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REDUCING TRADE DOCUMENT PROCESSING TIME BETWEEN SRI LANKA AND ITS SOUTH ASIAN NEIGHBOURS BY APPLYING BLOCKCHAIN AND MACHINE LEARNING SOLUTIONS

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ABSTRACT

International trade documentation in South Asia are complex and time-consuming to process, and they are often hindered by delays and inefficiencies. This study investigates the potential of Blockchain (BC) and Machine Learning (ML) to reduce trade document processing time and improve trade efficiency. Using an explanatory sequence design, the research combines quantitative analysis of survey data with qualitative insights from case studies. The quantitative phase revealed that BC, ML, and trade facilitation regulations are significant in reducing trade documentation processing time. Consequently, reducing trade documentation processing time requires the implementation of BC and ML with supporting new trade facilitation regulations. The qualitative phase identifies key challenges to the adoption of BC and ML, including legal and regulatory hurdles (e.g., legal recognition of smart contracts, unclear data ownership, and unclear data privacy regulations), organisational barriers (e.g., Resistance to change, lack of awareness, and lack of skilled personnel), and technological limitations (e.g., scalability issues, integration challenges, and security concerns). The study underscores the importance of addressing these challenges through collaborative efforts between governments, financial institutions, and technology companies. This research contributes to the growing body of knowledge on BC and ML applications in international trade, providing valuable information for policy makers and practitioners seeking to modernise trade processes in South Asia.

Keywords: *Blockchain, machine learning, trade documentation, international trade, trade facilitation.*

1. INTRODUCTION

The South Asian region is an international trade hub with a population of more than 1.8 billion. It is also a significant market for international trade. The growing population constitute a large workforce that contributes to the region's export potential. South Asian countries that belong to the South Asian Association for Regional Cooperation (SAARC) are progressively expanding their exports beyond traditional commodities. The region is governed by several trade agreements such as the South Asian Free Trade Agreement (SAFTA) and Bangladesh, Bhutan, India, and Nepal (BBIN) initiatives focused on reducing trade barriers and improving the volume of trade.

There are several documents involved in foreign trade that facilitate accountability and transparency, as shown in Figure 1. These documents are classified as commercial documents and regulatory documents.

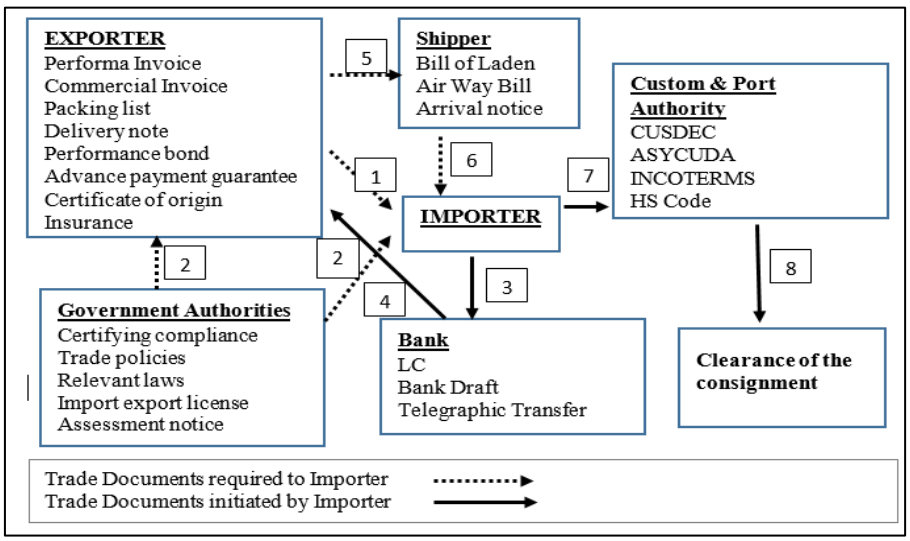

Figure 1: Documentation involved in foreign trade

The documentation process, as illustrated in Figure 1, follows a sequential order indicated by ascending numbers. Each step in the process is represented by an arrow symbol, which signifies the flow of documentation from one stage to the next.

The current system in the world is based on many documents on paper and the participation of 30 people and many organisations with more than 200 interactions [1] that require physical exchange and verification between numerous parties. In practice, the original document must be signed or stamped by several authorities and sent by courier separately while containers are at sea. If a document is missing or filled out incorrectly, it can delay the shipment's journey. The US Department of

Commerce (2018) estimates that the process of documentation, handling, customs clearance, and inland shipping results in 30 days of delay in total shipping time [2]. IBM has estimated that paper documentation costs 15% of total shipping costs [3]. In June 2021, Hapag-Lloyd announced that they with Japan's shipping company jointly developed a Trade Lens platform that uses BC and ML and conducted 42 million shipments, 2.2 billion events, and more than 20 million documents [4].

Traditional international trade relies heavily on paper documentation that leads to slow and error-prone processes [5]. The use of BC in international trade facilitates digital documentation, immutable record keeping, automated workflows, and improved visibility and tracking. Meanwhile, ML facilitates document automation, fraud detection, predictive analytics, and improved customs clearance. In the application of both technologies, international trade reduces processing time, improves efficiency, increases transparency and trust, reduces costs and improves trade compliance [5]. As such a few European states, the US and Japan have partially attempted and experimented to apply BC and ML to overcome challenges in international trade by reducing the document processing time.

Consequently, this study focused on exploring the potential for the application of BC and ML to reduce processing time between Sri Lanka and its South Asian neighbours. Therefore, the study focused mainly on exploring the impact of the combination of BC and ML, IoT, on the average processing time of trade documents in Sri Lanka compared to current procedures and followed by exploring the potential challenges and mitigation strategies associated with the implementation of a combination of BC, ML, and IoT to improve processing time in international trade between Sri Lanka and its South Asian neighbours.

2. INTERNATIONAL TRADE

International trade is simply defined as the exchange of goods and services between territories that facilitates market access between countries and individual firms [6]. This will help customers experience different products with high quality at competitive lower prices. These transactions are executed with trust, and the trade documentation ensures reliability, accountability, transparency, and compliance with the laws of the territory [7].

2.1. Trade between Sri Lanka and South Asian Neighbours

To maximise the time used in both import and export, Sri Lanka Customs initiated a paperless export clearance initiation in December 2013 to reduce the number of export documents from 12-16 documents to 4-5 documents. Under this programme, exporters must submit the Customs Declaration (CUSDEC) electronically through

Direct Trader Input (DTI). Additionally, electronic payments can be made via accounts held at 2 banks. Through these initiatives, the export process has been greatly improved. The statistics of Sri Lanka's trade under SAFTA are shown in Table 1.

Table 1: Sri Lanka exports (EX) and imports (IM) under SAFTA (value in US$ million)

Country	2018		2019		2020		2021	
	EX	IM	EX	IM	EX	IM	EX	IM
Afghanistan	-	--	--	--	--	--	--	--
Bangladesh	4.25	0.17	8.33	0.60	5.75	0.55	10.87	2.40
Bhutan	--	--	--	--	--	--	--	--
India	30.47	5.27	46.62	5.78	35.88	3.57	89.52	5.26
Maldives	0.03	--	0.05	--	0.15	--	0.29	--
Nepal	0.15	--	0.04	--	0.09	--	0.70	--
Pakistan	0.44	0.22	0.36	0.01	0.38	--	0.27	--
Total	**35.34**	**5.46**	**55.89**	**6.39**	**42.25**	**4.13**	**101.64**	**7.65**

Source: Department of Commerce, International Trade Statistics of Sri Lanka – 2021

Table 1 shows the current state of Sri Lanka's exports and imports under SAFTA. By understanding these statistics, it is revealed that Sri Lanka's trade is centralised to India. Table 2 below denotes statistics relevant to time and cost involvement in regional trade.

Table 2: Enabling Trade Index 2014: South Asia

Enabling Trade Scores 2014	Sri Lanka	India	Pakistan	Bangladesh	Nepal
Efficiency of Clearance Process (1-5)	2.6	2.7	2.8	2.1	2.3
No. of days to import	17	20	18	35	39
No. of documents to import	7	11	8	8	11
Cost to import (US$ per container)	775	1250	725	1470	2400
No. of days to export	20	16	21	25	42
No. of documents to export	5	9	8	6	11
Cost to export (US$ per container)	595	1270	725	1470	2400

Source: World Economic Forum, 2014

Table 2 shows that 7 to 5 main documents are required for imports and exports, respectively. However, in Sri Lanka, international trade encompasses a wide range of documents between stakeholders, as shown in Figure 1. Table 3 below denotes the most problematic import factors within the major SAARC countries.

Table 3: Most problematic importing factors (normalised severity scores)

Factors	Sri Lanka	India	Pakistan	Bangladesh
Tariffs	28.2	21.4	22.4	21.0
Burdensome import procedures	21.3	28.7	15.6	20.5
Corruption at the border	17.8	15.5	20.0	19.1
High costs of international transportation	9.7	9.3	9.1	10.2
Crime and theft	8.7	6.1	10.5	6.0
Domestic technical requirements	6.1	7.1	8.4	7.1
High costs of domestic transportation	6.0	14.0	9.3	11.1

Source: World Bank Doing Business Database (2024)

Table 3 presents the perceived severity of import-related challenges in four South Asian countries based on World Bank data. Tariffs and burdensome import procedures emerge as the most significant obstacles, followed by corruption, transportation costs, and security concerns. Although the ranking of these challenges varies between countries, the overall picture highlights the complexities faced by importers in the region. Values represent normalised severity scores, reflecting the perceived magnitude of each factor as an obstacle to importing, as reported in the World Bank Doing Business database (2024).

2.2. The Blockchain (BC)

The concept of BC was first introduced by Satoshi Nakamoto in 2008, and the first studies exploring its application in supply chains emerged in 2017 [1]. At its core, BC comprises a chain of interconnected blocks [7]. Figure 2 provides a visual representation of the operational mechanism of BC technology.

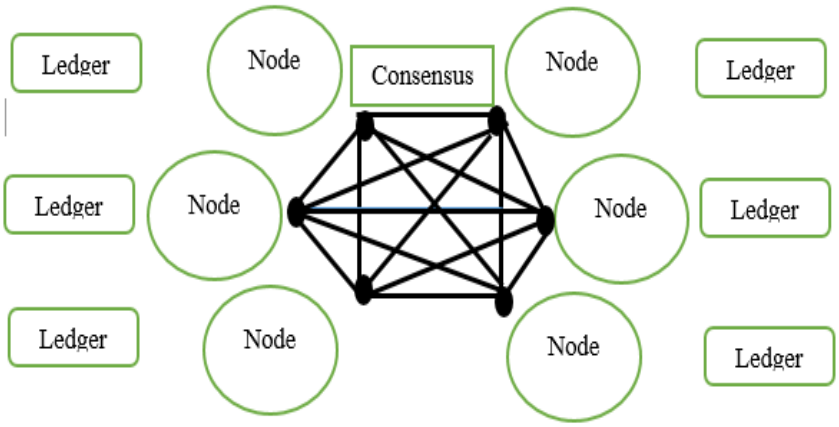

Figure 2: Blockchain technology

According to Figure 2 BC is a chain of interrelated transactions [1]. Transactions are verified as interwoven blocks that are connected to each other [2]. In this concept, centralised BC enables parties who do not know each other to deal securely through the 'Distributed Ledger' without the need for a centrally trusted middleman, reducing legal and transaction expenses as practice today through financial institutions [3]. The name 'Distributed ledger' comes from the fact that records can be shared with different parties and maintained in multiple locations facilitated by decentralised BC technology and a database of distributed or shared public/private digital ledgers throughout the network. Thus, record transactions executed and shared between participating agents [4].

When a transaction occurs, such as in international trade scheduling a shipment document (e.g. purchase orders, bills of lading, invoices), it is recorded within a block. After validation and approval by all parties involved, this block is added to the existing chain. Once a block's storage capacity is reached, a new block is created and linked to the previous one, forming a sequential chain of records. This interconnected structure represents a chain of interrelated transactions [8], with each transaction verified and integrated within BC [9]. BC empowers parties to conduct secure transactions without the need for a central intermediary, such as a financial institution, significantly reducing legal and transaction costs [10, 11]. Key characteristics of BC include traceability, decentralisation, security, auditability, and the ability to execute smart contracts [12, 13].

Due to data centralisation, businesses face challenges with manipulation and alteration, compromising transparency and traceability. BC offers a solution through decentralised traceability, ensuring data immutability between networks [9]. This also improves data exchange, real-time access, and promotes continuous supply chain improvement. The versatile applications of IoT and BC in Industry 4.0, such as

enhanced visibility, provenance, digitalisation, disintermediation, and smart contracts, have garnered considerable interest. These applications within the food sector reveal that supply chain management benefits significantly from these technologies in various processes [8]. The transformative potential of BC in supply chain management, focussing on its ability to address inefficiencies, improve transparency, and reduce fraud, while evaluating its integration with IoT and AI to provide predictive, data-driven decision-making [10, 11]. The study identified challenges such as scalability, regulatory constraints, and cultural barriers, and proposed industry collaboration to facilitate ethical and sustainable practices and advance international trade.

2.3. Machine Learning (ML)

ML, a subfield of Artificial Intelligence (AI), has witnessed significant advancements since its origins in the 1950s [14]. Fuelled by the exponential growth of data in the 1990s, the field experienced a rebirth [15]. ML algorithms enable machines to learn from data and make informed decisions [16]. This evolution encompasses a variety of techniques, from classical methods such as decision trees and support vector machines to cutting-edge approaches in reinforcement and unsupervised learning [15]. By analysing vast datasets, identifying correlations, and extracting meaningful patterns, ML assists in effective decision making [16]. The ability to analyse complex patterns and variables, coupled with its accurate predictive capabilities, improves efficiency and effectiveness [17].

Increasingly, ML techniques are being used to forecast international trade trends, offering a potential advantage over traditional economic models [3]. This growing interest underscores the potential of ML to refine trade analysis and inform policy decisions. A wide range of ML algorithms, including integrated autoregressive moving average (ARIMA), gradient-boosting variants, and neural networks, have been explored for this purpose [17]. In particular, graphic neural networks (GNNs) have shown significant promise in modelling international trade by effectively capturing the properties of exchangeability and locality [18]. Recent research highlights the integration of ML, BC and the IoT in enhancing supply chain management. Various ML models, within a BC framework, emphasise improvements in transparency and real-time monitoring [14]. Integration of BC, ML, and IoT technologies to improve supply chain management. BC improves data integrity, traceability, and real-time monitoring across supply chains [17]. IoT technologies, including sensors and GPS, provide data for ML algorithms to analyse patterns in various supply chain processes [15]. This integration of BC, ML, and IoT offers significant potential to improve supply chain resilience, transparency, and decision making in diverse industrial applications [12, 13].

2.4. Empirical Evidence: Application of BC and ML in International Trade

BC technology can enable faster, safer, and more efficient business processes in the maritime industry. Therefore, BC technology in the maritime industry can lead to significant cost and time savings and reduce paper usage in the maritime industry [19]. BC can speed up certification processes, improve safety and quality assurance, and improve supply chain traceability [20]. Therefore, BC and ML in transport and logistics amalgamate technology and improve trust, trade, and traceability/transparency [21]. The potential challenges of the adoption of BC and ML in supply chains include technical, organisational, and regulatory issues. The combination of machine learning and BC demonstrates that both can collaborate efficiently and effectively [22]. Future, such as designing "smart agents" with learning abilities, using learning-based analysis to evaluate BC-based systems, and applying multi-agent reinforcement learning to model pool mining activity [20]. Maersk achieved technical sustainability for the combination of BC and ML system through the scalability and big data analytics capabilities of the Microsoft Azure cloud platform [23]. Maersk's BC and ML based system supported reduced paperwork, energy savings, and optimised routing of container ships. Furthermore, economic sustainability was achieved through reduced insurance processing costs and optimised shipment routes and resource utilisation [23].

BC applications address challenges in international trade documentation and BC technology as a solution [24]. This study proposed that immutability, decentralisation, security, privacy, compatibility, scalability, and inclusiveness are achieved through the BC application. This study was further evaluated by [21], considering IBM and Maersk's Trade Lens with the Joint Global Trade Digitisation (GTD) initiative, revealed that integration issues as each organisation operates its own IT SCM system, lack of incentives to share digital information, inefficient flow of interorganisational information, discrepancies in format and interpretation of documents, uncertainty about lead times and security risks [25] are challenges in the BC application. Despite this, the introduction of BC-powered Trade Lens ensured standards for documentation among various stakeholders while reducing operational costs [2, 26].

In international trade, an important role in the execution of the transaction lies with the exporter/importer, government ministries, Customs and Port Authority, Chambers of Commerce, Freight Forwarders, Shippers, Banks, etc. As such, for entities involved in export/import operations, BC and ML will offer several advantages, such as real-time verification of the accuracy of documents, financial documents accessible through BC can be verified and accepted, reducing the preparation time [13], facilitating payments between banks [2]. When contract execution is recorded

with contract clauses in BC, the status is updated [24]. The Bill of Lading is available in BC; therefore, transparency and proof of ownership are ensured [27] thus, reducing transaction costs by executing smart contracts through the correspondent banks [28]. Accurate customs and other taxes through transparency and accountability eliminate the malpractice of any party [2].

2.5. Empirical Studies on the Challenges in the Application of BC and ML in International Trade

BC and ML are evolving technologies to streamline processes and unlock a new era of innovation. From secure financial transactions to intelligent automation, the potential applications are vast and transformative. However, widespread adoption is experiencing many unique challenges.

- Regulatory uncertainty - The application of BC and ML for the transformation of document traffic/burden in international trade is imminent. However, the lack of legal implementation hinders progress. In the existing legal framework, there are no clear definitions for BC and ML applications in the context of trade, logistics, and finance. This gap hinders the application of two technologies while complying with legal obligations and compliances [29]. In terms of South Asian countries, existing regulations do not adequately address specific aspects such as data privacy, security, and consumer protection in the context of trade finance [30]. Therefore, collaboration between governments and regulatory bodies in South Asia is necessary to develop cross-border trade documentation based on BC and ML [31].
- The main legal frameworks in the Sri Lankan context are the Sri Lanka Customs Act, No. 17 of 1965, Import Control Act, No. 31 of 1968, Export Control Act, No. 46 of 1970, Regulations issued by the Sri Lanka Customs Department, notifications issued by the Sri Lanka Export Development Board, regulations issued about consulting a Customs Broker, updated regulations issued by Central Bank of Sri Lanka, Treasury, and Ministry of Defense, BOI regulations. These regulations are by and large the same in the South Asian region, as all countries follow the regulating mechanism under the World Trade Organisation (WTO), Trade Agreements, International Law of the Sea, Private International Laws such as the Law of Contracts, Payment methods, Intellectual Property Law, Customs Law, Product Safety regulations, and sanctions and embargoes [28].
- Data Quality Concerns BC and ML require enormous data to train and perform. Accuracies, consistencies, complete data sets, and data standardization are significant for BC and ML [32]. Transaction failures based on inaccurate data caused disputes, reducing trust and transparency [33]. Additionally, the complexity of trade documentation in international trade involves data

inconsistencies due to formatting. This factor hinders data exchange and integration with BC and ML [34].

- Need for skilled personnel - It is necessary to develop the workforce to ensure the expertise to implement and achieve the value of ML [35] through a holistic approach that includes technology [36].
- Model Interpretability- Interpretability means that a human can understand the cause of the decision [37]. How models arrive at specific predictions is crucial to building trust and confidence in the system [38]. Therefore, overcoming the balance between the interpretability and sophistication of models is a challenge.
- Integration Challenges - Ensuring compatibility, interoperability, and minimal disruption during the integration process are essential considerations [39]. The main challenges in data integration in ML are multiple data sources.
- Lack of awareness and knowledge - Many small businesses Small and Medium-sized (SMEs) have a very limited understanding of the application of both technologies and their benefits. Poor knowledge of potential risks and security measures further discourages adoption [40]. Further resistance to change in Asian culture also contributed to this.
- Cost and investment - The amalgamation of BC and ML solutions with existing trade documentation and logistics processes is expensive due to the application of hardware, software, infrastructure, training, and integration [41]. ML maintenance denotes activities that range from performance monitoring, model retraining, and updating to anomaly detection and troubleshooting [42].
- According to the literature review, BC, ML, Internet of Things (IoT), Trade Regulations, IT infrastructure, and current procedures are challenges to document processing time in international trade.

3. METHODOLOGY

This study used mixed explanatory sequential methods as shown in Figure 3, to investigate the impact of BC, ML, Internet of Things (IoT), IT infrastructure, current procedure, and Trade Facilitation Regulations considered Independent Variables in International Trade and Trade documentation processing time as Dependent Variable**.**

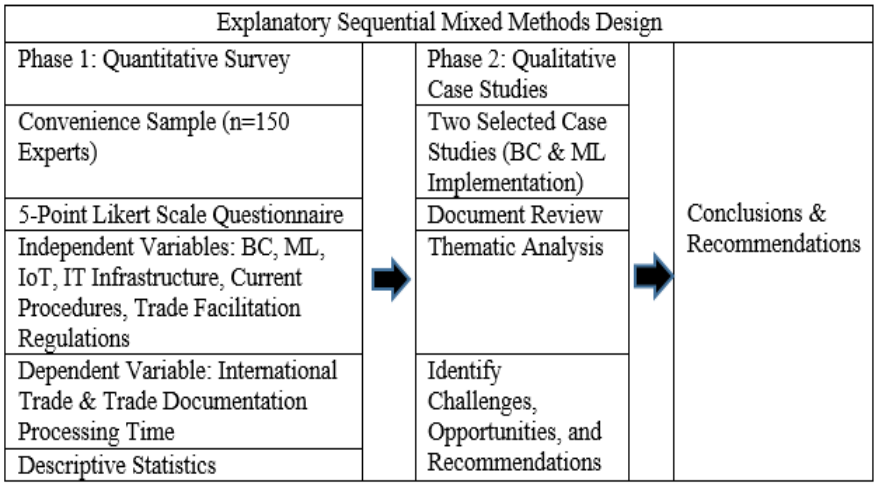

Figure 3: Research methodology

Figure 3 explains the design of sequential mixed methods that involves a two-phase approach in which quantitative data collection and analysis are performed first, followed by qualitative data collection and analysis. The quantitative phase typically involves surveys or statistical analysis, while the qualitative phase includes two case studies to provide deeper context and understanding of the quantitative results. The findings of both phases are then integrated to provide a more comprehensive understanding of the research problem.

3.1. Phase 1: Quantitative Survey

A convenience sample of 150 academic experts (including professors, researchers, and faculty members specialising in international trade, logistics, and supply chain management) and industry (including executives, managers, and professionals working in customs brokerage and related fields) was used. This convenience sample was used due to the practical limitations of accessing a truly random sample of this population. To ensure that participants had adequate knowledge of BC and ML, several factors were considered. Firstly, these technologies are now integral components of logistics curricula in many academic institutions. Second, numerous industry-led seminars and workshops have been conducted on BC and ML applications in supply chain management in Colombo and the surrounding region. Third, there is a substantial body of literature, including research papers and industry reports, providing readily accessible information. Furthermore, during the data collection process, the questions were phrased in a way that focused on the application and implications of the technologies, rather than on the highly technical details.

The sample size was decided by the calculation of the margin of error of approximately +/- 8% at a 95% confidence level. The formula for sample size was;

$$E = Z * \sqrt{(p * (1 - p) / n)} \quad \text{----------(1)}$$

Where:

- E = Margin of error
- Z = Z score corresponding to the desired confidence level (1.96 for 95% confidence)
- p = Estimated sample proportion (used 0.5 for maximum variability)

Accordingly;

E = 1.96 * √ (0.5 * (1-0.5) / 150) = 0.08 = 8%

Thus, this estimate, a proportion based on the sample, can be 95% confident that the true population proportion falls within 8 percentage points of the sample estimate.

A structured questionnaire was developed using a 5-point Likert scale to assess participants' perceptions regarding the impact of independent variables on dependent variables. The questionnaire was distributed electronically through email and online platforms. Participants were invited to complete the survey voluntarily. Among the sample, 139 responded to the questionnaire. Preliminary tests, Pearson's correlation coefficient, and multiple regression were used to analyse the survey data.

3.2. Phase 2: Qualitative Case Studies

Two case studies were selected to investigate the real-world implementation of BC and ML in international trade. These were The Monetary Authority of Singapore (MAS) and Traceability: Provenance in Indonesia. These cases were chosen because they represent various applications of BC and ML in the trade, showcasing both regulatory initiatives and practical implementations in the field. Data analysis was carried out in thematic analysis to identify key themes and patterns related to the challenges and opportunities of implementing BC and ML in international trade.

Case Study 1: The Monetary Authority of Singapore (MAS), MAS, the central bank and financial regulator of Singapore, has actively promoted the adoption of BC and ML in trade finance. Their Project Guardian initiative explored the use of these technologies to enhance efficiency, transparency, and security in trade transactions. Through collaborations with industry partners and pilot projects, MAS has demonstrated the potential of BC and ML to streamline trade processes and mitigate

risks. Data for this case study were collected through a review of publicly available reports and project documentation released by MAS.

Case Study 2: Traceability: Provenance in Indonesia - Indonesia's traceability initiative in the fisheries sector utilises BC and ML to track the origin and movement of seafood products, aiming to combat illegal fishing and promote sustainable practices. By implementing a digital catch documentation system and using ML for data verification, Indonesia has improved transparency and accountability in its seafood supply chain. Data for this case study were collected from government reports and news articles that cover the initiative.

3.3. Conceptual Framework

This study investigates the impact of emerging technologies, including BC, ML, and the Internet of Things (IoT), on the processing time of trade documentation. The framework explores how these technologies, in conjunction with Trade Facilitation Regulations, robust IT infrastructure, and existing Trade Documentation Procedures, influence the efficiency and speed of trade document processing. Figure 4 explains the relationship of the independent variables with the dependent variable.

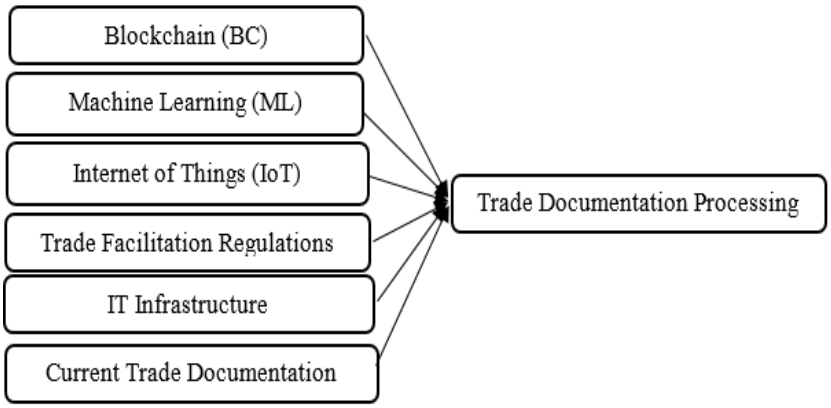

Figure 4: Conceptual framework

BC: BC technology enables secure and transparent record-keeping, potentially streamlining trade documentation processes by reducing the need for intermediaries and paper-based documentation.

ML: ML algorithms can automate various aspects of trade documentation, such as data extraction, document classification, and risk assessment. This automation can significantly reduce processing times and improve accuracy.

IoT: IoT devices can provide real-time data on the movement of goods, enabling better visibility and tracking throughout the supply chain. These data can be

integrated with BC and ML systems to further optimise trade documentation processes.

Trade Facilitation Regulations: Trade facilitation regulations play a crucial role in enabling or hindering the adoption of new technologies. Supportive regulations that provide legal clarity and address privacy concerns can encourage the use of BC, ML, and IoT in trade.

IT Infrastructure: A robust IT infrastructure is essential for the effective implementation of BC, ML, and IoT in trade documentation. This includes network connectivity, data storage and processing, security measures, and interoperability.

Current Trade Documentation Procedures: Existing trade documentation procedures and practices within an organisation or country can influence the impact of new technologies.

The study hypothesises that the integration of BC, ML, and IoT, when aligned with supportive regulatory frameworks and advanced IT infrastructure, will significantly reduce the processing time of trade documentation, leading to improved trade efficiency and competitiveness.

4. STUDY RESULTS

The quantitative analysis focused on exploring the impact of the combination of BC and ML, IoT, on the average processing time for trade documents in Sri Lanka compared to current procedures. Subsequently, qualitatively focused on exploring the potential challenges and mitigation strategies associated with implementing a combination of BC, ML and IoT to improve processing time in international trade between Sri Lanka and its South Asian neighbours.

4.1. Quantitative Analysis

The survey included 150 respondents from various sectors related to international trade in Colombo. Most of the respondents (70%) were male, with an average age of 42 years (range: 23-68 years). Most of the respondents (80%) had at least a bachelor's degree, with 25% having obtained a master's degree or higher. The average years of experience in international trade was 15 years (range: 3-20 years). Common job roles among the respondents included: All respondents were based in Colombo and held job roles including Lecturers teaching logistics and supply chain at academic institutions (10%), Logistics Managers (25%), customs brokers (15%), Trade Analysts (10%), IT specialists (10%), and Supply Chain Managers (30%). The majority of respondents (75%) reported having at least a basic understanding of BC and ML technologies. This suggests a growing awareness and adoption of BC and

ML within the international trade community in Colombo. Among the sample, 139 responded to the questionnaire.

4.1.1. Descriptive analysis

This section presents a descriptive analysis of the key independent variables in the study, providing insights into the respondents' perceptions and attitudes toward emerging technologies and trade practices. The analysis explores the mean values of the independent variables, as shown in Figure 5.

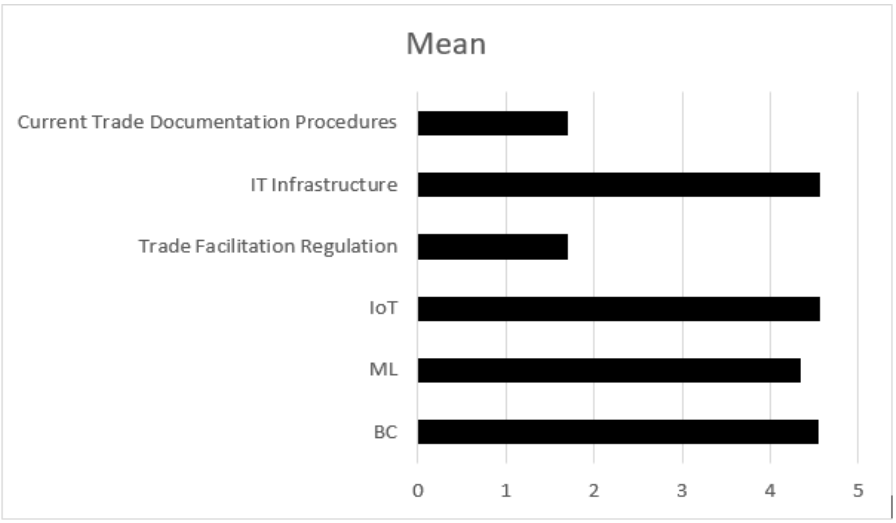

Figure 5: Mean values of independent variables

The mean values as shown in Figure 5, for BC, ML, IoT and IT infrastructure, are all above 4 on a 5-point Likert scale, indicating a strong positive perception or agreement regarding these technologies. This suggests that respondents generally have a favourable view of these technologies and their potential role in international trade. In contrast, the mean values for Trade Facilitation Regulation and Current Trade Documentation Procedures are significantly lower, around 1.7. This suggests that respondents are less satisfied with the current regulatory environment and the procedures for obtaining trade documentation. They may perceive these to hinder the adoption of new technologies or create inefficiencies in trade processes.

4.1.2 Preliminary Tests

- Preliminary analysis was initially performed to confirm the data normality of the collected data using the Collinearity Diagnostic Analysis, reliability, and validity test. Both tolerance values were above .01 and the VIF values were below 10, indicating that the data set was free of significant multicollinearity errors.
- The KMO value of the current study is 0.935, and the significance level of the Bartlett Sphericity test was less than 5%, so the sample size was adequate.

- The Cronbach Alpha values were above the value of 0.70, revealing that the operationalisation and internal consistency of the questionnaire were at an accepted and satisfactory level.

4.1.3 Pearson correlation coefficient analysis

- The Pearson correlation coefficient (r) values between all independent and dependent variables lie between the coefficient ranges of +/-0.71 to +/-0.90. It shows the strong relationship between the independent and dependent variables.
- The P value of all relationships was 0.000, which is a significant and strong positive correlation between all independent variables and dependent variables.

4.1.4 Multiple regression analysis

Multiple linear regression model analysis was performed to find the impact of independent variables on dependent variables. The Model Summary is shown in Tables 4, and 5 respectively.

Table 4: Model summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.866	.749	.743	.217

Note: Predictors: (constant), BC, ML, IoT, Trade Facilitation Regulation, IT Infrastructure, and Current Trade Documentation Procedure.
Dependent variable: Trade Documentation Processing Time.

Source: Survey data (2024)

According to Table 4, the adjusted square R square was 0.743, indicating that 74.3% of the variation in the processing time of the trade document can be explained by the multiple linear regression model and the goodness of fitness is strong. The value of the F test was 0.000 of the estimated models since all aspects of the model were significant.

Table 5 shows the standard coefficients Beta values of the independent variables towards the dependent variable. When considering the Beta values, only BC, ML, and the Trade Facilitation Regulation have a significant impact on the processing time of trade documents. The P values of the other variables are greater than 0.05, and the impacts are negative and direct. BC impacts trade document processing time (-.143), where a one per cent increase in BC impacts a decrease in trade document processing time by 14.3%. ML and the Trade Facilitation Regulation contribute to the total impact of the model by -.116 and -.105, respectively, to make changes in the dependent variable. BC negatively affects the processing time (-.143), where a 1% increase in the impact of BC decreases the trade document processing time of trade

documents by 14.3%. ML and Trade Facilitation Regulation contribute to the total impact of the model by 116 and.105 per cent, respectively, to make changes in the dependent variable. Therefore, a percentage increase in ML and Trade Facilitation Regulation reduces Trade Documentation Processing Time by 11.6% and 10.5%, respectively.

Table 5: Estimated coefficients significance values of the model

Model	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std. Error	Beta		
(Constant)	5.18	.113		45.71	.000
BC	.164	.056	-.143	2.908	.004
ML	.224	.093	-.116	2.408	.016
IoT	.030	.115	.034	.261	.794
Trade Regulation	.237	.050	-.105	4.782	.000
IT Infrastructure	.005	.106	-.106	-.049	.961
Current Trade Documentation	.122	.117	-.131	-1.044	.078

Note: Dependent variable: Trade Documentation Processing Time

Source: Survey data (2024)

4.2 Qualitative analysis - Case Studies Application of BC and ML

The qualitative analysis of this study was carried out by evaluating two case studies that applied both technologies to international trade to reduce documentation processing time, followed by empirical studies on the application of BC and ML in international trade.

4.2.1 Case Study 1 - The Monetary Authority of Singapore (MAS)

The Monetary Authority of Singapore (MAS) has been actively exploring the potential of BC and ML to modernise international trade processes. One of their key initiatives is Project Guardian, a collaborative effort with the financial industry to test BC applications in trade finance. This project aimed to improve efficiency and transparency, improve fraud detection, refine credit risk assessment, and optimise trade finance operations.

To facilitate innovation and mitigate regulatory uncertainty surrounding BC and ML, MAS initially adopted a "regulatory sandbox" approach. This allowed companies to experiment with BC-based solutions under relaxed regulations for a defined period. MAS also collaborated with international regulatory bodies to develop global

standards for BC and ML in finance, with the goal of reducing uncertainty for businesses operating across borders.

However, the regulatory sandbox was abandoned in November 2022 due to several challenges, including limited network effects, integration difficulties, persistent regulatory uncertainty, and low participation rates. Despite this setback, MAS remains committed to exploring the potential of BC and ML in trade finance and continues to collaborate with industry partners to develop innovative solutions.

MAS has also recognised the importance of developing a skilled workforce in BC and AI/ML. They have implemented training programmes in collaboration with universities, tech companies, and industry experts to equip professionals with the necessary expertise. Furthermore, MAS promotes the use of open standards and protocols for BC and ML platforms to ensure interoperability and facilitate data exchange, which is crucial for a wider adoption.

The case of MAS highlights both the potential and the challenges of implementing BC and ML in international trade. While the regulatory sandbox approach faced limitations, MAS's ongoing efforts in research, collaboration, and talent development demonstrate a commitment to leveraging these technologies to modernise trade finance.

4.2.2 Case Study 2 Traceability: Provenance in Indonesia

Indonesia is actively pursuing traceability systems in its agricultural and seafood sectors to enhance sustainability, ensure food safety, and combat illegal practices. Traceability initiatives in Indonesia primarily focus on:

- **Sustainability:** Ensuring that products come from responsible sources, minimising deforestation, and promoting environmentally sound practices.
- **Food Safety:** Tracking products "from farm to fork" to quickly identify and respond to contamination issues, safeguarding public health.
- **Combating Illegal Practices:** Address illegal logging, illegal, unreported, and unregulated (IUU) fishing, and product fraud to maintain fair and sustainable trade.

Specific examples of Indonesia's traceability efforts include:

- **Palm Oil:** The Indonesian government is developing a national platform for the traceability of palm oil to comply with the European Union's Deforestation-Free Regulation (EUDR). This initiative aims to ensure that palm oil exports are not linked to deforestation.

- **Seafood:** The Ministry of Marine Affairs and Fisheries (MMAF) has established a national fish traceability and logistics system. This system tracks fish from capture to processing and export, ensuring compliance with regulations and promoting sustainable fishing practices.

Despite the potential benefits, traceability initiatives in Indonesia face challenges:

- **Infrastructure:** Small-scale farmers often lack the infrastructure and resources to participate effectively in traceability systems.
- **Data Management:** Robust data collection, storage, and security are crucial for effective traceability, and ensuring data accuracy and integrity can be challenging.

Despite these challenges, the Indonesian government and the private sector recognise the importance of traceability. Continued development and investment in these systems are expected to enhance sustainability, food safety, and fair-trade practices in the agricultural and seafood sectors of Indonesia. Based on the range of potential deterrents through empirical studies and affirmed by the two case studies, Technological Infrastructure, Regulatory Uncertainty, Adoption and Awareness, Security Considerations, Unwillingness to Change and Cost of Investment are considered the most important deterrents in the application of BC- and ML-based trade documentation solutions in international trade. The other challenges revealed in the study are summarised in Table 6.

Table 6: Challenges of implementation of BC and ML

Case Study 1	Case Study 2	Empirical Literature
Existing regulations	Existing regulations	Regulatory uncertainty [29] [31]
Lack of technical expertise	Poor infrastructure	Need for Skilled Personnel [35], Lack of Awareness and Knowledge [40]
Protocols for BC and ML platforms to ensure interoperability between different systems	Businesses are reluctant to invest in traceability solutions	Model Interpretability [37] [38]
Scalability of BC and ML solutions	Data accuracy and security	Data Quality concern [32] [34]
Limited network effect	Cost of implementation	Cost and investment [41] [42]
Integration challenges	Data management	Integration Challenges [39]

Source: The Study

5. DISCUSSION

Traditional trade documentation processes in the South Asian region are beset by delays and corruption resulting from a lack of transparency and accountability. These delays are exacerbated by factors such as cumbersome certification processes, long border clearances, poor interagency coordination, logistical challenges, and inadequate port facilities. On the contrary, BC and ML offer transformative potential, fostering transparency, accountability, decentralisation, data security, auditability, and smart contract execution. These findings are consistent with research by [43], which highlights that developing countries face significant obstacles to implementing trade facilitation reforms, including limited financial resources, inadequate infrastructure and human capital.

Quantitative findings underscored the significant positive impact of BC, ML, and robust Trade Facilitation Regulations in reducing Trade Documentation Processing Time. This finding aligns with research [44], which emphasises the transformative potential of BC in addressing inefficiencies within international trade, while highlighting the critical need for supportive legal and regulatory frameworks to facilitate its successful integration. According to [44], this study confirms that BC technology possesses the inherent ability to enhance international trade and customs practices by enabling faster and more secure trade processes. However, the analysis revealed a less pronounced effect of IoT, Information Technology (IT) infrastructure, and existing trade documentation procedures. This finding may be attributed to the relatively advanced state of IT infrastructure and digitalisation within the logistics sector, with many companies already utilising advanced technologies and operating within a largely digitised trade environment. The implementation of a paperless custom clearance system since 2013, coupled with the widespread adoption of advanced IT infrastructure and IoT solutions by logistics companies, may already have mitigated the potential impact of these factors.

Furthermore, the perceived importance of customs procedures and regulations as the main bottlenecks probably overshadowed the perceived impact of these factors in the assessments of the respondents. These findings are supported by the study by [45], which emphasised the critical role of trade facilitation in improving trade flows. [45] Highlights that reducing trade-related fees, streamlining documentation requirements, and minimising processing times are crucial for facilitating trade. The article further emphasises that non-tariff barriers, such as cumbersome customs procedures, stringent inspections, and inadequate infrastructure, can significantly impede international trade by causing delays and incurring hidden costs.

The key to realising the full potential of BC and ML in reducing Trade Documentation Processing Time lies in addressing the various challenges that hinder their widespread adoption. These challenges, as summarised in Figure 6 below, are the result of legal and regulatory hurdles, organisational barriers, and technological limitations.

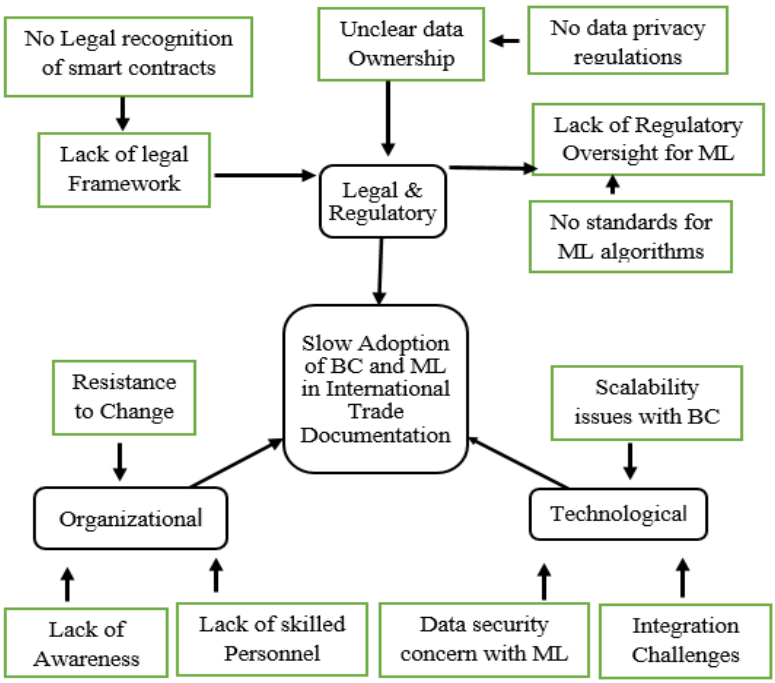

Figure 6: Summation of challenges for the slow adoption of BC and ML

Figure 6 provides a visual representation of these challenges, categorised into three main branches:

- **Legal & Regulatory:** This branch highlights the significant impact of inadequate legal frameworks and regulations on BC and ML adoption. As shown in the figure, the lack of legal recognition of smart contracts and unclear data privacy regulations are major concerns. This is corroborated by the study of [7], which emphasises the crucial role of robust legal and regulatory frameworks for the successful integration of BC and ML in international trade.
- **Organisational:** This branch emphasises the internal challenges within organisations that hinder technology adoption. Resistance to change, lack of awareness of the benefits of BC and ML, and skill gaps in implementing these technologies are key deterrents. Addressing these organisational barriers

through change management initiatives and training programmes will be essential to successful adoption.

- **Technological:** This branch focuses on the technological limitations that can hinder the implementation of BC and ML. Scalability issues, integration challenges with existing systems, and security concerns are among the key technological barriers that need to be addressed.

This study underscores the critical need for a deeper qualitative investigation into the specific aspects of 'Trade Facilitation Regulations' that exert the most significant influence on the effectiveness of BC and ML in streamlining trade documentation. This deeper analysis would provide valuable information on the regulatory landscape and its impact on technology adoption. Additionally, the successful implementation of BC within international trade depends on overcoming challenges such as limited stakeholder participation, reluctance to embrace change, and insufficient government agency involvement.

By addressing these challenges through collaborative efforts between governments, financial institutions, and technology companies, BC and ML can realise the full potential to reduce trade document processing time. Continued research and development, coupled with a growing understanding of these technologies, will undoubtedly pave the way for their successful integration into global trade practices.

6. IMPLICATIONS FOR RESEARCH, PRACTICE, AND SOCIETY

This research offers significant implications for the evolution of academic understanding, improving industry practices, and shaping broader social approaches to international trade from the perspective of evolving technologies.

Research implications - This study contributes to the growing academic domain on the applications of BC and ML in international trade. The study revealed empirical evidence of the potential of BC and ML to streamline trade documentation processes and reduce processing times. The findings challenge the notion that legal & regulatory, technological and organisational barriers are the primary obstacle to adoption, highlighting the critical role of legal and regulatory frameworks. This work initiates a new line of inquiry, driving the development of legal frameworks that ensure a responsible and secure implementation of BC and ML in international trade. Thus, future research could explore the specific legal challenges associated with different types of BC and ML applications in trade, across different countries.

Practical implications - The findings of this study offer valuable insights for stakeholders involved in international trade, including exporter, importer, government authorities, banks, shippers, customs officials, logistics providers, and

policymakers. The study highlights the need for greater collaboration between the public and private sectors to develop SOPs and guidelines for the implementation of BC and ML. All stakeholders can leverage these findings to streamline their operations and reduce documentation times, while integrating BC and ML solutions. Policymakers can use this research to inform the development of legal frameworks that promote the application of BC and ML while ensuring the legal framework, data security, and ethical considerations.

Societal Implications This research is significant by demonstrating the potential of BC and ML to improve the efficiency and transparency of international trade, contribute to economic growth, and facilitate global trade facilitation. The findings also highlight the importance of addressing ethical considerations, ensuring data privacy, and organisational considerations such as developing worker/leader attitudes. This research reveals the responsibility of stakeholders in international trade, promoting a balanced approach that fosters the application of BC and ML while protecting social values.

7. POLICY RECOMMENDATIONS

The evolving fields of BC and ML ensure the revolutionization of various sectors. However, the widespread adoption of both technologies in reducing the time needed for trade documentation in international trade is hindered by the lack of a robust legal framework, which is more critical, as found in the study. Therefore, key policy recommendations for legal enactments to bridge the gap and encourage the way for responsible and secure BC and ML applications are multifaceted.

a. Create legal acknowledgement for BC transactions: the widespread application hindered international trade because of a lack of legal enactment to validate smart contracts and other BC transactions. This involves defining digital signatures, electronic records, and distributed ledger technology within legal frameworks.

b. Creating a Regulatory Framework for ML: The need for a regulatory body tasked with the administration of the expansion and positioning of ML algorithms. This body will be responsible for setting standards for data privacy, security, and fairness in ML applications.

c. Ensuring Data Privacy and Ownership in the Context of BC and ML: The legal frameworks that clarify data ownership rights in the context of decentralised BC networks are necessary to secure through proper legal enactment. Regulations should be established to ensure user privacy and control over the data collected and used by ML algorithms.

d. Assuring Transparency and Explainability in ML: The AI framework necessary to ensure transparency in the decision-making processes of ML algorithms fosters public trust and mitigates potential biases.

e. Promotion of Collaboration between Public and Private Sectors: Establish widespread application partners/stakeholders dedicated to best practices and standards for BC and ML applications. This will balance innovation and regulatory oversight.

f. In addition, the challenges shown in Table 6 are also to be considered as barriers to the implementation of BC and ML in international trade documentation and are essential to overcome by a well-articulated roadmap.

8. CONCLUSION

BC was invented and developed for decentralised record keeping, secure data transfer, traceability and auditability, and smart contracts. ML is for pattern recognition and prediction, automated decision-making, personalization, and recommendation, and improved efficiency and optimisation. Both technologies are widely used in many business disciplines. However, many stakeholders around the world are still trying to use both technologies in international trade. The main barriers to implementation are technological infrastructure, regulatory uncertainty, adoption and unawareness, security considerations, unwillingness to change, and cost of investment. Despite the lack of a robust legal framework that is mandatory for implementation due to the nature of international trade, the legislature needs to enact essential laws considering regional and beyond regional territories.

FUTURE STUDIES

Future studies shall focus on standardised protocols for data exchange, improving interoperability with existing enterprise resource planning (ERP), and minimising regulatory uncertainty through statutory institutions.

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