While organizational culture is a broad discussion and outside of the scope of this study, top management support is discussed as a factor defined by Clohessy (2019) as a key factor. Top management support is managerial participation and advocacy of blockchain in the supply chain (Clohessy, 2019).

The last open-ended question was an invitation to add any comments or suggestions. Beyond flattery for a useful survey, a few comments stand out in this category. One notable comment is another mention of needing top management support. This was included as a factor in the survey as mentioned above and ranked highest (on average) among all the survey responses. The other stand out comment is about public knowledge of blockchain stating, “Block chains [sic] still not familiar with the middle-class people like credit card. Once it reaches middles [sic] class its hype will be in a different range. It takes [sic] hardly 5 to10 years”. The respondent could be referencing the critical user mass factor based on the 5-to-10-year timeframe cited.

This additional information was gathered from the survey to see if any critical areas were not included and to provide areas of further research. A full list of all responses to these questions are given in Appendix D.

Summary of Findings

The survey had 88 respondents but only 58 that had useable data provided about the critical success factors. There were 9 respondents who had implemented blockchain. All 58 respondents were used to answer research question 2 while the smaller set of 9 respondents, who had implemented blockchain, were used to build the model for research question 1.

Research question 1 did not have a hypothesis. A regression model was created to correlate the critical success factors to successful implementation.

Research question 2 had three hypotheses associated with the question.

The first null hypothesis was rejected. There is a significant difference on the critical success factors between small and large organizations for implementing blockchain in the supply chain.

The second null hypothesis was not rejected. There is no significant difference on the critical success factors between low and high revenues for implementing blockchain in the supply chain.

The third null hypothesis was rejected. There is a significant difference on the critical success factors between manufacturing and service industry for implementing blockchain in the supply chain.

Chapter five gives the summary, conclusions (and discussion of the findings of this study) and recommendations for future research.

SUMMARY, CONCLUSIONS AND DISCUSSION

This chapter provides the summary, conclusions, and recommendations as the three major sections. The first section is a summary and includes a restatement of the problem, restatement of the research questions, and summary of data analysis. The second section discusses the conclusions of this study and provides some discussion. The third section gives recommendations for those wanting to implement blockchain in the supply chain for product traceability, and recommendations for further research.

Summary

Investment is ongoing as companies work to develop blockchain technology. One of the main goals of the technology is disintermediation. By removing the banks and brokers from the payment process in the supply chain, transactional costs can be eliminated. By eliminating the supply chain transactional costs, the benefits can be monetarily beneficial. Use cases of blockchain are being explored. One of the identified advantages of blockchain beyond disintermediation is to incorporate traceability. This immutable database of provenance makes traceability a natural fit with blockchain technology.

Companies want to be successful when implementing a technology. Clohessy (2019) identified critical success factors for the implementation of blockchain. Since there are 25 Clohessy identified critical success factors, the next question for companies is which are the most important? Does company size or revenue effect which factors are most important? What about industry. Are the critical success factors that are most important different for different industries?

The purpose of this study had two parts to help answer these questions. The first purpose was to evaluate a relationship that might exist between the identified critical success factors and use those relationships to design a model for the successful implementation of blockchain in the supply chain as it relates to product traceability. The second purpose of the research was to determine if organization size, revenues, or type of industry have an impact on the ranking of critical success factors.

The purpose of the research led directly to the research questions. Research question 1: What factors most influence the implementation of blockchain in the supply chain for product traceability? Research question 2: Does organization size, revenue, or type of industry have an impact on which critical success factors are considered most important for implementing blockchain in the supply chain?

Research question 1 did not have any hypotheses. To answer research question 2, the following research hypotheses are set up:

$H_0 1$: There is no significant difference on the critical success factors between small and large organizations for implementing blockchain in the supply chain.

$H_a 1$: There is a significant difference on the critical success factors between small and large organizations for implementing blockchain in the supply chain.

$H_0 2$: There is no significant difference on the critical success factors between low and high revenues for implementing blockchain in the supply chain.

H_a2: There is a significant difference on the critical success factors between low and high revenues for implementing blockchain in the supply chain.

H_03: There is no significant difference on the critical success factors between manufacturing and service industry for implementing blockchain in the supply chain.

H_a3: There is a significant difference on the critical success factors between manufacturing and service industry for implementing blockchain in the supply chain.

The methodology used to answer these questions was a quantitative non-probabilistic study using a convenience sample of supply chain professionals. A non-probability convenience sample was taken of ASCM members.

The analysis for research question 1 was correlational using stepwise regression. The analysis for research question 2 was causal comparative using t-tests.

The survey instrument was divided into two sections. Section one included eight multiple choice or yes/no questions regarding respondent's company demographic data and participants' use of blockchain and traceability systems. Section two contained a 10-point rating system to rate the influence of each critical success factor, as well as three open-ended questions. Section two was divided into three parts. Part one asked for rating the relative importance of technological factors. Part two asked for rating the relative importance of organizational factors. Part three asked for rating the relative importance of environmental factors. The ratings were on a 1 to 10 scale with 1 being no influence on implementation and 10 being extremely high influence on implementation.

The survey was developed with the help of an expert panel which also confirmed validity after it was fully developed. The panel of experts were from the fields of information technology, blockchain, and supply chain. Reliability was confirmed using the test-retest method with the help of the local ASCM chapter.

After IRB approval (shown in Appendix E), the survey was administered to ASCM members. Originally it was the researcher's intention to administer the survey during the 2020 ASCM national conference. Due to COVID-19 restrictions ASCM conducted the conference with an in person and a virtual conference option. For this reason, the data was gathered by posting a link to the survey instrument in conference chat rooms, sent via conference message to attendees that had agreed to share their contact information, and posted in a LinkedIn ASCM group during the calendar month of September 2020.

There were 88 survey responses. After removing those that did not rate any critical success factors there were 56 participants that completed the full study and 3 others that completed parts of the survey.

The data were gathered using Qualtrics software online and exported to an excel spreadsheet. Once the responses that contained no critical success factor ratings were removed, the data were entered into Minitab for analysis. Since this was an exploratory situation, a .05 significance level was selected.

Conclusions and Discussion

To evaluate a technology from the initial innovation to full acceptance the Gartner Hype Cycle proves useful. It is a graphic representation of technologies life cycle from inception to maturity. On the X axis is time and on the Y axis is expectations of the technology. Depending where a technology is in maturity, the amount of expectation over time raises and lowers creating a wave form graph. According to Gartner Research, different parts of blockchain technologies are at different places along the graph. What Gartner terms "authenticated provenance" can also be termed product traceability. Gartner places authenticated provenance as being on the rise in 2020 in terms of expectations of the technology (Litan, and Leow, 2020).

As technologies continue to mature the Gartner cycle predicts a “trough of disillusionment” as implementations fail. It is the intent of this research to lessen the number of failures by providing a better understanding of what factors most influence the implementation of blockchain in the supply chain.

Research Question 1

To answer research question 1, the 25 critical success factors had to first be divided into implementation factors and decision factors. The implementation factors are what were considered in developing the model for implementation. The findings for research question 1 indicate that of the eight implementation factors, only three are needed to model successful implementation. A multiple linear regression was calculated to predict successful implementation of blockchain (the dependent variable) based upon the independent variables of the implementation factors ((blockchain knowledge, organizational size, permissions (public vs private), architecture, smart contract coding, business use cases, top management support, and industry pressure/standards)). A significant regression equation was found ($F(3,5) = 47.29$, $P<.000$), with an R^2 of .966. Participants’ predicted successful implementation of blockchain is equal to 0.286 + 0.1512 Permissions + 0.0745 Organizational size + 0.1589 Blockchain knowledge, where permissions, organizational size, and blockchain knowledge is measured as a 1 to 10 ranking. Permissions, organizational size, and blockchain knowledge were significant predictors of successful implementation.

The R^2 value predicts 96.6% of the variability of its response data around its mean. This is not to say that the factors not included in the model are not important to implementation. It is to say that these 3 best represent the regression line.

Figure 4 (below) shows the bar chart presented earlier with the critical success factors determined in the model highlighted in red. One thing to note about the factors represented in the model is that they do not include the highest ranked factor.

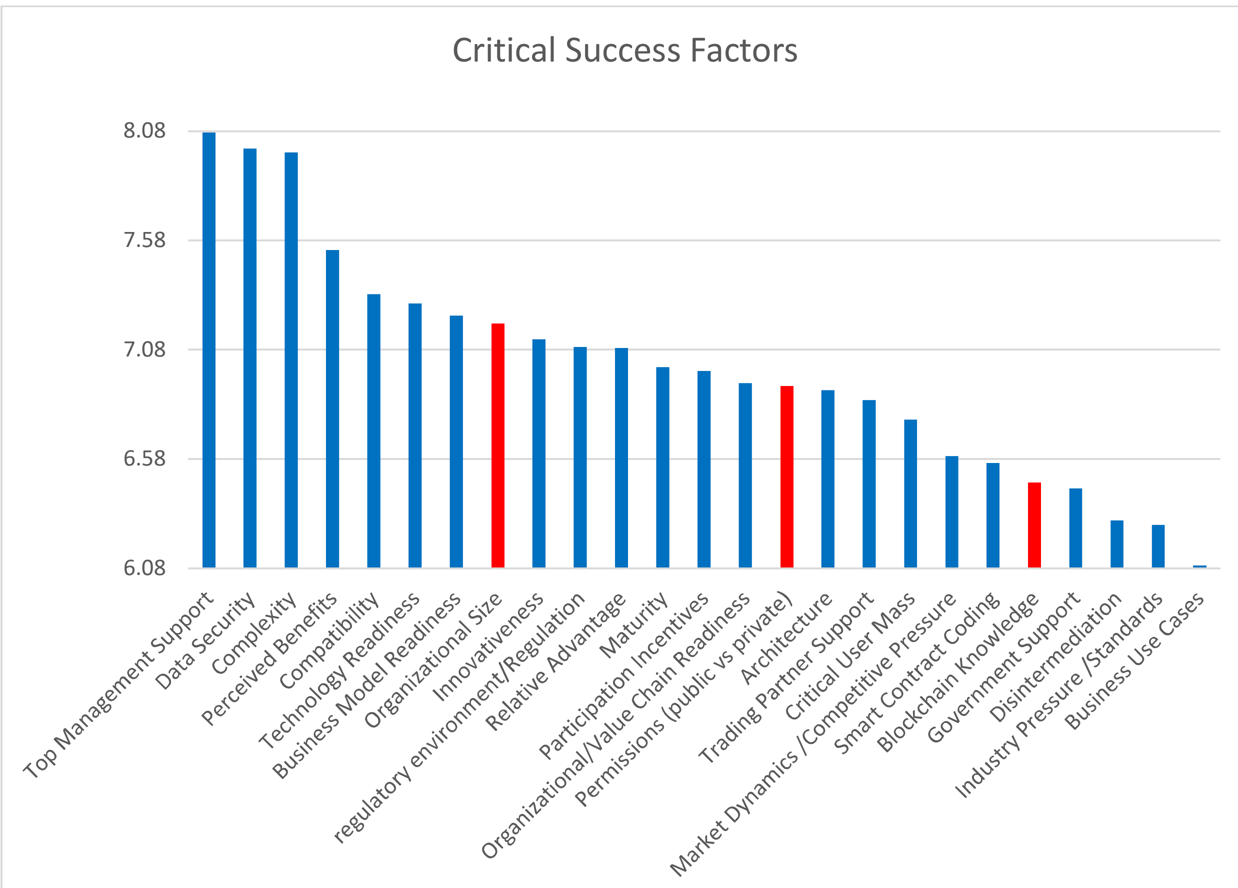

Figure 4. *Highlighted Bar Chart of Critical Success Factor Rankings*

Another area of note when looking at the model is that technological and organizational factors are represented (bolded) but environmental factors are not.

- Technological
    - Perceived Benefits
    - Complexity
    - Compatibility
    - Data Security
    - Smart Contract Coding
    - Maturity
    - Relative Advantage
    - Disintermediation
    - **Permissions (public vs private)**
    - Architecture
- Organizational
    - Organizational/Value Chain Readiness
    - Top Management Support
    - **Organizational Size**
    - Business Model Readiness
    - Technology Readiness
    - Innovativeness
    - Participation Incentives
    - **Blockchain Knowledge**
- Environmental
    - Regulatory Environment/Regulation
    - Market Dynamics/Competitive Pressure
    - Industry Pressure/Standards
    - Government Support
    - Business Use Cases
    - Trading Partner Support
    - Critical User Mass

Figure 5, 6, and 7 show a bar chart of the technological, organizational, and environmental factors (respectively) by ranking. All three figures use the same scale for comparison. Note that the environmental factors have only one factor above 7 while the technological and environmental factors have at least half of the factors above 7 (50% for technological, and 62.5% for organizational).

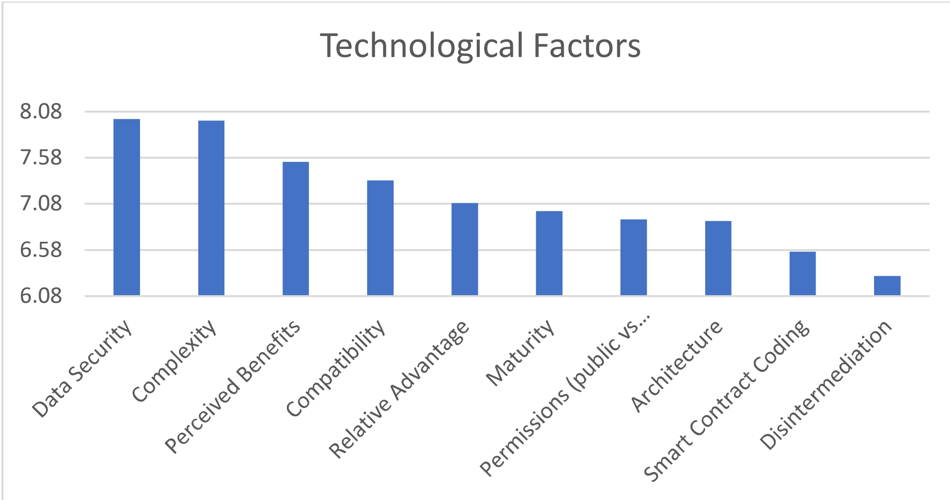

Figure 5. *Bar Chart of Technological Factors*

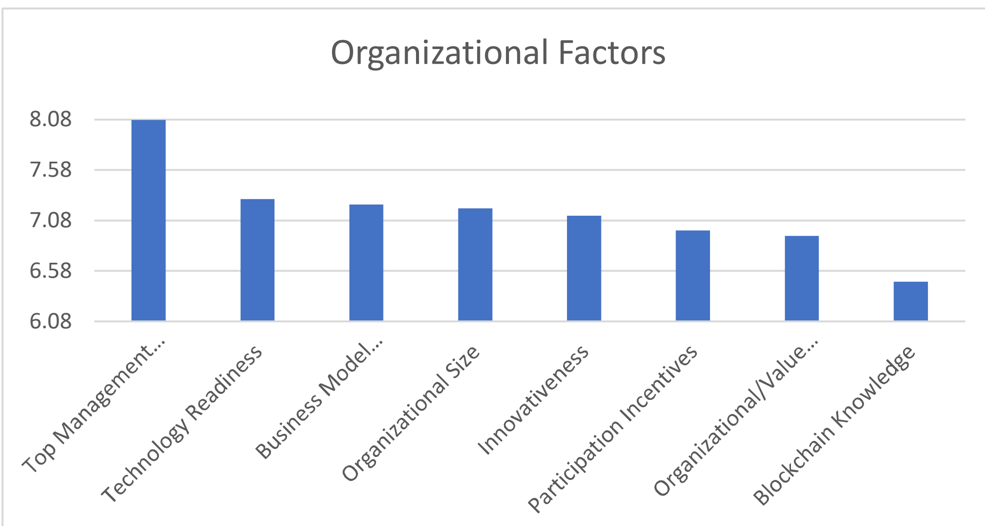

Figure 6. *Bar Chart of Organizational Factors*

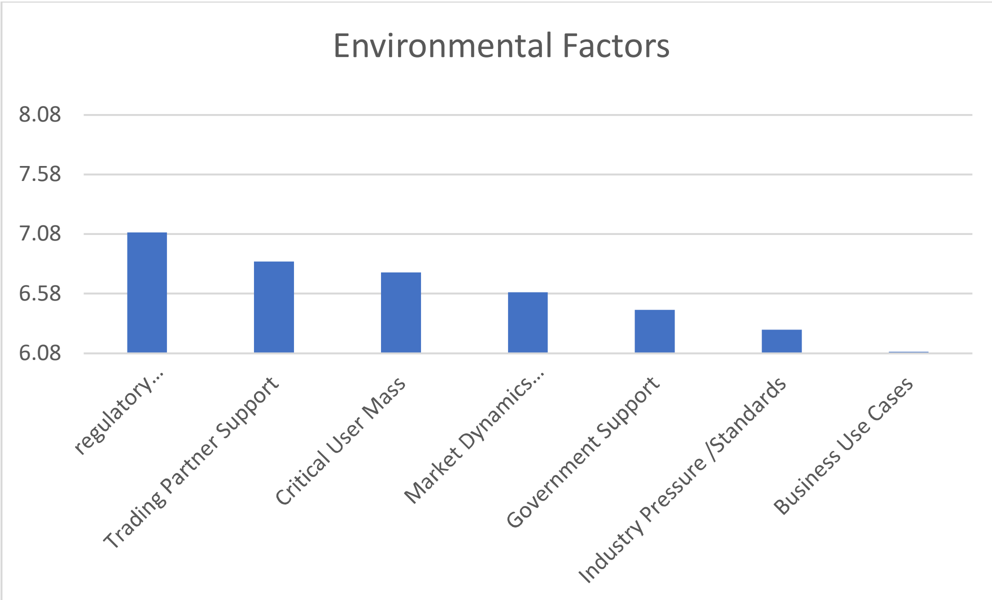

Figure 7. *Bar Chart of Environmental Factors*

When a bar chart of the average rankings of the critical success factors is created using only those respondents who have implemented blockchain, the results differ from that of all respondents. Consistent from all respondents to implemented respondents is top management support. Figure 8 is the bar chart of the average rankings of the critical success factors is created using only those respondents who have implemented blockchain. Table 6 is a side-by-side comparison of all respondents' average rankings with those who have implemented blockchain average rankings.

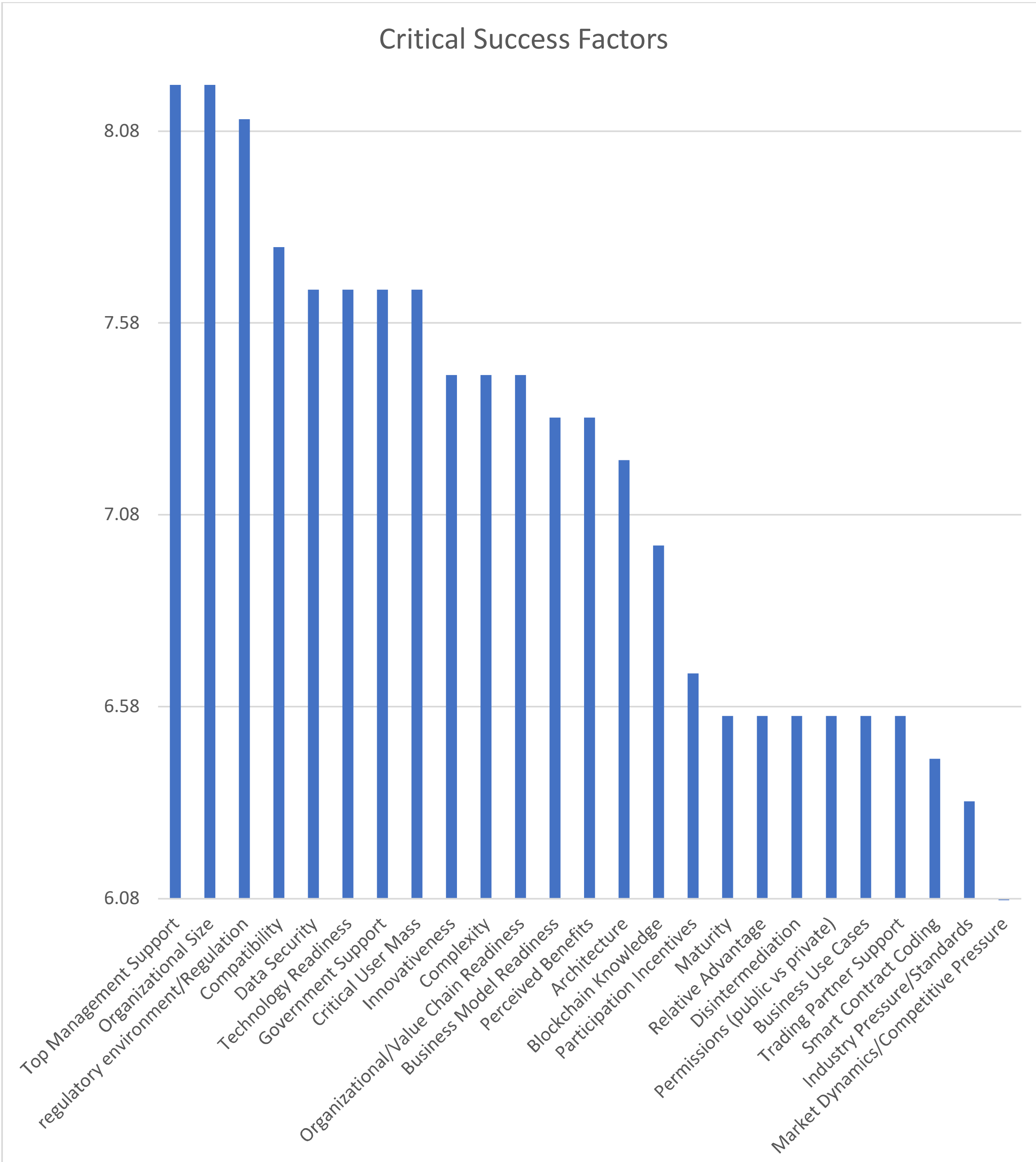

Figure 8. *Bar chart of rankings by respondents who have implemented blockchain*

Table 6

Critical Success Factor Rankings

Critical Success Factor	All Respondents Ranking	Implemented Respondents Ranking
Perceived Benefits	4	13
Complexity	3	10
Compatibility	5	4
Data Security	2	5
Smart Contract Coding	20	23
Maturity	12	17
Relative Advantage	11	18
Disintermediation	23	19
Permissions (public vs private)	15	20
Architecture	16	14
Organizational /Value Chain Readiness	14	11
Top Management Support	1	1
Organizational Size	8	2
Business Model Readiness	7	12
Technology Readiness	6	6
Innovativeness	9	9
Participation Incentives	13	16
Blockchain Knowledge	21	15
Regulatory environment /Regulation	10	3
Market Dynamics /Competitive Pressure	19	25
Industry Pressure /Standards	24	24
Government Support	22	7
Business Use Cases	25	21
Trading Partner Support	17	22
Critical User Mass	18	8

To represent the mathematical model in a visual way, only the implementation factors are presented. The implementation factors are those that help determine how well blockchain is implemented. The factors that help determine how well blockchain is implemented include architecture, permissions (public vs private), industry pressure/standards, top management support, blockchain knowledge, organizational size, smart contract coding, and business use cases.

When viewed this way, a visual representation of the model becomes apparent. Figure 9 represents the visual model.

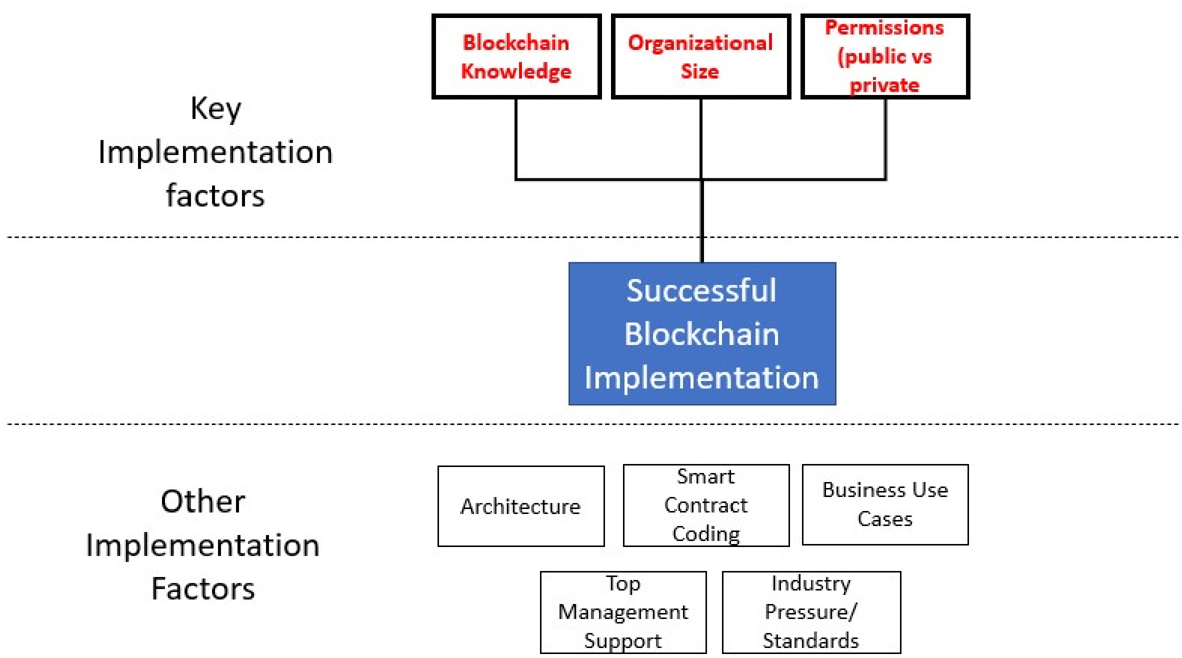

Figure 9. *Model of Factors Influence on Implementing Blockchain*

Blockchain knowledge, organizational size and permissions (public vs private) are the factors that predict successful implementation of blockchain. The other five factors in the model (Top management support, industry pressure/standards, architecture, smart contract coding, and business use cases) are implementation factors to be considered as well.

Blockchain Knowledge is how well do the people in the organization know blockchain. This may initiate hiring of additional resources or require training. Organizational Size relates to if companies' large organizational size gives them the necessary IT budgets and resources to implement blockchain, or if their small organizational size gives them the flexibility to implement blockchain. Permissions (public vs private) is less a consideration of architecture than a consideration of identity. In a public blockchain the nodes existing on the chain are anonymous. In a private blockchain, all of the nodes represent identifiable members (Pilkington, 2016). In this instance it would be members of the supply chain. As many companies often buy from competitors, these kinds of privacy matters come into consideration.

Research Question 2

The findings for research question 2 are in three parts. First is organizational size. The null hypothesis was rejected indicating there is a significant difference between small and large organizations for implementing blockchain in the supply chain. Of note here is that of the respondents to this survey, there was not a statistically significant difference for the organizational size factor between large and small companies (organizational size). Small firms (those with 500 or fewer employees) did not rate organizational size significantly different from large organizations (those with more than 500 employees). Keep in mind that organizational size is in the model.

The two factors that did have a statistically significant difference are trading partner support and participation incentives. Neither of these factors are in the regression model. Also of note is that both factors are decision factors. This could be interpreted that even though the null hypothesis was rejected it does not have an effect on the model. This is supported by both not being in the model and not being implementation factors.

The second comparison made was based upon revenue. The researcher failed to reject the null hypothesis for organizational revenue that there is no significant difference between the critical success factors between low and high revenues for implementing blockchain in the supply chain. None of the critical success factors had a statistically significant differences between low revenue (less than $250 Million in revenue) and high revenues (more than $250 Million in revenue).

The final comparison made was based on industry. The null hypothesis was rejected indicating there is a significant difference between manufacturing and service industry.

The one factor that did have a statistically significant difference was organizational/value chain readiness. This factor is not in the regression model. This factor is also a decision factor. This could be interpreted that even though the null hypothesis was rejected it does not have an effect on the model. This is supported by both not being in the model and not being an implementation factor.

By failing to reject the second null hypothesis, the model would apply in organizations of different revenue levels. The implication of rejecting the first and third null hypothesis is whether or not the implementation model still applies in organizations of different size and different industries. On the face of it, the model would not apply to different organizational sizes or different industries. Looking deeper it can be seen that the critical success factors that had a statistically significant difference are those that are not in the model. It is further shown that the critical success factors that had a statistically significant difference are decision factors and not implementation factors. Based on this further examination, the model would still apply to organizations of different sizes and different industries.

Recommendations for Further Study

The results of this research may help in improving the successful implementation of blockchain in the supply chain. While the findings from this research have led to a greater understanding of implementing blockchain in the supply chain, there is a need for further research.

One area for further research is based on a key delimitation of the study. The survey was administered to supply chain professionals. Information technology (IT) and quality professionals were not surveyed for this study. This survey should be administered to these groups of professionals and compared to the results of this study.

As with most research, a larger sample may give a more complete picture. This study should be replicated with a larger sample. With the limited sample of respondents who have implemented blockchain, this research may not be universally applicable. A larger sample would provide a better representation of blockchain implementations and allow for a refined analysis by industry, organization size, and organizational revenue.

This research is valuable. It was built upon previous research and information from supply chain professionals. Information gathered during this study included comments from survey respondents. One of the open-ended questions asked survey respondents to list any additional factors that were not covered. These data were not coded in their responses as it was outside of the research questions posed. However, to aid future research, appendix D gives a full listing of the responses given by the survey respondents. Earlier discussion talked about the distinction between implementation factors and decision factors. Further research should be conducted using the additional implementation factors provided in appendix D as well as the implementation factors evaluated here. A better picture of the critical factors influencing implementation of blockchain in the supply chain can be gained by having additional implementation factors evaluated.

These additional factors should be considered in future research for determining critical success factors for implementing blockchain in the supply chain. Until more research can be completed, supply chain professionals should begin using the 17 decision factors (compatibility, complexity, data security, regulatory environment/regulation, participation incentives, maturity, business model readiness, critical user mass, technology readiness, government support, perceived benefits, trading partner support, organizational/value chain readiness, innovativeness, disintermediation, relative advantage, and market dynamics/competitive pressure) when deciding to implement blockchain in the supply chain. When implementing blockchain in the supply chain, supply chain professionals should use the eight implementation factors (top management support, blockchain knowledge, organization size, smart contract coding, architecture, permissions (public vs private), industry pressure/standards, and business use cases) as shown in Figure 9.

Traceability data is used in recalls, logistics, quality, security, accounting, and after-sales applications (Töyrylä, 1999). These traceability requirements do not exist within a single company but across the entire supply chain (Caplan, 1989; Abeyratne, & Monfared, 2016; Kim, & Laskowski, 2018; Limón, & Garbajosa, 2005). Blockchain is a technological enabler of traceability systems across a supply chain. This research is based on previous research into traceability and blockchain using information from supply chain professionals to provide insight into how best to implement blockchain in the supply chain. Having a model for implementing blockchain in the supply chain will be of value to both academia and practitioners.

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APPENDIX A: SURVEY INSTRUMENT

INDIANA STATE UNIVERSITY

Technology Management Program, Quality Systems Specialization

Ph.D. Research for Gary Lee

A Model for Blockchain Implementation in the Supply Chain and Product Traceability

Blockchain: Blockchain is considered to be an immutable database – Sometimes it may be referred to as a distributed ledger and can be used to enhance product traceability – there are 25 critical success factors to implementing blockchain that have been identified which are under the scope of this study.

This questionnaire is related to implementing blockchain in your supply chain. Please answer the following questions about your industry and organization size. Also please provide your opinions on the relative importance of the critical success factors listed below. **Your responses will be held in strict confidence. No question asks for your company's name and address.** The questions are in two sections. Section one includes eight multiple choice or yes/no questions regarding your company's demographic data and participants' use of blockchain and traceability systems. Section two contains a 10-point rating system to rate the influence of each critical success factor, as well as some open-ended questions. Please make sure to answer all questions and rate each critical success factor separately to ensure the accuracy of the results. Your participation is greatly appreciated.

Section One: Company demographic data and participants use of blockchain and traceability systems. Select only one answer, please underline, circle, or check on your selected answer.

1. Please indicate which type of industry with which you are associated:

   ☐ Agriculture ☐ Mining ☐ Construction
   ☐ Manufacturing ☐ Wholesale Trade ☐ Retail Trade
   ☐ Services ☐ Public Administration ☐ Finance, Insurance, and Real Estate
   ☐ Transportation, Communications, Electric, Gas, and Sanitary Services

2. Please indicate the number of employees in your organization:

   ☐ 500 or more ☐ Less than 500

3. Please indicate the revenue of your organization in US dollars:

   ☐ <50M   ☐ 50M – 250M   ☐ 250M – 1B   ☐ >1B

4. Which category best describes your position?

   ☐ Buyer level – some decision making   ☐ Manager – decision making
   ☐ Upper Management – strategy decisions

5. Are you familiar with blockchain?

   ☐ Yes   ☐ No
   If yes – What is your familiarity with blockchain

   ____
   ____

6. Do you have product traceability requirements of your suppliers?

   ☐ Yes   ☐ No

7. Has your company adopted blockchain?

   ☐ Yes   ☐ No

8. Is your company considering adopting blockchain?

   ☐ Yes   ☐ No

9. Was the blockchain implementation successful?
   ☐ Yes   ☐ No

<u>Section Two:</u> 10-point rating system to rate the influence of each critical success factor. Select only one answer, please underline, circle, or check on your selected answer.

10. In your opinion, to what extent do the following **technological factors** influence implementation? Please rate how much you think the listed factor will influence the implementation of blockchain in the supply chain. 1 is no influence on implementation and 10 is extremely high influence on implementation.

Perceived Benefits – the degree to which blockchain will enhance performance

1 2 3 4 5 6 7 8 9 10

Complexity – how complicated blockchain will be to implement in your organization

1 2 3 4 5 6 7 8 9 10

Compatibility – technical compatibility with current IT infrastructure

1 2 3 4 5 6 7 8 9 10

Data Security – security of company data in an open network structure

1 2 3 4 5 6 7 8 9 10

Smart Contract Coding – the inclusion of code into the blockchain transaction that automatically executes when conditions are met

1 2 3 4 5 6 7 8 9 10

Maturity – how well developed blockchain is as a technology

1 2 3 4 5 6 7 8 9 10

Relative Advantage – how well blockchain will provide a strategic or position advantage in the market

1 2 3 4 5 6 7 8 9 10

Disintermediation – eliminating transactional intermediaries, such as banks

1 2 3 4 5 6 7 8 9 10

Permissions (public vs private) – in a public blockchain the nodes existing on the chain are anonymous. In a private blockchain, all of the nodes represent identifiable members

1 2 3 4 5 6 7 8 9 10

Architecture – how the blockchain is structured including who has read-write permissions, which nodes can perform validation, and how are various nodes connected

1 2 3 4 5 6 7 8 9 10

11. In your opinion, to what extent do the following **organizational factors** influence implementation? Please rate how much you think the listed factor will influence the implementation of blockchain in the supply chain. 1 is no influence on implementation and 10 is extremely high influence on implementation.

Organizational/Value Chain Readiness – the human resources facet and the financial facet

1 2 3 4 5 6 7 8 9 10

Top Management Support – managerial participation and advocation of blockchain in the supply chain

1 2 3 4 5 6 7 8 9 10

Organizational Size – supportive IT budgets and organizational flexibility

1 2 3 4 5 6 7 8 9 10

Business Model Readiness – the business model of the supply chain as a whole

1 2 3 4 5 6 7 8 9 10

Technology Readiness – how well the organization is prepared to support a new technology like blockchain

1 2 3 4 5 6 7 8 9 10

Innovativeness – the culture of innovativeness necessary to implement blockchain

1 2 3 4 5 6 7 8 9 10

Participation Incentives – ability to sell to certain customers by being on the blockchain or financial incentives provided as part of participating in the blockchain

1 2 3 4 5 6 7 8 9 10

Blockchain Knowledge – how well do the people in the organization know blockchain

1 2 3 4 5 6 7 8 9 10

12. In your opinion, to what extent do the following **environmental factors** influence implementation? Please rate how much you think the listed factor will influence the implementation of blockchain in the supply chain. 1 is no influence on implementation and 10 is extremely high influence on implementation.

Regulatory Environment/Regulation – unsure regulatory environment or internationally different requirements

1 2 3 4 5 6 7 8 9 10

Market Dynamics/Competitive Pressure – pressure to implement blockchain and not get left behind the market

1 2 3 4 5 6 7 8 9 10

Industry Pressure/Standards – standards on how to implement blockchain or on how transactions are conducted

1 2 3 4 5 6 7 8 9 10

Government Support – acknowledging blockchain transactions and being able to convert transactions on a blockchain to government currency

1 2 3 4 5 6 7 8 9 10

Business Use Cases – industry specific examples of how to implement blockchain

1 2 3 4 5 6 7 8 9 10

Trading Partner Support – knowing that their customers and suppliers have the same commitment to the technology

1 2 3 4 5 6 7 8 9 10

Critical User Mass – implementing blockchain when enough other companies have begun implementation

1 2 3 4 5 6 7 8 9 10

13. Are there any other factors for implementing blockchain in the supply chain that were not covered? Please list them here.

____

____

14. Are there any problems or issues you have experienced in implementing blockchain in your organization or in the supply chain? Please describe them here.

____

____

15. Feel free to add any comments/suggestions.

____

____

CONSENT FORM

Title of Project: A Model for Blockchain Implementation in the Supply Chain and Product Traceability

Investigator: Mr. Gary Lee

Purpose of Project: The study intends to investigate the critical success factors for implementing blockchain in the supply chain. It will also develop a model for implementing blockchain in the supply chain.

Procedures: If you volunteer to participate in this study, you will be asked to fill out the questionnaire and return the completed form via e-mail or mail to the researcher.

Potential Risks and Discomfort: We expect that any risks, discomforts, or inconveniences will be minor and we believe that they are not likely to happen. If discomforts become a problem, you may discontinue your participation.

Potential Benefits to Subjects and/or to Society: You will receive a research result upon your request. The research will be helpful to you and other industries for improving the implementation of blockchain in the supply chain.

Payment for Participation: You will not receive any payment or other compensation for participation in this study. There is also no cost to you for participation. You will be entered into a drawing for one of three$50.00 gift cards to be randomly drawn and the conclusion of the research.

Anonymity: The questionnaire doesn't ask for your company's name or your name or any personal information. Information that can identify you individually will not be released to anyone outside the study. Mr. Lee will, however, use the information collected in his dissertation and other publications for the purpose of education.

Participation and Withdrawal: You can choose whether or not to be in this study. If you volunteer to be in this study, you may withdraw at any time without consequences of any kind. You may also refuse to answer any questions you do not want to answer.

Identification of Investigator: Gary Lee, Principal investigator, Ph.D. Candidate. Phone: (417) 773-9604, Email: glee13@sycamores.indstate.edu

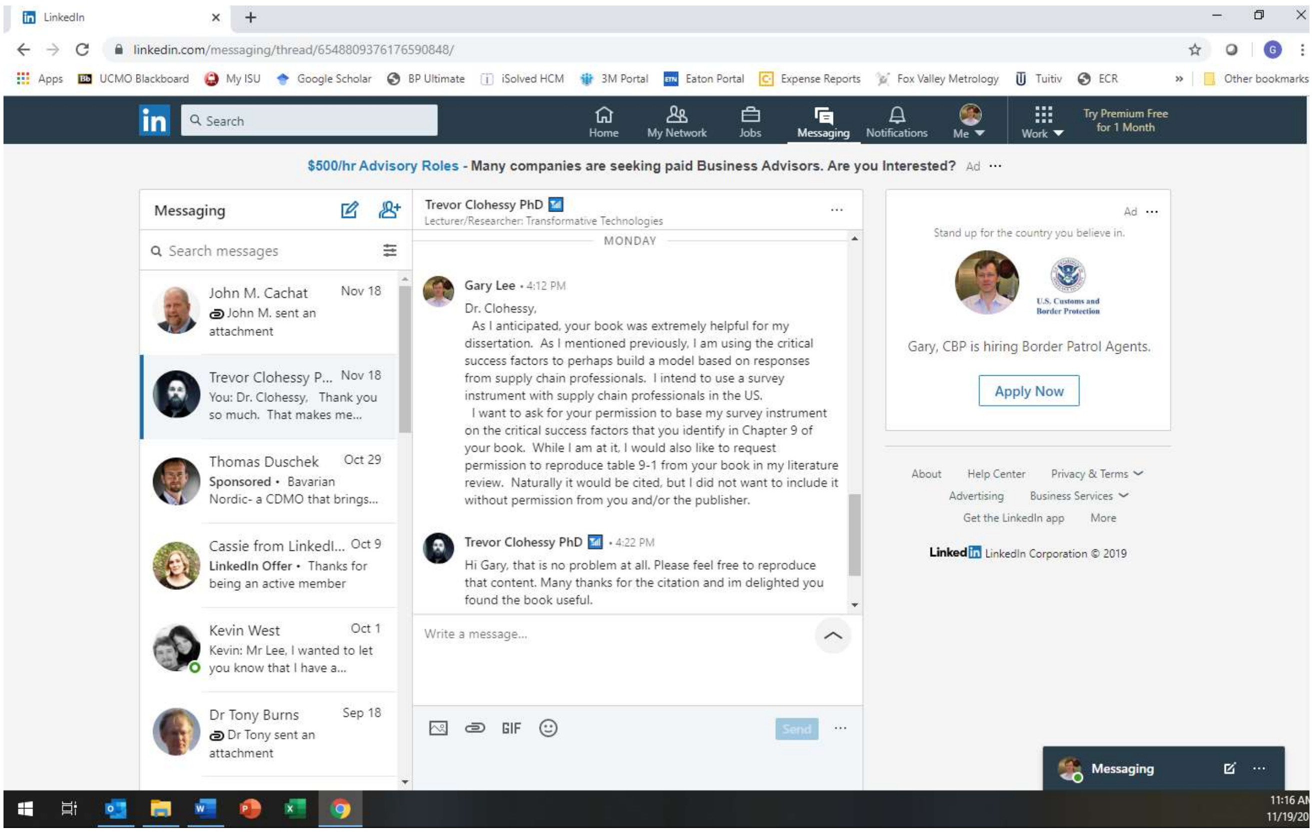
If you have any questions about your rights as a research subject, you may contact the Indiana State University Institutional Review Board (IRB) by mail at 114 Erickson Hall, Terre Haute, IN47809, by phone at (812) 237-8217, or by e-mail at irb@indstate.edu.

<u>If you understand to the procedures described above, your questions have been answered to your satisfaction, and you agree to participation in this study, please select "Agree" and circle or underline it.</u>

Agree Disagree

Indiana State University – Institutional Review Board
IRB Number: 1594953-2 Approval: June 26, 2020

APPENDIX B: AUTHOR PERMISSION



APPENDIX C: ASSOCIATION FOR SUPPLY CHAIN MANAGEMENT PERMISSION

Mail - Gary Lee - Outlook - Google Chrome

outlook.office.com/mail/deeplink?version=2020032904.07&popoutv2=1&leanbootstrap=1

Reply all | Delete Junk Block ···

Re: ASCM Research Surveys

From: Matthew Talbert <mtalbert@ascm.org>
Sent: Monday, October 7, 2019 9:03 AM
To: Gary Lee <glee13@sycamores.indstate.edu>
Subject: RE: ASCM Research Surveys

CAUTION: This message originated from outside of Indiana State University. Do not click links or open attachments unless you recognize the sender and know the content is safe.

Hi Gary,

You are welcome, however I must clarify what I meant and intend. We don't have the bandwidth to help you first hand. The lift would be upon you to post your survey link if you go the electronic route. You would be responsible for posting to the LinkedIn group, Supply Chain Channel and/or the Conference App for ASCM 2020. If you do need help setting up your account in Supply Chain Channel, that is something our customer relationships team would be more than happy to help with. Let me know if you have any additional questions.

Best,
Matt

From: Gary Lee <glee13@sycamores.indstate.edu>
Sent: Monday, October 7, 2019 7:49 AM
To: Matthew Talbert <mtalbert@ascm.org>
Subject: Re: ASCM Research Surveys

Matt,
I am not tied to the conference, but was thinking simplistically in terms of a paper survey so a conference fit that assumption. I like your idea of the linkedin group of Supply Chain Channel.
This is great news that you are willing to let me gather data through your group. I thank you for your help in this effort. I need to finish my proposal now and will be in touch with you again, probably in the spring.

From: Matthew Talbert <mtalbert@ascm.org>
Sent: Friday, October 4, 2019 3:15 PM
To: Gary Lee <glee13@sycamores.indstate.edu>
Subject: RE: ASCM Research Surveys

CAUTION: This message originated from outside of Indiana State University. Do not click links or open attachments unless you recognize the sender and know the content is safe.

Hi Gary,

9:28 AM 4/6/2020

Mail - Gary Lee - Outlook - Google Chrome

outlook.office.com/mail/deeplink?version=2020032904.07&popoutv2=1&leanbootstrap=1

Reply all | Delete Junk Block ···

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Sent: Monday, October 7, 2019 7:49 AM
To: Matthew Talbert <mtalbert@ascm.org>
Subject: Re: ASCM Research Surveys

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I am not tied to the conference, but was thinking simplistically in terms of a paper survey so a conference fit that assumption. I like your idea of the linkedin group of Supply Chain Channel.
This is great news that you are willing to let me gather data through your group. I thank you for your help in this effort. I need to finish my proposal now and will be in touch with you again, probably in the spring.

From: Matthew Talbert <mtalbert@ascm.org>
Sent: Friday, October 4, 2019 3:15 PM
To: Gary Lee <glee13@sycamores.indstate.edu>
Subject: RE: ASCM Research Surveys

CAUTION: This message originated from outside of Indiana State University. Do not click links or open attachments unless you recognize the sender and know the content is safe.

Hi Gary,

What I recommend is developing an electronic version of your survey, either in Survey Monkey or Qualtrics.

For each conference we have an app that contains a discussion board where you can post. Is there a reason you are focusing on conference? If you are flexible and use an electronic means to collect data you are welcome to post on Supply Chain Channel or on the ASCM LinkedIn group.

Best,
Matt

From: Gary Lee <glee13@sycamores.indstate.edu>
Sent: Friday, October 4, 2019 8:48 AM
To: Matthew Talbert <mtalbert@ascm.org>
Subject: Re: ASCM Research Surveys

Matthew,
Thank you for getting back to me. I want to mention that I would be on site to distribute and collect the surveys. Would that make a difference in being allowed to conduct the surveys? I would also be offering a monetary drawing for survey participants as well.

9:29 AM 4/6/2020

APPENDIX D: ADDITIONAL SURVEY COMMENTS

Are there any other factors for implementing blockchain in the supply chain that were not covered? Please list them.

- All the factors covered. More emphasis on cyber security and traceability.
- cost aspect
- Demand, Planning and Quality
- different country/laws/regulations involved for Global companies
- Employee training
- Issues of accuracy and timeliness of transactions
- N/A
- No
- No
- Nothing
- Organization's culture, public perception towards blockchain.
- Perhaps capabilities compared to legacy EDI transactions.
- reduce workforce
- requirements
- Risk assessment; Insurance coverage
- Tarrif circumvention, Quotas, Section 232
- The politics within the company mane the change very difficult until we can get alignment with the CEO taking the lead.

Are there any problems or issues you have experienced in implementing blockchain in your organization or the supply chain? Please describe them here.

- Lack of general knowledge about blockchain
- we did not. But we want to. So, initial knowledge, change management is a challenge.
- primary technology requisites
- Fidelity that culture an Software
- Other country culture
- Have not implemented to my knowledge.
- TBD
- Keeping abrest of changing technology
- Blockchains will be implemented by only the management decisions. You need to check with the financial level and higher rank officials.
- No.

- Just general knowledge of blockchain and its utility and use cases.
- limited awareness within senior management
- fear
- n/a
- IT doesn't see the need of moving to this technology. They see the push to move into blockchain as a move against them and they are digging in.

Feel free to add any comments/suggestions.

- depicting simple road map steps will be helpful, good to AI based questionnaire
- Associated Bloclchain and Suplay Chain being planning strategic of Company an planning global
- Great survey! Thanks!
- Great approach, quite innovative
- Block chain still not familiar with the middle class people like credit card. Once it reaches middles class its hype will be in a different range. It takes hardly 5 to10 years.
- I enjoyed participating on this survey as this one of my subject of interest. I was nominated to take participation in Block chain Conference in Cleveland on 2018 but I could not attend it. Hopefully, I'll attend at earliest convenient.
- I believe this will need top leadership mandate and support to be successful.
- As with anything some industries will have more use for tracking of the supply chain like pharmaceutical distribution. We tend to be earlier adopters of technology deeply entrenched in an industry of laggards. Tech will run B2C and high use areas and work out the bugs long before it impacts our niche.

APPENDIX E: IRB APPROVAL LETTER

Indiana State University
More. From day one.

Institutional Review Board

Terre Haute, Indiana 47809
812-237-3088
Fax 812-237-3092

DATE:	June 26, 2020
TO:	Gary Lee
FROM:	Indiana State University Institutional Review Board
STUDY TITLE:	[1594953-2] A MODEL FOR BLOCKCHAIN IMPLEMENTATION IN THE SUPPLY CHAIN AND PRODUCT TRACEABILITY
SUBMISSION TYPE:	Amendment/Modification
ACTION:	DETERMINATION OF EXEMPT STATUS
DECISION DATE:	June 26, 2020
REVIEW CATEGORY:	Exemption category # 2

Thank you for your submission of Amendment/Modification materials for this research study. The Indiana State University Institutional Review Board has determined this project is EXEMPT FROM IRB REVIEW according to federal regulations (45 CFR 46). You do not need to submit continuation requests or a completion report. Should you need to make modifications to your protocol or informed consent forms that do not fall within the exempt categories, you will have to reapply to the IRB for review of your modified study.

Internet Research: If you are using an internet platform to collect data on human subjects, although your study is exempt from IRB review, ISU has specific policies about internet research that you should follow to the best of your ability and capability. Please review Section L. on Internet Research in the IRB Policy Manual.

Informed Consent: All ISU faculty, staff, and students conducting human subjects research within the "exempt" category are still ethically bound to follow the basic ethical principles of the Belmont Report: 1) respect for persons; 2) beneficence; and 3) justice. These three principles are best reflected in the practice of obtaining informed consent.

If you have any questions, please contact Anne Foster within IRBNet by clicking on the study title on the "My Projects" screen and the "Send Project Mail" button on the left side of the "New Project Message" screen. I wish you well in completing your study.

APPENDIX F: STATISTICAL TABLES

Table 7

Organizational Size T-Tests

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means					95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
S1	Equal variances assumed	.076	.784	-.104	56	.917	-.072	.688	-1.450	1.306
	Equal variances not assumed			-.104	54.821	.917	-.072	.688	-1.451	1.308
S2	Equal variances assumed	.003	.956	-.577	56	.566	-.314	.544	-1.405	.776
	Equal variances not assumed			-.578	55.278	.565	-.314	.543	-1.403	.775
S3	Equal variances assumed	1.430	.237	-.309	56	.758	-.191	.618	-1.430	1.048
	Equal variances not assumed			-.306	52.369	.761	-.191	.624	-1.443	1.061
S4	Equal variances assumed	.432	.514	-1.574	56	.121	-.975	.620	-2.216	.266
	Equal variances not assumed			-1.586	55.960	.118	-.975	.615	-2.206	.256
S5	Equal variances assumed	3.282	.075	-.246	56	.806	-.155	.631	-1.418	1.108
	Equal variances not assumed			-.243	50.623	.809	-.155	.639	-1.438	1.128
S6	Equal variances assumed	.001	.976	-.186	56	.853	-.111	.598	-1.308	1.086
	Equal variances not assumed			-.187	55.557	.853	-.111	.596	-1.304	1.082
S7	Equal variances assumed	1.299	.259	-1.762	56	.084	-.989	.561	-2.114	.136
	Equal variances not assumed			-1.784	55.914	.080	-.989	.555	-2.100	.122
S8	Equal variances assumed	.200	.657	-1.619	56	.111	-.986	.609	-2.205	.234
	Equal variances not assumed			-1.638	55.962	.107	-.986	.602	-2.191	.220
S9	Equal variances assumed	1.053	.309	-.377	56	.707	-.231	.611	-1.455	.994
	Equal variances not assumed			-.377	54.826	.707	-.231	.611	-1.456	.995
S10	Equal variances assumed	.002	.964	-.597	56	.553	-.387	.648	-1.685	.911
	Equal variances not assumed			-.600	55.713	.551	-.387	.645	-1.679	.905
S11	Equal variances assumed	.921	.341	-1.038	54	.304	-.608	.585	-1.782	.566
	Equal variances not assumed			-1.055	53.676	.296	-.608	.576	-1.763	.548

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
S12	Equal variances assumed	3.304	.075	-1.441	54	.155	-.877	.609	-2.097	.343
	Equal variances not assumed			-1.489	48.969	.143	-.877	.589	-2.060	.307
S13	Equal variances assumed	.000	.986	-1.370	54	.176	-.826	.602	-2.034	.382
	Equal variances not assumed			-1.386	53.994	.171	-.826	.596	-2.020	.369
S14	Equal variances assumed	.031	.861	-.751	54	.456	-.400	.532	-1.467	.667
	Equal variances not assumed			-.757	53.873	.453	-.400	.529	-1.460	.660
S15	Equal variances assumed	.087	.769	-.530	54	.599	-.300	.566	-1.436	.836
	Equal variances not assumed			-.539	53.584	.592	-.300	.557	-1.417	.817
S16	Equal variances assumed	.173	.679	.084	54	.934	.046	.551	-1.058	1.150
	Equal variances not assumed			.083	49.120	.934	.046	.558	-1.075	1.167
S17	Equal variances assumed	.364	.549	-2.002	54	.050	-1.082	.540	-2.165	.001
	Equal variances not assumed			-2.013	53.686	.049	-1.082	.538	-2.160	-.004
S18	Equal variances assumed	.385	.537	-1.024	54	.310	-.651	.636	-1.926	.623
	Equal variances not assumed			-1.033	53.968	.306	-.651	.630	-1.915	.612
S19	Equal variances assumed	.008	.927	.705	53	.484	.568	.805	-1.046	2.182
	Equal variances not assumed			.707	52.704	.483	.568	.803	-1.043	2.178
S20	Equal variances assumed	.461	.500	-.872	53	.387	-.655	.752	-2.163	.853
	Equal variances not assumed			-.875	52.897	.386	-.655	.749	-2.157	.847
S21	Equal variances assumed	.987	.325	-.770	53	.445	-.585	.760	-2.109	.940
	Equal variances not assumed			-.764	50.265	.448	-.585	.765	-2.122	.952
S22	Equal variances assumed	.601	.442	1.170	53	.247	.893	.763	-.638	2.423
	Equal variances not assumed			1.165	51.086	.250	.893	.766	-.646	2.431
S23	Equal variances assumed	.868	.356	-.271	53	.787	-.200	.739	-1.683	1.282
	Equal variances not assumed			-.270	51.141	.788	-.200	.742	-1.691	1.290
S24	Equal variances assumed	1.541	.220	-2.147	52	.036	-1.365	.636	-2.641	-.090
	Equal variances not assumed			-2.159	51.761	.036	-1.365	.632	-2.635	-.096
S25	Equal variances assumed	.445	.508	-.380	53	.705	-.272	.715	-1.705	1.162
	Equal variances not assumed			-.382	52.937	.704	-.272	.712	-1.699	1.156

Table 8

Organizational Revenue T-Tests

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
R1	Equal variances assumed	.400	.530	-.011	55	.991	-.008	.706	-1.423	1.407
	Equal variances not assumed			-.011	49.264	.991	-.008	.698	-1.410	1.394
R2	Equal variances assumed	.029	.866	.078	55	.938	.043	.560	-1.080	1.167
	Equal variances not assumed			.080	52.522	.936	.043	.541	-1.042	1.129
R3	Equal variances assumed	.698	.407	.077	55	.939	.049	.633	-1.221	1.318
	Equal variances not assumed			.079	52.326	.937	.049	.612	-1.180	1.277
R4	Equal variances assumed	.005	.943	1.886	55	.065	1.196	.634	-.075	2.466
	Equal variances not assumed			1.908	49.224	.062	1.196	.627	-.064	2.455
R5	Equal variances assumed	4.410	.040	-.190	55	.850	-.123	.647	-1.419	1.173
	Equal variances not assumed			-.202	54.730	.841	-.123	.608	-1.341	1.096
R6	Equal variances assumed	.895	.348	-.547	55	.587	-.335	.613	-1.563	.893
	Equal variances not assumed			-.563	51.712	.576	-.335	.595	-1.530	.860
R7	Equal variances assumed	.155	.695	.669	55	.506	.395	.591	-.789	1.579
	Equal variances not assumed			.662	45.507	.512	.395	.597	-.808	1.598
R8	Equal variances assumed	.651	.423	.259	55	.797	.165	.637	-1.111	1.441
	Equal variances not assumed			.252	42.678	.802	.165	.655	-1.156	1.486
R9	Equal variances assumed	2.230	.141	.163	55	.871	.101	.619	-1.140	1.343
	Equal variances not assumed			.169	52.341	.867	.101	.599	-1.100	1.302
R10	Equal variances assumed	.075	.785	1.303	55	.198	.830	.637	-.447	2.107
	Equal variances not assumed			1.287	45.369	.205	.830	.645	-.469	2.128
R11	Equal variances assumed	3.335	.073	1.198	53	.236	.712	.594	-.480	1.904
	Equal variances not assumed			1.121	34.942	.270	.712	.635	-.578	2.002

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
R12	Equal variances assumed	3.506	.067	1.030	53	.308	.652	.633	-.618	1.921
	Equal variances not assumed			.952	33.406	.348	.652	.684	-.740	2.043
R13	Equal variances assumed	1.187	.281	1.150	53	.255	.712	.619	-.530	1.954
	Equal variances not assumed			1.087	36.452	.284	.712	.655	-.616	2.040
R14	Equal variances assumed	.006	.937	-.193	53	.848	-.106	.551	-1.211	.999
	Equal variances not assumed			-.189	41.877	.851	-.106	.563	-1.241	1.029
R15	Equal variances assumed	.855	.359	-.026	53	.979	-.015	.585	-1.189	1.159
	Equal variances not assumed			-.024	35.966	.981	-.015	.621	-1.276	1.245
R16	Equal variances assumed	.306	.582	-1.192	53	.239	-.667	.559	-1.789	.455
	Equal variances not assumed			-1.214	47.904	.231	-.667	.549	-1.771	.438
R17	Equal variances assumed	.008	.927	.928	53	.357	.530	.571	-.615	1.676
	Equal variances not assumed			.931	45.645	.357	.530	.569	-.616	1.677
R18	Equal variances assumed	.993	.323	.553	53	.582	.364	.657	-.954	1.681
	Equal variances not assumed			.537	40.294	.595	.364	.678	-1.006	1.733
R19	Equal variances assumed	.119	.731	-.582	52	.563	-.489	.840	-2.175	1.197
	Equal variances not assumed			-.585	43.314	.562	-.489	.837	-2.176	1.198
R20	Equal variances assumed	1.742	.193	1.021	52	.312	.797	.780	-.770	2.363
	Equal variances not assumed			.982	37.344	.333	.797	.811	-.847	2.440
R21	Equal variances assumed	.706	.405	.651	52	.518	.515	.792	-1.073	2.104
	Equal variances not assumed			.667	46.109	.508	.515	.773	-1.040	2.070
R22	Equal variances assumed	.637	.429	-.572	52	.569	-.459	.802	-2.067	1.150
	Equal variances not assumed			-.581	44.810	.564	-.459	.790	-2.050	1.132
R23	Equal variances assumed	.189	.666	-.333	52	.741	-.255	.768	-1.796	1.285
	Equal variances not assumed			-.336	44.283	.738	-.255	.759	-1.785	1.274
R24	Equal variances assumed	3.715	.059	1.983	52	.053	1.364	.688	-.016	2.744
	Equal variances not assumed			1.861	34.167	.071	1.364	.733	-.125	2.853
R25	Equal variances assumed	.961	.331	-.326	52	.745	-.242	.743	-1.733	1.248
	Equal variances not assumed			-.312	36.482	.757	-.242	.777	-1.818	1.333

Table 9

Industry T-Tests

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
I1	Equal variances assumed	.024	.878	.667	54	.508	.489	.733	-.980	1.958
	Equal variances not assumed			.684	42.429	.497	.489	.714	-.952	1.930
I2	Equal variances assumed	.008	.930	.709	54	.482	.411	.580	-.752	1.574
	Equal variances not assumed			.729	42.732	.470	.411	.564	-.727	1.549
I3	Equal variances assumed	.026	.872	.963	54	.340	.628	.652	-.679	1.934
	Equal variances not assumed			.943	36.978	.352	.628	.666	-.721	1.977
I4	Equal variances assumed	.217	.643	1.359	54	.180	.906	.667	-.431	2.242
	Equal variances not assumed			1.320	36.190	.195	.906	.686	-.485	2.296
I5	Equal variances assumed	.055	.816	.395	54	.694	.261	.661	-1.064	1.586
	Equal variances not assumed			.390	37.981	.698	.261	.669	-1.093	1.615
I6	Equal variances assumed	2.076	.155	.491	54	.625	.311	.634	-.959	1.581
	Equal variances not assumed			.454	31.371	.653	.311	.685	-1.086	1.708
I7	Equal variances assumed	.178	.675	.742	54	.462	.444	.599	-.757	1.646
	Equal variances not assumed			.710	34.603	.483	.444	.626	-.828	1.716
I8	Equal variances assumed	.062	.804	-.916	54	.364	-.594	.649	-1.896	.707
	Equal variances not assumed			-.905	37.991	.371	-.594	.657	-1.924	.736
I9	Equal variances assumed	.188	.667	-.506	54	.615	-.322	.637	-1.600	.956
	Equal variances not assumed			-.522	43.114	.605	-.322	.618	-1.568	.923
I10	Equal variances assumed	.407	.526	-.176	54	.861	-.117	.664	-1.448	1.214
	Equal variances not assumed			-.172	36.797	.865	-.117	.679	-1.493	1.260
I11	Equal variances assumed	1.800	.186	2.543	52	.014	1.510	.594	.319	2.701
	Equal variances not assumed			2.363	30.122	.025	1.510	.639	.205	2.814

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
I12	Equal variances assumed	1.836	.181	1.630	52	.109	1.060	.651	-.245	2.366
	Equal variances not assumed			1.506	29.717	.143	1.060	.704	-.378	2.498
I13	Equal variances assumed	2.726	.105	.481	52	.633	.314	.654	-.997	1.626
	Equal variances not assumed			.446	29.991	.659	.314	.705	-1.125	1.753
I14	Equal variances assumed	.497	.484	.224	52	.823	.128	.569	-1.015	1.271
	Equal variances not assumed			.236	42.886	.814	.128	.541	-.963	1.218
I15	Equal variances assumed	.302	.585	-.050	52	.961	-.030	.606	-1.246	1.186
	Equal variances not assumed			-.047	32.584	.962	-.030	.634	-1.321	1.261
I16	Equal variances assumed	.112	.739	.203	52	.840	.119	.586	-1.057	1.295
	Equal variances not assumed			.194	32.779	.847	.119	.612	-1.126	1.364
I17	Equal variances assumed	.343	.561	1.250	52	.217	.726	.581	-.440	1.893
	Equal variances not assumed			1.250	37.114	.219	.726	.581	-.451	1.903
I18	Equal variances assumed	.214	.646	-.143	52	.886	-.098	.681	-1.465	1.270
	Equal variances not assumed			-.142	36.170	.888	-.098	.687	-1.491	1.296
I19	Equal variances assumed	7.020	.011	-1.407	51	.165	-1.195	.849	-2.900	.510
	Equal variances not assumed			-1.543	47.618	.129	-1.195	.774	-2.753	.362
I20	Equal variances assumed	.137	.713	.281	51	.780	.226	.805	-1.389	1.841
	Equal variances not assumed			.277	35.926	.783	.226	.815	-1.428	1.880
I21	Equal variances assumed	.700	.407	-.034	51	.973	-.028	.810	-1.654	1.598
	Equal variances not assumed			-.033	33.646	.974	-.028	.839	-1.734	1.678
I22	Equal variances assumed	2.496	.120	-1.325	51	.191	-1.070	.807	-2.691	.551
	Equal variances not assumed			-1.393	43.087	.171	-1.070	.768	-2.619	.479
I23	Equal variances assumed	1.184	.282	-.732	51	.468	-.568	.777	-2.127	.991
	Equal variances not assumed			-.701	32.963	.488	-.568	.810	-2.217	1.081
I24	Equal variances assumed	.174	.678	-.979	50	.332	-.690	.704	-2.104	.725
	Equal variances not assumed			-.960	32.888	.344	-.690	.718	-2.151	.772
I25	Equal variances assumed	.063	.802	-1.431	51	.159	-1.068	.746	-2.567	.431
	Equal variances not assumed			-1.400	35.008	.170	-1.068	.763	-2.617	.481

Table 10

Regression Coefficient Table

Coded Coefficients

	Estimate	SE	95% CI	P
			LL UL	
Constant	0.7778	0.0343	0.6896, 0.8660	0.000
Q9	0.1512	0.0134	0.1168, 0.1855	0.000
Q13	0.0745	0.0244	0.0119, 0.1372	0.028
Q18	0.1589	0.0255	0.0934, 0.2244	0.002