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HOW BLOCKCHAIN BASED SMART-CONTRACTS CAN IMPROVE INVOICING ACCURACY

MASTER THESIS

STUDENT DETAILS

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Declaration of Authorship

With my signature, I confirm to be the sole author of the thesis presented. Where the work of others has been consulted, this is duly acknowledged in the thesis 's bibliography. All verbatim or referential use of the sources named in the bibliography has been specifically indicated in the text.

The thesis at hand has not been presented to another examination board. It was neither in the same nor in a similar version part of an examination in the previous course of studies and has not yet been published. The paper version of this thesis is identical to the digital version handed in.

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Summary

Blockchain and smart contracts are technologies that improve supply chain efficiency. Initially invented to support Bitcoin, its underlying properties like decentralization, consensus-based immutability and enhanced security make for applications in sectors like finance and supply chain management. The goal of this thesis is to analyse the problem of invoice inaccuracies in the business-to-business (B2B) sector and how blockchain based smart contracts can solve the problem.

The thesis uses anchors from liquidity management, the operating cycle and economic theories about trade and comparative advantages to form a theoretical framework. The problem and its implications are explored further from the perspective of relevant use-cases. Literature is selected based on a criterion that applies to scientific papers and whitepapers published by organisations on the topic. The literature is reviewed, and conclusions are drawn to find specific use-cases where blockchain and smart contracts are viable. To deliver a proactive method of detecting issues within corporations that involve invoice inaccuracies, a Strategic Early Warning System is proposed. It is modified with the Cynefin Framework and the Proactive Method of Fraud Detection to provide a more precise guideline. Furthermore, a decision matrix and two decision trees are analysed to consolidate the rationale for a business case.

The general methodology for assembling the thesis is designed intuitively. The topicality of the subject is introduced in the first chapter along with the research topics. The second chapter is dedicated to analysing the problem of invoicing inaccuracy faced by organisations as documented in business journals and news outlets. The third chapter is about how the problem can be solved. The theme of the third chapter is preparation. It describes the methodology of solving the problem in general and the methodology for collecting the necessary information. The fourth chapter constitutes the theoretical framework and its connections with the various aspects of the problem from an academic perspective. The subject is discussed further in the fifth chapter from a practical stand-point. Finally, conclusions are drawn in the sixth chapter along with future directions the research should take.

Blockchain and smart contracts are still nascent in its practical maturity. However, its full potential is only discussed by industries that venture into its adoption. This thesis focusses on the blockchain use-cases of invoice processing in organisational functions like the so-called order-to-cash and procure-to-pay processes. Excerpts from web resources published by consulting organisations and experts that have identified this use-case in their practice/research are collected and analysed. Their claims fit well with the background theory. This validates blockchain based smart contracts as a strong candidate for solving invoicing inaccuracies in B2B organisations.

Chapter 1: Introduction.

1.1 Topicality of the subject

Blockchain was invented by Satoshi Nakamoto in October 2008 with the goal to create Bitcoin- a 'new cash system that's fully peer-to-peer, with no trusted third party'. However, ever since its invention, blockchain has been scrutinised in its ability to fully uphold its core principle- freedom from trust-based institutions. As a concept presented by Satoshi Nakamoto it has been implemented in various business applications and not all users could find its value over traditional technologies based on trust that is more social. Blockchain and its credibility also comes under scrutiny because 'Bitcoin' and other cryptocurrencies are often associated with the 'Silk-Road' (a Bitcoin-powered online drug marketplace) and as means of aiding criminality [1]. This breeds a misconception among people as the underlying technology i.e. blockchain is what enforces criminal activity. However, it is only the underlying technology that cryptocurrencies are typically built upon. Further, this technology is not just restricted to creating cryptocurrencies. It is widely mentioned as a transformative tool in the fields of supply chain, real estate, and government services, much like the Internet [2]. Nevertheless, how far is its reach with enforcing better commerce? Consider the example of blockchain adoption in Germany. Its economy is among the top ten most-research intensive economies in the world. However, the German government's position with regard to cryptocurrencies is not set in stone. On one hand, Germany funds research in blockchain applications under initiatives like the Modernity Fund (mFund) Research Initiative as stated in the official publication by the Federal Ministry of Education and Research (BMBF) Division for Innovation and Transfer Policy Issues-The High-Tech Strategy 2025. On the other hand, there are major concerns with cryptocurrencies driven by investor protection considerations [2], [3]. It has issued a public warning which states that unlawful marketing of cryptocurrencies may raise consumer protection concerns, legal concerns, and cause its use in Ponzi schemes. It underlines the fact that cryptocurrencies are not legal tender but merely a substitute to legal currencies [2]. This goes to show that blockchain is not a 'one-size-fits-all' type solution to the problem of automating trustworthiness when dealing with business transactions. The advantages that uniquely differentiate blockchain systems from other technologies, were used against itself by hackers to siphon money. The distributed control of data in blockchains is achieved without a central database by running it on a preponderance of servers. If a few servers fail, the blockchain starts shifting to other servers connected worldwide, therefore there is no off-on switch. In the case of an attack being discovered on a blockchain system, no 'circuit breaker' is applicable as that would require all the servers of the blockchain around the world to stop. Such was the incident where an intruder took notice and exploited a flaw in the Ethereum blockchain platform, specifically the smart contract for the distributed autonomous organization (DAO). The intruder was able to siphon away about $50 million dollars' worth of cryptocurrency and no one in the blockchain network could stop the act on time because a consensus could not be achieved quickly enough. Another difficulty that is a cause of concern is the risk of losing cryptographically encrypted keys. These keys are used in blockchain systems to cryptographically provide anonymity to its users. However, if the user loses their key, then they lose access to their account for good because that key cannot be retrieved, thereby loosing access to any funds in that account stored in the form of cryptocurrency [4]. The potential of blockchain technology is thus hindered by the risks imposed with its adoption. It is still a field vastly explored in terms of application besides cryptocurrency.

1.2 Problem Statement

The subject at hand can be divided into four parts as described below:

1. Blockchain based smart contracts
2. Invoices and invoicing mechanisms
3. The accuracy and effectiveness of invoicing mechanisms
4. Blockchain based smart contracts and its application in improving accuracy and effectiveness of invoicing.

The basic problem this research will address involves invoicing and its decreasing accuracy. This problem is found to incur costs in the shipping and freight transportation industry. Many factors contribute to this problem. Factors such as the number of parties involved in moving containers in the supply chain, the number of movements between locations, a lack of standardization, high volatility of current shipping prices, non-binding agreements in contracts, and general calculation errors contribute to the increase in complexity of invoice processing. These factors contribute to the increasing cases of inaccurate invoices [5].

1.3 Research Objectives and Structure

The focus of this thesis is finding the relevance of blockchain based applications besides cryptocurrencies in business mechanisms involving invoices and if it is worth the risks imposed. The purpose of this thesis is to analyse smart contract use cases in invoicing and extrapolate future improvements that blockchain and blockchain based smart contracts could bring to improving the process of invoicing.

The main research question is - 'How do blockchain based smart contracts improve invoicing accuracy?' This question topic is further broken down into sub-questions to conduct a systematic understanding of the main topic, with a focus on building a rationale for a business case. These sub-questions are as follows:

1. What are the current problems with invoicing and invoicing mechanisms?
    I. Why does the shipping and freight transportation industry face problems with invoicing?

2. What are the possible advantages or disadvantages with applying blockchain based applications and smart contracts?
    I. Why are blockchain based solutions eligible to solve this problem?
    II. What are the most relevant cases?

The challenges to this research come from the lack of any significant academic literature on the main topic at large, although there are websites which share information on how invoicing accuracy is decreasing in the shipping and freight transportation industry. Further, there is little to no literature that combines all four parts of the subject. This includes information and use-cases where achieving optimal invoicing accuracy is the most difficult challenge and its costs remain unnoticed.

The significance of the study is on the hypothesis that blockchain technology is a prime candidate to solve the problem of invoicing accuracy caused when multiple parties engage in operations like the so-called order-to-cash and procure-to-pay processes. This hypothesis is based on blockchain properties like data immutability, traceability, and decentralization.

Chapter 2: Problem Analysis

2.1 Basic Concepts- Blockchain and Smart Contracts

Blockchain is a type of Distributed Ledger Technology (DLT) that is designed to be immutable. It stores records into data structures called blocks, in a ledger that is openly distributed between two or more parties. Like any other form of DLT, blockchain is also used to simultaneously access, validate, record and update data in an immutable manner across a network. The network may be spread across multiple entities or locations. This is possible due to its fundamental characteristic of decentralized access to the immutable data in its database [6], [7]. All parties may verify these records however no party may retroactively alter the records in these blocks without altering all the subsequent blocks. This activity requires the consensus of the majority in a Blockchain network [6]. The fundamental difference between blockchain and DLT is blockchain's defining feature of cryptographically linking time-stamped blocks. Each new block created is supplied with the hash (a cryptographically generated code that uniquely identifies a block) of its previous block. This aspect of blocks forming a chain of data structures is illustrated in Fig. 1 below.

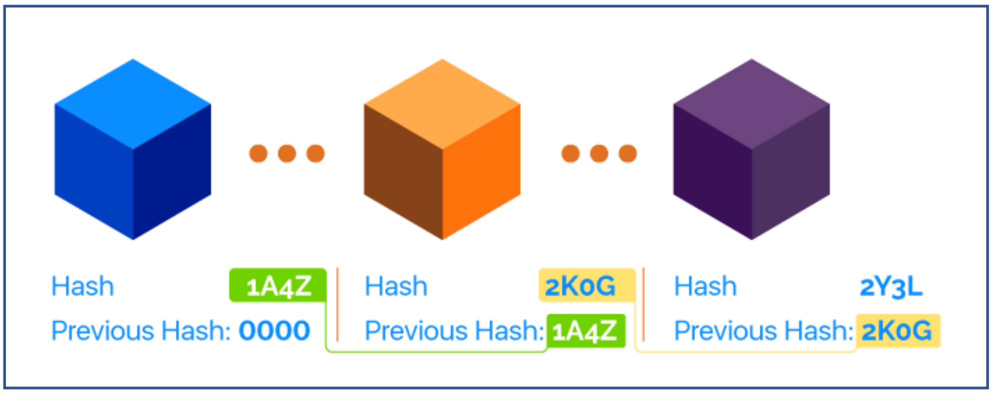

Fig. 1- Basic Structure of a blockchain (Source: [8])

There are three types of blockchain, namely public, private, and consortium, each briefly described below:

- A public blockchain network is completely open, and anyone can join and participate in the network. It allows anyone in the world to read, make transactions, validate transactions and be a part of the consensus process in the blockchain. It is the ultimate embodiment of decentralization [9], [10].
- A private blockchain network requires an invitation and must be validated by either the network starter or by a set of rules put in place by the network starter. Access to a private blockchain may be open to the outsiders for read only purposes. For actions that involve privileges to write, make transactions and be a part of its consensus protocol requires permission. These permissions are granted by an individual or an organization [10].

- The consortium blockchain is a combination of private and public blockchains. The most notable difference from either system can be observed at the consensus level. Instead of an open system where anyone can validate blocks or a closed one where only a single entity appoints block producers, a consortium chain sees a handful of equally powerful parties function as validators [11].

Blockchain applications can achieve automation of certain operational functions through smart contracts, which would otherwise require human intervention. Smart contracts are computer code designed to automatically facilitate, verify, or execute all or parts of an agreement between two or more parties, provided the agreed upon terms and conditions are met. These contracts are stored and executed on blockchain based platforms like Ethereum [12]. Smart contracts can essentially behave as a form of non-human legal authority and issue fines and tickets if certain contractual clauses in an agreement are breached. The logical connections between contractual clauses and its corresponding computerised code follow typical conditional constructs, like an '`if-then-if`' or '`if-then-else`' statement. This allows smart contracts to execute specific actions after conducting tests to find whether certain pre-determined conditions (terms) in the contractual clauses are met [13]. Let us consider a use-case that replicates the concept of crowd-sourcing platforms where project teams suggest their ideas and request supporters to donate funds for its realization. The team sets a certain minimum level of funding necessary for initiating the project and so decide to implement a smart contract to achieve this task. The smart contract can collect and store the funds from each supporter and then release it to the team once the minimum level of funding is met. '`If`' for instance the minimum funding is not received, '`then`' the smart contract returns the respective funds back to the supporters, '`else`' the funds are released to the team.

2.2 Terms and explanations

- SECURITIZATION- Securitization is a financial process that offers opportunities for investors and frees up capital for originators, both of which promote liquidity in the marketplace [14].
- INVOICE ACCURACY- Invoicing accuracy measures the percentage of invoices that were issued without errors and with the right cost on them the first time they were written [15], [16].
- GENERAL RATE INCREASE (GRI)- A GRI is the amount by which ocean carriers increase their base rates across specific lines, generally because of increased demand [17]. The freight rates are adjusted across a trade route over a set timeframe depending on the supply and demand of freight across that trade route. The shipping line in charge of setting the GRI announce these changes publicly [18].

- **SHIPPING LINE**- A shipping line is a company that operates the ships that carry the containers and cargo from load port to discharge port [19].

2.3 Problems with invoice processing in the transportation and logistics industry

Boston Consulting Group (BCG) conducted an online survey to assess the blockchain adoption in the transportation and logistics (T&L) industry. Participants were from over 100 global companies and their survey covered multiple T&L subsectors, including air freight; courier, express, and parcel; logistics; rail; and shipping. They claim that a 'blockchain paradox' exists within the T&L industry. The claim is based on the argument that blockchain can mitigate the mistrust between transacting parties, yet at the same time, the same mistrust keeps these organisations from a common blockchain ecosystem. According to their web publication, 'Resolving the Blockchain Paradox in Transportation and Logistics' by Schmahl et al. (7), the 15 use cases which were identified for blockchain are presented in Fig. 2 below.

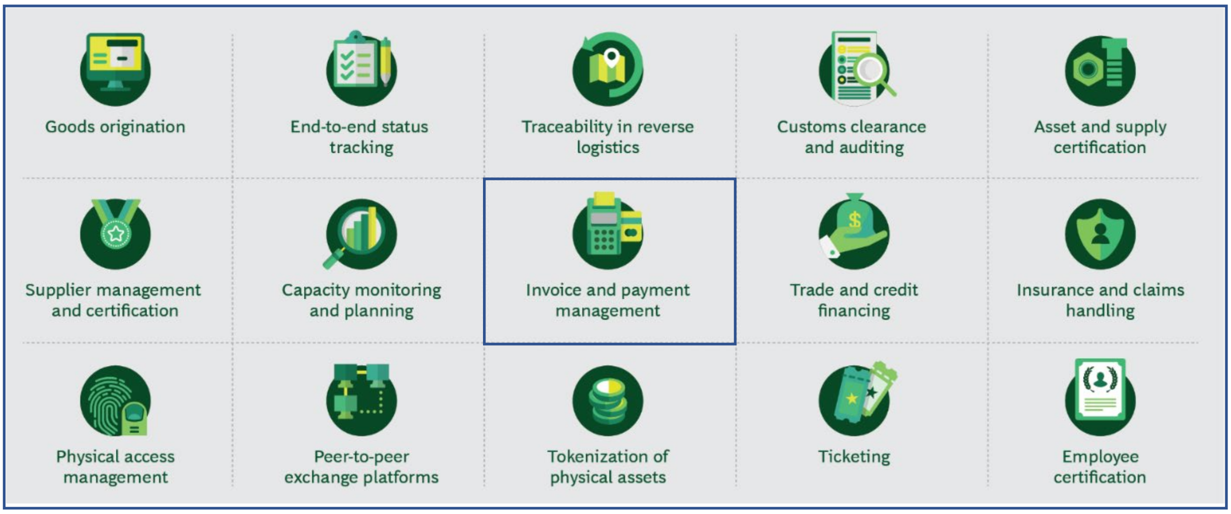

Fig 2. Blockchain Use Cases (Source: [20])

'Invoice and payment management' as highlighted in Fig. 2 above, is considered among the high priority blockchain use cases [20]. It summarizes the importance of managing invoices and payments in the T&L industry and provides the example of CargoX as follows:

> 'Because the multiple parties involved in T&L transactions maintain their own records and ledgers, invoicing and payments are paper-intensive processes that often entail manual entry. To check for mistakes and inaccuracies (and potential fraud), companies need to conduct a time-consuming reconciliation step before payments are released. Blockchain can be used to store and share digitized records and create smart contracts that automatically execute invoices and payments. Automated processing reduces settlement times, ensures accuracy, and detects fraud, while eliminating the need for intermediaries and paper-based processes. For example, a startup called CargoX has launched a blockchain-based bill-of-lading platform. Its features include smart contracts and the automated execution of peer-to-peer payments.' [20]

The problem was also mentioned in the whitepaper 'Blockchain in Logistics- Perspectives on the upcoming impact of blockchain technology and use cases for the logistics industry' on DHL's website, published by DHL Customer Solutions & Innovation [21]. Here, DHL describes the issues with logistics and the complexity of the logistics process including the flow of information and transactions. The article mentions the positive impact of blockchain with logistics. It briefly describes how blockchain based smart contracts can automate commercial processes as,

> 'Current industry estimates indicate that 10% of all freight invoices contain inaccurate data which leads to disputes as well as many other process inefficiencies in the logistics industry. This problem is so prevalent that in the oil and energy industry alone, Accenture expects that at least 5% in annual freight spend could be reduced through improved invoice accuracy and reduction of overpayments. Blockchain has the significant potential to increase efficiency along the entire logistics and settlement process including trade finance and help to resolve disputes in the trade industry. As digitized documents and real-time shipment data become embedded in blockchain-based smart contracts. These contracts can automate commercial processes the moment that agreed conditions are met.' [21]

A summary of the most relevant claims in the above-mentioned article about the problem scenario in the logistics industry and invoicing are as follows:

- There are too many stakeholders involved in the supply chain. Fig. 3 below illustrates how stakeholders like terminal operators, trucking companies, banks, insurers and customs authorities besides the carrier and freight forwarders that exchange information within the supply chain to transport freight from point A to point B.

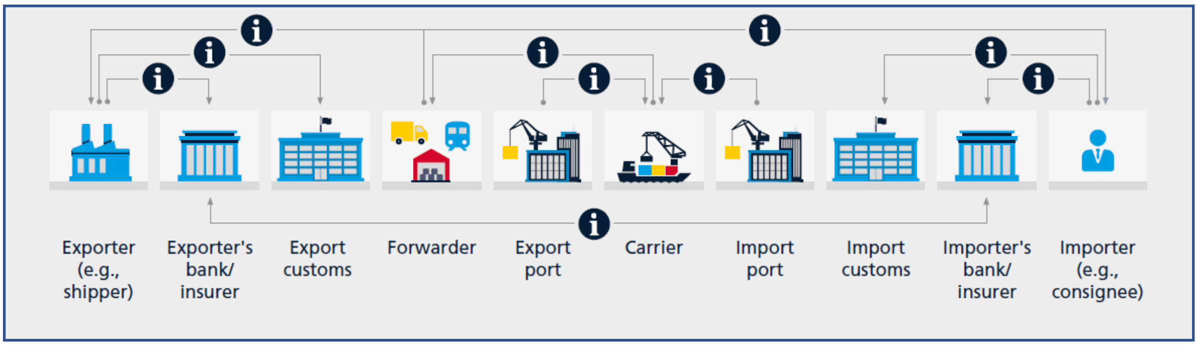

Fig. 3 Information flow between stakeholders in the supply chain (Source: Accenture)

- There are manual data entry and paper-based documentation processes bound to the supply chain that have been mandated by regulatory activities. This makes tracking the provenance and status of goods and shipments difficult which in turn causes friction in global trade.

- The logistics behind global trade is complex. This complexity is caused due to the involvement of multiple parties with conflicting interests and/or too many different systems for tracking shipments.
- The multitude of customs authorities regulating the passage of freight also contributes to the complexity behind the logistics of global trade. An example was mentioned to illustrate this aspect with an estimation. A simple shipment of refrigerated goods from East Africa to Europe can go through nearly 30 transitions including individuals, with more than 200 different interactions and communications among these parties [21], [22].

Another source of information in this regard is a maritime news article published by JOC Group Inc. JOC Group Inc. is a provider of global intelligence for trade, transportation and logistics professionals and it claims to be an authority in their field. JOC Group Inc. mentions in their article that the tension between shippers and carriers over invoice accuracy is rising. According to this article, the problems relating to invoice accuracy are more along the lines of human error rather than systematic errors with invoice accuracy. It described how the situation has deteriorated in recent years after back-office functions have been outsourced or by laying off back-office personnel, rather than being handled in-house. The reason mentioned for outsourcing these back-office functions are primarily to reduce costs by outsourcing to cheaper and less experienced workers as declining container and shipping rates results into budgetary restrictions. A summary of the negative impact of this phenomenon on invoicing accuracy is demonstrated by the following influencing factors:

- ‘Offshore’ workers or the outsourced workers have no connections with workers that have been working longer and with more experience in that container line. These workers are therefore not as knowledgeable of the business and its clients as the personnel that have been laid off to cut costs.
- The volatility and speed of GRI changes pushes carriers to focus on generating more invoices over assuring their accuracy.
- Improper software algorithms draw incorrect information from contracts to make invoice calculations.
- The difficulty of disputing and fixing errors in invoices is increasing. Even though overbilling is identified in invoices they are not addressed by their vendors when disputed. Some shippers do not even bother to dispute incorrect invoices because it slips through miscommunication via email or it is not perceived to be worthwhile within a context of managing relatively higher number of containers within the allocated timeframe.

- The language used by carriers to generate invoices differ from that of the contracts. This makes the job of the shipper much more difficult to validate the reasons certain charges or claims have been made and their legitimacy [5].

The exact details to the causes of an inaccurate invoice can only remain speculative in nature unless the guilty party discloses their fault. This context becomes more apparent when invoices need to be reconciled. Tradelens, a company formed by the collaboration between IBM and Maersk, for the purpose of implementing blockchain based technology in the supply chain, report how inaccurate freight invoices impact accounting, as shown in Fig. 4 below [23]. They also suggest how TradeLens, their blockchain platform can mitigate that problem as shown on the right side of Fig. 4.

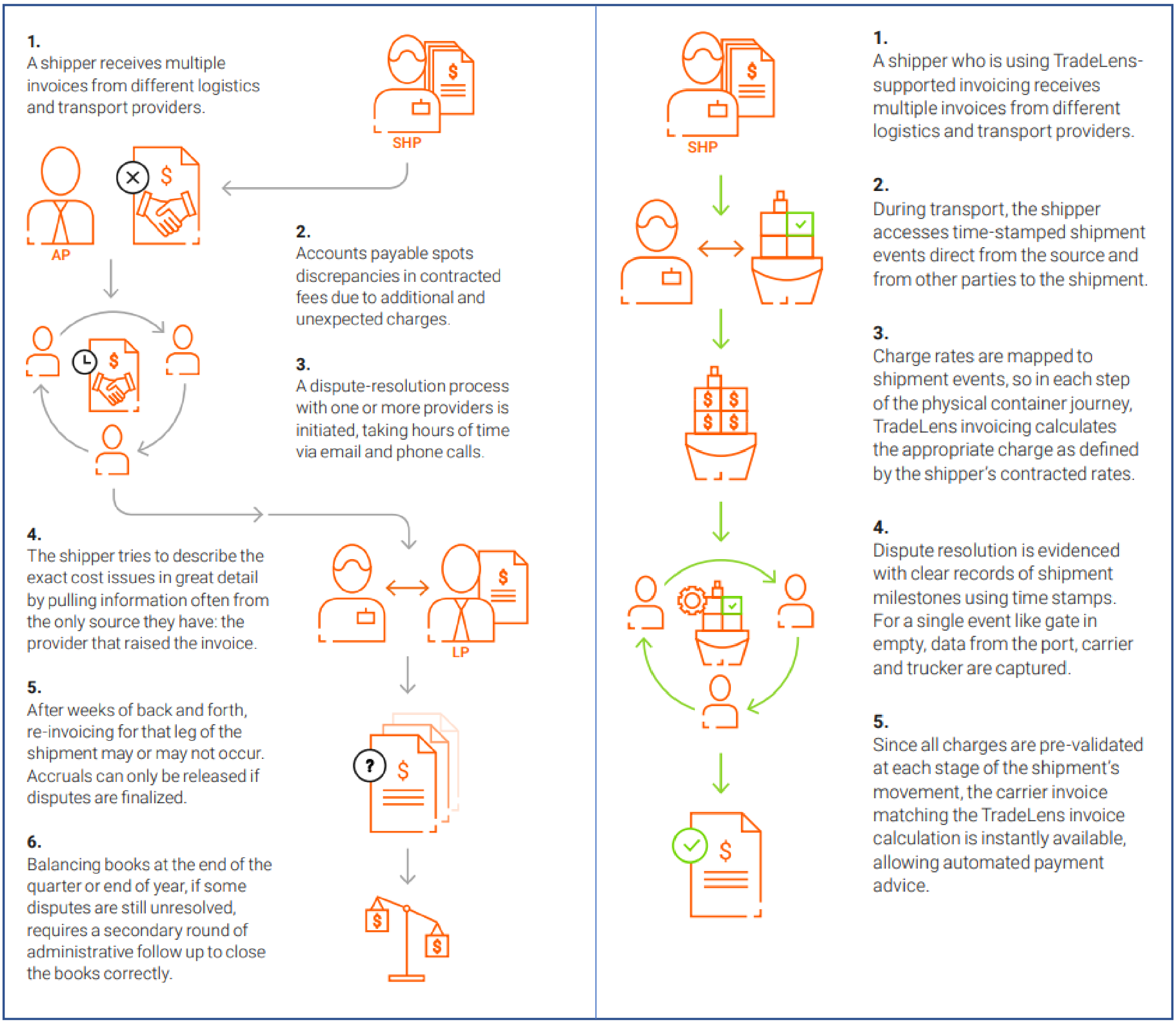

Fig. 4- Freight invoicing inaccuracies as demonstrated by TradeLens (Source: [23])

Chapter 3: Methodology

3.1 Modification of the Strategic Early Warning System

The purpose of this thesis is to outline the problems with invoicing inaccuracies within global supply chains, their causes and possible methods of detecting and mitigating them. This research primarily involves analysing data on a qualitative basis. A quantitative research to satisfy the scientific rigor and enquiry of answering the research questions is not possible within the assigned timeframe, mainly due to travel restrictions (quarantined zones) combined with time and budget constraints. Another feasibility factor which usually is taken for granted is a healthy work environment, free from the proliferation of the corona virus disease (COVID-19). With these conditions in mind, the most suitable method of data collection for this qualitative research is based on literature selection that meets the following inclusion and exclusion criteria.

Inclusion Criteria:

- The literature that examines blockchain adoption in supply chain management and supply chain finance.
- The literature that examines invoicing as a use-case for blockchain and blockchain based smart contracts.
- The literature that examines informational asymmetry as a cause of invoicing errors.
- The literature that examines the working capital requirement, the operating cycle, liquidity management, and comparative advantages in relation to international trade.
- The literature that examines Strategic Early Warning Systems (SEWS), Cynefin framework and fraud detection.
- The literature that examines smart contracts adoption in the order-to-cash (OTC) and procure-to-pay (PTP) processes.

Exclusion Criteria:

- All literature not fulfilling any of the inclusion criteria above.
- All literature not written in English except for Prof. Dr. Stefan Stein's contribution in the field of liquidity management, written in German.

The outline of the main steps in qualitative research which were followed are based on the step wise instructions as described by Alan Bryan (2015).

STEP 1: Formulate general research questions.

STEP 2: Select relevant site(s) and subjects.

STEP 3: Collect relevant data.

STEP 4: Interpret the data.

STEP 5: Specify research questions further (5a) and collect more data (5b).

STEP 6: Write findings and conclusions [24]. Fig. 5 below presents the flow of these steps.

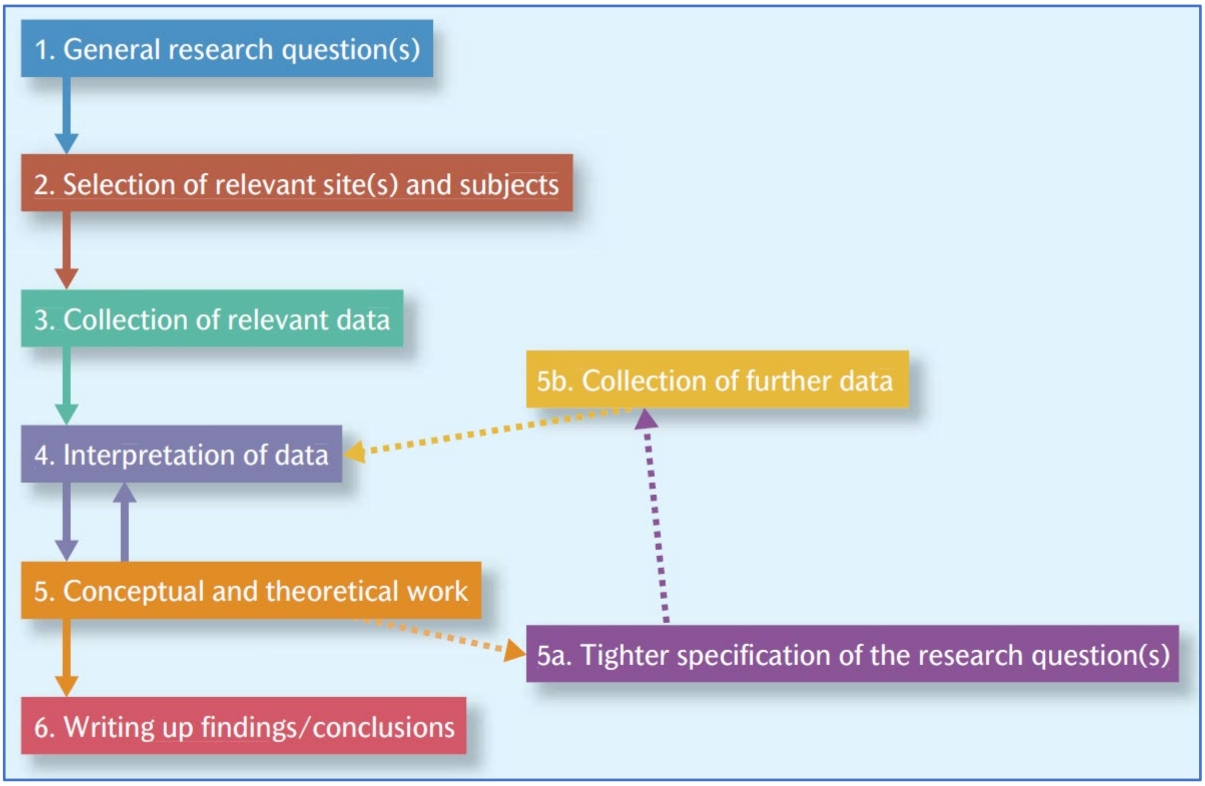

Fig. 5- An outline of the main steps of qualitative research (Source: [24])

Invoicing inaccuracies is a financial problem that involves organisations in large supply chains. These problems need to be detected and solved quickly. Before blockchain based smart contracts can be deployed, management needs to detect these problems in their organisation. The responsibilities of detecting these invoicing inaccuracies in a corporate environment and proactively solving them belong to that corporate's management [25]. A Strategic Early Warning System (SEWS) is proposed to establish a general guideline to proactively detect invoicing inaccuracies in the supply chain [26]. The conceptual basis of the proposed framework is on the hypothesis that fraud detection methods can provide a frame of reference for detecting invoicing inaccuracies. The proposed system incorporates the Cynefin framework and the Proactive Method of Fraud Detection to drive an even tighter form of guideline.

3.2 PHASES OF SEWS

The literature associated with this concept is scant. Multiple sources provide the same literature, thus leaving room for interpretation. According to the literature, the ideal SEWS process has three phases. The proposed methodology applies the SEWS process as a general guideline and the other methodologies are incorporated within the three phases of SEWS. These three phases are summarised below.

3.2.1 SEWS PHASE 1- Information Gathering

This phase requires gathering information about possible causes of the concerned effect, which according to the literature named as 'weak signals', or trends and issues. The sources of information are primarily media.

3.2.2 SEWS PHASE 2- Diagnosis

This phase constitutes three steps.

- In the first step, an in-depth analysis of the trend or issue is prescribed, along with the various contexts within which the trend or issue could perpetrate. The aim is to gain an impression of the possible potential developments of such trends and issues.
- The second step requires creatively thinking along the lines of the trend or issue's development and cluster them into certain contexts. The aim is to understand the mutual influences.
- The last step requires prioritizing the trends or issues based on the available resources and constraints within the organisation.

3.2.3 SEWS PHASE 3- STRATEGY FORMULATION

In this phase, the appropriate strategy is formulated, based on the Information Gathering and Diagnosis phases [26], [27].

3.3 The Proactive Method of Fraud Detection

The SEW phase and its descriptions provide a very generalised guideline and it needs to be calibrated to the specific scenario within which it will operate. The methodology suitable for this purpose is the Proactive Method of Fraud Detection. It was determined through literature analysis of works by Albrecht et al (2015). It was initially realised based on the assumption that detection of fraud and inaccuracies in Accounts Payable will correlate with fraud and inaccuracies in invoicing. It is based on proactively approaching the detection of symptoms or 'weak signals', which in this case is framed as 'red-flags'. It also provides a much more detailed guideline on detecting certain anomalies. Fig. 6 below summarizes the methodology with its six steps in a work-flow diagram.

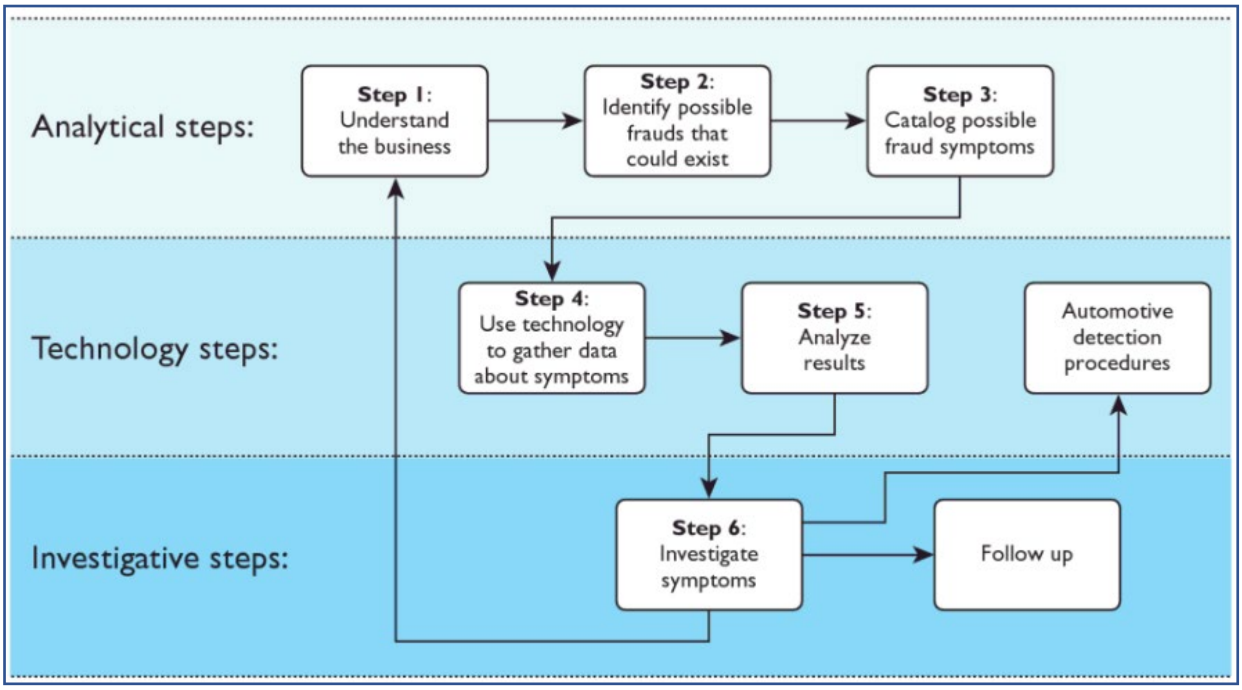

Fig. 6- The Proactive Method of Fraud Detection (Source: [28])

These steps are briefly described as:

3.3.1 STEP 1- Understanding the business

Each business environment or unit is different, even within the same firm. The proactive approach of detecting any anomaly starts with understanding the business or the sub-unit from an analytical perspective. The step emphasizes the statement that, 'the same fraud detection procedures cannot be applied generically to all businesses or even to different units of the same organisation'. This requires the analyst to have a good understanding of the business procedures and processes of the business. Further recommendation mentioned in this step is employing a team of varying expertise for such projects or initiatives. Some methods prescribed for understanding the business are as follows:

- Tour the business, department, or plant
- Become familiar with competitor processes
- Interview key personnel (ask them where fraud might be found)
- Analyse financial statements and other accounting information
- Review process documentation
- Work with auditors and security personnel
- Observe employees performing their duties

3.3.2 STEP 2- Identifying possible frauds that could exist

In this step, the effort of the team or the responsible individual(s) are directed towards identifying possible frauds by anticipating the actions of rule breakers and human errors. This step requires understanding the nature of different frauds and the mechanism of their occurrence along with the symptoms they exhibit. However, businesses and their sub-units may constitute procedures too large for analysts to consider simultaneously. This requires splitting and focusing on individual functions to understand each process. If the people involved within these business units are interviewed, certain questions that could be asked are:

- Who are the key stakeholders in the business?
- What types of employees, vendors, or contractors engage in business transactions?
- How do insiders and outsiders interact with each other?
- What types of fraud have occurred or been suspected in the past?
- What types of fraud have been committed against the company or on behalf of the company?
- How could employees or management acting alone commit fraud?
- How could vendors or customers working in collusion with employees commit fraud?

The fraud detection team responsible should also cluster potential frauds by type and of each stakeholder within the organisation. The likely occurrence of the plausible frauds by such criteria should also be considered, and a list should be produced.

3.3.3 STEP 3- Cataloguing possible fraud symptoms

The symptoms of fraud are usually found first and then the fraud. Certain fraud symptoms may even reflect nonfraud factors. These symptoms, also referred to as 'red-flags' do show certain properties like:

- A lack of confirmation as the actual causes of fraud.
- An increased probability of fraud if the number of confirmed red-flags increases.
- A universally applied and effective form of fraud detection if not the only form of fraud detection scheme.

Types of fraud symptoms detected in an organisation include:

- Accounting anomalies
- Internal control weakness
- Analytic anomalies
- Extravagant Lifestyles
- Unusual Behaviours
- Tips and complaints

The first three steps are analytical and applicable in every organisation. This strategic overview is however useful in systematically approaching the data collection process. It necessitates further customization within each contextual implication formed in an organisation to correlate specific symptoms with specific possible frauds.

3.3.4 STEP 4- Using technology to gather data about symptoms

The previous three steps are generalized to provide an analytical approach in the detection methodology. However, from step four, the detection methodology requires specific tools and technology to take it forward and recognize actual fraudulent activity occurring in an organisation. The underlying assumption is that each organisation is uniquely disposed to their business practices and fraudulent activity can only be observed and analysed from the exact point of view of the organisation. Organisations develop and use data analysis applications and custom Structured Query Language (SQL) queries and scripts specifically to meet their unique requirements. The development and the analysis of the data set produced is based on an iterative process where it can represent fraudulent behaviour with sufficient accuracy. The first three steps support step four in the following ways:

- Hypothesis testing for each fraud symptom
- Cause and effect of each fraud symptom
- Structured focus on each fraud symptom

3.3.5 STEP 5- Analysing Results

Step 5 is the continuation of step four for further analysis to articulate the exact causes of fraud. This step primarily dedicates the use of technology-based methods to detect and analyse the filtered data from step four. The use of computer algorithms should always be prioritized first and other traditional methods of analysis like investigation of leads should be done only when certain anomalies cannot be explained through continued analysis. Such initiatives may include talking to co-workers, investigating paper documents, and contacting outside individuals. The advantage of the deductive approach using technology is its potential for reuse and automation. It can be integrated into corporate systems to provide real-time analysis and detection of fraud and prevention of known fraud types. This claim is summarised in a way that relates to economics of finance as,

> 'Subsequent runs through the deductive steps reach economies of scale because many of the steps can be reused. [28]'

3.3.6 STEP 6- Investigate Symptoms

In this final step of the data-driven approach, the investigation targets the most promising indicators through computer analyses to discovering further details. This approach allows the investigator freedom from depending on tips and indicators egregious enough to surface on its own. However, the data-driven approach 'can be' more expensive in terms of time and labour if constructing and implementing the filtering mechanism in Step 5 and 6 is complex [28].

3.4 Cynefin Framework

The Cynefin Framework describes a context as either 'simple', 'complicated', 'complex', 'chaotic' or 'disorder' based on common constraints and relationships of causality i.e. between a cause and its effects, within each domain.

- 'Simple and Known, in which the relationship between cause and effect is obvious to all. The approach suited to this context is to Sense – Categorise – Respond (SCR) then apply best practice.
- Complicated or Knowable, in which the relationship between cause and effect requires analysis or some other form of investigation and/or the application of expert knowledge. The approach suited to this context is to Sense – Analyse – Respond (SAR) and then apply *good* practice.
- Complex, in which the relationship between cause and effect can only be perceived in retrospect, but not in advance. The approach suited to this context is to Probe – Sense – Respond (PSR) and then allow emergent practices.
- Chaotic, in which there is no relationship between cause and effect at systems level. The approach suited to this context is to Act – Sense – Respond (ASR) to discover novel practice' [29].

The fifth central domain is Disorder, which is the destructive state of not knowing what type of causality exists and thus not knowing which way of working is best. While problems may legitimately be allowed to exist in the other four domains if approached with suitable solutions, those in states of disorder are normally harmful and should be guided into one of the other domains. Fig. 7 illustrates the Cynefin Framework.

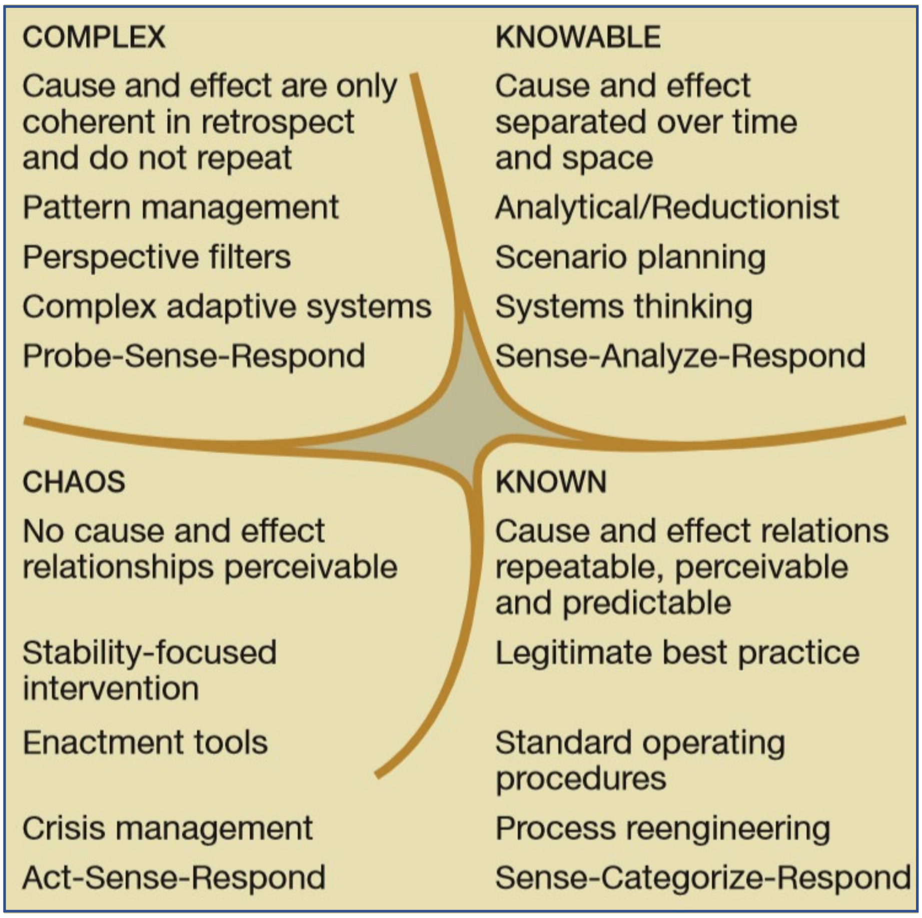

Fig. 7- The Cynefin Framework (Source: [30])

People are usually most comfortable in one of the first four Cynefin domains. In the domain of Disorder, individuals from each domain:

> 'Compete to interpret the central space on the basis of their preference of action. Those most comfortable with stable order seek to create or enforce rules; experts seek to conduct research and accumulate data; politicians to increase the number and range of their contacts; and finally the dictators, eager to take advantage of a chaotic situation, seek absolute control. The stronger the importance of the issue, the more people (Seem) to pull it towards the domain where they feel most empowered by their individual capabilities and perspectives.' [29]

3.5 Proposed SEWS for invoice inaccuracies

3.5.1 PHASE 1: Information Gathering

This is the first phase of the SEWS. The objective of this is exactly as prescribed by the generic SEWS model, i.e. 'gathering information about possible causes of the concerned effect, 'weak signals', or trends and issues.' The methodology used is adapted from Step 1, and Step 2, from the Proactive Method of Fraud Detection. Here the detection of the specific anomaly is in the context of invoicing inaccuracies found in an organisation.

3.5.2 PHASE 2: Diagnosis

- Based on the general guideline provided for implementing a SEWS, the first step is to create a contextual understanding of the anomaly. The Cynefin framework is used for this step to map the various contexts within which the causes of invoicing inaccuracies and its effects apply.
- Step 3 of the Proactive Method of Fraud Detection is used as the second step of the Diagnosis phase according to SEWS implementation guideline.
- The third step of the SEWS implementation instructs to prioritize the 'trend' or 'weak signal' based on the available resources and constrains. Steps 4, 5 and 6 of the Proactive Method of Fraud Detection are consolidated to form this step in the proposed SEWS model.

3.5.3 PHASE 3: Strategy Formulation

In the final phase of the proposed SEWS formation, a strategy is formulated based on the previous phases. The final steps of the Proactive Method of Fraud Detection, provide the following strategies,

- automate detection procedures using technology,
- follow up on the investigation.

The organisation can choose either or both strategies. Considering that the organisation takes the route of automating detection procedures through blockchain based smart contracts, their rationale for such a business case is formed.

Chapter 4: Literature Review

4.1 Liquidity Management

Ensuring solvency at all times is a necessary condition of economic activity for every holding financial industry. The recent financial crisis of 2020 has shown that there can be extreme market developments (even if only for short timeframes), as a result of which banks cannot borrow money from each other and even top addresses in the industry cannot raise funds. This has made companies aware of the importance of careful liquidity planning, particularly the need to ensure that sufficient liquidity buffers are available. In this respect, the holding financial manager must by no means hope to merely obtain a cash connection, but one of his core tasks is to conduct independent (and integrated with the profit plan) liquidity planning. Financial planning must be developed from the point of formulating the core business strategy because liquidity provision is susceptible to the fluctuations of a company’s cash flows. Its measurement and forecasting must not be based on a single-value scenario. Rather, stress tests must be used to precisely simulate those situations in which the markets are subject to particularly high liquidity stress and thus possible restrictions being placed on the company's liquidity potential available in "normal" times. Considering the risk tolerance of the owners, the extent of liquidity provisioning and a possible emergency plan with regard to extreme scenarios must be defined for these situations. As part of the regular reporting on liquidity developments, the organisation's financial management must demonstrate the extent to which the methods it has chosen to procure liquidity are sufficiently diversified in order to make the least possible use of the liquidity buffer [31].

4.2 Working Capital Requirement and the operating cycle

Working capital represents the liquidity buffer a company controls to finance its immediate operational needs, such as its obligation to its vendors, inventory, and accounts receivable [32]. It is the firm’s investment in its operating cycle. As fixed assets alone cannot generate profits, a firm depends on the managerial activities that operate these assets. These activities require investments in the form of trade receivables and inventory, which constitute the firm’s operating cycle. Fig. 8 below represents a schematic of a firm’s operating cycle.

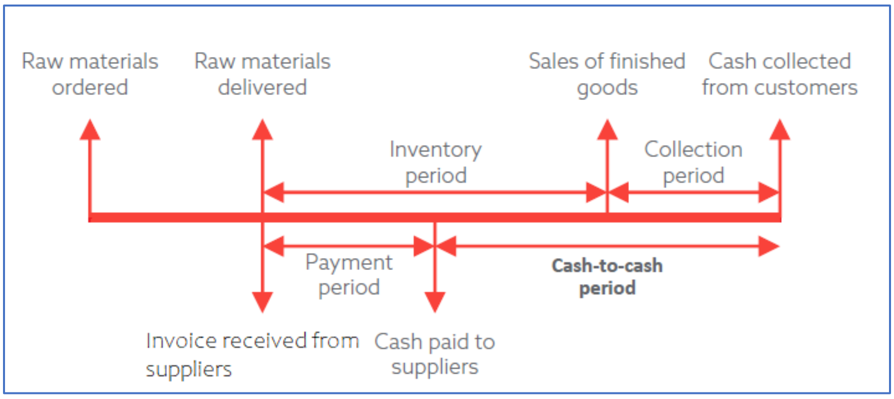

Fig. 8- Operating Cycle of a firm showing cash-to-cash period (Source: [33])

The schematic in Fig 8. above presents a realistic scenario of a manufacturing company where suppliers must be paid before collecting invoices from its customers. The timeframe between the point a supplier is paid off and invoices are collected from a customer is called the cash-to-cash period. The operating cycle is reinitiated by ordering new raw materials if the manufacturing activities continue. In decisions about financing investments like the WCR, firms try to apply the matching strategy. According to this strategy, long-term investments should be financed with long term funds and the WCR is a long-term investment. If the firm finds itself investing in permanent WCR through short-term debts it can face a liquidity problem. The decisions affecting a firm's WCR and its operating cycle are often made by operating managers and they have an influence over the firm's liquidity. The following quote summarises the cause and effect of fluctuations in a firm's WCR [33]:

> 'The lower the firm's investment in its operating cycle, the lower its WCR and the higher the firm's liquidity. Furthermore, the lower the frequency of unexpected changes in the firm's WCR, the less volatile the firm's liquidity position and the easier it is to manage. Clearly, control of the amount and fluctuations of a firm's WCR is the key to sound management of the firm's liquidity. [33]'

4.3 Blockchain application in Supply Chain Finance (SCF)

4.3.1 Blockchain may clear three major barriers in supply chain financing

The sharing of information between banks, buyers and suppliers creates opportunities for improving supply chain financing, contracting and international business [34]. The reason why suppliers need financing to maintain working capital is because invoices and bills are not reconciled in real time. Delays in this process leads to financial barriers that have the potential to disrupt and stop supply chains. Thus, banks need to be involved to keep the working capital levels optimal through financing instruments. The Global Supply Chain Finance Forum defines SCF as follows:

> 'SCF is the use of financing and risk mitigation practices and techniques to optimise the management of the working capital and liquidity invested in supply chain processes and transactions. SCF is typically applied to open account trade and is triggered by supply chain events. Visibility of underlying trade flows by the finance provider(s) is a necessary component of such financing arrangements usually enabled by a technology platform' [35].

Based on the definition above, the two components of supply chain finance i.e., working capital management and open account trading are brought together and facilitated by specialized technology platforms. This requirement in the market is fulfilled by fin-tech companies. These technology companies develop and offer platforms that facilitate the process of reconciliation (an accounting process that compares two sets of records to check that figures are correct and in agreement to confirm that accounts in the general ledger are consistent, accurate, and complete [36]), exchange of purchase orders (POs), invoices, credit notes and related information, thereby integrating the constituent parties in a supply chain. The purpose of facilitating the exchange of documents like purchase orders, invoices and credit notes is to initiate better financing prospects for those supply chain constituents that need working capital. However, certain financing mechanisms or techniques hold more share in the market than others, depending on the documents i.e. invoices or purchase orders being used as collateral. Invoice based financing techniques dominate the market with an estimated 80-90% market share because of the reduction of the risks imposed by engaging financial institutions later in the transaction. These three major barriers in SCF that is to be considered applicable for blockchain adoption are:

1. Know your customer (KYC) Requirements.
   Banks are obligated to perform background checks on their customers, which in the case of SCF are mostly the suppliers. These checks are performed to ensure that banks do not finance parties involved in illegal activities like money laundering, criminality, and terrorism. However, KYC policies require correct identification of customers and collection of relevant information, which are costly and time-consuming to perform. These tasks are especially difficult for multi-national corporation programmes with suppliers across multiple borders. The research paper 'KYC Optimization Using Distributed Ledger Technology' describes that 'the know-your-customer (KYC) due diligence process is outdated and generates costs of up to USD 500 million per year per bank' [37]. This is a major financial barrier for SCF because the key to a successful SCF relies on the ease of onboarding suppliers. A survey from ICC Global Trade Finance points out that the principal reason for rejecting trade financing proposals when dealing with foreign suppliers is because of the burden of KYC procedures. If a financial institution conducts a KYC check on a supplier and records that information on a blockchain, then other financial institutions can refer to this information as well, thereby avoiding repetition of KYC checks on the same supplier. This also has the to potential to make KYC checks more cost-effective and simpler for the banks and the suppliers.

2. Accounting Rules and Treatments
   Invoice based financial techniques can be divided into supplier-led or buyer-led instruments. Classic factoring falls under supplier-led programmes and constitute about 80% of the invoice based SCF market. Reverse factoring (where the buyer supplies the liquidity) fall under buyer-led programmes and constitute about 20% of the invoice based SCF market and hold potential for growth. The motivation of buyers to use instruments like reverse factoring may point to increased insolvency risk with suppliers and maintenance of the supply chain. However, the primary reason buyers initiate reverse factoring programmes is to capture the value from trade payables. Trade payables are not treated as debt for balance sheet purposes. Thus, reverse factoring does not affect the debt-ratio of the buyer. This creates a possibility over time for buyers to achieve a lowered financing rate from the banks. However, according to the rules of accounting, trade payables can be classified as finance payables if the buyer

wants to share some of the captured value with the financial institution. This reclassification may impact the buyer's loan covenants, leverage and access to additional credit. Their incentive to maintain optimal levels of working capital at the same time without impacting their leverage and loan covenants will be lost due to reclassification. Reclassification can however be avoided if certain conditions are met, which require buyers to not deviate from their commitment in any way. As the accounting rules cannot be changed, however, blockchain adoption could improve with saving time for complex transactions and internal control mechanisms. The manual auditing process altogether could be removed, through distributed ledgers and immutable records.

3. High Transaction Costs
   Securitization is another SCF instrument where there is no risk involved with accounting treatments and reclassification of balance sheet components. It is a procedure where an issuer designs a marketable financial instrument by merging and pooling various financial assets into one group. The issuer then sells this group of repackaged assets to investors. The risk in a supplier-led securitization programme is calculated based on the performance of the pooled assets. However, in buyer-led securitisation programmes or reverse securitisation programmes the diversification risk is nullified. The risks associated are now concentrated on the buyer which are larger corporations with investment grade rating. Risks when concentrated on these corporations makes it easier to clear, find and quantify. However, reverse securitisation incurs high transaction costs with post-trade processes. These high transaction costs necessary for setting up a securitisation structure along with the whole post-trade processing are a major barrier in delivering SCF. Settlements tie up capital and have a negative impact on transaction costs. Clearing and settlement are fundamental processes that require various intermediaries, the principal tasks of which rely on matching the buyer and seller records. The process requires data reconciliation and manual intervention to handle multiple ledgers consequently making post-trade processes time consuming and costly. Blockchain adoption will allow digital securities to be issued directly into the distributed ledger where ownership and transaction details are recorded immutably. Smart contracts can also be deployed to automate the process of executing contractual terms without any manual intervention. Further, settlement times will be reduced significantly as blockchain solutions can perform issuance, settlement, clearing and redemption related tasks in real time [38].

4.3.2 Experimental testing of a smart contract model developed for digitizing invoicing

An experimental model was developed to simulate the behavior of smart contracts when authenticating transactions that also involve invoices with a VAT payment component. The model targets to simplify the Digital Invoice Customs Exchange (DICE) paradigm by eliminating the requirement for a third-party and address the vulnerability of the Standard Audit File for TAX (SAF-T) to fraud. The results and the construction of the model is described in the paper, 'Digitizing Invoice and Managing VAT Payment Using Blockchain Smart Contract' which was published by the Institute of Electrical and Electronics Engineers (IEEE) [39], [40]. The model covers the roles of four different entities within the transaction process, namely the VAT administrator (VAD), sellers, buyers, and the bank. The model also leverages a Decentralized Storage Network (DSN) along with a private Ethereum Blockchain that supports the smart contract. The DSN is used to store all the invoices from the seller in an encrypted form via the InterPlanetary File System (IPFS) protocol to save on storage space in the Ethereum Blockchain. The way the model constructs the interaction patterns between these business entities is based on a fundamental practice in Computer Science called abstraction [41]. The developers of the model used abstraction to create a layer of complexity that is simple enough to process a blockchain based invoicing mechanism between the various parties in their model and eliminated the layers of complexity that does not serve their objective of model-building. The objective of building this model was to demonstrate the functionality of smart contracts and justify its effectiveness with countering VAT fraud and avoidance, over paper-based invoicing from a theoretical perspective. The model is however not directly usable on a realistic business case, but it can serve as a foundation for remodelling it with any number of variables in terms of buyers, sellers and VAT administrators as long as the technology components are fixed. The invoicing and VAT payment mechanism can be explained by the following steps:

1. Consider a transaction between the buyer and the seller that involves a specific VAT payment. Each VAT payment is calculated periodically, based on how the business is performing. According to the official website of the European Commission's Trade Helpdesk,

   'VAT is imposed on the added value at each stage of the production chain of any product or service, levied on final consumption and collected fractionally:
   - on all **commercial activities**, namely: supplies of goods and services, imports, and intra-Community transactions (goods brought into an EU country from another EU country)
   - at **each stage** of the production and distribution of a good or service by charging a percentage on the price of every transaction. However, VAT is ultimately borne by the final consumer
   - through a **scheme** where certain taxable persons (those VAT-registered) charge VAT on their sales (output tax) and reclaim the VAT charged on their purchases of goods or services used in their business activity (input tax). The difference between output tax and input tax is the VAT finally collected. [42]'

2. This periodic VAT payment (PV P) formula used in the model is,

$$PV\,P = \left[\sum_{i=1}^{n}(V_i) - \sum_{j=1}^{k}(E_j)\right] * r \qquad (1)$$

where *n* and *k* are the number of invoices sent (sales) and the number of invoices received (purchases). The difference between the total output tax *V* and the input tax *E* is multiplied by designated VAT rate *r.* The VAT rate depends on the country and the good and service delivered. The smart contract deployed by the VAT administrator in the model is encoded with this information (VAT calculator) and it serves the purpose of accurately calculating the PV P automatically after certain pre-conditions are met by the buyer and the seller.

3. The VAT administrator deploys the smart contract into the Ethereum blockchain that contains the list of all the registered VAT payers including the buyer and the seller.

4. The operation then moves to the seller's side where the seller encrypts their invoices to the buyer in the DSN. The encryption keys of these invoices in the DSN are stored as hash codes in the Ethereum Blockchain which also represent the location of the information in the DSN. The seller also uploads other information of the transaction, namely the Value of Goods and The Status into the blockchain as well.
   - The 'Value of Goods' is used by the smart contract to calculate the VAT payment without decrypting the invoice. Any user with the intent to decrypt the value of the invoice in the blockchain can do so, however the consensus protocol in place prohibits any form of data alteration without 51% of the users consenting to it.
   - 'The Status' is a piece of information indicating to the smart contract whether the buyer involved is the end customer. This indication is also used by the smart contract to generate the lawful invoice and accurately calculate the associated VAT payment.

5. After the seller has uploaded all the required information, the operation moves to the buyer. The buyer extracts the hash codes from the Ethereum blockchain and uses them to locate and decrypt the corresponding invoices. The buyer then uses the deployed smart contract to verify that the invoice has been received. This leaves the seller to validate the transaction in the smart contract.

6. If both parties validate the invoice, the smart contract is triggered to calculate the VAT payment concerned and save it in the blockchain. The

operation then moves to the VAT administrator who only requests the periodic VAT payment.

7. The smart contract generates the accurate periodic VAT payment based on the above-mentioned formula (1). It takes all the VAT payments corresponding to the party involved over a period, to calculate the PV P and sends it to the VAT administrator.

8. The VAT administrator checks for any discrepancy in the figures provided by the smart contract. If certain discrepancy or unsolicited alterations are found, the VAT administrator traces back the root cause of the issue in the DSN.

9. If no discrepancies are found the VAT administrator proceeds to approve the calculation, which triggers the transfer of the payment amount from the corresponding payer's bank account to the VAT administrators bank account.

In the model, the smart contract was designed with eight functions. These functions tie up the various parties involved in the invoicing mechanism with the Ethereum blockchain. They are described as follows:

- addVATPayer(): This function is exclusively executed by the VAT administrator to add the address of the registered VAT payers.
- addInforInvoice(): This function is exclusively executed by the sellers. It takes the information about the buyer's address and the price of the service as inputs. It also prohibits other user's access to this information.
- agreeFromBuyer(): This function is executed by the buyer to verify the invoice.
- agreeFromSeller(): This function is executed by the seller to verify the invoice after the buyer's verification. This also triggers the smart contract to calculate the VAT payment to be made by the seller and the buyer. In case the buyer is the end customer, the calculation of the payment is made only for the seller.
- requestForPVP(): This is another function that is exclusively executed by the VAT administrator. The VAT administrator periodically (e.g. monthly, quarterly) executes this function and the smart contract calculates the PVP.
- agreePVP() and disagreePVP(): These functions can only be executed by the VAT administrator. They are used to approve the PVP assembled by the smart contract.
- getInforPVP(): The bank runs this function to get a status of the PVP. Once the bank receives the status that the PVP calculations have been approved

by the VAT administrator, the bank proceeds to disburse the payment from the corresponding payer's bank account to the VAT administrator's bank account.

4.3.3 Cost analysis of the model's functions

The developers of the model also provided an estimation of the cost of executing those functions in the Ethereum blockchain in terms of gas used and gas prices, as of December 2018 [40]. 'Gas' is the abstract unit used by the designers of the Ethereum to quantify the computational effort necessary to execute every operation in a function. A complex function is computationally heavier compared to a simple function which uses less operations, thereby consuming more gas. The gas used for all the above functions remain constant, under the consideration that changes are not necessary for the purpose of the model-building. However, 'ether', the currency used in the Ethereum blockchain to assign a price for gas, experiences volatility as dictated by volatile market conditions. The model however does not take into consideration the price of gas and its relative volatility when using an Ethereum platform. As miners preferentially include transactions into blocks which are configured to pay the highest gas prices, which 'also follows that the higher gas price you are willing to pay, the faster your transaction will be processed, and sooner your contract will be allowed to execute' [43].

The Ethereum Gas Station [44] publishes real-time information on the price of gas and the transaction times. The site also provides a calculator which can be used to predict the transaction fee in Ether and the average time to confirm an execution in seconds, based on the transaction inputs, Gas Used and Gas Price. Table 1 below provides the comparison between the estimated cost of functions as of December 16th, 2018 (13:56 hrs GMT +9) with a gas price of 2.4 Gwei and July 11, 2020 (15:15 hrs GMT +1) with a gas price of 37 Gwei.

Table 1- Cost of functions analysis (Source: [40], [44]).

		December 16th, 2018 (13:56 hrs GMT +9)		July 11th, 2020 (15:15 hrs GMT +1)	
Function	**Gas Used**	**ETH**	**USD**	**ETH**	**USD**
addVATPayer()	41055	0.0000985	0.00857	0.001519	0.36152
addInforInvoice()	94560	0.0002269	0.01974	0.0034987	0.83269
agreeFromBuyer()	28603	0.0000686	0.00597	0.0010583	0.25188
agreeFromSeller()	24022	0.0000577	0.00502	0.0008888	0.21153
requestForPVP()	31528	0.0000757	0.00659	0.0011665	0.27763
agreePVP()	20879	0.0000501	0.00436	0.0007725	0.18385
disagreePVP()	16528	0.0000397	0.00345	0.0006115	0.14554
getInforPVP()	0	0	0	0	0
Total	257175	0.0006172	0.0537	0.0095153	2.26464

The price for executing all the eight functions of this smart contract as of July 11th, 2020 in the Ethereum blockchain is approximately **$2.26**. According to Ardent Partners, the average cost of processing an invoice manually in 2019 was **$10.08** [45], [46], [47]. This experimental result shows that the model may have a cost advantage over manual invoicing solutions. Depending on the number of operations the smart contract can handle, its cost changes in direct proportions. There is still a limit to the influence of gas prices on execution times. After a certain price point the acceleration of execution times stops and no higher price offer will result in a faster execution time [43]. Fig. 9 below shows the data from Ethereum Gas Station's Tx Calculator as of July 17, 2020 (12:15 hrs GMT +1).

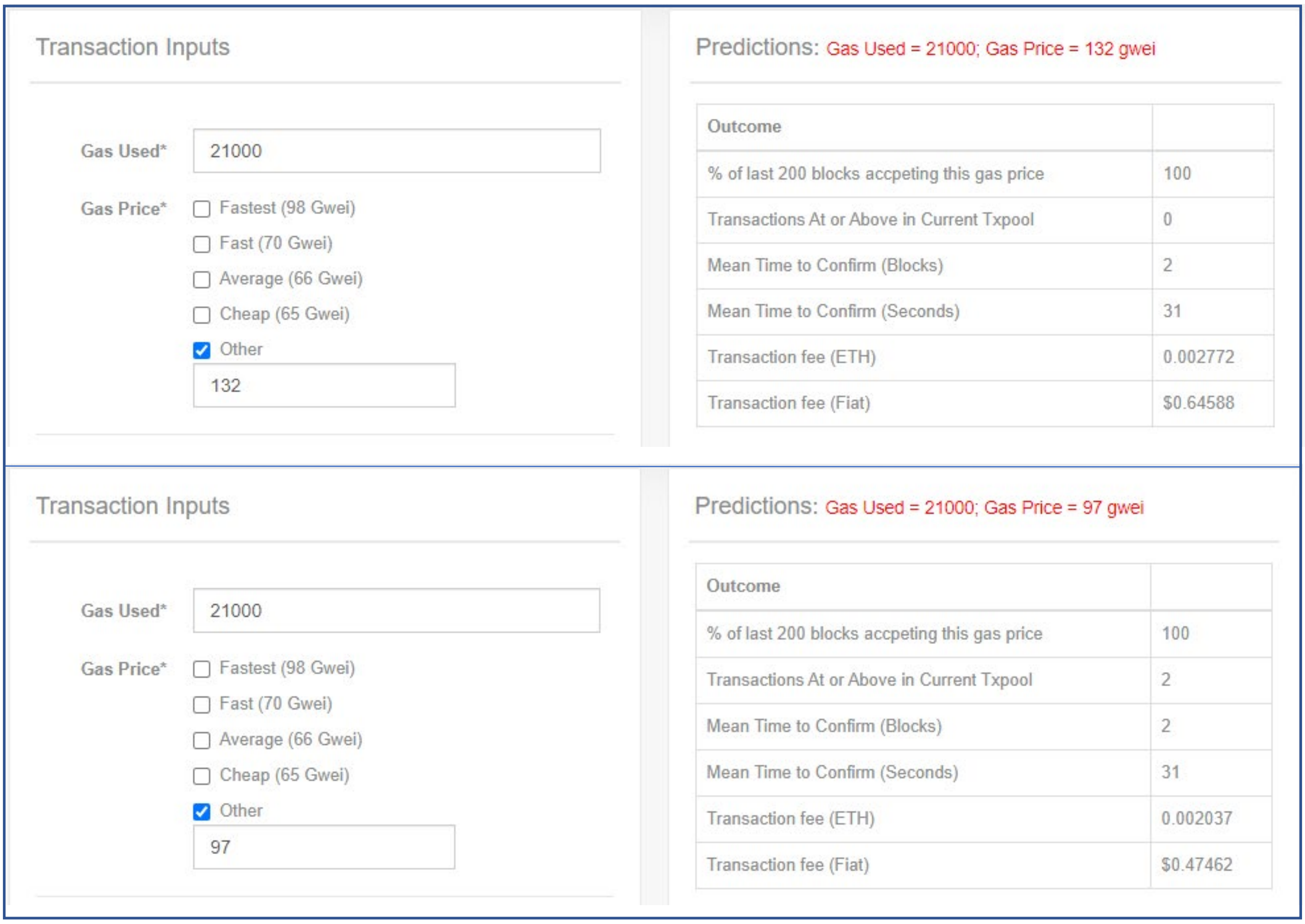

Fig. 9- Increasing gas price of 97 to 132 Gwei does not change 'Mean Time to Confirm (Seconds)' of 31 seconds.

4.4 Supply Chain

A supply chain is a network of organizations, people, activities, information, and resources involved in supplying a product or service to the final buyer. Supply chain activities involve the transformations of natural resources, raw materials, and components into a finished product that is delivered to the customer [48], [49]. The conceptual underpinning of a supply chain not only comes from an operational management perspective but also from international economics. Historically, the emergence of global supply chains (GSCs) is related to the economic theories of comparative advantage, namely Ricardo's theory and the Heckscher-Ohlin (H-O) theory [50]. Ricardo's model is based on the differences in the levels of technology or productivity. According to the Ricardo's theory of comparative advantage, a 'comparative' or relative advantage is still achieved when exporting goods and services that incur lower opportunity costs and importing goods and services that would otherwise incur higher opportunity costs when produced independently. This assumes that one of the trading nations is at an absolute advantage in terms of productivity and technology. However, Ricardo's model works on a constant marginal cost. It does not give a realistic conception of increasing marginal costs and the exchange of knowledge between countries to overcome technological barriers, that is made possible at the right price (payments of royalties, salaries of foreign experts etc.). The Heckscher-Ohlin theory of comparative advantage is based on the differences in factor endowments of nations. According to the Heckscher-Ohlin's model, 'a country exports the product (or products) that uses its relatively abundant factor(s) intensively and imports the product (or products) that uses relatively scarce factor(s) intensively' [51]. Similarly, the H-O theory does not take into consideration the institutional and technological infrastructure of developing countries and its ability to support the import or offshoring requests from firms in advanced economies. It assumes that technology is freely available across all countries and comparative advantages are determined only through relative factor endowments. Comparative advantage, whether seen from Ricardo or Heckscher-Ohlin's perspective, is still relevant in the formation of global supply chains because firms decide to establish production facilities for each production stage in the lowest cost location. It signifies a departure from the so-called 'Fordist' production system where all economic activity was organised within a single firm located on one site or in proximity. This relevance is observed as international production fragmentation is made feasible through the rapid development of information and communication technologies (ICT) and the proliferation of standards. ICT enabled the co-ordination of complex tasks regardless of proximity to the production facility and at a relatively low cost whereas standards enabled the modularisation of production processes through mechanisms for verifying complex information on quality [50].

4.4.1 Blockchain adoption in the supply chain

Blockchain implementation was studied in seven U.S. corporations namely Corning, Emerson, Hayward, IBM, Mastercard and two other corporations. The study was published at the Harvard Business Review website. It was conducted to understand if blockchain can solve certain supply chain problems like cost-inefficient delivery, lack of product traceability, lack of coordination between parties and difficulties finding access to financing. This study delivers relevant information regarding the state of play when it comes to blockchain based solutions for the supply chain. The authors of this publication consider blockchain as a potential solution to those problems and a 'game changer in the financial world'. The article can be summarised into three parts on a thematic basis. The first theme briefly describes the technical characteristics of blockchain. The fundamental points that can be drawn from this part when considering invoicing accuracy are as follows:

- Blockchain is a distributed ledger system. The transactions occur between multiple parties are verifiable and tamperproof.
- Transactions between parties need not be made manually in a blockchain. They can be made automatically by the ledger itself. The ledger can be programmed to 'trigger' these transactions based on certain pre-requisite conditions.
- Supply chain blockchain networks cannot be the same as cryptocurrency blockchain networks due to the simple fact that supply chains cannot allow *unlimited* number of *anonymous* parties to transact. On the contrary it is essential for blockchains built to support supply chains require a *limited* number of *known* parties to transact securely and protect businesses from malicious actors, whilst improving their traceability and invoicing accuracy.
- Without new rules to govern the system, new permissioned or private blockchains and new standards for representing transactions in a block, blockchain adoption will fail at solving these problems in the supply chain.

The second theme of the article is the advantages of blockchain technology over state-of-the-art ERP systems and its limitations. To elaborate on this aspect, a hypothetical example is presented, which involves three parties- a retailer, a supplier, and a bank. A simple transaction is made between the three parties where the retailer orders a product from the supplier and the bank finances the supplier with the working capital to fulfill that order. In this regard, the flow of information, inventory and finance cannot be reliably connected by state-of-the-art ERP systems, manual audits, and inspections. In other words, it is not easy to assess if journal entries (accounts receivable, payments, credit for returns etc.) correspond to the inventory transactions through ERP systems, thereby reducing the traceability of the inventory and the finance. Fig. 10 below illustrates this example.

‘’The financial ledgers and enterprise resource planning systems now used don’t reliably allow the three parties involved in a simple supply-chain transaction to see all the relevant flows of information, inventory, and money. A blockchain system eliminates the blind spots. [34]’’

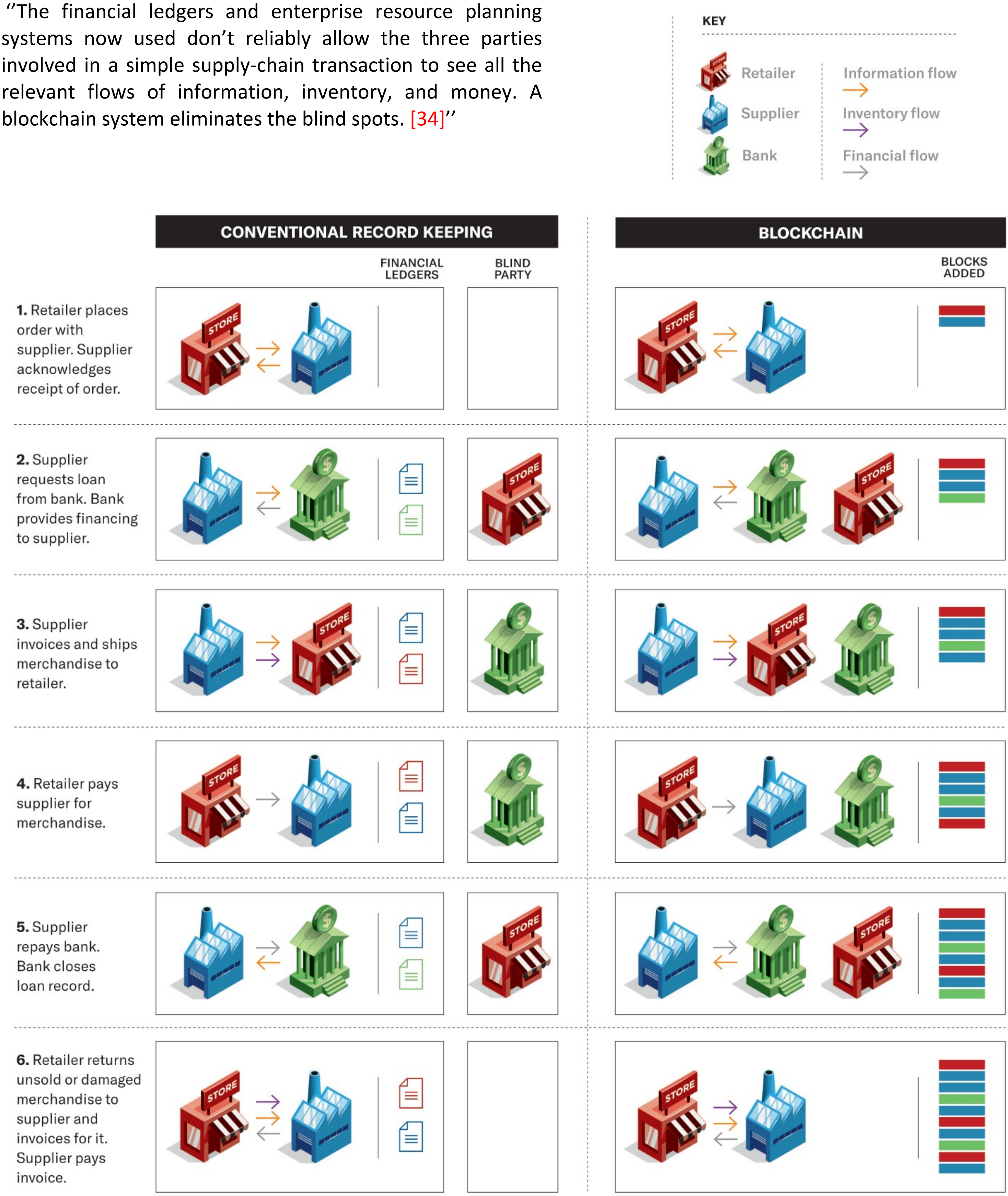

Fig. 10 “Capturing the Details of a Simple Transaction: Conventional vs. Blockchain Systems.” (Source: [34])

However, the illustration above depicts a very simplified example. Supply chain activities are much more complicated and prone to errors. The points in the article that are relevant to invoicing accuracy are as follows:

- Auditing is a process of verifying transactions and inspecting inventory, that can improve the supply chain by ensuring compliance with contracts. However, its limitations do not address operational deficiencies. For example, consider a food company which investigates their products reaching the end of their shelf life in a retail store. They find that auditing only helps with knowing the number expired products but does not provide any intelligence regarding why their products reach expiration dates.
- Integrating ERP systems of the companies and their buyers after marking their inventory with RFID tags is a plausible solution. This will help construct a complete record of transactions. However, the study of the companies found that integrating ERP systems is expensive, labour intensive and time consuming. Large organisations may have more than 100 ERP systems and integrating all ERP systems is not sustainable.
- Although integration of ERP systems is not feasible, the alternative solution is in using blockchain technology. ERP systems can be easily modified to produce blocks of transaction data which is then deployed into a blockchain network with all the parties involved in that transaction. Thus, blockchain technology can interface between multiple ERP systems to communicate transaction data.

The third part of the article contributes to an in-depth understanding of how blockchain is perceived by those companies and the systematic requirements that the companies had to first meet. The benefits like enhancing traceability of inventory throughout the supply chain and other benefits like increasing its speed and efficiency, reducing supply chain disruptions, and improving financing, contracting and international transactions are theoretically achievable through blockchain. Not all companies have fully developed their supply chains with blockchain technology, and some companies are only considering the possibility of blockchain interface as a viable alternative. However, the companies do agree that blockchain adoption will require new rules and regulation for it to function effectively. The factors necessary for blockchain to work in a supply chain are:

- Participants in the blockchain network cannot remain anonymous. Transparency in the blockchain will enforce the reliability of each party to deliver on their end. Their identity will be associated with each transaction thereby ensuring accountability.
- Public blockchains require a consensus protocol. It is a mechanism that blockchain uses to maintain a single record of the history of transactions that is agreed by every party in the blockchain. However, the consensus protocol is a slow process. It is not fast enough to keep up with the volume of transactions in the supply chain. This makes private blockchains applicable in situations where

the consensus protocols are designed to allow the adding of new blocks in an order pre-determined by all the parties, like the round-robin protocol. This will also make identifying malicious actors and resolving disputes easier.

- Blockchain records are immutable however they are still not going to solve human errors like mistakes with scanning, tagging and data entry. The companies mitigate this risk by conducting physical audits of inventory to match blockchain records, 'building distributed applications that track products throughout the supply chain, check data integrity and communicate with the blockchain to prevent errors and deception' [34].

4.4.2 Information asymmetry in the supply chain

The article, '*A systematic literature review of blockchain-based applications: Current status, classification and open issues*' summarises the work of Polim, Hu, & Kumara (2017) as 'the usage of blockchain-based applications in supply chain networks can lead to more robust contract management mechanisms between third and fourth party logistics (3PL, 4PL) for combating information asymmetry' [52]. Retailers entrust the management of their third-party logistics activity to a 4PL provider to focus on their retailing competencies. They prefer a single point of accountability as managing (multiple) 3PL providers is a resource consuming task for the retail management teams. The informational asymmetry that exists between the 4PL provider and the retailers is pertaining to information about the faults of 3PL providers and the 'root cause of unsatisfactory delivery'. In their paper, Polim, Hu, & Kumara propose a smart-contract design which maps all transactions between members while at the same time keeping their privacy intact. Their proposed database architecture incorporates computational and energy friendly mechanisms where miners with sufficient computational resources are elected and competition among miners which causes heavy computational expenditure is minimised. They designed a structure of smart contracts that secures retailers from collusive behaviour between logistics providers by leveraging blockchain properties like immutability and encryption, as shown in Fig. 11 below. Further, it makes the involvement of the 4PL providers redundant [53].

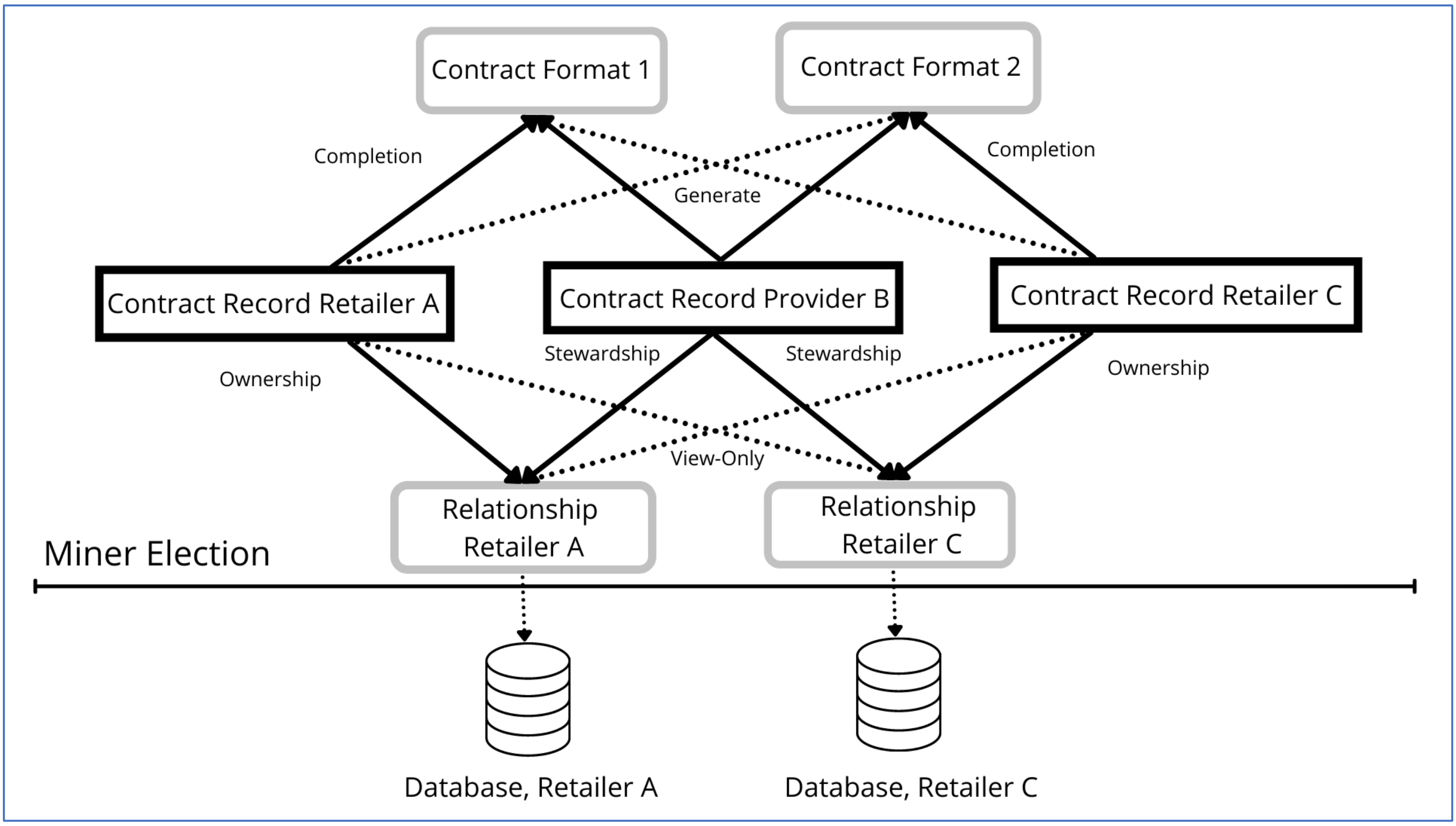

Fig. 11 Smart-contract structure to mitigate collusion among 3PL logistics providers (Source: [53])

The semantics of the structure is provided as follows,

> 'The structure of our smart contract must map all the transactions made by members while maintaining privacy. In order to do this, providers first generate contract formats which retailers complete. Within each contract record, retailer's (hashed) identity, logistics requirements, and fund source must be available. Second, the data ownership is administered to the retailer in order to make this blockchain retailer-centered. Third, the relationship tables are issued for each retailer. A relationship table details the list of permissions or concealments, nonce, and initialization vectors from a particular retailer [53].'

As information does not always flow smoothly in all cases, asymmetrical information between two parties is seen when all relevant details and knowledge factors are not available on both sides. This can lead to the party with less information getting exploited. Economic development and globalization encourage specialization within certain fields. This form of asymmetrical information is essential in cases which require specialization (e.g. doctors should have higher levels of informational asymmetry with patients in medicine). However, such informational asymmetry in logistics and accounting may be used for exploitation and fraud (e.g., a moral hazard). An empirical study conducted on financial reporting frequency shows that 'information asymmetry and the cost of equity decrease significantly for firms that increase their reporting frequency relative to control firms, regardless of whether the increase in reporting frequency is voluntary or mandatory' [54], [55]. The type of supply chain contracting, and the use of information also influences the modern supply chain. Supply chain performance is negatively affected by information asymmetry. The ways to eliminate or mitigate these negative effects require supply chain members to share the information they harbor privately with other supply chain members. Such collaborative efforts can be hindered by issues like:

- Alignment of business interests.
- Long-term relationship management.
- Reluctance to share information.
- Complexity of large-scale supply chain management.
- Competence of personnel supporting supply chain management.
- Performance measurement and incentive systems to support supply chain management.

In most companies these issues have not been addressed to enable effective supply chain collaboration. Moreover, in multiple supply chains there are power regimes and sub-power regimes that can prevent supply chain optimization. Even if it is technically feasible to integrate systems and share information, it may not be organisationally feasible because it may cause upheavals in the power structure. Another conflicting factor is the possibility of the introduction of inaccurate information into the system. Inaccurate information too would lead to demand distortion. The case that was reported in a study of the telecom industry demand chain where some partners were double forecasting and ration gaming, despite the fact there was a collaborative system in place and a push for the correct use of this system. There is also an increasing tendency towards more 'dynamic' and 'agile' supply chains arising from the advances in E-business. This trend enables the supply chains to be more flexible and adaptive. However, it may prevent companies from investing into forming long-term collaborative relationships among each other due to the restrictive nature of such commitment [56].

4.5 A multi-criteria decision matrix for blockchain adoption.

International fragmented production depends on co-ordination of complex tasks and the prompt flow of materials through supply chains. The development of information and communication technologies has enabled its practice [50]. Businesses are confronted with the risk of not meeting their objectives from investments in innovative technological solutions. Such scrutiny is also introduced when considering blockchain adoption based on the theoretical benefits it offers like traceability and immutability of information within supply chains. A study conducted to assist a global logistics company with making the correct decisions when adopting a blockchain platform was published by Springer, although the name of the company was not disclosed. The study approach is primarily dedicated to setting a grid of criteria for blockchain adoption by reviewing available literature and analysing the preferences of the company over certain criteria by using the Buckley's Fuzzy Analytical Hierarchical Process (Fuzzy AHP). Table 2 below provides these criteria in a hierarchical structure [57].

Table 2- Criteria for blockchain adoption

Main Criteria	Sub- Criteria
C_1: Cost	C_{11}: Purchase Cost
	C_{12}: Maintenance Cost
	C_{13}: Additional Cost
C_2: Speed	C_{21}: Encryption Speed
	C_{22}: Speed of Transactions
	C_{23}: Latency in results of queries
C_3: Privacy Concerns	C_{31}: Security
	C_{32}: Anonymity
	C_{33}: IP Tracking
C_4: Logistics Issues	C_{41}: Work-in-harmony with Internet of Things
	C_{42}: Interoperability with other supply chains
	C_{43}: Range of services provided
	C_{44}: Adaptability to logistics business process
C_5: Functionality	-
C_6: Developer Availability	-

The Fuzzy AHP incorporates a pairwise comparison matrix which simplifies preferential choice, as it allows the comparison of only two criteria at a time. However, preferential choices between two criteria are made based on the subjective expertise by a decision maker. Fuzzy AHP systematically cuts such subjectivity by using fuzzy set theory concepts and hierarchical structure analysis [58]. A ranged assessment with fuzzy numbers also provides a sense of security over fixed assessments. The step wise method used is described below:

- A hierarchical structure is formed as shown in Table 2.
- Linguistic variables considered namely, Very Low, Low, Medium, High, Very High and Triangular Fuzzy Numbers (TFN) are assigned to each. Consider three numbers m1, m2, and m3 where m1 and m3 are the left and right spreads of m2 respectively. In general, a TFN shows its relationships as (m2-m1, m2, m2+m3). If this triplet is converted into a TFN, then it must be presented in the format (m1, m2, m3) [59]. Table 3 below provides the linguistic variables, its abbreviations and its associated TFN.

Table 3- 'Linguistic variables for pairwise comparison' (Source: [57])

Abbreviation	Linguistic Variables	Triangular Fuzzy Number
VL	Very Low	(1,1,3)
L	Low	(1,3,5)
M	Medium	(3,5,7)
H	High	(5,7,9)
VH	Very High	(7,9,9)

- A pairwise comparison matrix of the format,

$$\tilde{A}^k = \begin{bmatrix} \tilde{a}_{11}^k & \cdots & \tilde{a}_{1n}^k \\ \vdots & \ddots & \vdots \\ \tilde{a}_{n1}^k & \cdots & \tilde{a}_{nn}^k \end{bmatrix} \tag{2}$$

was constructed where $\tilde{a}_{ij}^k$ denoted the kth decision maker's preference of the ith criterion over the jth criterion. Three decision makers participated in the study, each with varying preferences over multiple criteria. Their opinions were recorded in pairwise comparison matrices, which are presented Table 4 below:

Table 4: Pairwise Comparison matrices of the three decision makers (Source: [57]).

DM_1	C_1	C_2	C_3	C_4	C_5	C_6	DM_2	C_1	C_2	C_3	C_4	C_5	C_6	DM_3	C_1	C_2	C_3	C_4	C_5	C_6
C_1	1	M	H	L	VH	VH	C_1	1	L	L	M	H	VH	C_1	1	H	M	M	H	VH
C_2		1	H	M	VH	VH	C_2		1	M	L	H	VH	C_2		1	L	H	VH	VH
C_3			1	H	H	VH	C_3			1	M	L	VH	C_3			1	M	H	H
C_4				1	H	VH	C_4				1	VH	VH	C_4				1	H	H
C_5					1	M	C_5					1	H	C_5					1	VH
C_6						1	C_6						1	C_6						1

Since there are multiple decision makers, an aggregate decision matrix with their weighted averages was constructed, using the formula:

$$\tilde{a}_{ij} = \frac{\sum_{k=1}^{K} \tilde{a}_{ij}^k}{K} \tag{3}$$

Here K is the total number of decision makers. Table 5, below presents this aggregated matrix:

Table 5: Aggregated matrix based on decision maker's preferences (Source: [57]).

	C_1	C_2	C_3	C_4	C_5	C_6
C_1	(1,1,1)	(3,5,7)	(3,5,7)	(7/3, 13/3, 19/3)	(17/3, 23/3, 9)	(7, 9, 9)
C_2	(1/7, 2/9, 1/2)	(1,1,1)	(11/3, 17/3, 23/3)	(3, 7, 7)	(19/3, 25/3, 9)	(7, 9, 9)
C_3	(1/7, 2/9, 1/2)	(1/8, 2/7, 1/6)	(1,1,1)	(11/3, 17/3, 23/3)	(11/3, 17/3, 23/3)	(19/3, 25/3, 9)
C_4	(1/8, 1/6, 2/7)	(1/7, 2/9, 1/2)	(1/8, 1/6, 2/7)	(1,1,1)	(17/3, 23/3, 9)	(19/3, 25/3, 9)
C_5	(1/8, 1/8, 1/6)	(1/9, 1/8, 1/6)	(1/7, 1/5, 1/2)	(1/9, 1/8, 1/6)	(1,1,1)	(5, 7, 25/3)
C_6	(1/9, 1/9, 1/7)	(1/9, 1/9, 1/7)	(1/9, 1/8, 1/6)	(1/9, 1/8, 1/6)	(1/8, 1/7, 2/9)	(1,1,1)

To verify how the aggregates, hold true to these weighted average calculations, consider the C_1 and C_2 pair in Table 5 above which has the TFN (3,5,7). The linguistic variables assigned for the C_1 and C_2 pair by the decision makers are M, L and H with TFNs (3, 5, 7), (1, 3, 5) and (5, 7, 9) respectively. The aggregate TFN (3, 5, 7) is formed using formula (3) above as ((3+1+5)/3, (5+3+7)/3, (7+5+9)/3)).

- A geometric mean for each parameter of $\tilde{a}_{ij}^{k}$ is calculated using the formula,

$$\tilde{r_i} = \left(\prod_{j=1}^{n} \tilde{a}_{ij}\right)^{1/n} \qquad (4)$$

where i, j = 1, 2, ... n. The geometric mean is used to convert $\tilde{A}$ into a n × 1 matrix. Table 6 below provides the geometric means of the aggregated fuzzy numbers from Table 5 as a n × 1 matrix.

Table 6- Geometric mean of each main criteria (Source: [57])

Geometric Mean of criteria	TFN of geometric mean
$\tilde{r_1}$	(3.07, 4.42, 5.41)
$\tilde{r_2}$	(2.05, 2.8, 3.61)
$\tilde{r_3}$	(1.09, 1.49, 2.07)
$\tilde{r_4}$	(0.68, 0.88, 1.23)
$\tilde{r_5}$	(0.32, 0.28, 0.52)
$\tilde{r_6}$	(0.16, 0.17, 0.02)

To verify how the geometric mean calculations of each criteria holds true to formula (4) consider the first vector with $\tilde{r_1}$ i.e., 3.07.

It is calculated as, $\sqrt[6]{1 \times 3 \times 3 \times 7 \times \left(\frac{7}{3}\right) \times \left(\frac{17}{3}\right) \times 7} = 3.0674 \approx 3.07$

- The fuzzy weights are determined by finding the vector summation of each $\tilde{r_i}$, their inverse values. Two fuzzy numbers $\tilde{A}_1$and $\tilde{A}_2$ can be added and multiplied using formulas (5) and (6) respectively as shown below:

$$\begin{aligned}\tilde{A}_1 \oplus \tilde{A}_2 &= (l_1 + m_1 + u_1) \oplus (l_2 + m_2 + u_2) \\ &= (l_1 + l_2, m_1 + m_2, u_1 + u_2)\end{aligned} \qquad (5)$$

$$\begin{aligned}\tilde{A}_1 \otimes \tilde{A}_2 &= (l_1, m_1, u_1) \otimes (l_2, m_2, u_2) \\ &= (l_1 * l_2, m_1 * m_2, u_1 * u_2)\end{aligned} \qquad (6)$$

And the reciprocal of a fuzzy number $\tilde{A}^{-1}$ can be found using the formula:

$$\tilde{A}^{-1} = (l, m, u)^{-1} = \left(\frac{1}{u}, \frac{1}{m}, \frac{1}{l}\right)^{-1} \qquad (7)$$

- Using (5), (6) and (7), fuzzy weights are calculated for the formula:

$$\tilde{w_i} = \tilde{r_i} \otimes (\tilde{r_1} \oplus \tilde{r_2} \oplus \dots \tilde{r_n})^{-1}$$

$$= (lw_i, mw_i, uw_i) \tag{8}$$

where i = 1, 2, … n and l, m and u refer to 0.08, 0.1 and 0.14 respectively. Table 7 below provides the information necessary to calculate the fuzzy weights.

Table 7. Information necessary for calculating fuzzy weights (Source: [57])

Vector Summation	7.37	10.1	13.1
Reciprocal	0.14	0.1	0.08
Reverse order	0.08	0.1	0.14

- These fuzzy weights are then defuzzied (M_i) and normalized (N_i) using formulas (9) and (10) respectively, as shown below:

$$M_i = \frac{lw_i + mw_i + uw_i}{3} \tag{9}$$

$$N_i = \frac{M_i}{\sum_{i=1}^{n} M_i} \tag{10}$$

Table 8 below provides the fuzzy weights calculated using l, m, u and their defuzzied and normalized values.

Table 8- Fuzzy weights of the criteria along with their defuzzied and normalized values (Source: [57])

Geometric Mean of criteria	Fuzzy Weights	M_i	N_i
$\tilde{r}_1$	(0.23, 0.44, 0.73)	0.47	0.42
$\tilde{r}_2$	(0.16, 0.28, 0.49)	0.31	0.28
$\tilde{r}_3$	(0.08, 0.15, 0.28)	0.17	0.15
$\tilde{r}_4$	(0.05, 0.09, 0.17)	0.1	0.09
$\tilde{r}_5$	(0.02, 0.04, 0.07)	0.04	0.04
$\tilde{r}_6$	(0.01, 0.02, 0.03)	0.02	0.02

The results from the above calculations show that C_1 i.e. cost as a criterion holds the most weight of 0.42 amongst all other criteria. This shows that the company mostly prefers to have the costs of adopting blockchain based software meet their budget. After costs, the company prioritizes speed and privacy concerns.

4.6 Barriers in blockchain adoption in the supply chain

Market research conducted by interviewing executive MBA alumni of the University of Arkansas reveal that the most common barriers in the implementation of blockchain technologies in the supply chain is a 'lack of understanding' (LOU). This lack is not in the technology and in the formation of use-cases but much rather in the gap between the initial pilot as a proof-of-concept and the scaling in the supply chain. LOU about integrating blockchain into existing processes, potential benefits, implementation costs, uncertainty of Return on Investment (ROI) and its technical limitations were reported (in decreasing order) to be the greatest concerns in their findings. Certain details like the size of the sample from which their data was collected is not mentioned but the inferences of their findings were summarised based on the 29 parameters (potential barriers) they selectively targeted as polls. Their goal was to validate certain assumptions about navigating partnerships between organisations and their study allowed them to conclude that most of these barriers arise when dealing with other parties in the supply chain. These barriers are briefly described below:

- COLLABORATION:
  Potential players do not participate in fear of losing their roles in the supply chain or giving away information to competitors. Other reasons include a lack of financial stability, general resistance to technology or process changes, security concerns or a combination of these factors.
- STANDARDIZATION:
  Varying methods in terms of terminology, technology and measurements between collaborating parties pose inefficiencies and contribute to the general LOU of the blockchain integration process. Furthermore, it hinders partnership over software compatibility between blockchain members.
- INTEROPERABILITY:
  Interoperability here refers to the standardized capacity with which partners in a blockchain network have managed to integrate their current software systems for data exchange. This area is highly prone to miscommunication, lack of uniformity in data streams and technological constraints.
- BUREAUCRACIES:
  Global supply chains span across international borders and thereby interact with various government agencies. They provide the necessary checks and balances, oversight, and regulation for commerce. Transparency that comes from blockchain adoption may not be desirable to all governmental agencies. This can be a strong barrier for blockchain adoption.
- COMPETITIVE INSTINCTS:
  Prospects for informational symmetry trigger competitive instincts between the major links such as retailers, shippers, railways, trucking companies, distributors in the supply chain. Those parties that intend to keep a hold on their information for the sake of maintaining a competitive advantage, presents a barrier for blockchain adoption.
- IMMUTABILITY:
  Blockchain immutability renders data incapable of possible updates and deletion. This poses as a barrier if low quality data or unknown errors remain permanently embedded in the blockchain and the responsible parties are unable to recover it for correction.
- SECURITY:
  Security is a major concern in blockchain adoption. No countermeasure can be devised in time to stop a breach if an exploit is discovered. The underlying belief

is the matter of human ingenuity. Even if the creator of a smart contract develops it with all protective measures plausible, it is still susceptible to innovative disruption. Newer systems and technologies may emerge, which may dictate changes to the consensus protocols in place, leaving its code vulnerable to quality downgrades and security breaches. This can pose as a barrier for blockchain adoption if there is no governance system in place for the proposing party to show for.

- DATA QUALITY:
  Getting and cleaning the data before deploying it into the blockchain ensures that it delivers of the business intelligence that is necessary for conducting commerce. Dirty data will eventually degrade the utility of blockchain.
- COST:
  Cost is a variable in blockchain adoption, and it can be influenced by multiple factors. As blockchain networks grow in complexity and stored information, the computational expenses increase in direct proportions. Other influencing factors are resources that specialize in blockchain development and the hiring process involved with such resources [60].

Another source presents other barriers in blockchain adoption, relevant to supply chains in further granularity. The method of data collection used is through a systematic review of relevant literature from 2014 to 2019. It identifies 18 possible barriers from literature reviews and broadly classifies them into 4 groups as mentioned in Table 9 below [61].

Table 9- Barriers in blockchain adoption identified from literature review (Sources: [61])

Technological and Security barriers	Lack of technological maturity
	Data Security
	Usability
	Complexity
	Interoperability
	Forking
	Performance and scalability
Financial and human resources barriers	Lack of IT personnel
	High investment cost
	Lack of research and development units
	Lack of technological infrastructure
	Lack of financial subvention for blockchain technology
Organisational and individual barriers	Strong hierarchical structure and bureaucracy
	Strict administrative control
	Information and sharing obstacles
	Mind set of people needs to be changed
Social and environmental barriers	Information sharing (environmental and social aspects)
	Wasted Resources

The barriers not discussed in greater detail in the former literature are highlighted in Table 9 and briefly described below:

- USABILITY:
  The usability of blockchain applications depend on its user-friendliness. A lack of specific design standards and the incompatible mechanisms between existing IT systems pose as barriers.
- FORKING:
  A schism is formed between system developers when one group in the blockchain network does not update their version of blockchain information. These updates are configured to improve the network's capabilities, facilities, and performance. This schism results in multiple blockchain networks when only one was intended. Bifurcation is a major barrier in blockchain adoption as it can result in one or more members in the blockchain losing their privileges and the possession of legitimate information.
- PERFORMANCE AND SCALABILITY:
  Transactions in the blockchain are computationally heavy and slower than modern credit card platforms. Institutions that transact high volumes of data may not find blockchain adoption as adequate substitutes for current transaction processes due to its speed and volume limitations.
- LACK OF RESEARCH AND DEVELOPMENT UNITS:
  Lack of research and development teams and human resource policies in companies slows the awareness of the technology and the technological transition period. This poses as a barrier in establishing a pilot phase.
- LACK OF TECHNOLOGICAL INFRASTRUCTURE:
  Blockchain adoption requires changes to local technology infrastructures. Changes require time and management, which might not be prioritised by companies.
- LACK OF FINANCIAL SUBVENTION FOR BLOCKCHAIN TECHNOLOGY:
  Government aids and support for blockchain is low because it is relatively new and unproven in traditional supply chain systems. Banks play a central role in managing finances and are integrated with other governmental institutions. Transformative changes on a global scale require independence from existing traditional changes and a top-down approach, which is a significant barrier for blockchain adoption in the supply chain [61].

Chapter 5: Discussion

5.1 Blockchain adoption in the Freight Bill Audit and Payment (FBAP) process.

In this study by Accenture, blockchain technology is considered as a tool to reduce the discrepancies in the Freight Bill Audit and Payment process. This process constitutes functions like freight rate management, track-and-trace, invoice calculation and payment remittance. The observed shippers in this case are from the Oil & Gas industry. The author claims that blockchain has 'wide potential to drive savings in oil and gas (O&G)' with an estimated reduction of 5% in transportation expenditure. The information to support the author's argument are as follows:

- Shippers receive a lot of freight invoices from carriers. These freight invoices include charges called accessorials in addition to the price of the freight move. These additional charges are calculated against the circumstances that arise from the freight shipment, such as the number of miles driven or the idle time.
- Matching functions need to be performed by shippers where they evaluate the sameness between the ordered and received services from their carrier(s). The invoices sent by their carriers need to be used for this task. As these matching functions are not the shipper's core competence, they employ third party audit and payment service providers. However, these third parties spend 25% of their time managing exceptions. According to observations made by Accenture on these third-party auditors, certain organizations have on average 200,000 invoices outstanding due to matching errors i.e., no records are available of those invoices matching any carrier's service. Thus, the effort then shifts to the shipper's freight bill department, taking additional time and resources.
- Shipper's do not put the extra effort to match freight orders to bills of lading and invoices. They instead make overpayments within thresholds to disputed invoices. Thus, shippers suffer from 'process-outsourcing costs, high exceptions rates, time and effort for reconciliations and overpayments within thresholds' in the current FBAP.
- If the current FBAP process was produced into a blockchain network then every transaction between the shipper and the carrier, would add to a single record of the history of transactions and will be distributed between all involved parties. Details of the transaction like contracted rates can be recorded in this blockchain along with each step the freight takes from freight order to payment submission.
- Invoices can be accurately calculated based on embedded business logic or smart contracts. For example, if the origin and the destination of the freight matches to that on the smart contract, then the smart contract is triggered to charge a rate that has been agreed contractually.

- Track-and-trace capabilities can be added to the blockchain to trace movement of the freight and calculate the miles moved. Accessorial fees can also be calculated accurately with inputs taken from the blockchain, like the miles moved, idle time and other circumstantial factors. Sending invoices and remittances can be automated on the network based on the contracted rates [62].

5.2 Blockchain adoption leads to 100% invoicing accuracy

Two corporations namely, DHL Global Forwarding and Hewlett Packard Enterprise, collaborated to address the problems with their supply chain. DHL Global Forwarding is an air and ocean freight transportation company that also had to suffer from error-prone and tedious back-end processes. Their collaborative effort to reduce these errors and tedium is based on blockchain and smart contracts. It is a minimum viable product (MVP) according to the information presented in its press release. However, the information in their press release is limited. It does not provide further technical details necessary to validate the process used to create their product. The claims they make that their collaborative effort brings are:

- Their MVP product was deployed on July 1, 2019 and it operates their supply chains to deliver 'one-off' orders. One-off orders are defined in their publication as those orders or shipment requests that can be supported by their network but are not part of their standard contract.
- The product leverages blockchain properties like decentralization and immutability to solve problems with approving shipment quotes.
- The initial results of the product's performance include 100% invoice accuracy.
- Both parties have saved time taken by post-delivery checks necessary for approving shipments, after deploying their blockchain based product.
- The product sends out invoices automatically after getting triggered by proof-of-delivery (POD) instances in the blockchain. The invoices are sent out to their customers based on the contractual payment terms [63].

5.3 The Cynefin mechanism of the proposed SEWS

Coming from an analytical standpoint, the exact cause(s) of invoice inaccuracies found in one company will not be the same for all other companies. This makes setting a specific and standardized guideline not suitable for all scenarios. The specific conditions of pre-existing systems will produce outcomes uniquely affected by its conditioning. These details are not meant to be articulated by a general model. Rather, the objective here is to only articulate those aspects that may resemble organisational setups that are scanning for possible methods of detecting fraud and errors still unknown. As discussed in Chapter 4, the Cynefin Framework is not meant to be a 'specific guideline' tool. It is a sense-making tool for contexts. However, the attempt is made to map and classify certain cause and effect scenarios using the constraints in the Cynefin

Framework. As the effect is fixed i.e. inaccurate invoicing, certain causes are mapped based on the relative effort in identifying the cause from a corporate management perspective. The first level of classification is based on two domains, namely, ordered and un-ordered [30]. In the ordered domain, the reasons that cause invoicing inaccuracies are technical in nature, i.e. the error is not caused intentionally, for example, unfavourable weather conditions for transportation, insolvency, diminished natural resources for production, a pandemic, accounting mistakes, data-entry and calculation errors. The focus on the un-ordered side is on activities that involves operations executed by humans to intentionally create invoicing problems, directly or indirectly. In the second level, the ordered domain is further classified into the 'known' and 'knowable' domains and the un-ordered domain is classified into the 'complex' and 'chaotic' domains. For the sake of abstraction, the constraints that determine the cause of invoicing inefficiencies for each domain are taken from the Cynefin Framework in the following ways:

- KNOWN or SIMPLE- The cause of an inaccurate invoice is obvious. It could be that the vendor or the supplier that sent the invoice made a calculation error and clarified their mistake and resent the correct invoice in a short duration.
- KNOWABLE or COMPLICATED- The cause of an inaccurate invoice requires some investigation and analysis before it can be reported. However, these errors can still be detected before they can cause harm to the organisation. For example, 'the materialisation of an information asymmetry within an intra-Community supply chain generally implies that one or more taxable persons are unable to comply with the legal VAT requirements applicable to them' [64]. This means that one party is unable to draft an invoice in conformity with invoicing obligations [64]. Thus, the reasoning for such a cause requires analysis, however it can still be detected before such an error occurs. The volatility of freight rates as adjusted with the GRI, can also affect the cost of products. Buyers and sellers may need to adjust the costs of their products to accommodate the costs of shipping [18]. Following the same line of reasoning, freight rate volatility as a cause for an inaccurate invoice can be detected after analyzing the GRI changes announced by the shipping line.
- COMPLEX- The cause of an inaccurate invoice can only be identified in retrospect i.e., after it has already occurred. These errors are perpetrated intentionally and therefore can only be detected in retrospect. For example,
    - 4PL providers may not disclose that a certain 3PL is not delivering on the agreed quality, if the 4PL is the only single point of accountability for a retailer (customer). The retailer will only realise that their invoices are inaccurate after they measure the quality they are receiving.

❖ Another cause of inaccurate invoices that is much more severe than simple accounting errors is informational asymmetry between buyers and sellers and within departments of a business entity in the B2B sector. Businesses procure goods and services first and make payments in cash later. Based on the terms of trade agreed upon, a payment period can be from 30 days to 120 days in their operating cycle. This stretch of time within the transaction's lifespan gives enough opportunity for informational asymmetry to infect the transaction between a buyer and a seller. Consider a single transaction where the supplier ships physical goods to the buyer as illustrated in Fig. 12 below. Solid arrows show the movement of physical goods and dotted arrows show financial and documentary workflows.

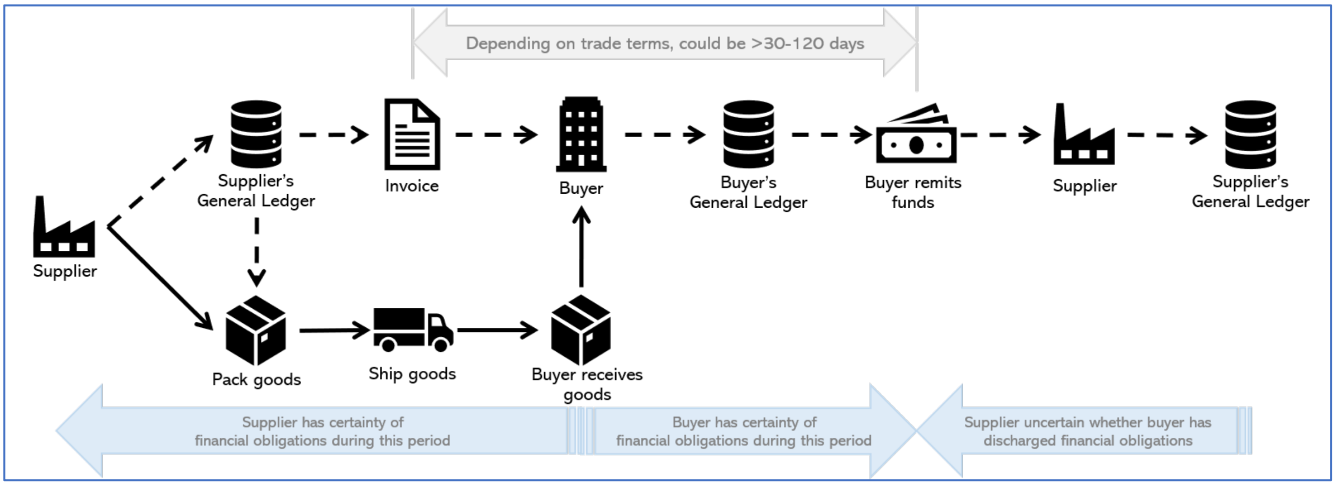

Fig. 12 Buyer-seller informational asymmetry occurring in the payment period of the operating cycle in B2B enterprises. (Source:[65])

The blue arrows show informational asymmetry between the buyer and the seller in the following ways:

- The seller has perfect knowledge of the goods shipped, the timing of delivery, the financial amount receivable and when that financial amount falls due. The buyer still does not have complete certainty over the information even when using the purchase order (PO) mechanism. Certain details like the timing of the delivery will remain to its best knowledge in the hands of the seller.
- The goods and its invoice do not always arrive simultaneously. Even when goods are received without an invoice, they still need to be incurred as a liability. This form of imperfect knowledge of when the invoice will arrive, creates a difficulty, and can be described as a 'pain-point' for the accountants. They need to reconcile the receipt of physical goods with the receipt of financial invoices.

- The supplier issues an invoice for payment but there is no guarantee that the buyer will pay according to the trade terms on the invoice. The supplier may need to follow-up incessantly if it does not have perfect knowledge of when the cash will be remitted to their bank account.

The problem of informational asymmetry is amplified when departmental segregation of duties is introduced within large organisations. Fig. 13 below represents both vertical and horizontal forms of informational asymmetry in a single transaction.

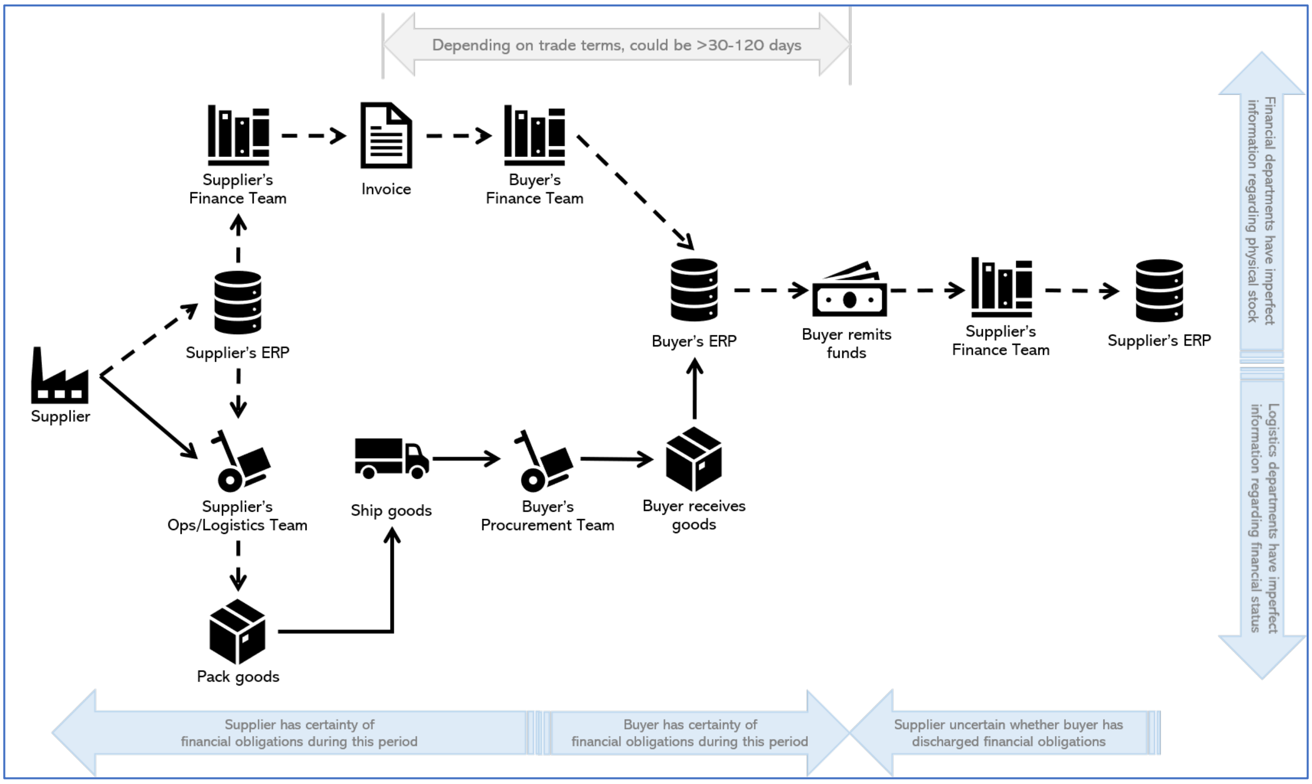

Fig. 13 Informational asymmetry in the buyer-seller transaction in a large organisation with departmental segregation of duties. (Source:[65])

Three active forms of informational asymmetry that companies dealing with physical goods and logistics are: GRNI, GINR, and Credit Control which are described below. It needs to be noted that many other examples can exist, and the list should not be limited to only these three examples.

- Goods Received, Not Invoiced (GRNI)- As mentioned above, suppliers of physical goods usually deliver shipments first and send invoices later. Accountants have created an account called the GRNI which is used to record such transactions which have no invoice attached to it yet. This leaves the issue of informational asymmetry in accounting unsolved.

- Goods Invoiced, but Not Received (GINR)- A finance team may receive an unsolicited invoice. Good business sense dictates that this invoice be checked to correspond to the goods that were received and in conditions that were agreed upon with the supplier. If the invoice is received before the goods are delivered, then the finance team should not process that invoice.
- Credit Control- The department responsible for following up on outstanding invoices and collecting payments from customers may not always receive accurate invoices. Sometimes, the suppliers might send invoices with errors due to internal miscommunication created by informational asymmetry [65].

- CHAOTIC- In this context, the cause of an inaccurate invoice is not perceivable. In such a scenario, the decision that needs to be made involves intervention through trial and error. As such the response from the system should be recorded. Chaotic scenarios in a supply chain can occur if the number of involved parties in a supply chain are unknown and these unknown parties manage to influence the movement of goods and services in the supply chain. For example, collusive behaviour between manufacturers to fix a price and achieve an unfair advantage in the market [53].

5.4 Smart Contracts in the order-to-cash (OTC) process

Venture capitalists have already invested approximately $300 million for the development of blockchain systems in the T&L industry [20]. Aspects of smart contract technology which enable the automation of transactions between parties are built upon sophisticated scripts in languages like eSourcing Markup Language (eSML) and Solidity. These scripts comprise of conditional constructs which function only when pre-determined conditions for each transaction are met in the form of Boolean statements like `'if-then-else'` or `'if-then-if'`. This property which is simplified as 'self-enforcing' opens use-cases for smart-contract in supply chain management (SCM) and the IoT. The implementation of smart-contracts for the realization of Industry 4.0 adds the property of 'self-enforcing' to its already known 'self-organising' and 'self-optimising' properties, which fit well with each other. This explains why more than 70% of the existing or ongoing projects for smart contract application in business are in the domains of SCM and IoT [66]. One other domain where smart-contracts can directly tackle invoicing and prevent inaccuracies from human intervention is the order-to-cash process. The analysis of Deloitte's findings in this regard are mentioned below:

- The OTC process is time-consuming. According to the Deloitte CFO Survey from 2019, its digitization was prioritized to achieve cost optimization and reduce errors. The root cause on an inefficient OTC process is the company's faulty master data. This can even lead to disputes and decreased customer satisfaction. Blockchain technology is suggested to provide the necessary validation and informational symmetry to optimize the OTC and invoice processes.

- Smart contracts are suggested for ensuring corporate commercial policies. They are supported in scenarios where a buyer of goods has contractually agreed on a timeframe within which an invoice needs to be paid. A smart contract can be deployed which either settles the invoice or reserves funds after the agreement is finalized by both parties. It can even be used to automate bookkeeping where the invoice is posted in the ERP system as an asset or a liability depending on when the income is fulfilled. Deloitte claims that the integration of blockchain and modern ERP systems for the automation of bookkeeping will reduce the effort and the cost of the OTC process. Fig. 14 below shows a blockchain and smart-contract framework for the OTC process as proposed by Deloitte (black arrows represent the flow of information) [67].

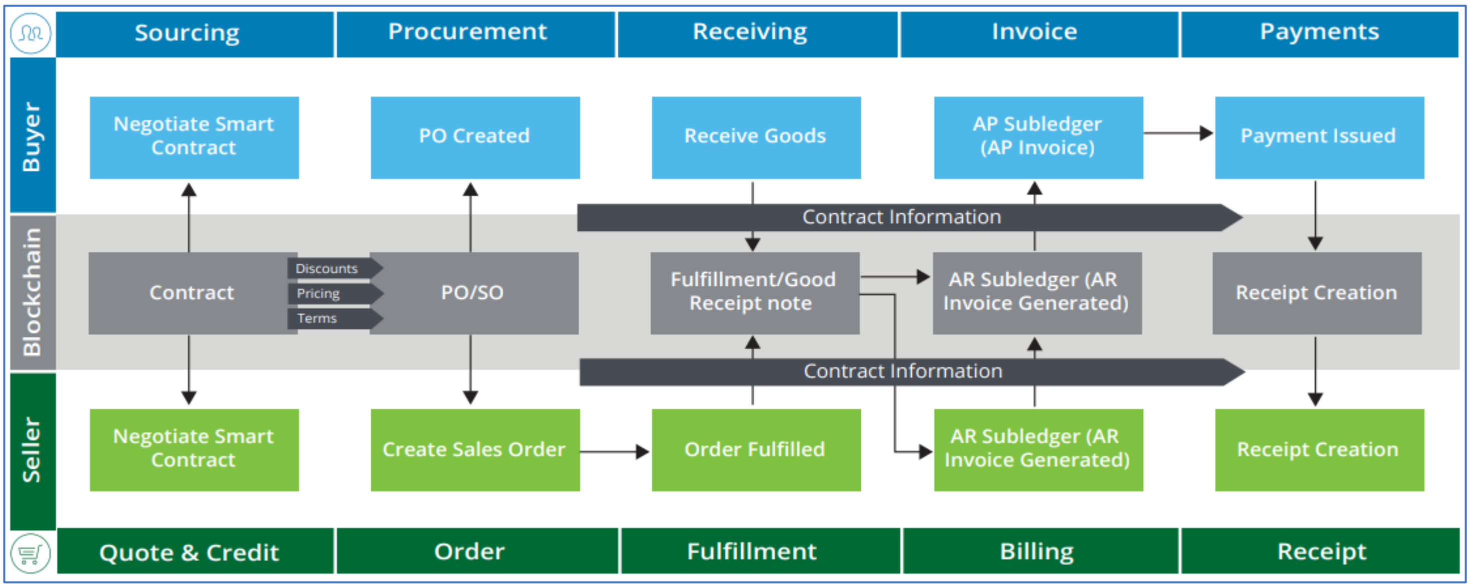

Fig. 14 A blockchain and smart contract-based framework for the OTC process. (Source: [67])

- Invoice reconciliation and approval is made more efficient when finance personnel can extract all the necessary data from the blockchain instead of seeking it from sales personnel. Similarly, smart contracts will automatically handle creating and changing invoices in real-time and according to the requirements of the order. This will reduce invoicing inaccuracies and eliminate the need for rounding off essential invoices. An example provided by Deloitte which encapsulates this phenomenon is as follows:

  > "As an example, should a customer need a change in the order before shipment, the customer can submit a request for change. Once accepted by the supplier, the shared record on the blockchain will be updated and inform all parties automatically. The finance function can automatically adjust the invoice on the blockchain platform, and the warehouse will alter

> the order with full traceability and immutable audit trail. If the item breaks during shipment, the incomplete delivery will automatically result in an adjusted invoice, and the customer can optionally reorder the missing goods right away. Other benefits could be improved customer satisfaction, on improved working capital position, and a reduced number of reconciliation errors. [67]"

A team at Capgemini developed a proof-of-concept (POC) for the application of blockchain based smart-contracts in the OTC process. Their POC qualifies as leverage for the OTC operations in a retail company (name and base of the company were not mentioned). They share that blockchain positively impacts the OTC process and identifies three major areas within which it improves upon their current process. These areas are summarised below:

- Proactive Credit Control- Certain attributes of the finance function like accounting can be securely digitized to not only achieve factual accuracy but also proactively control customer credit through blockchain. The attributes which help achieve such functionality are Purchase Order (PO) attributes, payment receipt information and invoice/payment timestamps. The POC leverages a private blockchain and provides the necessary functionality to achieve proactive credit control. Customers can be notified if they have reached their credit limit when they are expected to place an order or inform them of the outstanding invoices that need to be resolved before they can reorder. Customers can authorize payments in advance and information relating to such upcoming transactions can be used to increase credit volumes based on trust enforced by the blockchain system. This will prevent new orders from being rejected or placed on-hold due to an insufficient credit balance. A virtual form of credit balance assembled from all pending payments in the blockchain can be set against the customer's credit limit to make proactive credit control possible. Insight into when invoices are received and accepted is made instantaneously, which can be used to trigger events further upstream like supply chain financing. The accuracy and timing of each invoice needs to be immutably recorded before it can be securely attributed to supply chain finance functions further upstream. Other insights like the acceptance confirmation of products and notifications of missing and damaged items [68].
- Exception handling with smart contracts- Exceptions are difficult and time consuming to handle manually, especially in the FBAP process [62]. Smart contracts deployed in the blockchain ledger can be encoded with business rules or conditional logic where pricing variances can be instantly reported and adjusted with the invoices prepared for an order. Smart contracts can also be configured to notify their customers on the necessary updates to their accounts payable master data or sales tax certificate in real time. This will eliminate the need for corrections, rework and manual exception handling and reduce delays in the OTC process.

- **Accurate Payment Reconciliation-** The POC blockchain can provide real-time data about payments like the time of transaction and the pricing amount. This makes the reconciliation of payments from invoices more accurate. This can also assist organisations in the OTC process by providing accurate estimations of credit risks taken by their customers. This is made possible with the transparency achieved in the remittance trail of payments in the blockchain [68].

5.5 Smart-contracts in the Procure-to-Pay (PTP) processes

At best we are many years away from considering smart contracts as a substitute for text-based legally binding contracts. However, the two types of transactions that smart contracts are currently well suited to execute automatically involve '(1) ensuring the payment of funds upon certain triggering events and (2) imposing financial penalties if certain objective conditions are not satisfied [12]'. The maritime news article by JOC Group Inc. mentions that faulty software algorithms are also a cause for inaccurate invoice calculations. This can apply to smart contracts as well. Faulty smart contracts can draw incorrect information from contracts to make inaccurate invoice calculations. The technical limitations of smart-contracts like the inability to independently extract off-chain information and the inconsistent spreading of data between nodes when in a state of flux, call for third-party involvement or oracles. These oracles are trusted to deploy information into the blockchain at predetermined times, thus containing any volatility. Use-cases of smart contracts in the PTP processes demonstrate that its technical limitations can be advantageous. It can be used to eliminate gaps in the PTP processes as events in the supply chain can be pre-determined. Off-chain information like invoices, bill-of-lading documents etc. can be deployed according to those pre-determined times when the original data is not in a state of flux. Organisations like CargoX and Tradelens specialize in creating blockchain based smart-contract platform in these sectors and take into consideration the volatility of freight rates [69], [70]. Applications go even further into warehouses where goods are scanned. An example where smart-contracts can eliminate procure-to-pay gaps is when goods are scanned in a warehouse. The quote below describes such a prospect.

> "A smart contract can immediately trigger requests for the required approvals and, once obtained, immediately transfer funds from the buyer to the seller. Sellers would get paid faster and no longer need to engage in dunning, and buyers would reduce their account payable costs. This could impact working capital requirements and simplify finance operations for both parties. On the enforcement side, a smart contract could be programmed to shut off access to an internet-connected asset if a payment is not received. For example, access to certain content might automatically be denied if payment was not received. [12]"

5.6 Decision trees for blockchain adoption

The decision tree is another tool to be considered during blockchain adoption. There are multiple such decision trees proposed by various organisations and authors for blockchain adoption. They range from a simplified abstraction to much granular levels of decision making. Fig. 15 below demonstrates one such a decision tree. Based on the seven questions as shown, a decision maker can understand if they need a blockchain. Further, they can also use this decision tree to determine if they need a public or a private blockchain [71].

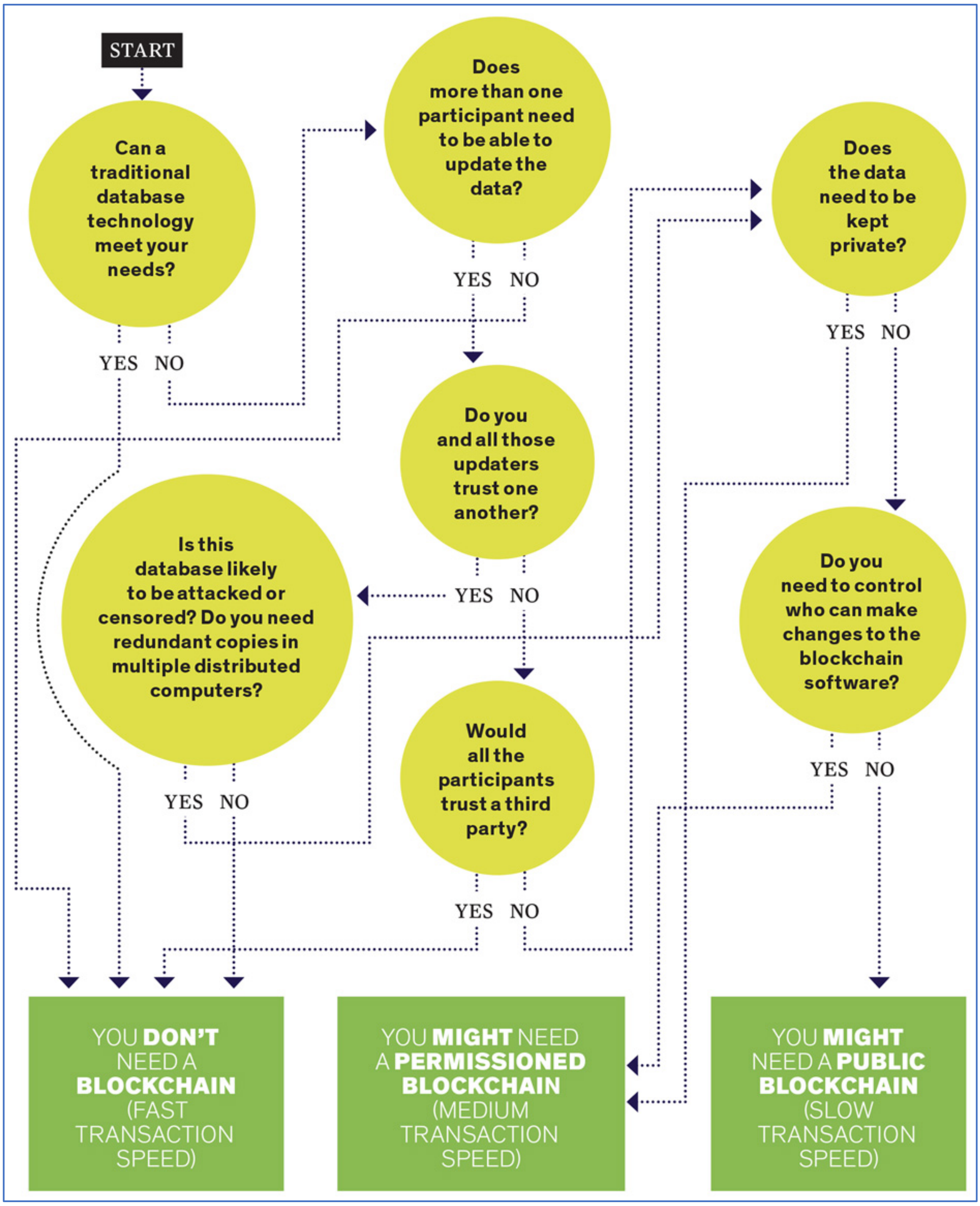

Fig. 15- Decision Tree for blockchain adoption (Source: [71])

It may not always be that a specific decision tree fulfils all criteria for decision makers when considering blockchain adoption. A simplified and linear decision tree, like the one in Fig. 16 by Accenture can provide a generic model for the decision maker to build a much more granular decision tree customised to their specific requirements.

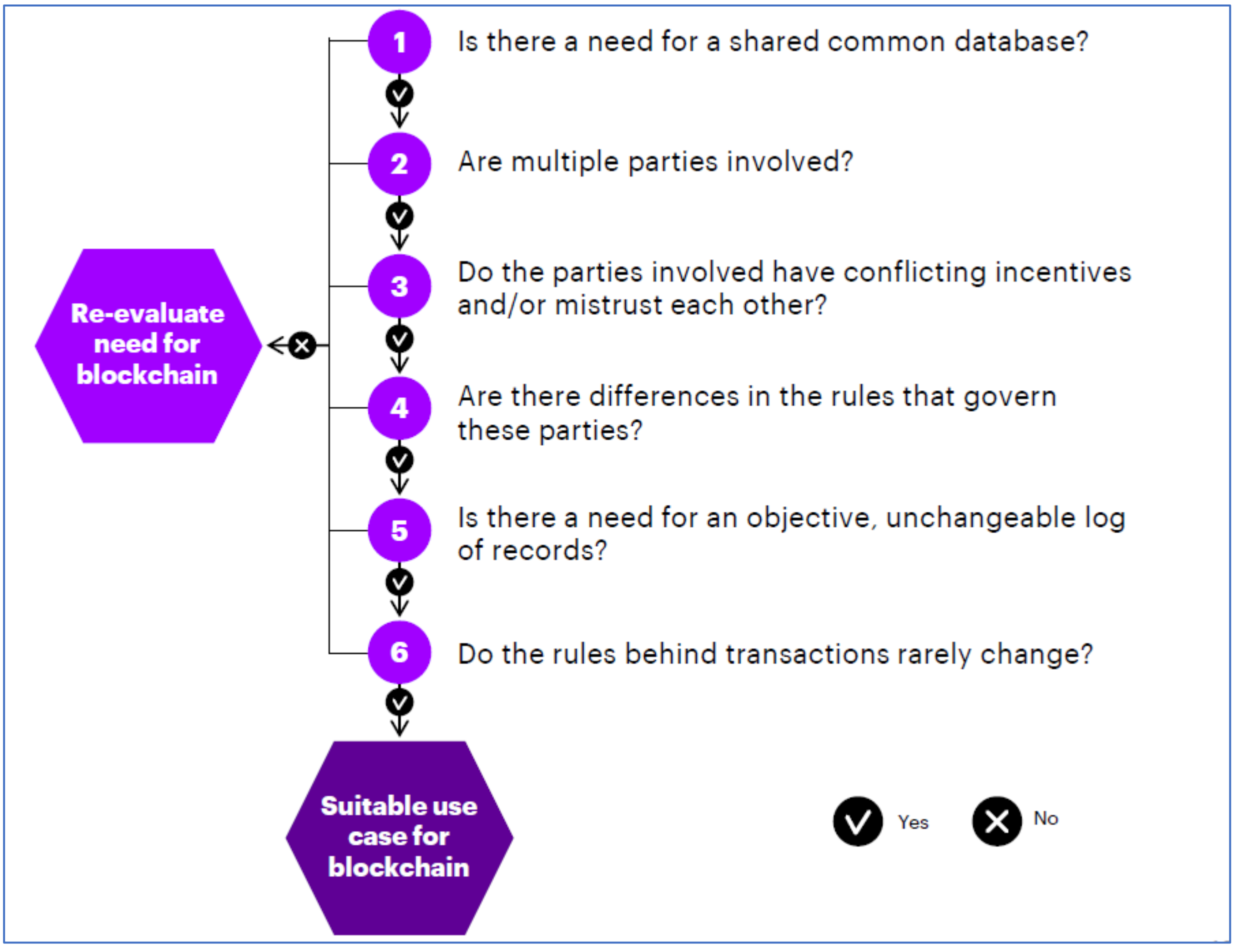

Fig. 16 Simplified decision tree for blockchain-adoption (Source: [72])

As seen from both decision trees, a common deciding factor is trust. Blockchain as a technology is considered a promoter of trustworthy operations where involved parties can safely rely on. It is nascent in its technological maturity however decision trees can provide a general understanding of who should consider blockchain adoption and who should not. Trust and its commodification can be achieved through blockchain and organisations can leverage its properties to improve invoicing processes. There are certain use-cases where blockchain may seem fit for use, but it may not always be the case. Blockchains are not equipped to check the physical properties of goods. Even if an object wears a marker that points to a certain digital asset in the blockchain, it is not sufficient to ascertain any physical changes to that object. Thus, wine in a bottle that has a tokenized QR-code of a blockchain asset can be replaced with sparkling water and it will go unnoticed in the blockchain. This requires sensors enabled with technology like IoT to create a much more robust detection scheme [73].

Chapter 6: Conclusions and Future Work

Global competition is severe and rivalry over informational asymmetry can lead to the insolvency of great companies, which is not good for the economy in general. Be it the discovery of fire or the wheel, technology has saved mankind from extinction. However, the struggles of corporate restructuring to change reluctant mental-models of people when encountering innovative technology will remain. Same can be said for current blockchain adoption which was addressed as a “buzzword” in discussions even though enough about it may not have been understood. Although small and medium sized enterprises (SMEs) may not have the investment requirements for full scale adoption of blockchain based smart contracts, research, and knowledge of its state-of-the-art should not be ignored. Enterprises with operations across global supply chains deal with its complexity and consider various techniques and mediums to maintain an immutable track of events happening in a chronological order. Blockchain and blockchain based smart contracts are currently the only commercially available technology that can achieve that without third party involvement. Understanding its potential and its applicability will allow transparency and insight into global supply chains. However, blockchain or any technology should not be adopted based on hype. Specific business cases need to be identified by each company before they move towards its adoption through experimental simulations and pilots. This practice will give a better understanding of the strengths and limitations of the technology within the context they are going to operate in and its successful adoption.

Organisations should also consider the customization of blockchain and smart-contract applications to incorporate the business rules of their blockchain network. A well-calibrated SEWS can proactively identify faults in their supply chain. However, certain suspicious events will remain speculative if there is no form of evidence to call otherwise. Blockchain based smart contracts will allow such evidence to surface in real-time and it can be mitigated in real-time. Future work should follow blockchain adoption in the OTC and PTP processes and how it can be optimised. Currently there is a gap in the literature about this topic and no profile to safely examine the changes before and after blockchain adoption in the OTC and PTP processes. Such work should focus on multiple organisations facing the problem of invoice inaccuracies in the OTC and PTP processes. Qualitative and quantitative research methodologies need to be used in tandem to address the pain points and the applicability. Different technologies like quantum computing and AI will further disrupt supply chains in the future. However, blockchain integration with IoT is now the next logical step in blockchain’s evolutionary ladder to achieve Industry 4.0.

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