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ORJI, Ifeyinwa Juliet, KUSI-SARPONG, Simonov, HUANG, Shuangfa and VAZQUEZ-BRUST, Diego

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Factors that influence blockchain adoption in the freight logistics industry

Ifeyinwa Juliet Orji

Research Centre for Smarter Supply Chain, Dongwu Business School, Soochow
University, 215021, Suzhou, Jiangsu Province, China
Email: ifyorji09@yahoo.com

Simonov Kusi-Sarpong

Southampton Business School, University of Southampton, Southampton S017 1BJ,
United Kingdom
Email: simonov2002@yahoo.com

Shuangfa Huang

Portsmouth Business School, University of Portsmouth
United Kingdom
Email: shuangfa.huang1@port.ac.uk

Diego Vazquez-Brust

Portsmouth Business School, University of Portsmouth
United Kingdom
Email: diego.vazquez-brust@port.ac.uk

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Abstract - This study proposes a technology- organization- environment (TOE) theoretical framework of critical factors that influence the successful adoption of blockchain technologies in the freight logistics industry and prioritize them using the analytic network process (ANP). The research findings indicate that 'availability of specific blockchain tools', 'infrastructural facility', and 'government policy and support' are the three topmost ranked significant factors that influence the adoption of blockchains in the freight logistics industry. These findings will aid government agencies, freight logistics firms and blockchain service providers in strategizing for the advancement and successful adoption of blockchain and improvement of overall organizational competitiveness.

1   Introduction

Digitalization of all economic activities is happening at a fast pace and it has been expected that the pace will be faster in the coming years. Digital economy accounted for 22.5% of the global GDP in 2015 and is expected to increase to 25.5% by 2020 (Brilliantova and Thurner, 2019). Most part of existing digital resources (e.g., servers, data bases, services or even smart objects, from smart watches to last generation cars) are connected to the internet due to the ever-increasing coverage of internet connectivity (Maesa et al, 2019). The digitization phenomenon is leveraging new relationship models throughout the entire supply chain network (Queiroz and Wamba, 2019). Business operations in the supply chain network have been transformed from manual operations into electronic communication and processing using information and communication technology systems (Chang et al, 2019). Moreover, the freight logistics industry is undergoing a transformation from the conventional freight logistics system into a decentralized and digitized freight logistics system. The digitized freight logistics system builds on complex interrelated hardware systems and requires novel technologies that support exchange of financial transactions and related data. The decentralized and digitalized logistics systems can form distributed freight logistics markets, which promise financial transparency and facilitates mature supply chain networks. These distributed freight logistics markets require a nascent distributed ledger technology, blockchain technology, that supports peer-to- peer exchange thereby assisting in overcoming the hurdles faced by decentralized and digitized freight logistics systems (Schuetz and Venkatesh, 2019).

A blockchain can be defined as a shared digital ledger, which is maintained by a group of nodes that are not fully trusted by each other (Huimin et al, 2019) and allows one to build upon cryptographic algorithms to ensure data integrity, standardized auditing, and some formalized contracts for data access (Chen et al, 2019). It can also be defined as a secure record of historical transactions, collected into blocks, chained

in chronological order, and distributed across a number of different servers to create reliable provenance (Angelis and Ribeiro da Silva, 2019). More importantly, blockchains allow for the automated execution of smart contracts in peer-to-peer networks (Andoni et al, 2019). Smart contract is a computer protocol that can control digital assets and formulate the participant's rights and obligations thereby reducing 'third party costs', simplifies the supply chain management process and also reduce risks (Helo and Hao, 2019). This has, in turn ensured that the flow of information and currency may rely on the consensus of participating nodes without the need for a third trusted party, such as banks and clearing houses (Chang et al, 2019). In fact, hacking attacks that commonly impact large centralized intermediaries like banks would be nearly impossible as blockchain can keep track of all transactions (Min, 2019). Additionally, blockchain technology makes it more possible to maintain immutable information of products and producers as they flow through the supply chain from extraction to end-of-life management and governing supply chain activities and its financial flow with smart contracts (Saberi et al, 2018). Similar to other emerging technologies, blockchains regularly serve as enabling forces for economic, social and business transformation and are predicted to challenge existing business models and offer opportunities for new value creation (Morkunas et al, 2019). The core innovation of blockchain lies in its ability to validate record and distribute transactions in immutable, encrypted ledgers (Wang et al, 2019). The validation process in blockchains can be done either by authorized users with permissioned access in private blockchains or implemented by unauthorized users with rewarding computer utilization in public blockchain technologies (Helo and Hao, 2019). Hyperledger is an example of a permissioned/ private blockchain while hyperledge and Ethereum are amongst the private blockchain platforms. The public blockchains usually allows virtually anybody to freely interact during transactions, with or without prior knowledge of the identity of the interacting parties. On the other hand, there is sufficient prior knowledge of the identities of interacting parties in private blockchain systems during transactions. The public blockchains can also be differentiated from private blockchains in terms of selling dispositions; public blockchains can assist firms to save cost and time while private blockchains can aid in the disintermediation of traditional intermediaries (e.g. banks) during business transactions. The freight logistics sector can utilize private blockchain systems for more transaction privacy critical for sensitive data while using the public ledger for data that require a high trust level and a substantial amount of computational power that is necessary to maintain distributed ledger on a larger scale (Morkunas et al, 2019). Blockchains accelerates the transfer of data streams between parties, thereby reducing the transit time of products, improving inventory management and reducing waste and cost (Bedell, 2016). Having the potential of being transparent, secure and decentralized, blockchain is considered useful for dealing with operational and business issues including financial transactions. Blockchains has the characteristics of high reliability, data integrity, decentralization and distrust and can realize the transmission and transaction of information between any nodes (Leng et al, 2018). Organizations are demonstrating increasing interest in blockchain technology evidenced by the increasing number of blockchain- based solutions in a broad range of

fields (Zhu et al, 2019) due to the number of significant benefits it offers to businesses (Hughes et al, 2019). Two prominent benefits of blockchain technology are that, it provides a permanent transaction records which are grouped into individual blocks and cannot be tampered with; and replaces those traditional paper tracking and manual monitoring systems which prevent the traditional way of doing business, characterize by inaccuracies (Zhao et al, 2019). Moreover, blockchain is likely to affect supply chain management objectives such as cost, quality, speed, dependability, risk reduction, sustainability and flexibility (Kshetri, 2018). Therefore, it is imperative for supply chain managers to adopt blockchain for their operations because all transactions with blockchain are safer, more transparent, traceable and efficient and leads to increased cooperation between supply chain members (Queiroz and Wamba, 2019).

The adoption of blockchains refers to its replicative uptake, incorporation or use of technology for private, public or individual purposes (Tob- Ogu et al, 2018). Currently, the adoption of blockchains by the freight logistics industry is still at its nascent stage (Wang et al, 2019), although research on the adoption of information technology is one of the most mature streams of IS research (Venkatesh et al, 2016). Researchers have studied the adoption of blockchains in supply chain management, hospital records management, government transparent voting and other areas (Kamble et al, 2018; Laaper et al, 2017; Makdoom et al, 2019; Min, 2019; Olnes et al, 2017; Roehrs et al, 2017; Schuetz and Venkatesh, 2019), yet it is unclear how freight logistics managers would adopt blockchains. There is potentially great need for freight logistics sector to use digital innovations because its operations typically spread across regions and entities, and such management of information flows is critical to operational efficiency (Nguyen, 2013). Lately, with the advent of digital technologies (such as sensor technologies, blockchains and big data), the operational landscape of the freight logistics industry is changing. The blockchains differs from other digital innovations by four key characteristics including; decentralization, security, auditability and smart execution (Saberi et al, 2019). The application of blockchains in the logistics sector is expected to have far- reaching implications with some logistics experts considering blockchains to offer enormous potential to transform the supply chains (Dobrovnik et al, 2018). Although it can be expected that blockchains deliver significant benefits that could provide a thrust in technology adoption (Hughes et al, 2019), it is typical in freight logistics firms to utilize simple and established technologies rather than advanced technologies (Janjevic et al, 2019).

The scantily available literature on the adoption of blockchains in the freight logistics sector suggests that adoption will more likely be a complex undertaking (Andoni et al, 2019), holding its own contextual opportunities that have not been understood. Blockchains can assist freight logistics companies in a real- time tracking of material flows, improve transport handling as well as an accurate risk management (Morkunas et al, 2019). Moreover, freight logistics might be one of the most promising applications for a combination of IoTs and blockchains; IoTs sensors gather various data from the real world, thus the locations of products, packages and freight vehicles can easily be tracked at intervals (Helo and Hao, 2019). IoT, AI and smart contracts has been applied in the logistics domain to cause a major transformation particularly in

sensitive pharmaceutical shipments. Blockchain- enabled IoT sensors, SkyCell was used by a Swiss company to create air freight containers for refrigerated biopharmaceuticals that monitor temperature, humidity, and location, thereby reducing the temperature deviation to less than 0.1 percent (Dobrovnik et al, 2018). Blockchains can use smart contracts to deliver considerable savings in the context of operational efficiencies and reduced transaction costs within freight logistics (Hughes et al, 2019). For instance, a proof of delivery model for physical assets in the logistics sector has been built with Etherum based smart contracts to allow for traceability of the products as well as rewarding and payment process for the buyers and transporters (Meyer et al, 2019). However, most logistics professionals misunderstand the concept of blockchain and tend to not know how to utilize the technology for the benefit of their companies (Min, 2019). It becomes highly expedient to provide practical insights and in-depth understanding on the significant factors which can facilitate the successful adoption of blockchains by the freight logistics industry.

While blockchain has seen many discussions in the literature as a technology that can offer many advantages, and have many success stories from the financial, supply chain and public sectors, yet, little is known about its disruption in transport and logistics, including the freight and passenger industries (Koh et al., 2020). Therefore, blockchain adoption in the freight logistics industry is one of the most important areas that require urgent investigation. This suggests that, more efforts are required to understand the adoption of blockchain and to identify factors that influence blockchain adoption decision. The technology-organization-environment (TOE) framework is therefore identified as a suitable theoretical lens for investigating blockchain adoption at the organizational level (Tornatzky et al., 1990; Ramdani et al., 2013). Utilizing the TOE framework, this paper proposes a list of factors that may influence the adoption of blockchain in the freight logistics industry. The decision to adopt technological innovation is based on internal organizational and external environmental factors in addition to the technology itself (Tornatzky et al., 1990). Thus, a threefold context framework is envisioning for the adoption of technological innovations – technological, organizational and environmental contexts. The adoption of the TOE theoretical framework for our study was motivated by the heavy application of the framework in many organizational technology adoption studies (see Lin, 2014; Mohammad et al, 2019; Pool et al, 2015; Ramdani et al, 2013; Safari et al, 2015; Wang et al., 2016). Thus, the use of the TOE framework in explaining and investigating technological adoption is a good framework supported by the literature.

Against this backdrop, this study proposes a research agenda that raises questions that, if addressed, will provide clarity on how blockchain technologies can be successfully adopted in the freight logistics sector. By drawing from existing adoption research, the research agenda in this paper highlights the gaps that broadly relate to the critical factors of adoption in the specific context of blockchain and Nigeria. The freight logistics industry in Nigeria can apply the insights on the critical factors to the adoption of blockchains to build effective strategies for increased competitiveness. Investigating new contexts, especially in developing countries and more so Nigeria, has been recognized as an important research direction for future studies in the technology

adoption research (Brilliantova and Thurner, 2019). Moreover, the Nigerian freight logistics industry has significant socio- economic implications for the country and remains under researched (Tob- Ogu et al, 2018). The socio- economic costs associated with the freight logistics sector is high due to the huge demand for transportation which constitutes a key UN sustainable development indicator (UN, 2016). Also, the unprecedented economic growth in developing countries especially Nigeria caused by global investment expansion, increases production and consumption, leads to a huge demand for freight transportation as well as its development (Kin et al, 2017; Wanke et al, 2016). To that end, this study serves the dual outcomes of (a) highlighting the significant factors that influences the adoption of blockchain technologies as they relate to technological, organizational and external environmental aspects of the freight logistics sector and (b) proposing research implications that will serve as a foundation for research on the adoption of blockchains in developing countries, especially Nigeria.

To realize these study outcomes, an extensive review of relevant available literature was carried out to identify the critical factors, and evaluate these factors using the opinions of managers in the Nigerian freight logistics sector. The opinions of these managers were sourced using Analytic Network Process (ANP) designed questionnaires and feedbacks analyzed using ANP-based Super- Decisions software (https://www.superdecisions.com/) (Kusi-Sarpong et al., 2016) to prioritize the significant factors that influence blockchain adoption in the freight logistics sector. The ANP is a multi- criteria decision model that makes possible the prioritization of improvements in the system while considering the interdependence and feedback among elements (Farias et al, 2019). The ANP method is adopted in this study because of its ability to model and capture more complex interrelationships among factors when computing the relative weights (priority weights) of the factors (Kusi-Sarpong et al., 2016), of which this study is involved. The ANP has been successfully applied in various real world decision making scenarios (Choi, 2018; Hosseini et al, 2019; Hu et al, 2019; Supeekit et al, 2016).

The rest of this paper is structured as follows; the literature is reviewed on the relevant adoption factors of blockchains and application of ANP in section 2. In section 3, the research methodology is explained and results of the analysis presented in section 4 together with the research implications. The conclusion of the study in addition to the limitations and future research directions are presented in section 5.

2 Literature review

Due to globalization, freight logistics has become an important part of the supply chain and many freight logistics service providers have realized the importance of adoption of technologies that can help manufacturers, warehouses, and retailers to communicate with each other more efficiently (Ramanathan et al, 2014). Thus, the research on the adoption of technology in freight logistics is a growing stream of research (Guerrero de la Pena et al, 2019; Nguyen, 2013; Ramanathan et al, 2014; Sureeyatanapas et al, 2018). For instance, Shankar et al (2019) conducted an empirical study to identify and validate the enablers of advance technology adoption for dedicated freight corridors through the lens of transition management theory. Their work also highlights the role of adoption of advanced technologies to achieve freight logistics

sustainability. Guerrero et al (2019) in their work, applied a System- of Systems engineering methodology to project truck technology adoption behaviors of heterogeneous fleets over the U.S. line- haul in the freight logistics sector. Likewise, Taefi et al (2016) in their study, analyzed the policy measures applied in Europe that supports the adoption of electric vehicles in the freight logistics sector and found that, electric urban mobility in the freight logistics sector requires dedicated policy support. Moreover, Ramanathan et al (2014) identified the impact of usability features of radio frequency identification (RFID) in its adoption by the UK freight logistics sector and showed that the usability of RFID positively influences its adoption. Nguyen (2013) developed a discrete variable model of investment and applied it to analyze the decision to adopt e- business in the Australian freight logistics sector and details the influential factors in the process. Subramanian et al (2014) in their study, posited that, the perceived green and cost benefits drive the need for adoption of cloud computing technology by the Chinese freight logistics sector. Additionally, Mondragon et al (2017) conducted a study to identified key elements that affect and influence the adoption of information and communication technology to support interoperability and connectivity in the freight logistics sector. Their analysis is used to identify groupings of influence linked to elements comprising institutional- related theories like coercion and mimesis, part of institutional isomorphism, among others.

The evidence of published studies on technology adoption in the freight logistics industry shows that the technology adoption research stream is an emergent literature because adoption is a significant factor which determines how it can yield outstanding benefits. For instance, Evangelista (2013) show that the adoption of the technology can yield environmental and efficiency benefits that the freight logistics industry can reap from. Yet, existing Nigerian freight logistics firms struggle with the adoption of blockchain technologies and factors that influences the effective adoption of blockchains by these firms remains unknown.

Currently, research on blockchain technologies as a means of financial transparency and cooperation between supply chain members in the freight logistics sector has not recognized the significance of adoption. Although previous studies have recognized the possibility of employing blockchain to be a bedrock technology for future supply chain operations (Kshetri, 2018; Wang et al, 2019), these studies are generally conceptual and do not actually apply blockchain to the problem. For example, Kshetri (2018) discusses the various mechanisms by which blockchain help to achieve the supply chain objectives including cost, quality, speed, dependability, risk reduction, sustainability and flexibility. His work presents early evidence linking the use of blockchain in supply chain activities to increase transparency and accountability. Wang et al (2019) investigated how blockchain technologies may transform supply chains by adopting sensemaking theory to gauge foresights via expert interviews. Their work established potential areas where blockchains may penetrate supply chains while elucidating the challenges of blockchain technology's further diffusion into supply chains. Queiroz and Wamba (2019) in their study draws upon the emerging literature on blockchain, supply chain and network theory, as well as technology acceptance models, to develop a model based on a slightly- altered version of the classical unified

theory of acceptance and use of technology. Their developed model was estimated using the Partial least squares structural equation modeling to reveal the existence of distinct blockchain adoption behaviors between India- based and USA- based professionals. Montencchi et al (2019) developed a provenance knowledge framework and showed that its application can enhance assurances and reduce perceived risks via the application of blockchain. Their work also presented a guide on how to implement blockchain to establish provenance knowledge in the supply chain and close with a kind of warning on the importance of demonstrating the value of blockchain to customers. Min (2019) in his article unlocked the mystique of blockchain technology and discussed ways to leverage blockchain technology to enhance supply chain resilience in times of increased risks and uncertainty. Chang et al (2019) proposed a blockchain- based business process reengineering framework to automate business flows in tracking supply chain processes. Their work showed that, blockchain- based business apps can be designed and implemented using the proposed framework to harvest blockchain benefits.

The available published research on blockchains provides a conceptual outlook and does not focus on the actual application of blockchains to an industrial sector particularly the Nigerian freight logistics sector. Nigeria continues to be faced with unique infrastructural and operations challenges, particularly in the freight logistics sector which has led to a slack in the economic growth of the country despite its huge population potentials (Ehinomen and Adeleke, 2012). Challenges such as time delays, bottlenecks for international shipments, poor tracking and tracing capabilities and poor logistics quality and competence are peculiar to the Nigerian freight logistics sector and these constrain its growth prospects (Oyebamiji, 2018). Other challenges that are unique to the Nigerian context include inefficient legal system, hostile business environments, multiple taxation, deficient infrastructures and lax regulations leading to alarmingly high logistics costs. Little wonder, the *2018 Logistics and Supply Chain Industry Report* indicated that, about three percent of the Nigerian budget in 2018 was lost by the inefficiency of the Nigerian freight logistics sector. Thus, literature identifies the increased penetration of information technologies in Nigeria to address some of the infrastructural and operational problems (Chiemeke and Longe, 2007). The Nigerian freight logistics industry is under constant pressure from stakeholders, suppliers and customers to upgrade their traditional mode of operations with information technologies to ensure improved information flow and increased competitiveness (Somuyiwa, 2010). Although there has been successful adoption of emerging digital technologies in the freight logistics sector of developed nations, the adoption of emerging information technologies is still in the nascent stage in Nigerian logistics firms (Ekene, 2014; Tob- Ogu et al, 2018). This is attributable to the perceived high costs of investment associated with acquiring emerging technologies and the absence of infrastructural facility to encourage the use of information technologies (Ayantoyinbo, 2015). Similarly, Tob- Ogu et al (2018) empirically highlighted the influence of contextual factors on the adoption of information and communication technologies in the Nigerian road freight transport sector. The evidence from the available published research suggests that technology adoption is an enabler of

operational efficiencies and sustainable solutions and hold much potential for the Nigerian freight logistics market to connect to global supply chain networks. Information and communication technologies regularly serve as enabling forces for economic, social and business transformation with blockchains being placed among the top five technology trends in 2018 (Kietzmann, 2019; Morkunas et al, 2019). More specifically, firms are reviewing their business models to identify key use cases where blockchains can deliver benefits and emerging markets are proving to be a viable area to apply blockchains to address issues of trust and transparency between parties (Hughes et al, 2019). There is intense competition in Nigerian freight logistics firms to ensure transparent transactions and simplify business process by removing intermediations of traditional intermediaries (e.g. banks), particularly through the use of blockchains. However, the extent to which blockchains differ from other information technologies in addition to the extent to which Nigerian freight logistics companies differs from other freight logistics firms and even other supply chain members, require investigation. Thus, the need arises for a study on the adoption of blockchains in the Nigerian freight logistics industry. This need is found in the sphere of the larger shortcoming on the research on blockchains which considers the actual application of this emergent technology (Schuetz and Venkatesh, 2019).

Hence, a research modeling technique is required to effectively address this need by identifying and ranking the significant factors which influence the adoption of blockchains in the Nigerian freight logistics industry by considering hierarchical relationships. The ANP modeling technique allows for more complex relationships and feedback among elements in the hierarchy (Farias et al, 2019). The research modeling framework in this study focuses on employing the ANP in analyzing and prioritizing the significant factors that influence blockchain adoption in the Nigerian freight logistics sector. The modeling framework provides a reliable process of identifying the critical factors and provides management with insights on what to consider ensuring the actual application of blockchains. The research implications are provided in this study to assist freight logistics professionals to effectively adopt blockchain technologies for financial transparency and operational efficiency.

2.1 Identification of blockchain adoption factors

The factors that influence the adoption of blockchain technologies in the freight logistics sector have been collated from review of available published literature and responses from two academics with over 20 years of experience and two consultants with over 15 years consulting experience in the Nigerian's freight logistics sector. The theoretical framework developed in this study focuses on technological, organizational and external environmental (institutional) main contexts that significantly influence the adoption of blockchain technologies in the freight logistics sector (see Table 1).

Table 1 A theoretical framework on the blockchain adoption factors in the freight logistics industry

Dimensions	Factors	References
Technological (TF)	Availability of specific blockchain tools (TF1)	Alharti et al, 2017; Brock and Khan, 2017; Hughes et al, 2019; Ksetri, 2018;
	Infrastructural facility (TF2)	Kuo and Smith, 2018; Lian et al, 2014;

	Complexity (TF3)	Moktadir et al, 2019; Pacheco et al,
	Ease of being tried and observed (TF4)	2018; Queiroz and Wamba, 2019; Shin,
	Perceived benefits (TF5)	2016; Wang et al, 2019
	Compatibility (TF6)	
	Security and privacy (TF7)	
Organizational (OF)	Presence of training facilities (OF1)	Brilliantova and Thurner, 2019; Chen et
	Top management support (OF2)	al, 2019; Hughes et al, 2019; Ksetri,
	Firm size (OF3)	2018; Makhdoom et al, 2019; Min, 2019;
	Capability of human resources (OF4)	Montecchi et al, 2019; Morkunas et al,
	Perceived costs of investment (OF5)	2019; Queiroz and Wamba, 2019; Wang
	Organizational culture (OF6)	et al, 2019; Zhao et al, 2019
Institutional (IF)	Government policy and support (IF1)	Angelis and Silva, 2019; Brilliantova
	Competitive pressure (IF2)	and Thurner, 2019; Min, 2019;
	Institutional based trust (IF3)	Montecchi et al, 2019; Morkunas et al,
	Market turbulence (IF4)	2019; Queiroz and Wamba, 2019;
	Stakeholders pressure (IF5)	Schuetz and Venkatesh, 2019; Wang et
		al, 2019

2.1.1. Technological context

This focuses on how technological features can impact the adoption of blockchain technologies in the freight logistics industry. Availability of specific blockchain tools such as smart contracts and Internet of things is a significant factor within the technological context, which entails the development of specific blockchain tools that can facilitate the adoption of blockchain technologies in the freight logistics industry for performance improvements (Ksetri, 2018; Wang et al, 2019). Infrastructural facility is also an important factor that can influence the adoption of blockchains in the freight logistics industry which ensures that present technologies are supported and able to meet current infrastructure requirements (Hughes et al, 2019). Infrastructural facility can have physical aspects such as transport route networks and logistics facilities e.g. delivery centers, origin/ destination facilities, loading/ unloading facilities and software aspects such as traffic management and control. Another factor that relates to the technological context is complexity which defines the attribute of blockchains requiring certain skills to facilitate its adoption. The ease of being tried and observed is an important factor which influences technology adoption even in the case of adopting blockchains in the freight logistics sector (Nilashi et al, 2016). Also, compatibility is an important factor within this context, which can be defined as the ease of integration of blockchain technologies on relevant platforms in the freight logistics sector (Schuetz and Venkatesh, 2019). Incompatibility may lead to costly and time consuming processes and cause disruption of the freight logistics supply chain (Rahman et al, 2019). The perceived benefits of blockchain is another important factor in this context which defines the expected value that blockchain technologies can add to the logistics industry (Queiroz and Wamba, 2019). Blockchain- based peer- to- peer architecture have perceived benefit of added value when compared with traditional centralized systems in the freight logistics firms (Drescher, 2017). The freight logistics industry can benefit

from the automation of blockchain specific to the smart contracts (Hughes et al, 2019). Additionally, security and privacy of information is a critical factor within the technological context which ensures that information shared is essentially secure to avoid manipulation during adoption of blockchain technologies in the freight logistics sector.

2.1.2. Organizational context

The organizational context describes the attributes, characteristics and resources of the freight logistics industry that can either facilitate or impede the adoption of blockchains. For example, the presence of training facilities is a significant factor within this context, which ensures that suitable training facilities are available for employees to enable adaptation of blockchain technologies within logistics industry (Morkunas et al, 2019). Training of employees in freight logistics firms have firm- specific requirements and is carried out with the aid of relevant facilities (Rivera et al, 2016). Top management support is another influential factor within this context, which is defined as the ability of top managers to provide direction, resources and necessities during and after the acquisitions of blockchain technologies in the freight logistics firm (Queiroz and Wamba, 2019). Firm size which comprises the number of employees within the company and the size of output is another factor which can influence blockchain technology adoption (Nilashi et al, 2016). Large- sized firms can access resources required to change business strategy more easily than small- sized firms (Lian et al, 2014). Hence, large- sized freight logistics firms can obtain more resources to adopt blockchains in their business operations for increased competitiveness. Moreover, small- sized firms are usually reluctant to embark on new business operations and hesitate to provide training for their employees due to perceived risks (Morgan, 2012). Also, organizational culture comprising of the pattern of people's behaviors and practices within the freight logistics firm is a significant factor which can influence the adoption of blockchains for performance improvements (Schuetz and Venkatesh, 2019). Organizational culture affects how firms respond to external pressures and makes strategic business decisions (Dubey et al, 2019). This means that when freight logistics firms consider adopting blockchains, their decisions are usually based on the unique set of their own organizational characteristics (Dai et al, 2018). Additionally, perceived costs of investment which entails the availability of funding to carter for the huge capital investment during the development of blockchain tools in the freight logistics industry is also influential within this context (Brilliantova and Thurner, 2019). Capability of human resources is also a critical factor within this context, which ensures that freight logistics professionals are skilled to ensure efficiency of blockchain technologies (Min, 2019).

2.1.3. External environmental context

This denotes factors that relates to the business operating domain including government policies, competitive pressure, institutional based trust, market turbulence and stakeholders' pressure. Competitive pressure is an important factor which relates to the external environment of the freight logistics industry and can be defined as the incessant urge among logistics firms to demonstrate competence to stakeholders or investors (Angelis and Silva, 2019). Competition and opportunities in the era of global trade,

investment and outsourcing have induced transport and logistics companies to look for ways to grow and improve their competitive advantage (Nguyen, 2013). Also, government policy and support is an influential factor within this context and entails the ability of relevant government agencies to provide aids and enact rules and regulations to encourage blockchain adoption in the logistics industry (Montecchi et al, 2019). Institutional based trust is another critical factor within this context, which can be defined as the acceptability of blockchain technologies by the external environment of the freight logistics industry. This is because trust suggests that customers are confident that the freight logistics firms will operate in a reliable, transparent and truthful manner, thereby facilitating the adoption of blockchains (Huo et al, 2015). In addition, stakeholder pressure is a significant factor which relates to the external environment that details the high and persistent requirements of various stakeholders or investors in the freight logistics sector (Brilliantova and Thurner, 2019). Firms usually act and respond differently to market pressures on the adoption of innovation (Dai et al, 2018). Freight logistics firms struggle to understand changing market trends usually driven by intense competition and unpredictable timing of technological advances necessitating for ensuring ways to safeguard their ideas (Wang et al, 2015). Hence, market turbulence which entails the uncertainty or volatility of incurring logistics services can influence the adoption of blockchains in the freight logistics sector (Wang et al, 2019).

2.2 Application of ANP in the logistics sector

This study applies the Analytic Network Process (ANP) to investigate the actual application of blockchain technologies in the Nigerian freight logistics industry. The ANP is an effective modeling technique whose feedback approach replaces hierarchies with networks in which the relationships between levels are not easily represented as higher or lower, dominant or subordinate, direct or indirect (Tadic et al, 2014). Many authors have employed the ANP to solve various problems in the freight logistics supply chain field and have derived effective solutions in such circumstances. Table 2 shows some of the application of the ANP modeling technique by different authors to proffer solutions to technology adoption in various industrial sectors. Currently, it is evident from available published literature that no study has investigated the factors that influence the adoption of blockchain technologies in the freight logistics industry and applied the ANP modeling technique. This study makes contributions in this direction.

Table 2 Application of Analytic Network Process methodology

Authors	Nature of contribution
Kengpol and Tuominen, 2006	Evaluation of information technology for logistics firms
Tuzkaya and Onut, 2008	Analyzing alternative freight transport modes
Hallikainen et al, 2009	Evaluating ERP implementation sequence in a manufacturing company
Kuo and Liang, 2011	Selection of distribution locations by freight logistics managers
Liou et al, 2011	Selection of strategic alliance partners in the air logistics sector
Onut et al, 2011	Evaluating alternative container sea ports in the freight logistics sector
Ordoobadi, 2012	Selection of a new technology of a manufacturing company
Shieh et al, 2014	Adoption of mobile computing
Tadic et al, 2014	Concept selection for freight logistics in a city

Fu et al, 2015	Adoption of RFID in the logistics industry
Lam, 2015	Designing a sustainable supply chain in the maritime logistics industry
Lam and Lai, 2015	Developing environmental sustainability in freight logistics operations
Nilashi et al, 2016	Adoption of hospital information system
Ozceylan et al, 2016	Evaluation of freight villages in the logistics sector
Dalvi- Esfahani et al, 2017	Adoption of Green information technology/ information system
Priyadarshinee et al, 2017	Adoption of cloud computing in Indian SMEs
Xia et al, 2017	Technology adoption in supply chain
Pineda et al, 2018	Improving the operational and financial performance of air logistics sector

3   Research methodology

The multi-case research approach is adopted in this study to gain insight into the subject of investigation. Many researchers including Lee, 2009 and Seuring, 2008 have utilized this approach to investigate various subjects using contextual data to support the investigation of specific phenomenon (Barratt et al., 2010).

Freight logistics industry's blockchain adoption factors are multi-criteria by concept. Evaluating this multi-criteria framework using multi-criteria decision-making/analysis (MCDM/A) methodology within a multi-case study setting can be beneficial. The analytical network process (ANP) is adopted and used in this case. We now provide some background discussions on some MCDM/A tools in section 3.1 and further provide some motivation for adopting and using the ANP methodological tool for this study in section 3.2.

3.1 Multi- criteria decision making/ analysis (MCDM/A) methodologies

The multiple nature of factors influencing blockchain adoption in the freight logistics industry makes it a multi-criteria decision problem. It is therefore necessary to determine each factor's relative impact on the decision problem. One way of doing this is by using multi-criteria decision-making techniques. Generally, multi-criteria decision methodologies are gaining popularity in organizational and supply chain strategic decision making and analysis. These methods provide solutions to increasingly complex problems involving conflicting and multiple objectives requiring some trade-offs. There exist numerous multi-criteria decision-making/analysis (MCDM/A) methods for supporting management decisions including ANP, AHP, Scoring Models, Outranking, MAUT, DEA, Goal Program, Simulation, Expert Systems, etc. Each of these methods has its own characteristics and strengths (Mardani et al., 2015) but also share some common characteristics such as conflict among criteria and incomparable units (Pohekar and Ramachandran, 2004). AHP, developed by Saaty (2008), happens to be one of the heavily used MCDM/A in the literature (see Mardani et al., 2015).

The AHP method decomposes and structures a complex problem into a hierarchy with the goal at the top, criteria and sub-criteria at levels and sub-levels respectively and the alternatives at the bottom (Wang et al. 2009). Elements at each given level, using a scale, are pairwise compared to evaluate their relative importance with respect to each of the elements of immediate higher level (outer dependencies). One shortfall of this method is that, it considers criteria as independent whilst in real-world situation,

criteria interact with each other and so, these interactions must be considered when modelling decision problem. Another MCDM/A methodology is the Scoring Models which are generally praised for their popularity and has been revealed to be capable of producing a strategically aligned portfolio that reflects the business's spending priorities and yield effective decisions resulting in high value projects (Cooper, 2003). The outranking approaches comprise of no underlying aggregative value function and the output of an analysis is not a value for each alternative but an outranking relation on the set of alternatives. An alternative *a* is said to outrank another alternative *b* if, taking account of all available information regarding the problem and the decision maker's preferences, there is a strong enough argument to support the conclusion that *a* is at least as good as *b* and no strong argument to the contrary (Belton and Stewart, 2002). Outranking approaches such as ELECTRE and PROMETHEE have been applied by various researchers for effective decision- making (Herva and Roca, 2013; Huang et al, 2011).

Multi attribute utility theory (MAUT), also part of the MCDM/A, is a performance aggregation-based approach, which requires the identification of utility functions and weights for each attribute that can be assembled in a unique synthesizing criterion, with the additive and multiplicative aggregations being the most widely applied (Cinelli et al, 2014). DEA is another MCDM that can assess the performance (efficiency) of a set of homogenous decision- making units (DMUs), with multiple inputs and multiple outputs, and classifies DMUs using linear programming into two mutually exclusives and collectively exhaustive groups and measures the performance score of each DMU (Khezrimotlagh et al, 2019). Although, DEA can assess the efficiency of organizations during benchmarking studies by classifying them as efficient and inefficient, its most important problem is giving the same efficiency score of one to all the efficient units (Blas et al, 2018). Goal programming (GP), also part of the MCDM/A group can be thought of as an extension or generalization of linear programming to handle multiple and conflicting objectives problem solution (Huang et al, 2017; Jones and Tamiz, 2010). Compared to other models, GP initially, sets a value for each goal or target, then these values and their deviation variables are constraints after which solving the GP model can enable the relative optimal outcome to be obtained (Huang et al, 2017). However, the lack of an effective way to give suitable weights remains the main pitfall of the GP approach (Chen and Xu, 2012). Also, expert system can help in reducing the time it takes to solve MCDM problems and address concerns more efficiently by combining machine intelligences and expert knowledge to reduce human error and bias and effectively increase accuracy (Gu et al, 2019). Likewise, simulations are decision-based support systems that not only find optimal option but rather options that are robust, i.e. less sensitive to uncertainties (Chandrasekaran and Goldman, 2007). But, then it is usually impossible or highly improbable to build simulations models that give an exact prediction of outcomes for running different options (Schubert et al, 2015).

The analytic network process (ANP) method as a part of the MCDM/A family, is an extension of the AHP (Saaty, 1996). Unlike the AHP that follows strict hierarchy network, the ANP approach considers both the hierarchy – relationships of lower level on upper level (outer dependencies) and interrelationships among the levels and

elements (Aragonés-Beltrán et al., 2014; Meade and Sarkis, 1998, Wong et al., 2014). In this study, the ANP is applied to help prioritize the factors that influence the adoption of blockchains in the Nigerian freight logistics industry. More details of the ANP method in comparison with the AHP and the reason it is more suitable for this study is discussed in the next section.

3.2 Motivation for the selection and use of ANP methodology

Blockchain adoption factors evaluation and prioritization is a strategic and multi-criteria task involving conflicting choices and therefore requires the support of a multi-criteria decision analytical (MCDA) models. Many MCDAs have been used by researchers to support similar decision making including AHP (see Vaidya and Kumar, 2006; Wang et al., 2018), BWM (see Kusi-Sarpong et al., 2019; Orji et al., 2020; Kumar et al., 2020), ANP (see Büyüközkan and Güleryüz, 2016; Chemweno et al., 2015; Hallikainen, 2009; Lam, 2015; Zhu et al, 2018), DEMATEL (see Si et al., 2018; Büyüközkan and Güleryüz, 2016; Ordoobadi, 2012; Wu et al., 2015), etc. Since the factors aiding blockchain adoption are not independent but rather interact with each other, the evaluation and prioritization decision-making task should also consider all these interactions. These interactions come from both within the elements of a cluster and between clusters/decision levels. AHP happens to be one of the most heavily used MCDA methodologies among the many tools used for aiding such similar strategic and multi-criteria task (Mardani et al., 2015) but unfortunately the method falls short for this study's evaluation. The reason being that, AHP uses a strict hierarchy network considering only interrelationships between the clusters/decision levels without considering the interdependencies within the elements/clusters (Kusi-Sarpong et al., 2016). DEMATEL, another MCDA tool that have seen some significant use in the literature for such similar evaluation also fall short for this task. DEMATEL only consider the interdependencies within the elements/clusters without capturing the interrelationships between clusters/decision levels (Miao et al., 2014; Liu et al., 2014). ANP method, an extension of the AHP method (Saaty, 1996), is more capable of capturing and modelling the interrelationships among the decision levels/between clusters and the elements within clusters (Meade and Sarkis, 1998; Wong et al., 2014; Zaim et al., 2014), which this study is involved, making it more suitable for providing a comprehensive structure for the evaluation of the blockchain adoption factors task (Zhu et al., 2018). The advantage of the ANP methodology is in its comprehensiveness (considering interdependencies within and between elements, and assesses the multi-directionality of the elements), which motivated its selection and use in this study.

The proposed research modeling framework consisting of the steps of the ANP is shown in Fig. 1 and further explained in section 3.3.
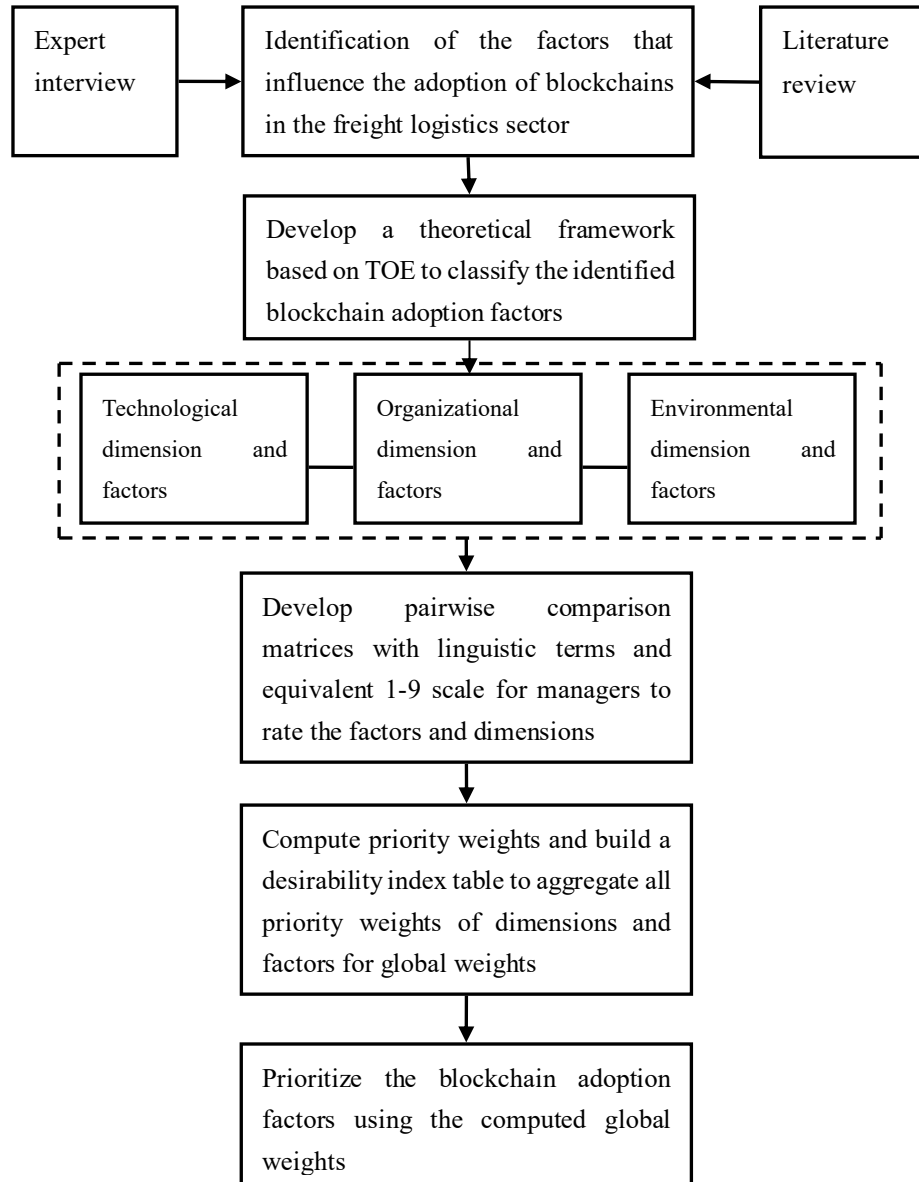
```
┌──────────┐     ┌─────────────────────────────┐     ┌──────────┐
│ Expert   │────▶│ Identification of the factors │◀────│ Literature│
│ interview│     │ that influence the adoption   │     │ review   │
└──────────┘     │ of blockchains in the freight │     └──────────┘
                 │ logistics sector              │
                 └─────────────────────────────┘
                               │
                               ▼
                 ┌─────────────────────────────┐
                 │ Develop a theoretical        │
                 │ framework based on TOE to    │
                 │ classify the identified      │
                 │ blockchain adoption factors  │
                 └─────────────────────────────┘
                               │
                               ▼
      ┌─────────────────────────────────────────────────┐
      ┊ ┌──────────────┐  ┌──────────────┐  ┌──────────┐ ┊
      ┊ │ Technological │  │ Organizational│  │Environ-  │ ┊
      ┊ │ dimension and │──│ dimension and │──│mental    │ ┊
      ┊ │ factors       │  │ factors       │  │dimension │ ┊
      ┊ └──────────────┘  └──────────────┘  │and factors│ ┊
      └─────────────────────────────────────────────────┘
                               │
                               ▼
                 ┌─────────────────────────────┐
                 │ Develop pairwise comparison  │
                 │ matrices with linguistic     │
                 │ terms and equivalent 1-9     │
                 │ scale for managers to rate   │
                 │ the factors and dimensions   │
                 └─────────────────────────────┘
                               │
                               ▼
                 ┌─────────────────────────────┐
                 │ Compute priority weights and │
                 │ build a desirability index   │
                 │ table to aggregate all       │
                 │ priority weights of          │
                 │ dimensions and factors for   │
                 │ global weights               │
                 └─────────────────────────────┘
                               │
                               ▼
                 ┌─────────────────────────────┐
                 │ Prioritize the blockchain    │
                 │ adoption factors using the   │
                 │ computed global weights      │
                 └─────────────────────────────┘
```

Fig. 1   Research modeling framework

3.3 Analytic Network Process (ANP)

The ANP is a multi- criteria decision making model (MCDM) that allows for complex interrelationships among decision levels and attributes unlike its AHP counterpart that is used for a unidirectional hierarchical AHP relationship (Nilashi et al, 2016). Generally, AHP structures the problem as a hierarchy while ANP structures the goal, factors and sub- factors and alternatives which constitutes a problem as nodes on a network. Hence, the ANP can illustrate interrelationships/ interdependence by allowing feedback connections and loops within and between nodes. The ANP procedure comprises of pairwise comparisons between the sub- factors and each alternative and further pairwise comparisons between the alternatives and each sub-factor. The steps involved in the ANP modeling technique that is applied in this study are presented below:

Step 1: Finalization of identified blockchain adoption factors

Here, 20 potential influential factors to blockchain adoption in the freight logistics sector were initially identified through extensive literature review and further refined (deleted 3 factors and added 1 factor) to arrive at 18 factors.

Step 2: Formation of the ANP model

The ANP model was formed using the main contexts and factors that were finalized in the first step.

Step 3: Design of pairwise comparison matrices

In this step, the decision makers who are managers in the freight logistics industry complete the pairwise comparisons of the dimensions and factors using a linguistic scale shown in Table 4. As an example of a question set, pairwise comparisons of main contexts with respective to the goal (adoption of blockchains in freight logistics industry) as part of a survey questionnaire is given below. A typical question asked in this context is, "With respect to the adoption of blockchains in freight logistics industry, how much more important is a main context in row *I* as compared to another main context in column *J* using the scale 1-9 as shown in Table 3. Please do not fill in boxes with *X or 1*, but do fill in empty boxes to answer the questions".

Table 3 An example question set matrix for main context comparisons with respect to goal (hierarchy) as part of a survey questionnaire

With respect to Adoption of Blockchain in Freight Logistics Industry		Main context in Column *J*		
		TF	OF	IF
Main context in Row *I*	TF	1		
	OF	X	1	
	IF	X	X	1

TF: Technological Main context, **OF**: Organizational Main context, **IF**: Institutional Main context

An exemplary question that was presented to informants from the above case was, "when considering blockchain adoption in your freight logistics company, how much more importance will you give to TF (Technology Factor) compared to OF (Organizational Factor) using a scale of 1-9, where 1 means equally important and 9 means extremely more important". So, if an informant indicates for example a "9", it means that, this informant considers "Technology Factor" to be extremely more important over "Organizational Factor" when considering blockchain adoption in their freight logistics company. Alternatively, if an informant indicates a "1", it means that, this informant considers both "Technology Factor" and "Organizational Factor" as equally important when considering blockchain adoption in their freight logistics company.

Step 4: Compute local priority weight of factors and form un- weighted and weighted (limiting) super- matrix.

There are several proposed algorithms for aiding the determination of the local priority weights (Saaty & Takizawa, 1986; Saaty & Hu, 1998; Meade and Sarkis, 1998; Saaty, 2004)**.** Also, there are many online-based multi-criteria decision-support softwares that have been designed to aid in the computation of these relative importance weights such

as Super-Decisions (http://www.superdecisions.com/) (Kusi-Sarpong et al., 2016) and Web-HIPRE3+ (http://hipre.aalto.fi/) (Mustajoki & Hamalainen, 2000).

The obtained relative importance weights of the various pair-wise comparisons matrices are used to construct the un-weighted super-matrix. The un-weighted super-matrix is formed using the various sub-matrices modeling the factor interrelationships as a partitioned matrix. The un-weighted super-matrix is further made column stochastic to achieve weighted super-matrix. The weighted super-matrix is then raised to the power of 2^z, where z is a large arbitrary number to converge and arrive at a long-term stable set of weights.

Table 4 Linguistic terms and equivalent 1-9 scale for pairwise comparisons in ANP

Linguistic Terms	Ratings
Equally important	1
Equal to moderately more important	2
Moderately more important	3
Moderately to strongly more important	4
Strongly more important	5
Strong to very strongly more important	6
Very strongly more important	7
Very strongly to extremely more important	8
Extremely more important	9

Step 5: Determine the global weights of factors and factors importance

The final weights of the blockchain adoption factors are determined using a desirability index table to aggregates main contexts and factors priority weights (local weights when separate) into a unified or single numeric score (global weights when aggregated). The higher the index value, the more important the factor. There are many aggregation models that have been used in the literature. However, this study adopts the multiplicative aggregation model since it is the most popular and dominated approach used in the literature (see Kusi-Sarpong et al., 2016), hence deems reliable.

The global relative importance desirability indices i of the blockchain adoption factor k is denoted as i_k and are determined for each factor using equation (1).

$$i_k = P_j^D P_j^I A_{kj}^D A_{kj}^I \qquad (1)$$

P_j^D represents the relative importance weight for main context j of goal for the hierarchical (D) relationship.

P_j^I represents the stable relative importance weight for the main context j of goal for the interdependent (I) relationship.

A_{kj}^D represents the relative importance weight for factor k of main context j for the hierarchical (D) relationship.

A_{kj}^I represents the stable relative importance weight of factor k of main context j for interdependency (I) relationship.

J is the index set for the main context where $j = 1, 2, \& 3$.

K is the index set for the factors where $k = 1 \ldots 18$.

i is the index for the global relative importance desirability indices

3.4 Data collection

The data for this study was sourced through questionnaires distributed to managers who were deemed knowledgeable to effectively complete them (purposive) having a minimum of five years of experience in the Nigeria freight logistics sector (De et al, 2018). Additionally, the managers were designated mid- level and above ranking executives, thus their responses sufficiently represented the freight logistics sector (Nilashi et al, 2016). Two of the fastest growing Nigerian freight logistics providers were used as multi-case in this study to allow for thorough investigation of the research problem and also allow for comprehensive model- building and results (Kumar and Rodrigues, 2018). The freight logistics firms considered in this study are similar in their commitment to adopt digital innovations particularly blockchains in order to encourage financial transparency and connect to the global supply chain networks. The selected firms are also similar in terms of their firm size, logistics profile and functional teams. Managers who are involved in the company's strategic decisions concerning financial operations and acquisition of digital innovations in the selected logistics companies were approached to participate in the survey and were also assured of the confidentiality of their responses if they consent to participate. 20 managers consented to participate in the survey, 10 each from the two selected Nigerian freight logistics companies. The questionnaire which was designed with four parts including the demographic information of the respondents, the directions to complete the questionnaire, the main question sets and the definitions of the identified blockchain adoption factors, were emailed to the managers who consented to participate in the study. The main questionnaire questions was aimed at obtaining the responses to a number of pair-wise comparisons of the blockchain factors in the freight logistics sector for determining factors indices for prioritization.

Several steps were taken in the course of this research to maximize response rate while minimizing the response bias amongst the managers in the selected freight logistics firms. For instance, a pilot- test involving two researchers and two information technology managers in the freight logistics industry was initially carried out to ensure that the questionnaire was clear and easy to understand, and any observations and comments used to improve to design of the questionnaire. The two researchers who participated in the pilot- test hold PhD degrees and have over twenty years of research experience in supply chain management. On the other hand, the information technology managers that participated in the pilot- test have over fifteen years of experience in the procurement of digital innovations in the freight logistics sector. In addition, phone conversations, email reminders and personal visits were employed as modes to follow-up on the emailed questionnaires as followed in Feng et al. (2018). A total of 15 completed questionnaires were received out of the 20 questionnaires that were emailed

to the managers, with a response rate of 75%. The demographic summary of the respondents is shown in Table 5.

The ANP can provide reliable results with a small sample size, hence the number of completed questionnaires was deemed sufficient to provide accurate results in this study (Farias et al, 2019; Hosseini et al, 2018). Furthermore, the non- response bias and the ability to generalize study results was examined using a t- test involving checking for any huge difference in the demographic characteristics particularly of the number of employees and revenue costs between the first and second half of the time period (McGovern et al, 2018). The t- test results indicate no significant differences ($p < 0.05$) between the checked demographic characteristics, hence proving the results to be unbiased.

Table 5 Demographics summary of respondents

Characteristic	Number of respondents	Percentage of samples (%)
Age		
25- 39	7	46.6
40-55	8	53.4
Gender		
Male	11	73.3
Female	4	26.7
Education		
Bachelors degree	3	20
Postgraduate degree	12	80
Years of experience		
5- 10	10	66.7
Above 10	5	33.3
Roles		
Director, Strategy	2	13.4
Information Technology manager	5	33.3
Financial manager	5	33.3
General manager	3	20
Annual revenue (million naira)		
5- 99	10	66.7
100- 500	5	33.3
Firm size (number of employees)		
20- 99	10	66.7
100- 200	5	33.3

4   Results and discussion

As the first step of the Analytic Network Process (ANP), the factors that influence the adoption of blockchains in the freight logistics industry were identified from literature review. The identified factors were further refined and classified into three groups/contexts based the TOE theory and the complementary views of two academics with over 20 years of experience and two consultants with over 15 years consulting experience who are currently consulting for the two Nigerian freight logistics

companies considered in this study on blockchain adoption initiatives. Then, an ANP model was formed using the finalized blockchain adoption factors and their respective dimensions. Fig. 2 shows the formed ANP model which comprises of three stages.
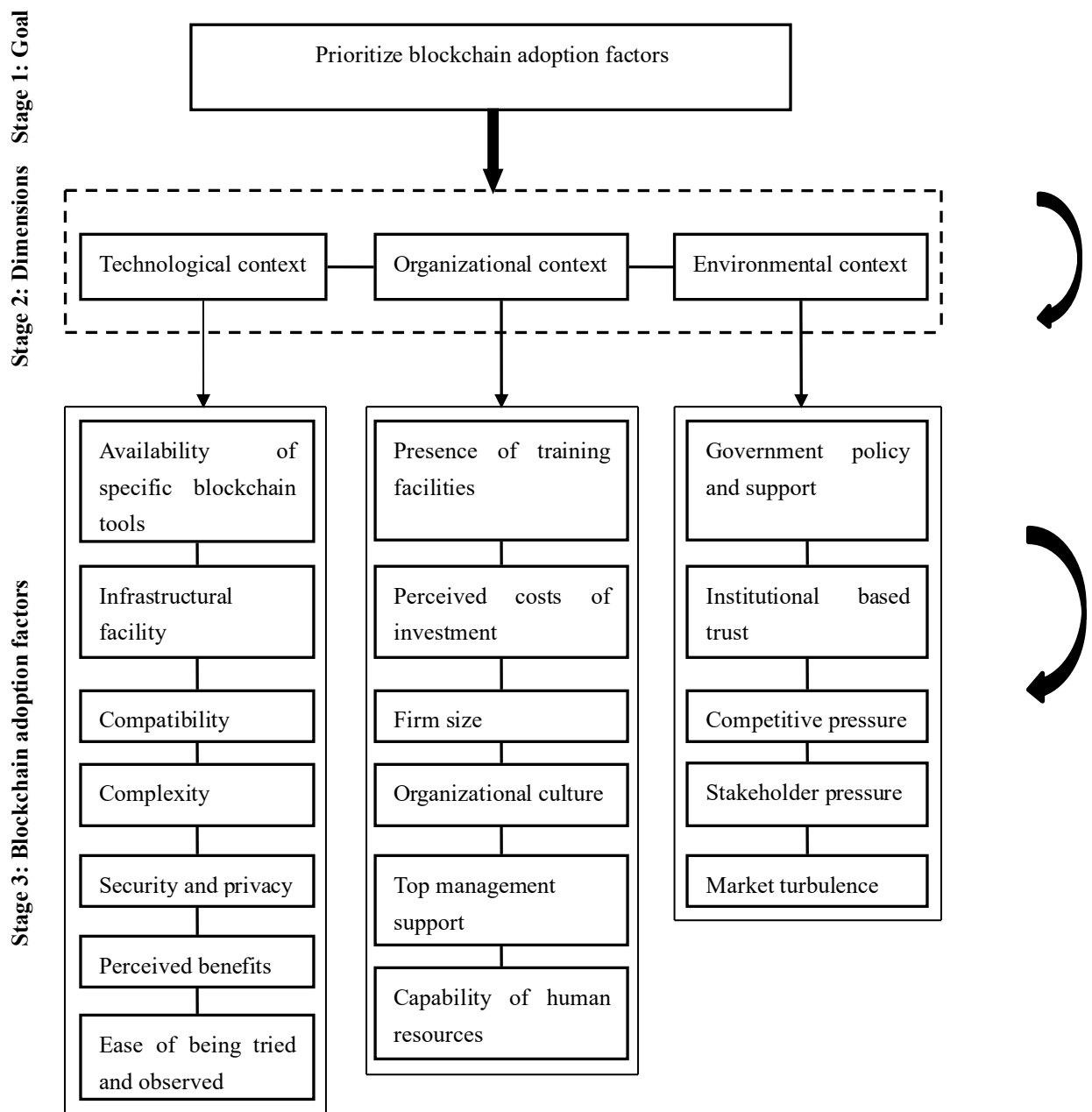

Fig. 2   ANP model to determine significant factor for blockchain adoption

The goal of the ANP model which is to help prioritize the factors that influence the adoption of blockchain, is presented in the first stage. In the second and third stage the dimensions and blockchain adoption factors are presented respectively. The hierarchical (comparison of dimensions with respect to the goal) and interdependence between the dimensions are considered in Stage 2 while the hierarchical (comparison of factors with respect to immediate top dimensions) and interrelationships between the blockchain adoption factors clusters are considered in Stage 3 of the developed ANP model.

4.1 Calculation of the weights of the blockchain adoption factors

From Figure 2, all the dimensions were compared with respect to the goal, and the set of factors under each dimension were also compared with respect to each of the main contexts for the hierarchical comparisons. The responses received from the 15 managers for all these 4 sets of comparisons were computed using super-decisions software for individual manager's response and then averaged. These averaged or final hierarchical weights for all the comparisons can be found in column 18 of Tables 6 -9 (Appendices 1-4). These were then followed by the comparison of the dimensions among themselves (interdependencies) and the factors under each dimension among themselves (interdependencies). Again, responses received from all the 15 managers were computed using the super-decisions software and outputs averaged and put together to build an initial super-matrix as shown in Table 10 (Appendix 5). This initial super-matrix is then raised to a large arbitrary number to converge and arrive at a long-term stable set of weights. In this study, the super-matrix converged at z=100 and this can be found in Table 11 (see Appendix 6). Finally, we aggregated all the dimensions and factors weights (local weights) into a single numeric score (global weights) using equation 1 and these can be found in column 8 of Table 12 and further normalized to take away the exponential elements from the score which can then be seen in column 9 of Table 12 and ranked in column 10.

Table 12 The Aggregated Desirability index Table

Goal	Dimension	P_j^D	P_j^I	Factors	A_{kj}^D	A_{kj}^I	i_k	Normalized i_k	Rank
Prioritization of blockchain adoption factors	TF			*TF1*	*0.2253125*	*0.333746*	*0.0165412*	*0.4936633*	*1*
				TF2	*0.100703*	*0.2235725*	*0.0049525*	*0.1478054*	*2*
		0.6719	*0.3273938*	*TF3*	*0.0569793*	*0.1393006*	*0.001746*	*0.0521074*	*4*
				TF4	0.0472732	0.1208349	0.0012565	0.0375005	7
				TF5	0.0320004	0.0826455	0.0005818	0.0173622	9
				TF6	0.0229538	0.0587885	0.0002968	0.0088588	11
				TF7	0.0164509	0.0410926	0.0001487	0.0044379	15
	OF			*OF1*	*0.1524124*	*0.2657414*	*0.0015688*	*0.0468213*	*5*
				OF2	0.1486249	0.2708373	0.0015592	0.0465333	6
		0.1310	*0.2957893*	OF3	0.0714264	0.166412	0.0004604	0.0137406	10
				OF4	0.0548997	0.1277043	0.0002716	0.0081048	12
				OF5	0.050557	0.1174064	0.0002299	0.0068618	13
				OF6	0.0220795	0.051932	4.441E-05	0.0013255	17
	IF			*IF1*	*0.2894125*	*0.3932298*	*0.0027069*	*0.0807852*	*3*
				IF2	0.1186047	0.3167783	0.0008936	0.0266702	8
		0.1972	*0.1206349*	IF3	0.0464933	0.1510367	0.000167	0.0049847	14
				IF4	0.0290488	0.0910973	6.294E-05	0.0018785	16
				IF5	0.0164406	0.047858	1.871E-05	0.0005585	18

4.2 Ranking the dimensions of the blockchain adoption factors

The results indicate that the factors under the technological main context are the major factors which influence the adoption of blockchain technologies in the freight logistics industry in Nigeria. These are followed by institutional factors and lastly organizational factors. The technological factors are highly critical (Yadegaridehkordi

et al, 2018) and efforts should be made to ensure they are integrated to enhance the adoption process of blockchain technologies in the freight logistics sector. Technological- related factors which encompass compatibility issues between digital innovations, standards, security and data protection have been confirmed in previous studies to be critical in implementing digital innovations (Giusti et al, 2019; Harris et al, 2015). The second main context is institutional, which is associated with the external environment of the company, will also aid the freight logistics sector in the adoption of blockchain technologies. The Nigerian freight logistics sector is in dire need of policies to harmonize regulations and stipulate standards to encourage the adoption of blockchain technologies. The organizational factors have the least influence on the adoption of blockchain technologies in the freight logistics sector.

4.3 Global rank of individual factors

The results indicate the global ranking of each respective factor that influences blockchain adoption in freight logistics industry as shown in column 10 of Table 12. The top four ranked factors belong to the technological and institutional main contexts except the organizational main context. This ranking shows that the adoption of blockchain technologies in the freight logistics sector is highly influenced by the availability of specific blockchain tools. The adoption process of digital innovations requires specific tools to ensure that it is a successful venture. Infrastructural facility is also a critical factor the influence the adoption of blockchain technologies in the freight logistics sector. Companies can effectively embark on acquiring and using blockchain technologies in their operations when there is sufficient presence of infrastructural facility. Other highly influential factors are government policy and support and complexity.

4.4 Rank of individual factors in each dimension

Technological factors: The evaluation of the factors that influence the adoption of blockchain technologies shows that the availability of specific blockchain tools has the highest rank. The next ranked in this main context is infrastructural facility which entails that adequate facilities should be made available to ensure that infrastructural requirements are met (Alharthi et al, 2017; Pereira et al, 2019). Freight logistics firms should endeavor that facilities such as transport route networks, traffic management and control, conveyance networks, are adequately provided to aid the blockchain adoption process. Complexity is also an influential factor within this technological context, which supports that, technology should be simple and easy to manipulate to enhance its adoption in the industrial sector (Hughes et al, 2019; Yadegaridehkordi et al, 2018). Blockchains require complex integration efforts and this may encourage freight logistics firms to develop their own blockchain system without being designed for interoperability but to match the needs of limited number of actors (Dobrovnik et al, 2018). The next ranked within this context is ease of being tried and observed. Although this factor does not rank amongst the top three factors in the global ranking, it is highly essential that innovations should possess the attribute of being easily experimented with and learnt by the potential adopters. Currently, blockchains are not considered easy to try and observe due to the lack of standardization of blockchain architectures. Perceived benefits of the adoption of blockchain technologies in the freight logistics sector is also

another influential factor under the technological main context. An in- depth understanding of the numerous benefits to adopting blockchain technologies can encourage firms to acquire such digital innovations. Developers are expected to promote the potential benefits of blockchain technology such as how this digital innovation can be utilized based on the available organization resources and characteristics to increase productivity. For instance, blockchains can enable freight logistics firms to reduce workload and ensure traceability, while increasing efficiency, reducing cost and securing the confidence of customers on the high quality of products and services (Helo and Hao, 2019). In addition, blockchains can assist firms to add new partners such as technology companies that develop application programming interfaces and software development kits , and maintain the transactional algorithms while eliminating the intermediation of intermediaries (e.g. banks) (Morkunas et al, 2019). Other factors which are lower in influence include compatibility and security and privacy.

Institutional factors: The institutional factors are ranked second in influencing the freight logistics firm to successfully adopt blockchain technologies. Among these, government policy and support occupies top rank and is a key factor which plays a huge role in the adoption process of blockchain. Government policy and support have been included in prior literature as influential factors that influence the adoption of innovations (Basole et al, 2013; Tutusaus et al, 2018). Presently, government laws are still unclear about the use of blockchains, and adverse policies issued against Bitcoin is a concern for markets and organizations that can affect broader usage of blockchain technology (Saberi et al, 2019). Regulatory bodies like government agencies and NGOs should enact policies and support to aid the adoption of blockchains. Competitive pressure is the next important factor, as the firms can acquire emerging technologies to be on par with other firms and attract more customers for sustained profitability. Competitive pressure in each logistics supply chain can restrict freight logistics firms from leaking their information through the use of blockchains to avoid undermining firm's competitive advantage (Pham et al, 2019). Institutional- based trust is next in rank and has a major influence on the adoption of blockchain technologies in the freight logistics industry. Market turbulence has a low influence on the adoption of blockchain technologies in the freight logistics industry and occupies the fourth position within the institutional context. Market turbulence arises in service- based settings such as in freight logistics sector in which the dynamism and complexity of the consumer, competitive, social, political, legal and technological contexts encourage continuous innovation in response to changes (Chen et al, 2016). The last factor within this main context is the stakeholder pressure.

Organizational factors: Amongst the factors within the organizational context, the presence of training facilities was ranked the highest. This factor is extremely important for the Nigerian freight logistics sector as this can influence the adoption of digital innovations. The successful adoption of blockchain technologies is dependent on the availability of suitable facilities to carry out training activities for the employees of the freight logistics firms. This is because blockchains require specialized developers and many companies including freight logistics firms still have little knowledge about

blockchain and there are still not many ready-to- use blockchain applications (Helo and Hao, 2019). Top management support is ranked second and is a critical factor that influences the adoption of blockchain technologies in the freight logistics sector. Top managers in the freight logistics industry can actively participate to ensure that blockchain technologies are effectively adopted by providing sufficient direction and necessities during and after the adoption process (Clohessy and Acton, 2019). This is because the top management team serves as an organization's primary interface to stakeholders and rivals and thus top management support influences organizational decision outcomes (Dai et al, 2014). Firm size is ranked third in this main context and has a huge influence on the adoption of blockchain in the freight logistics industry. Large- sized firms in the freight logistics sector can apply and adopt more sophisticated information technologies in their operations to increase competitive advantage (Clohessy and Acton, 2019; Haan et al, 2007). The next two factors include capability of human resources and perceived costs of investment which indicates that the availability of huge capital for the enormous investment in blockchain can influence its adoption. The least ranked factor in this main context is organizational culture.

4.5 Research implications

This study makes significant contributions. Studies that investigate the factors that influence the adoption of blockchain technologies in the freight logistics industry are evidently scarce in the available published literature. According to some authors (Ramanathan et al, 2014; Tob- Ogu et al, 2018), the freight logistics industry still struggle with technology adoption challenges and lack the practical insights on the significant factors that can aid the adoption of blockchains. Furthermore, blockchain is becoming an important tool in businesses and their supply chains, and can aid in achieving financial transparency and increased cooperation among members. With the successful adoption of blockchains, a conducive and secured environment can be created, whereby information can easily be shared and productivity increased.

There have been some studies on blockchains in supply chain management (Ksetri, 2018; Quieroz and Wamba, 2019; Wang et al, 2019). Nonetheless, those studies neither involve the actual application of blockchain technologies nor consider the freight logistics sector. Hence, this study seeks to provide and inspire a clear perspective on the actual application of blockchains by identifying and analyzing the significant factors that influence its adoption by freight logistics companies in Nigeria. This study also considered relevant main contexts namely technology, organization and external environment relating to blockchain adoption in order to increase the accuracy of the evaluation of the significant adoption factors. This is in line with Nilashi et al (2016) who advocated the need to delve deeper into different relevant characteristics that relate to the technology adoption process, which will lead to increased predictive power in evaluating the organizational adoption process. Our research findings corroborate published literature (Yadegaridehkordi et al, 2018) on the strong effect of technological factors on organizational and environmental factors.

Although, factors within the technological context were found in this study to be more important than organizational and institutional factors, all the factors must be taken into consideration in management decisions for acquisition of digital innovations.

Cross- functional teams involving different managerial categories should be established to oversee the adoption process of blockchains. Also, blockchain service providers should focus more efforts on the top- ranked factors within each context which influence the adoption of blockchains. Freight logistics companies are recommended to develop strategic plans based on the significance of the blockchain adoption factors and their determined factor indices for a successful adoption process. Government agencies are also encouraged to promulgate policies and provide sufficient supportive environment for freight logistics firms to adopt blockchains. Blockchain developers are also encouraged to provide freight logistics firms with specific solutions that are relevant for company decisions to adopt digital innovations. Additionally, they need to ensure that blockchain is adequately promoted by highlighting the benefits in providing financial transparency thereby increasing productivity and competitiveness. To ensure that this is effectively initiated, blockchain providers and vendors are suggested to analyze respective target firms in terms of their current environmental and financial practices in order to efficiently cover the supportive nature of blockchain technologies at the firm and eventually develop a customized promotional plan.

The proposed research modeling approach and findings of the current study can be utilized to offer support to decision making process in the Nigerian context. Some examples could be investing in reaching target market that was not previously accessible, developing new customer segments, removing the hassle of intermediaries during business transactions, etc given the specific operational circumstances peculiar to the Nigerian freight logistics company. The results of this study indicate that the Nigerian freight logistics sector can utilize blockchains to simplify the business process by reducing time delays and bottlenecks during international shipments while providing real- time tracking of services and improving material handling to increase operational efficiency. Also, the high logistics costs of logistics operations in the Nigerian freight logistics firms can be cut down through using smart contracts. This is because freight logistics firms can utilize smart contracts to provide less expensive transactions and deliver considerable savings with regards to operational efficiencies than those completed in traditional settings (Hughes et al, 2019; Morkunas et al, 2019). In addition, smart contracts can be utilized to automatically confirm the fulfillment of a contract and executes the rewarding for the fulfilled services and also refund amounts in the case that certain services differ from the set target (e.g. delayed delivery) can be specified in the smart contract (Meyer et al, 2019).

Regulatory agencies can provide financial incentives to reduce the perceived high costs of investing in blockchain technologies and also enact policies to coordinate regulations and consolidate the legal systems so as to encourage the Nigerian freight logistics firms to adopt blockchains. For instance, regulatory support is improving in the U.S. with legislation been passed to encourage the adoption of blockchain unlike in some countries where regulatory constraints prevent the rollout of smart contracts (Morkunas et al, 2019). In addition, infrastructure facilities such as logistics facilities, transport route networks and traffic management and control should be adequately provided to facilitate the adoption of blockchains in Nigerian freight logistics sector. Moreover, the use of blockchains in Nigerian freight logistics firms can assist in

improving information flow and increasing competitiveness. The results of the analysis indicate that, to make a successful blockchain adoption decision, Nigerian freight logistics companies may want to ensure that blockchain tools such as smart contracts are available and infrastructural facilities are not deficient. Also, relevant government policies to protect firms during innovation adoption decisions should be enacted and financial incentives should be provided to subsidize the costs of blockchains investments. In addition, the freight logistics firms may have to build up enough savings to ensure they avoid relying on external funding sources. Moreover, Nigerian freight logistics firms can utilize the cloud- based implementation templates for blockchains that is offered by Amazon, IBM and Microsoft to reduce the set up cost of blockchain applications.

Thus, with these contributions, the current study makes an effort to provide practical insights and also introduce a new channel for further study in fulfilling the voids regarding the adoption of blockchain technologies in the freight logistics industry in Nigeria and technology adoption literature at large.

5   Conclusion

5.1 Summary

Blockchain is one of the next- generation digital innovations just like internet of things, cloud computing and big data that has attracted worldwide attention in recent years. However, despite the numerous benefits offered by this technology, its adoption remains at the early stage in many industrial sectors, especially in the freight logistics industry. The nexus between the numerous benefits and the lack of expertise is evident in the logistics sector where most managers have little or no knowledge about blockchain and how its application may transform their industry (Dobrovnik et al, 2018). Based on the TOE theoretical framework, this study proposed a new and suitable research framework relevant to the context of Nigerian freight logistics industry in successfully adopting blockchain technologies. This would give a better understanding of the blockchain and address issues concerning its adoption as an outcome in the logistics firm level. Interestingly, the findings of this study presented that the adoption of blockchain technologies in the freight logistics industry particularly in Nigeria is still in the early stage, which shows that there is relatively slow rate of blockchain adoption, especially from emerging economies.

Three major contexts of technology, organization and external environment were highlighted to have critical effect on the overall adoption decision of blockchains. An ANP modeling framework was developed to rank the significant factors within the major contexts that influence the adoption of blockchains. Data was sourced from 15 managers who were involved in their company's decision concerning financial operations and acquisition of digital innovations in the Nigerian freight logistics sector. This study pioneers the application of the ANP modeling technique in exploring blockchain adoption in freight logistics companies from manager's perspective in the literature. The ANP model was applied to determine the factor indices for prioritization. The research results showed that technological factors are the highest influential factors on blockchain adoption compared to organizational and institutional factors. Additionally, among the global ranking of the individual factors in this study, the top

four factors include availability of specific blockchain tools, infrastructural facility, government policy and support and complexity.

The results of this study provide deeper understanding of the critical factors that promote/enable the adoption of blockchain in the freight logistics industry as against previous studies that focused on blockchain adoption from broader supply chains and sustainable supply chains (Azzi et al, 2019; Helo and Hao, 2019; Kamble et al, 2019; Saberi et al., 2019; Yadav and Singh, 2020). Additionally, there have been studies on the adoption of blockchains in the aircraft industry (Mandolla et al, 2019; Vaio and Varriale, 2020), construction industry (Li et al, 2019), steel industry (Yang et al, 2019), chemical industry (Sikorski et al, 2017) and music recording industry (Chalmers et al, 2019). The study introduces freight logistics blockchain critical factors as an important aspect of blockchain technologies adoption. From the TOE theoretical perspective, the adoption of blockchain technologies in the freight logistics sector is influenced by the factors that are related to technology, organization and external environment of the firm. Due to the incessant pressure from customers, regulatory agencies and other stakeholders, freight logistics firms are constantly facing intense competition (König et al., 2019; Mathauer and Hofmann, 2019; Orji et al., 2020), thus there is huge need to incorporate the TOE main contexts when assessing the blockchain adoption factors and to evaluate their relative importance. Using the TOE framework as a backbone, this study posited a new typology of critical factors that influence the successful adoption of blockchain technologies in the freight logistics industry. These constructs may serve as a useful framework for further and deeper theoretical investigations of the critical factors of blockchain technologies adoption in the freight logistics industry, especially from emerging and developing economies.

From a practical/managerial perspective, the results of this study are believed to be able to assist freight logistics industries, blockchain service providers, and government agencies to precisely focus on the highly ranked critical factors inferred from this study in order to successfully adopt of blockchain. Also, managers of the freight logistics industry can apply the sequential implementation path insights of the critical factors to the adoption of blockchain technologies to aid in building effective strategies for increased competitiveness (Vaio and Varriale, 2020). The study's results do provide and inform decision-makers and industrial managers of the freight logistics industry with options on which critical factors to initially emphasize and which ones to delay during implementation as a way to introduce systematically the critical factors due to the inability to simultaneously implement all critical factors, due to scarcity of resources (Fetterman et al, 2018; Giungato et al, 2017). The results although specific to freight logistics industry in an emerging economy, it does have certain implications for other industries in the same emerging economy and other developing countries as well (Hughes et al, 2019; Kin et al, 2017). This study outcome may be applicable to other industries in the emerging and developing economies and contexts that might be interested in the digitization of their operations to ensure transparency and increase competitiveness, reaffirming their usefulness (Orji et al., 2019, 2020; Janssen et al, 2020; Koh et al., 2020). Hence, this study provides a foundation for further investigation of the use of blockchain technologies in various industrial sectors to

maintain competitive edge in this digitization era.

Specifically, the Nigerian freight logistics sector may face more technological and institutional pressures when compared to organizational pressures when seeking to adopt and implement blockchain technologies. Thus, their critical foundation activities for blockchain technologies adoption and implementation programs come from outside, with little influence from the freight logistics organizations. The adoption and implementation is highly influenced by availability of specific blockchain tools, supporting infrastructural facility and government policy and support to the freight logistics industry. Blockchain is still an emerging technology, and organizations from emerging economics and freight logistics sector should focus on the critical factors to ensure its long-term success (Queiroz and Wamba, 2019). However, emerging economy freight logistics organizations may not have the necessary resources to adopt and implement simultaneously these critical factors (Wanke et al, 2016). It may be most appropriate for the companies in the freight logistics industry to choose among a set of critical factors focusing more on the highly ranked critical factors during adoption of blockchains. This modelling attempt and results can help set the stage for prioritizing the critical factors aiding blockchain adoption in a resource-constrained environment (Wong et al, 2020). Moreover, the Nigerian freight logistics firms can utilize blockchains for freight vehicles management within the firm's fleet (Dobrovnik et al, 2018). The information on the past performance and maintenance history of the freight vehicles can be authenticated using blockchains to ensure warranty and business transaction transparency (Christidis et al, 2016). In addition, blockchains can provide authenticated secure data to enable efficient freight tracking (Timothy, 2017). Furthermore, smart contracts can be deployed in the freight logistics firms to ensure the efficiency of settlements between transacting parties throughout the supply chain by reducing borrowing costs by 75%, increasing liquidity by 25% and increasing profit margin by 2 to 4% (Dobrovnik et al, 2018; Francisco and Swanson, 2018).

Also, noteworthy is the potential risks involved in the use of blockchains in freight logistics; there is still a lack of standardization of blockchains architectures with more than 6,500 active blockchain projects listed on GitHub in 2018 with projects based on different protocols, consensus and privacy measures (Morkunas et al, 2019). The logistics industry still lacks an overall Electronic Data Exchange standard; instead many technologies are utilized (Dobrovnik et al, 2018). It is expedient that standards be set for the use of blockchains to ensure interoperability, hence Blockchain in Transport Alliance is a company that assists in blockchain adoption and works on setting standards in the logistics industry. Also, there is an issue of data privacy not applied to transaction data and partners not allowed to use such with data protection, thus it is crucial to create certain boundaries to using blockchains (Helo and Hao, 2019). Moreover, manpower in the logistics sector lacks the willingness and competencies to use blockchains and this necessitates participating in trainings and technical development and encouraging effective communications through collaborations with other parties (Aste et al, 2017). In addition, blockchain application in industrial sectors is still in the early stage of adoption and requires a long lifecycle of implementation and full of uncertainties as to its relevance for business processes (Queiroz and Wamba,

2019). There is also demand for advanced technical infrastructures in the freight logistics sector (Alvarez- Diaz et al, 2017) so that computers for processing transactions during adoption of blockchains can be connected to the internet.

5.2 Limitations and future research directions

Although this study makes some consideration contributions, just like any other study, there exist some limitations. Yet, these limitations provide some important and additional research avenues for future and further studies into the subject. Future studies could occur in the same or different context. For instance, the ANP model can be replaced with other multi- criteria decision making (MCDM) models such analytic hierarchy process (AHP), fuzzy set, DEMATEL etc to study the relative importance of the critical factors that influence the adoption of blockchains in the freight logistics sector. Also, other industrial sectors can be studied to have a clear understanding of the critical factors to the blockchain adoption process. Moreover, results of this study can be generalized by considering various freight logistics companies not only in Nigeria but also other emerging and developing countries like China, India etc. A comparative study can be carried out to inform the variations in the importance of factors with regards to different industrial contexts and countries. Finally, this study investigated the factors that influence the successful adoption of blockchain technologies. The relationship between "successful blockchain adoption" and "freight industry performance improvement" remains a limitation to this study. Future studies could focus on investigating this relationship.

References

Alharthi A., Krotov V., Bowman M. (2017), Addressing barriers to big data, Business Horizons, 60 (3), 285- 292.

Alvarez- Diaz N., Herrera- Joancomarti J., Caballero- Gil (2017), Smart contracts based on blockchain for logistics management, In Proceedings of the 1st International Conference on Internet of Things, (p. 73), ACM (2017).

Andoni M., Robu V., Flynn D., Abram S., Geach D., Jenkins D., McCallum P., Peacock A. (2019), Blockchain technology in the energy sector: A systematic review of challenges and opportunities, *Renewable and Sustainable Energy Reviews*, 100, 143- 174.

Angelis J., Ribeiro da Silva (2019), Blockchain adoption: A value driver perspective, *Business Horizons*, 62, 3, 307- 314.

Aragonés-Beltrán, P., Chaparro-González, F., Pastor-Ferrando, J. P., & Pla-Rubio, A. (2014). An AHP (Analytic Hierarchy Process)/ANP (Analytic Network Process)- based multi-criteria decision approach for the selection of solar-thermal power plant investment projects. *Energy*, *66*, 222-238.

Aste T., Tasca P., Di Matteo T. (2017), Blockchain technologies: The foreseeable impact on society and industry, *Computer*, 50 (9), 18- 28.

Ayantoyinbo B.B. (2015), Assessing the impact of Information and Communication Technology (ICT) on the prominence of freight distribution, European Journal of Logistics, Purchasing and Supply Chain Management, 3(4), 18- 29.

Azzi R., Chamoun R.K., Sokhn M. (2019), The power of a blockchain- based supply

chain, *Computers & Industrial Engineering*, 135, 582- 592.

Barratt, M., Choi, T. Y., & Li, M. (2011). Qualitative case studies in operations management: Trends, research outcomes, and future research implications. *Journal of Operations Management*, *29*(4), 329-342.

Basole R.C., Seuss C.D., Rouse W.B. (2013), IT innovation adoption by enterprises: Knowledge discovery through text analytics, *Decision Support Systems*, 54 (2), 1044- 1054.

Bedell D. (2016), Landmark trade deal uses blockchain technology, Global Finance, 107.

Belton V., Stewart T.J. (2002), Outranking methods. In: Multiple Criteria Decision Analysis. Springer, Boston, MA, 233- 259.

Blas C.S., Martin J.S., Gonzalez D.G. (2018), Combined social networks and data envelopment analysis for ranking, *European Journal of Operational Research*, 266 (3), 990- 999.

Brilliantova V., Thurner T.W. (2019), Blockchain and the future of energy, *Technology in Society*, 57, 38- 35.

Büyüközkan, G., & Güleryüz, S. (2016). An integrated DEMATEL-ANP approach for renewable energy resources selection in Turkey. *International Journal of Production Economics*, *182*, 435-448.

Chalmers D., Matthews R., Hyslop A. (2019), Blockchain as an external enabler of new venture ideas: Digital entrepreneurs and the disintermediation of the global music industry, Journal of Business Research, https://doi.org/10.1016/j.busres.2019.09.002.

Chandrasekaran B., Goldman M. (2007), Exploring robustness of plans for simulation-based course of action planning: a framework and an example. In: Proceedings of the IEEE symposium on computational intelligence in multicriteria decision making; 185- 92.

Chang S. E., Chen Y-C., Lu M-F. (2019), Supply chain re- engineering using blockchain technology: A case of smart contract based tracking, *Technological Forecasting and Social Change*, 144, 1- 11.

Chemweno, P., Pintelon, L., Van Horenbeek, A., & Muchiri, P. (2015). Development of a risk assessment selection methodology for asset maintenance decision making: An analytic network process (ANP) approach. *International Journal of Production Economics*, *170*, 663-676.

Chen A., Xu X. (2012), Goal programming approach to solving network design problem with multiple objectives and demand uncertainty, *Expert Systems with Applications*, 39, 4160- 4170.

Chen L., Lee W-K., Chang C-C., Choo K-K. R., Zhang N. (2019), Blockcahin based searchable encryption for electronic health record sharing, *Future Generation Computer Systems*, 95, 420- 429.

Chen K-H., Wang C-H., Huang S-Z., Shen G.C. (2016), Service innovation and new product performance: The influence of market- linking capabilities and market turbulence, *International Journal of Production Economics*, 172, 54- 64.

Chiemeke S.C., Longe O.B. (2007), Information and communication technology

penetration in Nigeria: prospects, challenges and metrics, *Asian Journal of Information Technology*, 6, 280- 287.

Choi C-C. (2016), Application of ANP to the selection of shipping registry: The case of Taiwanese maritime industry, *International Journal of Industrial Ergonomics*, 67, 89- 97.

Choi T-M., Wen X., Sun X., Chung S-H. (2019), The mean- variance approach for global suppl chain risk analysis with air logistics in the blockchain technology era, *Transportation Research Part E: Logistics and Transportation Review*, 127, 178- 191.

Christidis K., Devetsikiotis M. (2016), Blockchains and smart contracts for the internet of things, *IEEE Access*, 4, 2292- 2303.

Cinelli M., Coles S.R., Kirwan K. (2014), Analysis of the potentials of multi criteria decision analysis methods to conduct sustainability assessment, *Ecological Indicators*, 46, 138- 148.

Cooper R.G. (2003), Profitable Product Innovation: The Critical Success Factors, *The International Handbook on Innovation*, 139- 157

Dai J., Montabon F.L., Cantor D.E. (2014), Linking rival and stakeholder pressure to green supply management: Mediating role of top management support, *Transportation Research Part E: Logistics and Transportation Review*, 71, 173- 187.

Dai J., Chan H.K., Yee R.W.Y. (2018), Examining moderating effect of organizational culture on the relationship between market pressure and corporate environmental strategy, *Industrial Marketing Management*, 74, 227- 236.

Dalvi- Esfahani M., Ramayah T., Nilashi M. (2017), Modelling upper echelons' behavioural drivers of Green IT/ IS adoption using an integrated Interpretive Structural Modelling- Analytic Network Process approach, Telematics and Informatics, 34 (2), 583- 603.

De D., Chowdhury S., Dey P.K., Ghosh S.K. (2018), Impact of lean and sustainability oriented innovation on sustainability performance of small and medium sized enterprises: A Data Envelopment Analysis- based framework, *International Journal of Production Economics*, https://doi.org/10.1016/j.ijpe.2018.07.003.

Dobrovnik M., Herold D., Furst E., Kummer S. (2018), Blockchain for an in logistics: What to adopt and where to start, *Logistics*, 2 (3), 18.

Dubey R., Gunasekaran A., Childe S.J., Roubaud D., Wamba S.F., Giannakis M., Foropon C. (2019), Big data analytics and organizational culture as complements to swift trust and collaborative performance in the humanitarian supply chain, *International Journal of Production Economics*, 210, 120- 136.

Drescher D. (2017), Blockchain basics: A non- technical introduction in 25 steps, (1st edn), Apress, Frankfurt am Main.

Ehinomen C., Adeleke A. (2012), An assessment of the distribution of petroleum products in Nigeria, *European Journal of Business Management Economics*, 3 (6), 232- 241.

Ekene E.A. (2014), ICT adoption in logistics operations: an emerging trend for sustainable development and human capacity building in South- Eastern Nigeria,

Journal of Emerging Trends in Engineering and Applied Sciences, 5 (7), 24- 28.

Evangelista P., Mckinnon A., Sweeney E. (2013), Technology adoption in small and medium- sized logistics providers, *Industrial Management and Data Systems*, 113 (7), 967- 989.

Farias L.M., Santos L.C., Gohr C.F., Rocha L.O. (2019), An ANP- based approach for lean and green performance assessment, *Resources, Conservation and Recycling*, 143, 77- 89.

Feng M., Yu W., Wang X., Wong C.Y., Xu M. and Xiao Z. (2018), Green supply chain management and financial performance: The mediating roles of operational and environmental performance, *Business Strategy and the Environment*, 2018, Pages 1- 14.

Fetterman D.C., Sa Cavalcante C.G., de Almeida T.D., Tortorella G.L. (2018), How does Industry 4.0 contribute to operations management?, *Journal of Industrial and Production Engineering*, 35 (4), 255- 268.

Francisco K., Swanson D. (2018), The supply chain has no clothes: Technology adoption of blockchain for supply chain transparency, *Logistics*, 2 (1), 2.

Fu H.P., Chang T.H., Lin A., Du Z.J., Hsu K.Y. (2015), Key factors for the adoption of RFID in the logistics industry in Taiwan, *The International Journal of Logistics Management*, 26 (1), 61- 81.

Giungato P., Rana R., Tarabella A., Tricase C. (2017), Current trends in sustainability of bitcoins and related blockchain technology, *Sustainability*, 9 (12), 1- 11.

Giusti R., Manerba D., Bruno G., Tadei R. (2019), Synchromodal logistics: An overview of critical success factors, enabling technologies, and open research issues, *Transportation Research Part E: Logistics and Transportation Review*, 129, 92- 110.

Gu W., Foster K., Shang J., Wei L. (2019), A game- predicting expert system using big data and machine learning, *Expert Systems with Applications*, 130, 292- 305.

Guerrero de la Pena A., Davendralingam N., Raz A.K., DeLaurentis D., Shaver G., Sujan V., Jain N. (2019), Projecting line- haul truck technology adoption: How heterogeneity among fleets impacts system-wide adoption, *Transportation Research Part E: Logistics and Transportation Review*, 124, 108- 127.

Haan J., Kisperska- Moron D., Placzek E. (2007), Logistics management and firm size; a survey among Polish small and medium enterprises, *International Journal of Production Economics*, 108 (1- 2), 119- 126.

Hallikainen P., Kivijarvi H., Tuominen M. (2009), Supporting the module sequencing decision in the ERP implementation process- An application of the ANP method, *International Journal of Production Economics*, 119 (2), 259- 270.

Helo P., Hao Y. (2019), Blockchains in operations and supply chains: A model and reference implementation, *Computers& Industrial Engineering*, 136, 242- 251.

Herva M., Roca E. (2013), Review of combined approaches and multi- criteria analysis for corporate environmental evaluation, *Journal of Cleaner Production*, 39, 355- 371.

Hosseini S., Ivanov D., Dolgui A. (2019), Review of quantitative methods for supply chain resilience analysis, *Transportation Research Part E: Logistics and*

Transportation Review, 125, 285- 307.

Hu Y., Xiao S., Wen J., Li J. (2019), An ANP- multi- criteria- based methodology to construct maintenance networks for agricultural machinery cluster in a balanced scorecard context, *Computers and Electronics in Agriculture*, 158, 1- 10.

Huang I.B., Keisler J., Linkov I. (2011), Multi- criteria decision analysis in environmental sciences: ten years of application and trends, *Science of the Total Environment*, 409 (2011), 3578- 3598.

Hughes L., Dwivedi Y.K., Misra S.K., Rana N.P, Raghavan V., Akella V. (2019), Blockchain research, practice and policy: Applications, benefits, limitations, emerging research themes and research agenda, *International Journal of Information Management*, 49, 114- 129.

Huimin T., Yong S., Peiwu D. (2019), Public blockchain evaluation using entropy and TOPSIS, *Expert Systems with Applications*, 117, 204- 210.

Huo B., Ye Y., Zhao X. (2015), The impacts of trust and contracts on opportunism in the 3PL industry: The moderating role of demand uncertainty, *International Journal of Production Economics*, 170, Part A, 160- 170.

Janjevic M., Knoppen D., Winkenbach M. (2019), Integrated decision- making framework for urban freight logistics policy- making, Transportation Research Part D: Transport and Environment, 72, 333- 357.

Janssen M., Weerakkody V., Ismagilova E., Sivarajah U., Irani Z. (2020), A framework for analyzing blockchain technology adoption: Integrating institutional, market and technical factors, *International Journal of Information Management*, 50, 302- 309.

Jones D., Tamiz M. (2010), Practical goal programming, *Management Science*, 141, 11- 23.

Kamble S., Gunasekaran A., Arha H. (2018), Understanding the Blockchain technology adoption in supply chains- Indian context, *International Journal of Production Research*, 57 (7), 1- 25.

Kamble S.S., Gunasekaran A., Sharma R. (2019), Modeling the blockchain enabled traceability in agriculture supply chain, International Journal of Information Management, https://doi.org/10.1016/j.ijingomgt.2019.05.023.

Kengpol, A., & Tuominen, M. (2006), A framework for group decision support systems: an application in the evaluation of information technology for logistics firms, *International Journal of Production Economics*, *101*(1), 159-171.

Khezrimotlagh D., Zhu J., Cook W.D., Toloo M. (2019), Data envelopment analysis and big data, *European Journal of Operational Research*, 274 (3), 1047- 1054.

Kietzmann J. (2019), From hype to reality: Blockchain grows up, *Business Horizons*, 62 (3), 269- 271.

Kin B., Verlinde S., Macharis C. (2017), Sustainable urban freight transport in megacities in emerging markets, *Sustainable Cities and Society*, 32, 31- 41.

Koh, L., Dolgui, A., & Sarkis, J. (2020). Blockchain in transport and logistics– paradigms and transitions. *International Journal of Production Research*, 58 (7), 2054-2062.

König, C., Caldwell, N. D., & Ghadge, A. (2019). Service provider boundaries in competitive markets: the case of the logistics industry. *International Journal of*

Production Research, *57*(18), 5624-5639.

Kshetri N. (2018), 1 Blockchain's roles in meeting key supply chain management objectives, *International Journal of Information Management*, 39, 80- 89.

Kumar, A., Aswin, A., & Gupta, H. (2020). Evaluating green performance of the airports using hybrid BWM and VIKOR methodology. *Tourism Management*, *76*, 103941.

Kumar M., Rodrigues V.S. (2018), Synergetic effect of lean and green on innovation: A resource- based perspective, *International Journal of Production Economics*, https://doi.org/10.1016/j.ijpe.2018.04.007.

Kuo M-S., Lian G-S. (2011), A novel hybrid decision- making model for selecting locations in a fuzzy environment, Mathematical and Computer Modelling, 54 (1- 2), 88- 104.

Kusi-Sarpong, S., Sarkis, J., & Wang, X. (2016), Assessing green supply chain practices in the Ghanaian mining industry: A framework and evaluation, *International Journal of Production Economics*, *181*, 325-341.

Laaper S., Fitzgerald J., Quasney E., Yeh W., Basir M. (2017), Using blockchain to drive supply chain innovation, Deloitte Development LLC, New York, NY.

Lam J.S.L. (2015), Designing a sustainable maritime supply chain: A hybrid QFD- ANP approach, *Transportation Research Part E: Logistics and Transportation Review*, 78, 70 -81.

Lam J.S.L., Lai K-H. (2015), Developing environmental sustainability by ANP- QFD approach: the case of shipping operations, *Journal of Cleaner Production*, 105, 275- 284.

Lee, K. H. (2009). Why and how to adopt green management into business organizations? The case study of Korean SMEs in manufacturing industry. *Management Decision*, *47*(7), 1101-1121.

Leng K., Bi Y., Jing L., Fu H-C., Nieuwenhuyse I.V. (2018), Research on agricultural supply chain system with double chain architecture based on blockchain technology, *Future Generation Computer Systems*, 86, 641- 649.

Li J., Greenwood D., Kassem M. (2019), Blockchain in the built environment and construction industry: A systematic review, conceptual models and practical use cases, *Automation in Construction*, 102, 288- 307.

Lian J.-W., Yen D.C., Wang Y.-T. (2014), An exploratory study to understand the critical factors affecting the decision to adopt cloud computing in Taiwan hospital, *International Journal of Information Management*, 34, 28- 36.

Lin, H. F. (2014). Understanding the determinants of electronic supply chain management system adoption: Using the technology–organization–environment framework, *Technological Forecasting and Social Change*, *86*, 80-92.

Liou J.J.H., Tzeng G-H., Tsai C-Y., Hsu C-C. (2011), A hybrid ANP model in fuzzy environments for strategic alliance partner selection in the airline industry, Applied Soft Computing, 11 (4), 3515- 3524.

Liu, H. C., You, J. X., Lin, Q. L., & Li, H. (2015). Risk assessment in system FMEA combining fuzzy weighted average with fuzzy decision-making trial and evaluation laboratory. *International Journal of Computer Integrated Manufacturing*, *28*(7),

701-714.

Maesa D.D., Mori P., Ricci L. (2019), A blockchain based approach for the definition of auditable Access Control systems, *Computers& Security*, 84, 93- 119.

Makhdoom I., Abolhasan M., Abbas H., Ni W. (2019), Blockchain's adoption in IoT: The challenges, and a way forward, *Journal of Network and Computer Applications*, 125, 251- 279.

Mandolla C., Petruzzelli A.M., Percoco G., Urbinati A. (2019), Building a digital twin for additive manufacturing through exploitation of blockkchain: A case analysis of the aircraft industry, *Computers in Industry*, 109, 134- 152.

Mardani, A., Jusoh, A., Nor, K., Khalifah, Z., Zakwan, N., & Valipour, A. (2015). Multiple criteria decision-making techniques and their applications–a review of the literature from 2000 to 2014. *Economic Research-Ekonomska Istraživanja*, *28*(1), 516-571.

Mathauer, M., & Hofmann, E. (2019). Technology adoption by logistics service providers. *International Journal of Physical Distribution & Logistics Management*. *49*(4), 416-434.

McGovern M.E., Canning D., Barnighausen T. (2018), Accounting for non- response bias using participation incentives and survey design: An application using gift vouchers, *Economic Letters*, 171, 239- 244.

Meade, L., & Sarkis, J. (1998). Strategic analysis of logistics and supply chain management systems using the analytical network process. *Transportation Research Part E: Logistics and Transportation Review*, *34*(3), 201-215.

Meyer T., Kuhn M., Hartmann E. (2019), Blockchain technology enabling the physical internet: A synergetic application framework, *Computers & Industrial Engineering*, 136, 5- 17.

Miao, R., Xu, F., Zhang, K., & Jiang, Z. (2014). Development of a multi-scale model for customer perceived value of electric vehicles. *International Journal of Production Research*, *52*(16), 4820-4834.

Min H. (2019), Blockchain technology for enhancing supply chain resilience, *Business Horizons*, 62 (1), 35- 45.

Mohammad, W. N. S. W., Abdullah, M. R., Ismail, S., & Takim, R. (2019). Technology-Organisation-Environment Framework for Building Information Modelling (BIM) Adoption Challenges for Contractor's Organisations in Malaysia. *Journal of Computational and Theoretical Nanoscience*, *16*(5-6), 2282-2288.

Moktadir M.A., Ali S.M., Paul S.K., Shukla N. (2019), Barriers to big data analytics in manufacturing supply chains: A case study from Bangladesh, Computers& Industrial Engineering, 128, 1063- 1075.

Mondragon A.E.C., Mondragon C.E.C., Coronado E.S. (2017), ICT adoption in multimodal transport sites: Investigating institutional- related influence in international seaports terminals, *Transportation Research Part A: Policy and Practice*, 97, 69- 88.

Montecchi M., Plangger K., Etter M. (2019),, It's real, trust me! Establishing supply chain provenance using blockchain, *Business Horizons*, 62, 283- 293.

Morgan J. (2012), Regional clusters and jobs for inner city workers: the case of

transportation, distribution and logistics, Community Development, 43 (4), 492-511.

Morkunas V.J., Paschen J., Boon E. (2019), How blockchain technologies impact your business model, *Business Horizons*, 62 (3), 295- 306.

Nguyen H-O. (2013), Critical factors in e- business adoption: Evidence from Australian transport and logistics companies, *International Journal of Production Economics*, 146 (1), 300- 312.

Nilashi M., Ahmadi H., Ahani A., Ravangard R., Bin Ibrahim O. (2016), Determining the importance of hospital information system adoption factors using fuzzy analytic network process (ANP), *Technological Forecasting and Social Change*, 11, 244- 264.

Olnes S., Ubacht J., Janssen M. (2017), Blockchain in government: Benefits and implications of distributed ledger technology for information sharing, *Government Information Quarterly*, 34 (3), 355- 364.

Onut S., Tuzkaya U.R., Torun E. (2011), Selecting container port via a fuzzy ANP-based approach: A case study in the Marmara Region, Turkey, 18 (1), 182- 193.

Ordoobadi, S.M. (2012), Application of ANP methodology in the evaluation of advanced technologies, *Journal of Manufacturing Management*, 23 (2), 229- 252.

Orji, I. J., Kusi-Sarpong, S., Gupta, H., & Okwu, M. (2019). Evaluating challenges to implementing eco-innovation for freight logistics sustainability in Nigeria. *Transportation Research Part A: Policy and Practice*, *129*, 288-305.

Orji, I. J., Kusi-Sarpong, S., & Gupta, H. (2020). The critical success factors of using social media for supply chain social sustainability in the freight logistics industry. *International Journal of Production Research*, *58*(5), 1522-1539.

Oyebamiji F. (2018), Information technology and its effects on performance of logistics firms in Nigeria, *Asian Research Journal of Arts & Social Sciences*, 6 (1), 1- 11.

Ozceylan E., Erbas M., Tolon M., Kabak M., Durgut T. (2016), Evaluation of freight villages: A GIS- based multi- criteria decision analysis, Computers in Industry, 76, 38- 52.

Pereira J., Tavalaei M. M., Ozalp H. (2019), Blockchain- based platforms: Decentrlized infrastructures and its boundary conditions, *Technological Forecasting and Social Change*, 146, 94- 102.

Pham H.C., Nguyen T-T., Mcdonald S., Tran- Kieu N.Q. (2019), Information sharing in logistics firms: An exploratory study of the Vietnamese logistics sector, *The Asian Journal of Shipping and Logistics*, 35 (2), 87- 95.

Pineda P. J.G., Liou J.J.H., Hsu C-C., Chuang Y-C. (2018), An integrated MCDM model for improving airline operational and financial performance, Transport Policy, 68, 103- 117.

Pohekar, S. D., & Ramachandran, M. (2004). Application of multi-criteria decision making to sustainable energy planning—a review. *Renewable and sustainable energy reviews*, *8*(4), 365-381.

Pool, J. K., Arabzad, S. M., Asadi, A., & Ansari, M. R. (2015). RFID acceptance in SMEs using TOE framework: an empirical investigation on Iranian SMEs. *International Journal of Logistics Systems and Management*, *21*(3),

335-347.

Priyadarshinee P., Raut R.D., Jha M.K., Kamble S.S. (2017), A cloud computing adoption in Indian SMEs: Scale development and validation approach, *The Journal of High Technology Management Research*, 28 (2), 221- 245.

Queiroz M.M., Wamba S.F. (2019), Blockchain adoption challenges in supply chain: An empirical investigation of the main drivers in India and the USA, *International Journal of Information Management*, 46, 70- 82.

Rahman S., Ahsan K., Yang L., Odgers J. (2019), An investigation into critical challenges for multinational third- party logistics providers operating in China, *Journal of Business Research*, 103, 607- 619.

Ramanathan R., Ramanathan U., Ko L.W.L. (2014), Adoption of RFID technologies in UK logistics: Moderating roles of size, barcode experience and government support, *Expert Systems with Applications*, 41 (1), 230- 236.

Ramdani, B., Chevers, D., & Williams, D. A. (2013). SMEs' adoption of enterprise applications: A technology-organisation-environment model. *Journal of Small Business and Enterprise Development*, *20*(4), 735-753.

Rivera L., Sheffi Y., Knoppen D. 92016), Logistics clusters: The impact of further agglomeration, training and firm size on collaboration and value added services, *International Journal of Production Economics*, 179, 285- 294.

Roehrs A., da Costa C.A., da Rosa Righi R. (2017), OmniPHR: A distributed architecture model to integrate personal health records, *Journal of Biomedical Informatics*, 71, 70- 81.

Saaty, T. L. (1996). *Decision making with dependence and feedback: The analytic network process* (Vol. 4922). RWS Publ.

Saaty, T. L. (2008). Decision making with the analytic hierarchy process. *International journal of services sciences*, *1*(1), 83-98.

Saberi S., Kouhizadeh M., Sarkis J. (2018), Blockchain technology: A panacea or pariah for resources, conservation and recycling?, *Resources, Conservation and Recycling*, 130, 80- 81.

Saberi S., Kouhizadeh M., Sarkis J., Shen L. (2019), Blockchain technology and its relationships to sustainable supply chain management, International Journal of Production Research, 57 (7), 2117- 2135.

Safari, F., Safari, N., Hasanzadeh, A., & Ghatari, A. R. (2015). Factors affecting the adoption of cloud computing in small and medium enterprises. *International Journal of Business Information Systems*, *20*(1), 116-137.

Seuring, S. A. (2008). Assessing the rigor of case study research in supply chain management. *Supply Chain Management: An International Journal*, *13*(2), 128-137.

Schubert J., Moradi F., Asadi H., Loutsinen L., Sjoberg E., Horling P., Linderhed A., Oskarsson D. (2015), Simulation- based decision making support for evaluating operational plans, *Operations Research Perspectives*, 2, 36- 56.

Schuetz S., Venkatesh V. (2019), Blockchain, adoption, and financial inclusion in India: Research opportunities, *International Journal of Information Management*, https://doi.org/10.1016/j.ijinfomgt.2019.04.009.

Shankar R., Pathak D.K., Choudhary D. (2019), Decarbonizing freight transportation:

AN integrated EFA- TISM approach to model enablers of dedicated freight corridors, *Technological Forecasting and Social Change*, 143, 85- 100.

Shieh L-F., Chang T-H., Fu H-P., Lin S-W., Chen Y-Y. (2014), Analyzing the factors that affct the adoption of mobile services in Taiwan, *Technological Forecasting and Social Change*, 87, 80- 88.

Si, S. L., You, X. Y., Liu, H. C., & Zhang, P. (2018). DEMATEL technique: A systematic review of the state-of-the-art literature on methodologies and applications. *Mathematical Problems in Engineering*, *2018*.

Sikorski J.J., Haughton J., Kraft M. (2017), Blockchain technology in the chemical industry: Machine-to- machine electricity market, *Applied Energy*, 195, 234- 246.

Somuyiwa A.O. (2010), Analysis of logistics cost in the supply chain management of manufacturing companies in Southwestern Nigeria, 2002- 2006. Unpublished Ph. D. Thesis, Olabinsi Onabanjo University, Ago- Iwoye.

Subramanian N., Abdulrahman M.D., Zhou X. (2014), Integration of logistics and cloud computing service providers: Cost and green benefits in the Chinese context, *Transportation Research Part E: Logistics and Transportation Review*, 70, 86- 98.

Sureeyatanapas P., Poophiukhok P., Pathumnakul S. (2018), Green initiatives for logistics service providers: An investigation of antecedent factors and the contributions to corporate goals, *Journal of Cleaner Production*, 191, 1- 14.

Supeekit T., Somboonwiwat T., Kritchanchai D. (2016), DEMATEL- modified ANP to evaluate internal hospital supply chain performance, *Computers& Industrial Engineering*, 102, 318- 330.

Tadic S., Zecevic S., Krstic M. (2014), A novel hybrid MCDM model based on fuzzy DEMATEL, fuzzy ANP and fuzzy VIKOR for cty logistics concept selection, Expert Systems with Applications, 41 (18), 8112- 8128.

Taefi T.T., Kreutzfeldt J., Held T., Fink A. (2016), Supporting the adoption of electric vehicles in urban road freight transport- A multi- criteria analysis of policy measures in Germany, *Transportation Research Part A: Policy and Practice*, 91, 61- 79.

Timothy L. (2017), Blockchain for transportation: Where the future starts, TMW Systems, Inc: Cleveland, OH, USA.

Tob- Ogu A., Kumar N., Cullen J. (2018), ICT adoption in road freight transport in Nigeria- A case study of the petroleum downstream sector, *Technological Forecasting and Social Change*, 131, 240- 252.

Tornatzky, L. G., Fleischer, M., & Chakrabarti, A. K. (1990). *Processes of technological innovation*. Lexington books.

Tutusaus M., Schwartz K., Smit S. (2018), The ambiguity of innovation drivers: The adoption of information and communication technologies by public water utilities, *Journal of Cleaner Production*, 171, s79- s85.

Tuzkaya U.R., Onut S. (2008), A fuzzy analytic network process based approach to transportation- mode selection between Turkey and Germany: A case study, Information Sciences, 178 (15), 3133- 3146.

United Nations, (2016), Revised List of Global Sustainable Development Goals, https://unstats.un.org/sdgs/indicators/Official%20Revised%20List%20of%20glob

al%20SDG%20indicators.pdf (2016), Accessed 17th May 2019.

Vaidya, O. S., & Kumar, S. (2006). Analytic hierarchy process: An overview of applications. *European Journal of operational research*, *169*(1), 1-29.

Vaio A.D., Varriale L. (2020), Blockchain technology in supply chain management for sustainable performance: Evidence from the airport industry, International Journal of Information Management, https://doi.org/10.1016/j.ijinfomgt.2019.09.010.

Venkatesh V., Thong J.Y.L., Xu X. (2016), Unified theory of acceptance and use of technology: A synthesis and the road ahead, *Journal of the Association for Information Systems*, 17 (5), 328- 376.

Wang G., Dou W., Zhu W., Zhou N. (2015), The effects of firm capabilities on external collaboration and performance: The moderating role of market turbulence, *Journal of Business Research*, 68 (9), 1928- 1936.

Wang, J. J., Jing, Y. Y., Zhang, C. F., & Zhao, J. H. (2009). Review on multi-criteria decision analysis aid in sustainable energy decision-making. *Renewable and sustainable energy reviews*, *13*(9), 2263-2278.

Wang, Y. S., Li, H. T., Li, C. R., & Zhang, D. Z. (2016). Factors affecting hotels' adoption of mobile reservation systems: A technology-organization-environment framework. *Tourism Management*, *53*, 163-172.

Wang Y., Singgih M., Wang J., Rit M. (2019), Making sense of blockchain technology: How will it transform supply chains?, *International Journal of Production Economics*, 211, 221- 236.

Wang, N., Chen, X., Wu, G., Chang, Y. C., & Yao, S. (2018). A short-term based analysis on the critical low carbon technologies for the main energy-intensive industries in China. *Journal of cleaner production*, *171*, 98-106.

Wanke P., Barros C.P., Nwaogbe O.R. (2016), Assessing productive efficiency in Nigerian airports using Fuzzy- DEA, *Transport Policy*, 49, 9- 19.

Wong, W. P., Ignatius, J., & Soh, K. L. (2014). What is the leanness level of your organisation in lean transformation implementation? An integrated lean index using ANP approach. *Production Planning & Control*, *25*(4), 273-287.

Wu, H. H., & Chang, S. Y. (2015). A case study of using DEMATEL method to identify critical factors in green supply chain management. *Applied Mathematics and Computation*, *256*, 394-403.

Xia D., Yu Q., Gao Q., Cheng G. (2017) , Sustainable technology selection decision-making model for enterprise in supply chain: Based on a modified strategic balanced scorecard, *Journal of Cleaner Production*, 141, 1337- 1348.

Yadav S., Singh S.P. (2020), Blockchain critical success factors for sustainable supply chain, *Resources, Conservation and Recycling*, 152, 104505.

Yadegaridehkordi E., Hourmad M., Nilashi M., Shuib L., Ahani A., Ibrahim O. (2018), Influence of big data adoption on manufacturing companies' performance: An integrated DEMATEL- ANFIS approach, Technological Forecasting and Social Change, 137, 199- 210.

Yang A., Li Y., Liu C., Li J., Zhang Y., Wang J. (2019), Research on logistics supply chain of iron and steel enterprises based on block chain technology, *Future Generation Computer Systems*, 101, 635- 645.

Zaim, S., Sevkli, M., Camgöz-Akdağ, H., Demirel, O. F., Yayla, A. Y., & Delen, D. (2014). Use of ANP weighted crisp and fuzzy QFD for product development. *Expert Systems with Applications*, *41*(9), 4464-4474.

Zhao G., Liu S., Lopez C., Lu H., Elgueta S., Chen H., Boshkoska B.M. (2019), Blockchain technology in agri- food value chain management: A synthesis of applications, challenges and future research directions, *Computers in Industry*, 109, 83- 99.

Zhu L., Wu Y., Gai K., Cho K-K. R. (2019), Controllable and trustworthy blockchain-based cloud data management, *Future Generation Computer Systems*, 91, 527- 535.

Zhu, Q., Shah, P., & Sarkis, J. (2018). Addition by subtraction: Integrating product deletion with lean and sustainable supply chain management. *International Journal of Production Economics*, *205*, 201-214.

Appendices

Table 6 The relative importance weights for dimensions of goal for the hierarchical (D) relationship (Appendix 1)

	Dimension	Mgr 1	Mgr 2	Mgr 3	Mgr 4	Mgr 5	Mgr 6	Mgr 7	Mgr 8	Mgr 9	Mgr 10	Mgr 11	Mgr 12	Mgr 13	Mgr 14	Mgr 15	Mean
Goal	**TF**	0.69406	0.70503	0.69406	0.79276	0.6282	0.60263	0.67817	0.69231	0.66667	0.65481	0.65481	0.6000	0.69424	0.6282	0.69231	**0.671884**
	OF	0.13151	0.08967	0.13151	0.13122	0.28538	0.31503	0.14241	0.07692	0.11111	0.09534	0.09534	0.1000	0.09551	0.08643	0.07692	**0.130953**
	IF	0.17443	0.2053	0.17443	0.07602	0.08643	0.08234	0.17942	0.23077	0.22222	0.24986	0.24986	0.3000	0.21025	0.28538	0.23077	**0.197165**

Table 7. The relative importance weights for factors of technological dimension (TF) for the hierarchical (D) relationship (Appendix 2)

	Factors	Mgr 1	Mgr 2	Mgr 3	Mgr 4	Mgr 5	Mgr 6	Mgr 7	Mgr 8	Mgr 9	Mgr 10	Mgr 11	Mgr 12	Mgr 13	Mgr 14	Mgr 15	Mean
TF	**TF1**	0.473576	0.36578	0.343367	0.369071	0.291911	0.455474	0.50044	0.519012	0.483155	0.490671	0.504809	0.466593	0.492527	0.491528	0.488918	**0.449122**
	TF2	0.251888	0.236592	0.259361	0.26129	0.206441	0.179381	0.184576	0.157231	0.175009	0.179951	0.182795	0.190024	0.183361	0.174463	0.188653	**0.200734**
	TF3	0.071112	0.151982	0.139995	0.157853	0.231374	0.091687	0.085916	0.089387	0.099867	0.089673	0.091457	0.106972	0.098969	0.08571	0.111722	**0.113579**
	TF4	0.086454	0.107649	0.121884	0.077948	0.136227	0.089905	0.092441	0.087442	0.097655	0.090304	0.087573	0.085765	0.082053	0.089964	0.080202	**0.094231**
	TF5	0.058516	0.07832	0.078545	0.072064	0.072462	0.066194	0.048336	0.058599	0.059663	0.068693	0.05933	0.063124	0.062628	0.058	0.052336	**0.063787**
	TF6	0.035103	0.032505	0.035602	0.04516	0.044888	0.063293	0.050855	0.048603	0.05047	0.047311	0.041335	0.046061	0.046805	0.052569	0.045756	**0.045754**
	TF7	0.023351	0.027172	0.021245	0.016614	0.016696	0.054066	0.037436	0.039726	0.034181	0.033397	0.032701	0.04146	0.033656	0.047766	0.032414	**0.032792**

Table 8. The relative importance weights for factors of organizational dimension (OF) for the hierarchical (D) relationship (Appendix 3)

	Factors	Mgr 1	Mgr 2	Mgr 3	Mgr 4	Mgr 5	Mgr 6	Mgr 7	Mgr 8	Mgr 9	Mgr 10	Mgr 11	Mgr 12	Mgr 13	Mgr 14	Mgr 15	Mean
OF	**OF1**	0.285052	0.367739	0.381552	0.358427	0.289941	0.312864	0.323437	0.275138	0.274031	0.284706	0.288944	0.282085	0.294036	0.23751	0.316911	**0.304825**
	OF2	0.353704	0.332939	0.334748	0.312372	0.302648	0.273095	0.317398	0.286565	0.29917	0.283697	0.274726	0.278432	0.261033	0.289987	0.258234	**0.29725**
	OF3	0.14772	0.116347	0.110837	0.120988	0.1459	0.171448	0.13025	0.156149	0.146728	0.151674	0.154967	0.157463	0.159746	0.128623	0.143951	**0.142853**
	OF4	0.113921	0.079231	0.085577	0.095339	0.128583	0.11031	0.111332	0.112088	0.104783	0.109786	0.111972	0.120017	0.114133	0.125939	0.123981	**0.109799**
	OF5	0.071738	0.071753	0.056574	0.087177	0.095358	0.1017	0.084682	0.117227	0.119506	0.120216	0.116635	0.112013	0.120503	0.13763	0.103998	**0.101114**
	OF6	0.027864	0.031989	0.030712	0.025697	0.03757	0.030584	0.032901	0.052833	0.055782	0.049922	0.052756	0.04999	0.050551	0.080309	0.052925	**0.044159**

Table 9. The relative importance weight for factors of institutional dimension (IF) for the hierarchical (D) relationship (Appendix 4)

	Factors	Mgr 1	Mgr 2	Mgr 3	Mgr 4	Mgr 5	Mgr 6	Mgr 7	Mgr 8	Mgr 9	Mgr 10	Mgr 11	Mgr 12	Mgr 13	Mgr 14	Mgr 15	Mean
IF	**IF1**	0.442046	0.590997	0.560401	0.591326	0.52963	0.544952	0.581535	0.620513	0.598045	0.578841	0.599885	0.615897	0.611571	0.620966	0.595766	**0.578825**
	IF2	0.27008	0.237542	0.254007	0.213511	0.230339	0.208422	0.209835	0.237327	0.232577	0.250527	0.254733	0.239966	0.235176	0.242767	0.241335	**0.237209**
	IF3	0.132172	0.102957	0.102614	0.096302	0.142298	0.150882	0.107294	0.062368	0.082496	0.079174	0.065588	0.068366	0.070373	0.058446	0.07347	**0.092987**
	IF4	0.114573	0.042763	0.055848	0.067301	0.063565	0.065927	0.072225	0.048352	0.045458	0.059766	0.045103	0.044728	0.044289	0.049101	0.052465	**0.058098**
	IF5	0.041129	0.025741	0.027129	0.03156	0.034168	0.029817	0.02911	0.03144	0.041423	0.031692	0.03469	0.031044	0.03859	0.02872	0.036964	**0.032881**

Table 10 Initial Super-matrix of all Interdependencies (dimensions and factors) (Appendix 5)

	TF	OF	IF	TF1	TF2	TF3	TF4	TF5	TF6	TF7	OF1	OF2	OF3	OF4	OF5	OF6	IF1	IF2	IF3	IF4	IF5
TF	0	0.75537	0.85384	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
OF	0.84696	0	0.14616	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
IF	0.14638	0.24463	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TF1	0	0	0	0	0.50513	0.50443	0.49514	0.49510	0.49745	0.50019	0	0	0	0	0	0	0	0	0	0	0
TF2	0	0	0	0.40130	0	0.18958	0.21297	0.20391	0.20455	0.20977	0	0	0	0	0	0	0	0	0	0	0
TF3	0	0	0	0.19570	0.17779	0	0.10865	0.11788	0.11278	0.11529	0	0	0	0	0	0	0	0	0	0	0
TF4	0	0	0	0.16993	0.13421	0.13025	0	0.08723	0.09068	0.08349	0	0	0	0	0	0	0	0	0	0	0
TF5	0	0	0	0.10744	0.08606	0.08272	0.08667	0	0.0563	0.05457	0	0	0	0	0	0	0	0	0	0	0
TF6	0	0	0	0.07387	0.05832	0.05693	0.05757	0.05690	0	0.03670	0	0	0	0	0	0	0	0	0	0	0
TF7	0	0	0	0.05176	0.03850	0.03609	0.03900	0.03898	0.03824	0	0	0	0	0	0	0	0	0	0	0	0
OF1	0	0	0	0	0	0	0	0	0	0	0	0.37725	0.34984	0.35738	0.35053	0.35733	0	0	0	0	0
OF2	0	0	0	0	0	0	0	0	0	0	0.45500	0	0.33522	0.30142	0.34203	0.29829	0	0	0	0	0
OF3	0	0	0	0	0	0	0	0	0	0	0.20896	0.24481	0	0.15047	0.14679	0.15651	0	0	0	0	0
OF4	0	0	0	0	0	0	0	0	0	0	0.14805	0.17305	0.14274	0	0.10464	0.10502	0	0	0	0	0
OF5	0	0	0	0	0	0	0	0	0	0	0.13675	0.14283	0.12390	0.13675	0	0.08284	0	0	0	0	0
OF6	0	0	0	0	0	0	0	0	0	0	0.05123	0.06206	0.04830	0.05399	0.05601	0	0	0	0	0	0
IF1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.64778	0.64539	0.65192	0.65115
IF2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.63685	0	0.23662	0.21962	0.22161
IF3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.20233	0.18862	0	0.08458	0.08397
IF4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.1079	0.10973	0.07837	0	0.04327
IF5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.05292	0.05388	0.03962	0.04387	0

Table 11 Converged (Stabilized) Super-matrix of all Interdependencies [dimensions and factors (Stabilized at K=100)] (Appendix 6)

	TF	OF	IF	TF1	TF2	TF3	TF4	TF5	TF6	TF7	OF1	OF2	OF3	OF4	OF5	OF6	IF1	IF2	IF3	IF4	IF5
TF	0.32739	0.32864	0.32854	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
OF	0.29579	0.29691	0.29682	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
IF	0.12063	0.12109	0.12106	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TF1	0	0	0	0.33375	0.33375	0.33375	0.33374	0.33374	0.33375	0.33375	0	0	0	0	0	0	0	0	0	0	0
TF2	0	0	0	0.22357	0.22357	0.22357	0.22357	0.22357	0.22357	0.22357	0	0	0	0	0	0	0	0	0	0	0
TF3	0	0	0	0.1393	0.1393	0.1393	0.1393	0.1393	0.1393	0.1393	0	0	0	0	0	0	0	0	0	0	0
TF4	0	0	0	0.12083	0.12084	0.12083	0.12083	0.12083	0.12083	0.12084	0	0	0	0	0	0	0	0	0	0	0
TF5	0	0	0	0.08265	0.08265	0.08265	0.08265	0.08265	0.08265	0.08265	0	0	0	0	0	0	0	0	0	0	0
TF6	0	0	0	0.05879	0.05879	0.05879	0.05879	0.05879	0.05879	0.05879	0	0	0	0	0	0	0	0	0	0	0
TF7	0	0	0	0.04109	0.04109	0.04109	0.04109	0.04109	0.04109	0.04109	0	0	0	0	0	0	0	0	0	0	0
OF1	0	0	0	0	0	0	0	0	0	0	0.26574	0.26574	0.26574	0.26574	0.26574	0.26574	0	0	0	0	0
OF2	0	0	0	0	0	0	0	0	0	0	0.27084	0.27084	0.27084	0.27084	0.27084	0.27084	0	0	0	0	0
OF3	0	0	0	0	0	0	0	0	0	0	0.16641	0.16641	0.16641	0.16641	0.16641	0.16641	0	0	0	0	0
OF4	0	0	0	0	0	0	0	0	0	0	0.1277	0.1277	0.12771	0.1277	0.1277	0.1277	0	0	0	0	0
OF5	0	0	0	0	0	0	0	0	0	0	0.11741	0.11741	0.11741	0.11741	0.11741	0.11741	0	0	0	0	0
OF6	0	0	0	0	0	0	0	0	0	0	0.05193	0.05193	0.05193	0.05193	0.05193	0.05193	0	0	0	0	0
IF1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.39323	0.39323	0.39323	0.39323	0.39323
IF2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.31678	0.31678	0.31678	0.31678	0.31678
IF3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.15104	0.15104	0.15104	0.15104	0.15104
IF4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0911	0.0911	0.0911	0.0911	0.0911
IF5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.04786	0.04786	0.04786	0.04786	0.04786