Military Supply Chain Security

A PROJECT REPORT

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BONAFIDE CERTIFICATE

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ABSTRACT

Military logistics in India is spread across a variety of terrains and states and is, therefore, the most outstretched among all the armies in the world. In the current geo-strategic environment, the wars are intense but short-lived demanding the field forces to execute swift and hard-hitting operations while constantly improving and adapting to the changing times. [1] Least logistics pause, agile support systems, no bureaucratic delays, and proper coordination among the army units and the contractor can significantly add up to the success of the Indian Army Supply Chain. Moreover, the Indian Army also requires the addition of new technologies for securing and restoring the supply chain artifacts while in transit or storage.

An effective military operation demands suitable supply chain management in all three chains.: fast and light stores, heavy equipment and deployment/movement of soldiers.[2] Compromise in a single chain can disrupt the entire supply chain lifecycle process. Thus, ensuring the security of these resources becomes paramount for the seamless functioning of ongoing theater, engagement, or strike operations. This paper conducts a comprehensive review of the diverse methodologies and strategies proposed globally for optimizing military logistics. The review is based on the examination of bibliographic records, comparative analysis and analysing the effectiveness of these techniques. The study aims to identify research gaps, explore the existing empirical study, evaluate real-world impacts, and discover cross-functioning trends that can be applied in this field of study. The study aims to uncover the emerging technological trends in the domain of army logistics and discuss the utilization of blockchain and other cutting-edge techniques.

Overall, Indian Army military supply chain security has various echelons and aspects due to varied scope and coverage and needs technically advanced, agile, and responsive strategies to cope with the demands of combat forces, disaster response, and humanitarian evacuations/aids. Least logistics pause, agile support systems, no bureaucratic delays, and proper coordination among the army units can be facilitated through the adoption of technologies like Distributed Ledger Technology (DLT), which have the potential to optimize the entire supply chain cycle.

GRAPHICAL ABSTRACT
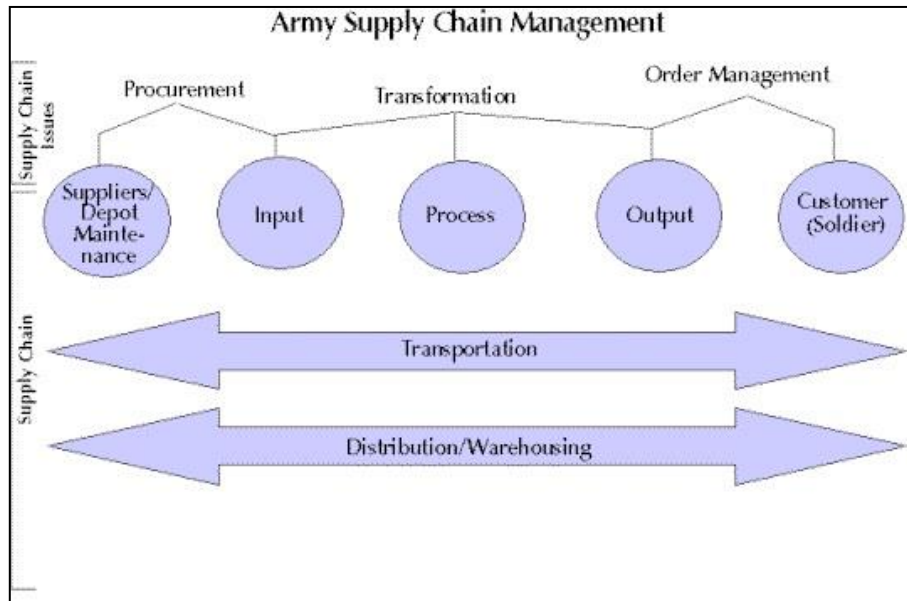
Fig. 1.   Flowchart of Military Supply Chain Management [1]

ABBREVIATIONS

Page Number	Acronyms	Abbreviation
1	AOC	Army Ordnance Corps
1	HADR	Humanitarian Assistance and Disaster Relief
1	CAG	Comptroller and Auditor General
2	OFB	Ordnance Factory Board
1	LOGINK	National Transportation and Logistics Public Information Platform
5	UAV	Unmanned Aerial Vehicle
6	RFID	Radio Frequency Identification
9	LIDAR	Light Detection and Ranging
13	DAG	Directed Acyclic Graph
13	DLT	Distributed Ledger Technology
13	GPR	Ground Penetration Radar
30	GIS	Geographical Information System

INTRODUCTION

1.1. Identification of Client /Need / Relevant Contemporary issue

The Indian Army is the central client necessitating a sophisticated and secure supply chain management system, crucial for sustaining operations, prioritizing troop welfare, and reinforcing defence strategies. The multifaceted operations of the Indian Army span from combat missions to peacekeeping endeavours, disaster relief, and aid operations. Within this complex operational framework, a seamless and uninterrupted flow of resources is a fundamental requirement for the Army's operational readiness and the accomplishment of its missions.

Managing the entire army supply chain involves specialized corps such as the Army Ordnance Corps, Indian Army Service Corps, Military Farms Service, and Army Medical Corps. These corps play a pivotal role in supplying essential provisions like food, medicine, clothing, equipment, and ammunition required by army personnel for survival and operational readiness. Operating primarily under a contractor system, these corps utilize government-authorized suppliers who engage local sources for production and distribution of goods to inward posts, strategically located within army-controlled areas for surveillance and early threat detection.

However, recent transformations within the Army Ordnance Corps and significant infrastructure upgrades, along with exercises focused on Joint Humanitarian Assistance and Disaster Relief (HADR), have been undertaken to bolster preparedness in managing the supply chain during natural calamities. Yet, critical issues affecting supply chain efficiency have been highlighted by the Comptroller and Auditor General (CAG) report of 2019. These issues include substantial overheads on the allotted budget, unmet production targets, surplus goods, prolonged delays in fulfilling orders, and bureaucratic inefficiencies.

To address these inefficiencies, measures such as the dissolution of the Ordnance Factory Board (OFB) into seven new government-owned corporate entities have been initiated to enhance efficiency within the defence manufacturing sector, aiming to fortify the overall supply chain process. Collaborations with international partners and local companies are underway, yet bureaucratic hurdles, funding shortages, and geopolitical tensions continue to cause delays in contract fulfilments. Geopolitical conflicts, such as the Russia-Ukraine tensions, have also impacted India's arms imports, prompting a push towards self-reliance in defence logistics.

The contemporary issue arises from the necessity to fortify India's self-sufficiency in defence manufacturing and logistics due to dwindling arms imports and global uncertainties. China's advancements in logistics, particularly through platforms like LOGINK utilizing blockchain in commercial logistic companies, pose challenges and highlight India's need to strengthen its digital

logistical capabilities. The lack of similar digital logistics control presents vulnerabilities, especially in predicting and managing critical logistics operations, prompting a need for adopting emerging technologies.

The main aim of this review paper is to analyse the use of various emerging technologies in military supply chain security and understand the varied actors in the overall logistics process. By understanding the underlying causes of the failed battles and evacuation/aid operations, one can better determine these challenges and understand the need of the hour to facilitate streamlining of the research with the objective instead of divergence. The significant issue to resolve here is to upgrade the existing security system of the military supply chain as per the ongoing advancements in technology and using different approaches.

1.2. Identification of Problem

The intertwining of logistics and battle strategy within military operations is crucial for achieving success on the battlefield. A successful strategy heavily relies on a robust and reliable supply chain to fulfil the needs of the forces engaged in combat. Many war strategies have failed because the logistics team could not deliver the supplies on time or due to poor quality of supplies for the combat force. Robust logistical planning, timely delivery of provisions, quality control of supplies, and adaptability in responding to changing operational needs are all pivotal aspects that contribute to the success of military endeavours. During the attempted invasion, the Japanese troops displayed bold and swift movements, indicating a strong strategic approach. However, despite their tactical prowess, the operation faltered due to critical inadequacies in the supply chain. As the campaign progressed, the lack of timely and adequate supplies became apparent, ultimately leading to the failure of the mission.[3] Such cases highlight the detrimental impact of inadequate supplies on military campaigns and emphasize the urgent need to fortify the military supply chain to ensure efficient management strategies capable of meeting battalion needs.
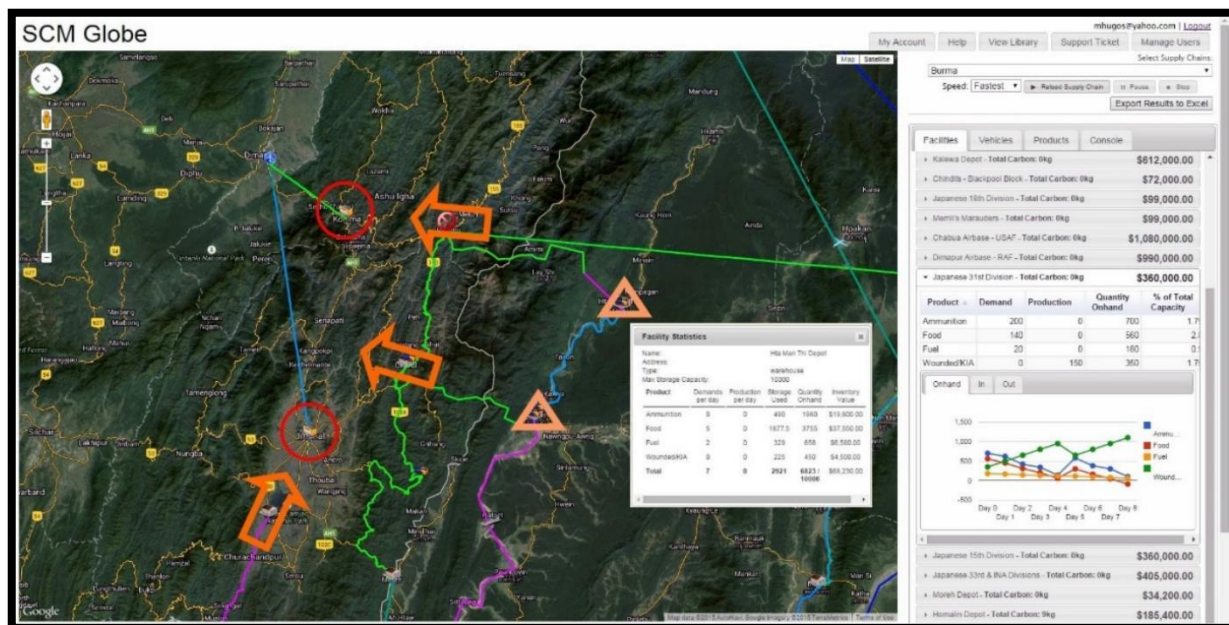
Fig. 2. (Operation U-Go and Supporting Supply Chain Simulation) Burma Campaign Case Study on SCM Globe [3]

Contemporary military confrontations frequently witness adversaries targeting supply chain routes, resulting in disruptions and scarcities during ongoing frontline engagements. The Indian Army, operating across multiple diverse fronts, faces substantial challenges in supplying goods to base stations situated in regions marked by diverse terrains, geopolitical complexities, ambush

vulnerabilities, and the looming threat of natural disasters. India's diverse landscape, encompassing mountainous regions, deserts, dense forests, and plains, presents logistical challenges in transporting supplies efficiently. Each terrain requires specialized logistical approaches, adding complexity to the supply chain management. Furthermore, border areas and conflict zones often have heightened security concerns and geopolitical sensitivities, impacting the ease of logistics and supply operations. Conflict-prone regions or areas with insurgent activities also serve as a hurdle in the overall logistics process due to the high risk of ambushes and attacks on supply convoys in those areas.

The complexities of the supply chain are further compounded by a range of issues, including legal delays, bureaucratic hindrances, inadequate inventory management, and a dearth of appropriate surveillance, engagement, and attack equipment. Administrative delays, bureaucratic procedures, and legal complexities can impede the timely movement of supplies, leading to bottlenecks in the supply chain. Inadequate inventory management practices can result in either overstocking or shortages of critical supplies, impacting operational readiness and efficiency. Additionally, despite having some sophisticated surveillance and engagement equipment, the Indian Army relies significantly on imports for such technologies, with few being domestically manufactured. Given the current geopolitical scenario, the nation's dependence on external sources for critical equipment poses a significant risk. The imperative need for self-reliance in defence technologies, including surveillance and engagement equipment, is crucial to secure the supply chain against disruptions and bolster national security.

Furthermore, the diverse terrains and climatic conditions across various fronts present significant challenges. The unpredictability of adversaries' actions, compounded by varying climates, complicates the delivery and storage of supplies. The wide spectrum of terrains, from mountains to deserts, makes it challenging to predict and strategize effectively, further complicating supply chain logistics. Lack of an effective system to map contingency plans and supply chain tracking further enhances the risk associated with the multifaceted challenges. While contingency plans exist, the absence of a cohesive system to map out actions and strategies leaves the supply chain vulnerable to disruptions caused by adversarial attacks.

Addressing these multifaceted challenges requires a concerted effort to bolster indigenous manufacturing capabilities for sophisticated surveillance and engagement equipment, encompassing improved infrastructure, enhanced security measures, efficient inventory management systems, streamlined bureaucratic processes, updated technology, and strategic planning. Developing a system to map out contingency plans becomes imperative to effectively counter disruptions caused by adversarial attacks on supply routes. Moreover, enhancing predictive capabilities to adapt supply chain logistics according to diverse terrains and climates is essential. Introducing specialized storage and transportation mechanisms adaptable to various environmental conditions becomes crucial for maintaining the supply chain's efficiency across different fronts. Employing innovative solutions adaptive logistics strategies tailored to diverse terrains, and establishing resilient supply networks to reduce attack surface area and bureaucratic delays is

imperative for the Indian Army to overcome these challenges and ensure a reliable and robust supply chain network in complex operational environments.

TABLE I.   KEY CHALLENGES IN MILITARY SUPPLY CHAIN MANAGEMENT

Challenges	Solutions
Lack of domestic logistics surveillance	Promoting more defence R&D among youth and awarding private companies with contracts for surveillance technologies.
Multitude of terrains and climatic conditions	Deploying various surveillance and delivery technologies as suitable like using UAVs, Air Drops in areas where rail road is vulnerable. Developing specialized storage transportation mechanisms for regions with extreme climatic conditions like Ladakh to ensure least logistic pause.
Legal Delays and Bureaucratic Withstand	Optimising the contract amendments, order changes and legal delays using smart contracts and using blockchain to avoid information asymmetry amongst the stakeholders.
Lack of inventory management	Using blockchain to increase transparency in the overall supply chain process by real-time tracking of the supplies and inventory to ensure that no goods are in store for longer than 3-4 months.
Geopolitical situations and diplomatic relations	Along with the international contracts, some proportion of the supplies contract can be awarded to the local companies to ensure efficient supplies are available even in ongoing conflicts.

1.3. Identification of Tasks

Within the sphere of national security and defence, the efficacy and resilience of the military supply chain stand as paramount factors in ensuring the preparedness and efficiency of armed forces. The intricate nature of a well-functioning military supply chain involves the acquisition, storage, and dissemination of a diverse range of critical resources - from weaponry and ammunition to equipment, fuel, and medical supplies. The scale and complexity of these supply chains, often spanning global networks, present distinctive challenges that necessitate innovative solutions focused on enhancing transparency, traceability, and security.

The primary task at hand is to ensure the prompt, adequate, and cost-effective delivery of supplies, crucial for facilitating efficient military operations both in combat situations and humanitarian events. The supply chain process can be broadly categorized into three stages: procurement, transformation, and order management, with a focus on four major components - products, facilities, vehicles, and routes. The overarching goal of a secure supply chain management is to mitigate the risks associated with potential failures across these stages and components, ensuring seamless operational continuity and preparedness even in the face of logistical challenges. It is necessary to ensure that none of these components face failover during the three stages, and even if they do, there is always a backup to ensure the least logistic pause.

A fundamental exploration into the inception of the supply chain process, its operational mechanics, and the integration of various technological solutions, ranging from blockchain to digital twins, is imperative. An in-depth analysis into the vulnerabilities, potential points of attack, and viable solutions to fortify these vulnerable aspects is necessary to ascertain the resilience and adaptability of the existing military supply chain processes and whether it has stood the test of time or not.

Conducting a comprehensive review of diverse publications becomes pivotal in identifying research gaps, understanding the latest strategies that have been implemented or discussed, and evaluating their viability within the intended operational environment. This review encompasses an exploration of potential applications of blockchain technology within the existing supply chain framework - from employing e-voting for bidding processes to order approval through consensus mechanisms and order tracking via blockchain-based systems. Additionally, leveraging technologies such as RFID, geofencing, checkpoints, supply chain simulation, sensors, and inventory management through transparent blockchain transactions stands as critical avenues for exploration.

The meticulous examination of these technological advancements and their potential integration into the military supply chain aims to fortify security, enhance efficiency, and foster resilience against potential disruptions. By identifying and understanding these tasks within the realm of military supply chain security research, a roadmap can be forged towards augmenting the effectiveness and adaptability of defence logistics in contemporary warfare scenarios.

1.4.   Timeline

The following Gantt chart shows our progress throughout the development of this review paper:
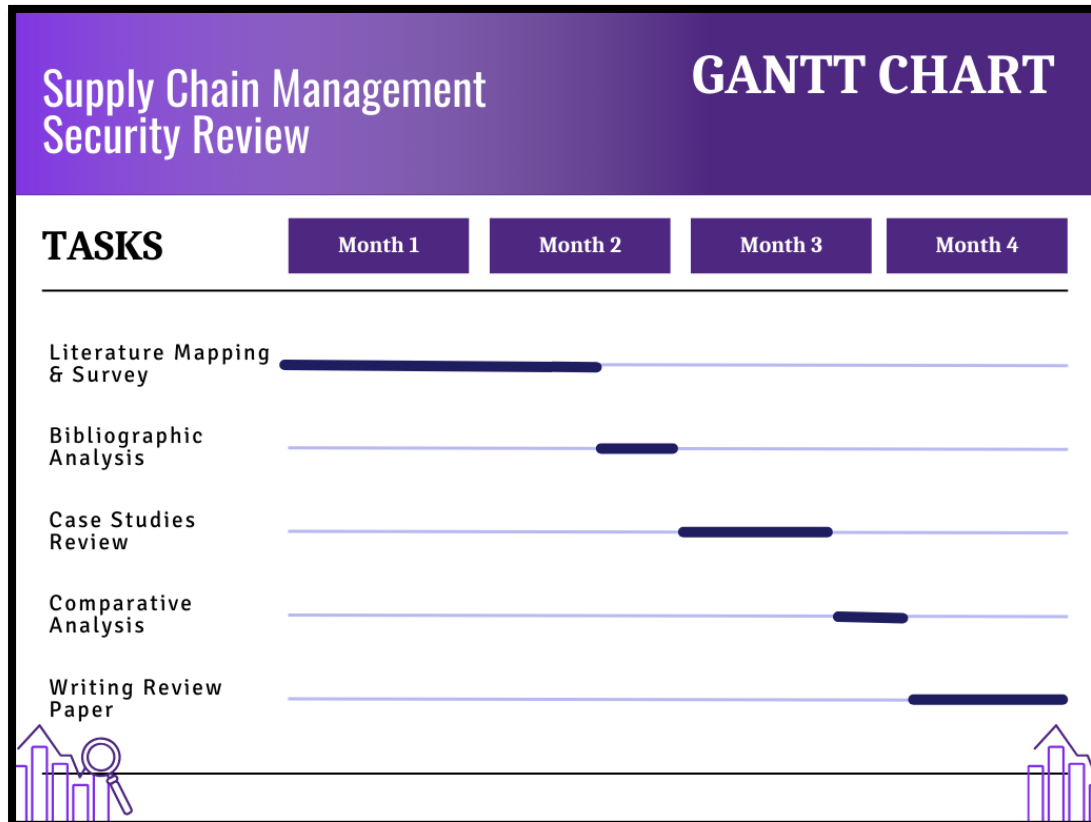
Gantt chart

Fig. 3.   Gantt Chart

1.5.   Organization of the Report

1. Problem Analysis:

Description: This section identifies and highlights the core issues that the project seeks to address. It delves into the challenges associated with accessing pertinent publications for analysis within the military domain, owing to the inherent covert nature of military operations. Unlike other sectors where information might be more openly available, the sensitive nature of military operations often restricts access to relevant publications, hindering comprehensive analysis and decision-making. Furthermore, it delves into elucidating the intricate operations embedded within the Indian Army's supply chain management system. This involves discussing the limitations of traditional mechanisms employed in this domain. These limitations might include inefficiencies, delays, logistical complexities, and the potential for vulnerabilities within the supply chain.

Content: A comprehensive discussion on the limitations inherent in traditional mechanisms employed in the Indian military supply chain management will be presented. Furthermore, it will spotlight the current global trends in supply chain management. This comparative analysis helps highlight the disparities and areas for improvement, especially in the context of an evolving geopolitical landscape, contrasting these with the challenges faced by India in an evolving geopolitical landscape, operating across 2.5 fronts, encompassing diverse terrains, and engaging in global humanitarian aid missions. By conducting a detailed analysis, the project aims to provide a comprehensive understanding of the hurdles faced in sourcing critical military supply chain information. It emphasizes the critical need for responsive and forward-thinking approaches in resolving these challenges. Such solutions should be intelligent and adaptable, tailored to the unique demands of the military domain, to ensure efficient and effective supply chain management for the Indian Army amidst diverse operational scenarios.

2. Solution Design:

Description: This segment details the proposed solutions intended to mitigate the identified problems. It offers an overview of the blockchain-based approach to military supply chain management and other complementary techniques enhancing operational efficiency.

Content: An in-depth exploration of the chosen distributed ledger technology, detailing its features and its suitability for addressing the identified problem will be presented. Special emphasis will be placed on highlighting the deployment and functionalities of smart contracts, their audit processes, and pertinent use cases. Explaining their role in the supply chain, including automated payment processing, order fulfillment, and tracking, demonstrates how they streamline operations and reduce manual intervention. It also includes emphasizing the ease for auditing processes due to the transparent nature of the blockchain records. Furthermore, this

section will highlight how a multi-layered security approach, incorporating blockchain, can fortify and empower military supply chain applications in this domain.

3. Implementation:

Description: This section outlines the practical execution of the proposed solution, incorporating bibliographic and comparative analyses of publications advocating blockchain applications and complementary security measures like route reconnaissance, LIDAR sensors, geofencing, and simulation techniques.

Content: This involves conducting a comprehensive review of existing publications, scholarly articles, and research papers by describing the systematic approach used to identify, gather, and analyse relevant papers for an in-depth study, including the selection criteria, databases utilized, keywords, and search techniques employed to ensure a comprehensive analysis of existing literature on blockchain applications and security measures in military supply chain management. Further, this section will detail the process of bibliographic analysis utilizing various tools and software, alongside comparing and contrasting the findings using case study simulations, correlations, emerging trends, potential research gaps and comparative analysis.

4. Evaluation:

Description: This part assesses the effectiveness of the research and identifies the research gaps. It involves working on finding the most optimal and viable solution. It consists of analysing the proposed and suggested solutions of the existing publications to the traditional methods currently in use.

Content: Presentation of comprehensive case study reviews inclusive of simulated network conditions and test cases will be provided. Comparative analysis of the proposed solutions against traditional supply chain management techniques will be articulated. Moreover, the discussion will encompass observations regarding research gaps, including the adaptability of the proposed solution to dynamic terrains, climates, and geopolitical scenarios. By meticulously addressing each section of the report, the study aims to provide a comprehensive and structured analysis of the challenges, proposed solutions, their implementation, and an evaluative assessment towards enhancing military supply chain security through technological innovations.

LITERATURE REVIEW/BACKGROUND STUDY

2.1. Timelem of the Reported Problem

1. Global Recognition:

The exploration of military supply chain resilience has been an enduring subject in academic research, evolving in prominence and terminology over time. Its roots extend back to historical events like World War II, where the challenges of maintaining resilient supply chains during wartime underscored their critical importance. Discussions on military supply chain issues also emerged in the late 18th and 19th centuries, notably through Antoine-Henri Jomini's theory of war, which emphasized the trinity of strategy, ground tactics, and logistics.

Formal academic scrutiny of military supply chain resilience began to surface notably in scholarly papers from the late 1940s onwards. Cureton M.K.'s 1948 paper delved into the underlying issues in medical logistics, marking an early exploration in this field. Streets R.E.'s 1956 study on performance testing of gear lubricants for military equipment highlighted the significance of chemical surface treatment in reducing logistical problems and eliminating errors in field operations. Concurrently, research in 1956 also emphasized correlations within the Department of Planning, Studies, and Research, signalling a broadening understanding of the complexity of military supply chains.

The year 1959 witnessed a pivotal shift with Durkee A.L. et al.'s introduction of the White Alice System, which focused on creating a secure network transmission channel to fortify the supply chain. Subsequent research endeavoured to integrate electronics and data handling into military logistics. The 1965 article by Fiore et al. reviewed developments in logistics support, stressing the importance of system engineering and personnel subsystems in ensuring effective supply chains.

Advancements continued with a focus on mathematical models to identify logistics problems and predict outcomes of proposed changes or corrective actions. Researchers ventured into exploring database security and data analysis to discern disruptions within military supply chain processes, advocating empirical studies and quantitative evaluations. The importance of simulation models emerged, enabling a deeper understanding of supply chain dynamics and disruptions.

In 2002, Thomas. U. et al. highlighted the issue of military supply chain reliability, defining it in terms of the probability of achieving objectives at critical transfer points for contingency operations. Publications during this period underscored the critical differences between commercial and military supply chains, stressing the need for securing the entire process lifecycle in the latter due to its unique challenges and security imperatives.

The journey of academic exploration into military supply chain resilience spans decades, marked by a progression from early inquiries into logistical challenges to sophisticated analyses involving technology integration, mathematical modelling, and an emphasis on security imperatives. This ongoing evolution reflects a deepening understanding of the complexities inherent in safeguarding and enhancing the resilience of military supply chains.

2. Academic Research:

Academic papers and journals from the late 1900s serve as historical archives that vividly depict the challenges inherent in supply chain management within military operations. Scholars of that era underscored the criticality of addressing these challenges and integrating new technologies into military logistics. These publications meticulously detailed real-world incidents and battlefield failures resulting from inefficient supply chains while advocating for technologically advanced solutions available at the time, such as forecasting, simulation, and the use of optimal path control methods and algorithms.

In these academic discussions, researchers extensively relied on analyses involving the F/A-18, aiming to quantify the significance of achieving specified field reliability levels. They delved into evaluating the adequacy of supply support funding and the pivotal role of test equipment capacity in achieving aircraft readiness objectives. Additionally, there was a concerted effort to adopt new software documentation standards to streamline joint operations within military logistics.

The 1990s marked the commencement of research focused on military intelligence and delineating the logistical requirements essential for unit success. As the early 2000s unfolded, scholars began venturing into uncharted territories, exploring the complexities of space logistics. During the initial years of the 21st century, numerous publications underscored the pivotal role of cutting-edge technologies in mitigating risks within military logistics. These studies emphasized the imperative utilization of technological tools such as digital twin models, blockchain, RFID sensors, among others, in crafting a cohesive system capable of efficiently managing logistics for military operations.

These scholarly works were grounded in identifying underlying causes contributing to supply chain vulnerabilities, including uncertain demand, declining innovation, limited competition, cyber threats, and reduced surge capacity. [23] Within these discussions, a recurrent theme emerged, emphasizing the critical necessity for resilience planning, robust risk management strategies, integrated logistics frameworks, and the infusion of modern technologies to ensure the sustained operational efficacy of military supply chains. [24]

In summary, the historical narrative depicted in these academic papers and journals from the late 1900s to the early 2000s highlights an evolution in understanding military supply chain

challenges and the continual push for technological advancements and strategic planning to fortify these chains against various threats and disruptions. These scholarly pursuits remain foundational pillars guiding the contemporary discourse on military logistics and supply chain resilience.

3. Industry Reports:

Over the past decade, leading technology companies, particularly those in China, have taken significant strides in revolutionizing their supply chain systems. These advancements have not only bolstered the efficiency of the military supply chain within their country but have also extended to encompass critical roles in various containment facilities established overseas. A noteworthy initiative supported and sponsored by the Chinese government is the National Transportation and Logistics Public Information Platform, known as LOGINK. This platform serves as a comprehensive resource offering users a centralized hub for managing logistics data, tracking shipments, and facilitating information exchange among enterprises and governments. [25]

Chinese companies, leveraging cutting-edge technologies, have been pivotal in transforming the landscape of supply chain operations. For instance, their integration of blockchain technology has been instrumental in streamlining and securing logistics processes. This technology has enabled transparent and tamper-proof tracking of goods, facilitating enhanced traceability and accountability across the supply chain. Such advancements not only fortify the domestic military supply chain but also contribute significantly to overseas logistics operations.

Moreover, exploring the global landscape of supply chain innovation, India has been actively testing and implementing blockchain technology within its logistics industry. Several Indian companies have harnessed blockchain to revolutionize their logistics operations. For instance, they've introduced features like efficient shipment tracking, real-time monitoring, documentation automation, and multi-point drop management. These advancements aim to enhance transparency, reduce inefficiencies, and optimize logistical processes within the military supply chain and beyond.

The adoption of blockchain technology in India's logistics industry has gained notable attention due to its potential to overhaul traditional supply chain operations. The country's top three blockchain-powered logistics companies have emerged as pioneers in deploying this technology, heralding a new era of efficiency and reliability within logistics. This transformative technology holds the promise of enhancing data integrity, securing transactions, and enabling seamless information exchange among stakeholders, thereby bolstering the resilience and effectiveness of military supply chains.

4. Recent Research and Conferences:

Recent research and conferences focusing on the military supply chain have been pivotal in exploring various technological advancements and strategic approaches aimed at bolstering logistical capabilities. These discussions and publications, showcased prominently at major international conferences, shed light on a spectrum of technological facets, including Directed Acyclic Graphs (DAG), Distributed Ledger Technologies (DLT) such as Blockchain, IOTA, and the integration of sensors like LIDAR and GPR.

The exploration of cutting-edge technologies within military logistics reflects a concerted effort to enhance efficiency, security, and resilience in the supply chain. Notably, discussions have centered around leveraging DAG and DLT, particularly Blockchain and IOTA, to establish robust, decentralized systems capable of facilitating transparent, secure, and immutable transactions across the military supply chain. These technologies offer promise in ensuring data integrity, traceability, and streamlined logistics operations, fostering greater trust and reliability in the flow of goods and information.

Moreover, recent articles have emphasized the significance of crafting logistics practices rooted in data utilization and wargaming methodologies. This strategic approach aims to enhance decision-making processes and planning amidst uncertainty and complexity. By integrating industry expertise, leveraging the capabilities of allies and partners, and harnessing their resources for logistical support, these practices seek to fortify the adaptability and responsiveness of military supply chains.[26]

An integral aspect highlighted in these discussions involves elevating cyber awareness and training among army personnel and contractors. Acknowledging the evolving cyber landscape's threats, these publications advocate for stringent cyber regulations and industry standards. Strengthening cyber resilience within the military supply chain is deemed crucial, underscoring the imperative of safeguarding sensitive data, fortifying digital infrastructure, and mitigating potential cyber threats that could compromise logistical operations.

The convergence of these research insights and conference deliberations signifies a concerted push towards leveraging advanced technologies and strategic methodologies to address the intricacies of military supply chains. By integrating technological innovations like DAG, DLT, and sensor technologies alongside comprehensive data-driven logistics practices, the goal is to optimize decision-making, fortify security measures, and enhance the agility of military supply chains amid evolving operational landscapes. Moreover, the emphasis on cyber resilience underscores the growing recognition of the imperative to safeguard critical logistics infrastructure in the face of contemporary cyber threats.

2.2 Existing Solutions

In the dynamic landscape of modern warfare, ensuring the security and integrity of military supply chains stands as a paramount concern. Traditional methods of securing these chains have faced challenges related to transparency, traceability, integrity, and efficiency. Addressing these issues, recent scholarly research has extensively explored the application of blockchain technology to fortify military logistics, communications, battlefield management, and repair parts management.

Numerous studies have underlined the potential of consortium blockchains in revolutionizing the transparency and traceability of military supply chain operations. This innovative approach involves multiple stakeholders collaborating within a permissioned blockchain network. Through secure information sharing among authorized participants, consortium blockchains minimize the risks associated with counterfeit goods, streamline procurement processes, and improve inventory management. Sharifah Saadiah and Syarifah Bahiyah Rahayu's study emphasizes these benefits, highlighting the substantial impact on enhancing supply chain operations. [8] To tackle integrity and security challenges within military logistics, Demertzis, Kikiras, and Iliadis advocate for a blockchained architecture. This proposed system aims to safeguard the authenticity of military logistics operations by maintaining an immutable record of transactions. Leveraging blockchain's cryptographic features, this architecture ensures data integrity, thereby reducing the likelihood of tampering and unauthorized access [9].

The integration of blockchain technology extends beyond supply chain operations into military communications and battlefield management. Studies, such as Ahmad et al., delve into the potential opportunities and challenges of integrating blockchain in aerospace and defence, highlighting its decentralized nature to enhance secure communication channels and facilitate the secure sharing of critical information in real time [10]. Furthermore, in the realm of unmanned vehicles and autonomous systems, Ghimire, Rawat, Liu, and Li propose a sharding-enabled blockchain to address scalability concerns. By dividing the blockchain into smaller segments or shards, this innovative approach increases transaction throughput. This technology holds promise in coordinating and exchanging data between autonomous units in a software-defined internet of unmanned vehicles on the battlefield. [11]

Not confined to supply chain operations, blockchain technology also finds application in repair parts management within military supply chains. Rahayu et al. present a conceptual model that utilizes blockchain to enhance repair parts management. This model, through a decentralized and transparent ledger, facilitates the tracking of repair parts, reducing downtime, and ensuring the authenticity of replacement components [12].

The recognition of blockchain's potential by institutions like the U.S. Department of Defence and NATO allies has accelerated its exploration in defence applications . They have begun to explore applications such as automatic execution of smart contracts, secure storage of sensitive files, and

reducing errors and interruptions. The U.S. Navy has also integrated blockchain technology to bolster the security of additive manufacturing systems .

TABLE II.   LITERATURE SURVEY

Year and Citation	Article/ Author	Tools/ Software	Technique	Source	Evaluation Parameter
2021 [8]	Consortium Blockchain for military supply chain. (Sharifah et al.)	Hyperledger Fabric framework	Consortium blockchain for military supply chain	https://doi.org/ 10.17762/turco mat.v12i3.101 1	Transparency , traceability, and accountabilit y
2022 [9]	A Blockchained Secure and Integrity-Preserved Architecture for Military Logistics Operations. (Demertzis et al.)	Hyperledger Fabric Project	A blockchained secure and integrity-preserved architecture for military logistics operations	https://doi.org/ 10.1007/978-3-031-08223-8_23	Data security and integrity
2021 [10]	Blockchain for aerospace and defence: Opportunities and open research challenges. (Ahmad et al.)	-	Blockchain for aerospace and defence: Opportunities and open research challenges	https://doi.org/ 10.1016/j.cie.2 020.106982	Data security, supply chain management and authenticatio n
2021 [11]	Sharding-Enabled blockchain for Software-Defined internet of unmanned vehicles in the battlefield. (Ghimire et al.)	Sharding-enabled blockchain	Software-defined internet of unmanned vehicles in the battlefield	https://doi.org/ 10.1109/mnet. 011.2000214	Performance, security and scalability

2021 [12]	Conceptual Model of Military Blockchain for Repair Parts Supply Chain Management. (Rahayu et al.)	Military blockchain model	Repair parts supply chain management	https://doi.org/10.1109/iccoins49721.2021.9497227	Cost, time and quality
2019 [13]	Military blockchain for supply chain management. (Rahayu et al.)	Hyperledger Composer framework	Military blockchain for supply chain management	https://www.researchgate.net/publication/336614544_Military_Blockchain_for_Supply_Chain_Management	Supply chain performance
2022 [14]	Blockchain resilient communication in military: A systematic literature review. (Mohamed et al.)	-	Systematic literature review using data analysis, keyword count and qualitative analysis of selected publications over time.	https://doi.org/10.11113/oiji2022.10nSpecialIssue1.181	Security of communication channel
2023 [15]	Role of cybersecurity and Blockchain in battlefield of things. (Sharma et al.)	-	Role of cybersecurity and blockchain in battlefield of things	https://doi.org/10.1002/itl2.406	Security and integrity of connected military devices and systems
2021 [16]	Military Supply Chain Management and Blockchain Development. (Rahayu et al.)	Blockchain development	Military supply chain management	https://doi.org/10.5121/csit.2021.111608	Efficiency, transparency and traceability
2020 [17]	Blockchain-Based Data Security in Military Autonomous Systems. (Angin et al.)	Blockchain-based data security	Military autonomous systems	https://doi.org/10.31590/ejosat.824196	Confidentiality, integrity and availability

2022 [18]	Blockchain-Based autonomous authentication and integrity for Internet of battlefield things in C3I system. (Rashid and Khan et al.)	Blockchain-based autonomous authentication and integrity	Internet of battlefield things in C3I system	https://doi.org/10.1109/access.2022.3201815	Authentication, integrity and non-repudiation
2022 [19]	Distributed Blockchain-Based platform for unmanned aerial vehicles. (Ahanger et al.)	Distributed blockchain-based platform	Unmanned aerial vehicles	https://doi.org/10.1155/2022/4723124	Reliability, security and privacy
2020 [20]	Applications of blockchain in unmanned aerial vehicles: A review. (Alladi et al.)	Blockchain applications	Unmanned aerial vehicles: A review	https://doi.org/10.1016/j.vehcom.2020.100249	Security, privacy and trust
2020 [21]	A study of blockchain technology development and military application prospects. (Zhu et al.)	Blockchain network simulation	Blockchain technology development and military application prospects	https://doi.org/10.1088/1742-6596/1507/5/052018	Security, scalability, efficiency, and applicability

2.3. Bibliometric Analysis

The systematic literature review conducted in this paper adopts a rigorous approach using bibliometric analysis, which involves analysing bibliographic data using various parameters to establish correlations through quantitative analysis. Such a methodical approach assists in evaluating article performance within a specific field of study, pinpointing central research themes, and identifying potential research gaps that could guide future investigations.

The initial phase involves collecting data from earlier publications advocating for securing military supply chains and the adoption of emerging technologies like blockchain, DLT, and digital twin. Due to the sensitive nature of military operations and the relatively recent application of technologies such as blockchain, online research within this domain is scarce compared to other fields. To comprehensively explore related literature, the search process begins by identifying relevant papers using Google Scholar and Litmaps to aid in expanding the study's scope and depth of insights.
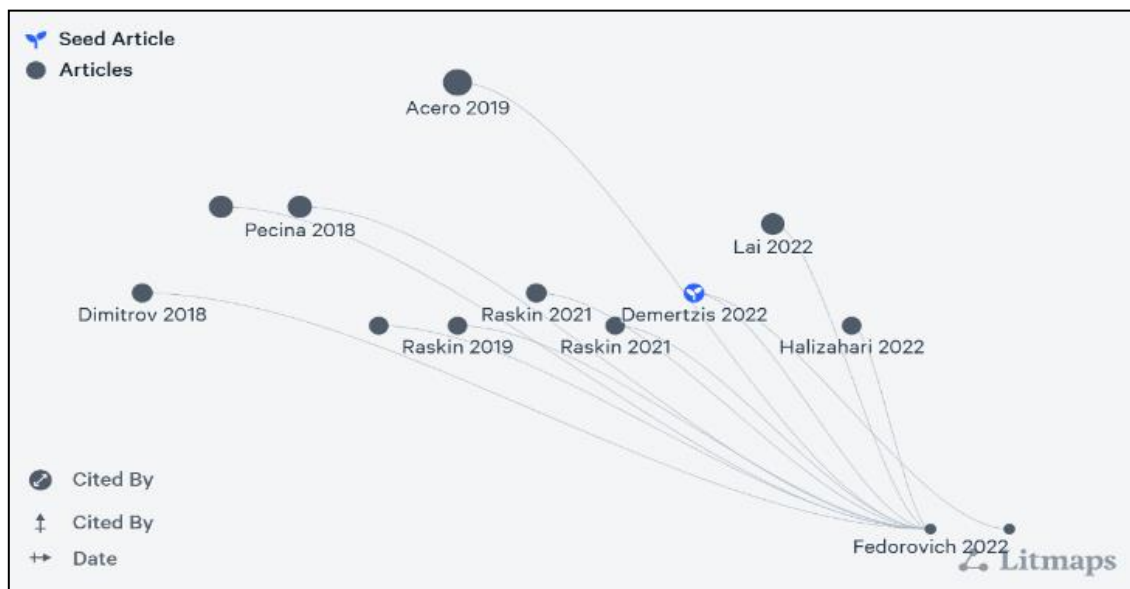

Fig. 4.   Related Research Work with A Blockchained Secure and Integrity-Preserved Architecture for Military Logistics Operations as Seed Article
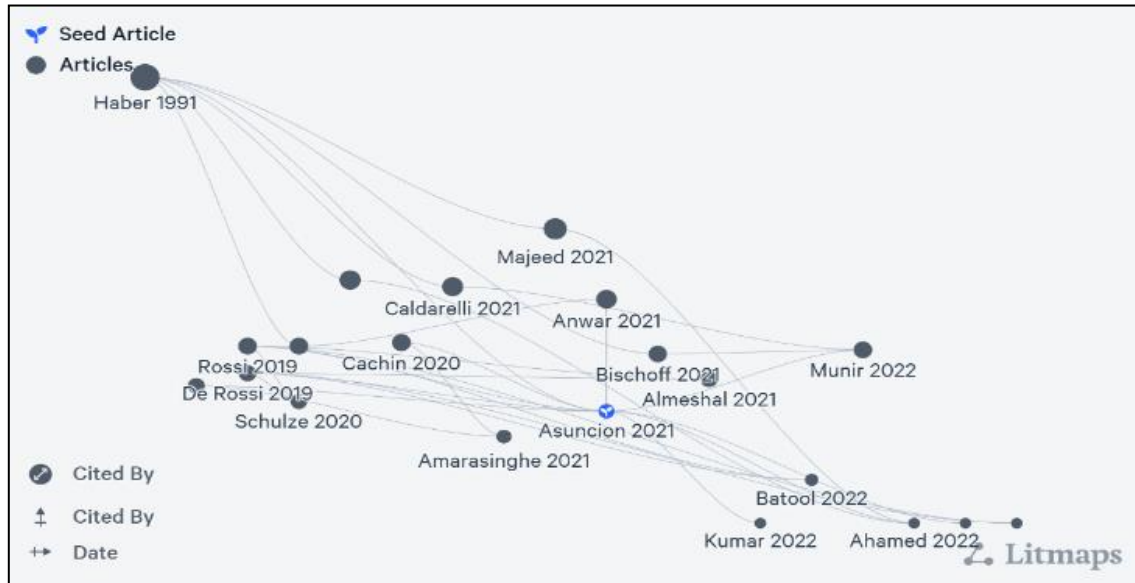
*Fig. 5.   Related Research Work with Connecting Supplier and DoD Blockchains for Transparent Part Tracking as
Seed Article*

To augment the study's depth and breadth, a multidisciplinary scientometrics database, Scopus, is employed to export papers obtained through Litmaps and Google Scholar.   VosViewer, a bibliometric analysis tool, is then utilized to map these papers, establishing correlations among co-occurring keywords within documents. This mapping reveals additional keywords, guiding further online searches for articles, thereby enriching the breadth of literature considered in the study for a comprehensive analysis and nuanced understanding of the research landscape concerning military supply chain security and emerging technologies.

Bibliometric analysis serves as a quantitative method used to gauge the impact of published documents and unveil correlations among them, thereby identifying patterns and discerning trends within a specific field.   In this study, the analysis begins with a citation analysis employing co-citation and bibliographic coupling techniques. These methods provide graphical representations illustrating backward and forward citation analyses, identifying authors frequently cited together and revealing influential papers within the domain of military supply chain security and emerging technologies.

The most cited paper identified in this domain is 'Ensuring Supply Chain Resilience: Development of a Conceptual Framework' authored by Pettit T.J. et al., signifying its significant influence and relevance within the literature.
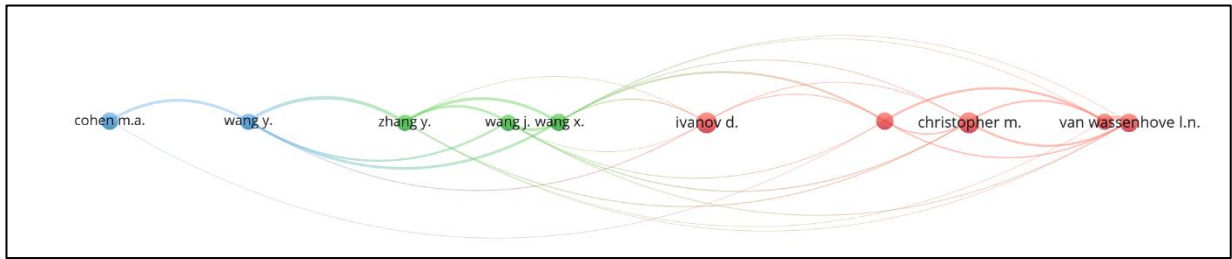
Fig. 6.   Citation Analysis using Co-citation in VosViewer
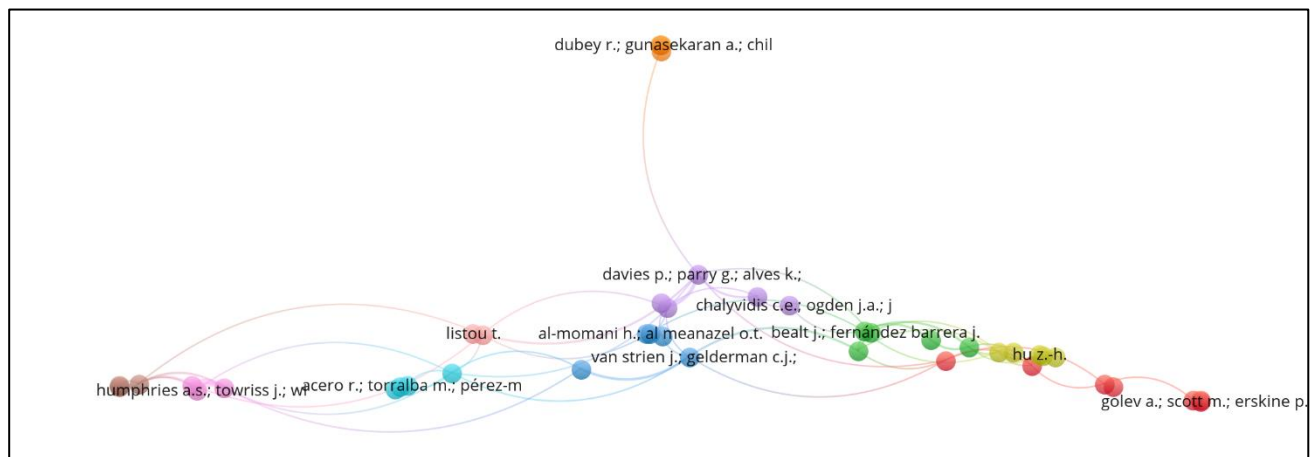
Fig. 7.   Citation Analysis using Bibliographic Coupling in VosViewer

The above figures showcase the outcomes of the citation analysis conducted using co-citation and bibliographic coupling in VosViewer, respectively. These graphical representations offer insights into the connections and relationships between cited authors and documents, revealing the interrelatedness and key works that have shaped the discourse within this field. Additionally, the study utilizes co-occurrence analysis under content analysis, a method that uncovers major research gaps and correlations, addressing key research questions outlined in the review paper. This analysis delves into the underlying causes contributing to the shortcomings of traditional supply chain methods.

2.4. Review Summary

The integration of blockchain technology offers promising solutions to fortify military supply chain security. Its applications span from enhancing supply chain transparency, ensuring data integrity, improving communication channels, managing autonomous systems, and tracking repair parts. The decentralized and distributed nature of blockchain technology offers resilience by thwarting intrusion attempts, which proves beneficial in preventing such large-scale data breaches by foreign actors. On the battlefield, ensuring the validity and accuracy of information and orders received by soldiers is critical. Centralized digital communication units are susceptible to attacks that could intercept or manipulate communications, jeopardizing the integrity of the entire network. Blockchain emerges as a potential solution in this scenario due to its decentralized nature, providing a safeguard against network compromise and ensuring the reliability of information transmission.

Blockchain technology, despite its potential, comes with inherent limitations, raising questions about its true transformative impact in military affairs, the extent of research conducted on it, and the allocation of resources for its optimization. Few studies have been published regarding blockchain's broader implications, prompting a need to explore the differences between authors' selected topics and ongoing research. Storing vast amounts of sensitive data in a centralized location poses significant risks, potentially leading to the unauthorized extraction of classified information. [14]

While blockchain indeed provides various solutions, it may not always be the most suitable or efficient choice for every scenario due to its characteristics, limitations, or the nature of the problem being addressed. Digital twin technology excels in creating virtual models mirroring physical systems, enabling simulations, testing, and optimization without directly affecting the real system. It finds extensive application in predictive maintenance, operational efficiency, and product development across industries. Furthermore, Fuzzy reasoning, on the other hand, is a method of handling uncertainty in decision-making, allowing for flexible reasoning based on imprecise or incomplete information, making it suitable for certain AI applications. Few studies also question the integration of RFID in the military supply chain.

Some research also suggests analysing the ongoing 24/7 operational data within the supply chain is vital for predicting adversaries' plans and comprehending the overall flow for proactive identification of potential threats and disruptions. Recent research has also shed some light on the use of additive manufacturing for on-demand production of spare parts and components, reducing lead times and enhancing flexibility in the supply chain, especially in remote or challenging operational environments.

DESIGN FLOW/PROCESS

3.1. Evaluation & Selection of Specifications/Features

The overarching goal of this review paper lies in the meticulous assessment and comprehensive analysis of the existing body of research within the domain of military supply chain security. Employing various features and methodologies, this paper employs a structured approach to delve into this critical realm.

The first significant feature utilized in this review involves leveraging bibliometric analysis to acquire connected papers and relevant keywords pertinent to military supply chain security. This initial step plays a pivotal role in shaping the subsequent search query, ensuring the comprehensive retrieval of relevant research material. These connected papers and keywords form the foundation for the extensive exploration and analysis conducted throughout the review. Building upon this foundation, the review employs a sophisticated search strategy within scientometrics databases. Utilizing obtained keywords, the methodology incorporates Boolean operators to refine the search, maximizing the inclusion of pertinent research papers. This meticulous approach enhances the accuracy and breadth of the review by sourcing diverse yet relevant scholarly material. The subsequent stage involves leveraging bibliometric analysis techniques to correlate the obtained papers, assess prevailing research trends, and identify the most cited paper within the domain of military supply chain security. This methodological approach enables a comprehensive evaluation of the landscape, offering insights into the evolving trends and significant contributions in the field.

An integral aspect of the review is the execution of a comprehensive trend analysis, utilizing volumetric analysis to scrutinize the trajectory and evolution of research trends over time within military supply chain security. This thorough examination helps in identifying emerging patterns, shifts, and the direction of research within this dynamic domain. A pivotal element of the review involves a comparative analysis, focusing primarily on assessing the suitability of blockchain technology within the context of military supply chain security. Additionally, other technologies, such as digital twin, are also scrutinized for their potential use cases and applicability. This comparative assessment aims to ascertain the strengths, weaknesses, and distinctive attributes of various technologies, aiding in understanding their suitability and potential contributions.

These distinct features collectively evaluate several crucial parameters. They meticulously assess the relevance of collected research data to the field of military supply chain security, including the applicability of blockchain technology within this covert domain. Moreover, the effectiveness of bibliometric analysis, encompassing the evaluation of the process of obtaining, sorting, and correlating research papers, ensures a comprehensive overview of the research landscape. Filters are employed to evaluate the quality and reliability of obtained papers, ensuring their credibility

and substantive contribution to the review's objectives. Lastly, the comparative analysis assesses the depth and thoroughness, facilitating the identification of technology suitability within military supply chain security contexts.

Through this systematic approach, the review aims to offer a comprehensive and insightful analysis of the multifaceted domain of military supply chain security, shedding light on pertinent research trends, technological advancements, and their implications within this critical field.

3.2. Design Constraints

Writing a comprehensive review paper on military supply chain security encounters significant challenges due to the inherent sensitivity of military operations and the consequent confidentiality of information. Historical data pertinent to research articles in this domain is often classified, limiting access to the general public without proper security clearance. As a result, the review's depth and breadth heavily rely on available unclassified data sourced from internet archives, government reports, and publicly accessible articles. This constraint substantially hampers the review's content analysis, restricting the thoroughness of examination.

Additionally, the adoption of Distributed Ledger Technology (DLT), including blockchain, is a recent development in military supply chains. The evolving nature of this technology presents a formidable challenge in maintaining the review's currency by keeping abreast of the latest advancements and changes in its application within the military context. The earlies use of blockchain in defence dates back to 2018. The scarcity of empirical analyses due to its nascent stage further complicates the review, making it challenging to draw comparative analyses based on features and techniques.

Furthermore, balancing the dissemination of valuable insights while ensuring confidentiality poses another constraint. This balance limits the depth of discussion on certain aspects, preventing detailed explanations of both existing and proposed architectures within military supply chain security. Striking this balance becomes a delicate task, necessitating careful consideration of the information's sensitivity and the need to impart useful knowledge to the reader.

In summary, the review paper on military supply chain security encounters formidable hurdles. Restricted access to classified information, the infancy of DLT implementation, scarcity of empirical analyses, and the need to balance insights with confidentiality collectively impede the review's comprehensive examination and analysis. Efforts to navigate these constraints require meticulous sourcing of available data, continual monitoring of technological advancements, and a judicious balance between informative content and sensitivity to classified information within the military domain.

3.3. Analysis of Features and finalization subject to constraints

In this study focused on exploring blockchain's potential within military supply chain security, several key features have been identified and critically analysed. The primary emphasis revolves around the examination of blockchain technology alongside other existing methodologies applicable to enhancing security within military supply chains.

1. **Identification of Key Features:** The primary feature under scrutiny is blockchain technology, renowned for its decentralized ledger, cryptographic security, and smart contract functionalities. This technology is pivotal in securing information, ensuring transparency, and enabling trust less transactions within supply chains. Additionally, alternative methodologies such as cryptographic security protocols, centralized databases, and traditional supply chain security frameworks are considered for comparative analysis against blockchain.

2. Evaluation Against Objectives: Blockchain's effectiveness in addressing security challenges within military supply chains is thoroughly evaluated. Its potential contributions to enhancing transparency, securing sensitive data, and ensuring the integrity of supply chain operations are assessed. Comparative evaluation against existing methodologies involves an assessment of how well blockchain aligns with the overarching objectives of military supply chain security.

3. **Strengths and Weaknesses:** The strengths of blockchain, including immutability, traceability, and cryptographic security, are highlighted. Simultaneously, potential weaknesses such as scalability limitations, energy consumption concerns, and regulatory complexities are critically examined. Comparative analysis showcases the specific strengths and weaknesses of each methodology, aiding in understanding their suitability within the military supply chain context.

4. **Alignment with Constraints:** The alignment of blockchain and alternative methodologies with constraints within military operations is thoroughly assessed. Considerations regarding data confidentiality, regulatory compliance, interoperability, and adaptability to existing systems are scrutinized for each methodology.

5. **Comparative Analysis:** A comprehensive comparative analysis is conducted, elucidating the strengths, weaknesses, and distinct attributes of blockchain against existing methodologies. This assessment identifies areas where blockchain technology excels and areas where other methodologies might offer advantages.

Constraints affecting the selection or implementation of blockchain and alternative methodologies within military supply chain security are outlined. This includes constraints related to security clearance, data sensitivity, regulatory compliance, and technological limitations. Detailed analysis illustrating how each constraint influences the selection, integration, or adaptation of blockchain and other methodologies within military supply chain security is performed for impact assessment.

3.4. Design Flow

This section entails a structured approach to conducting literature review and bibliometric analysis, identifying challenges, employing methodologies, and assessing technologies. This methodical approach encompasses several key components:

1. **Initiation and Data Collection:** The review commences by exploring earlier publications advocating for securing military supply chains and employing emerging technologies like blockchain, DLT, and digital twin. Due to the classified nature of military operations and the novelty of technologies, initial data collection relies on available research from Google Scholar, Litmaps, and the multidisciplinary scientometrics database, Scopus.

2. **Search Strategy and Refinement:** Employing Boolean operators and specific query strings like 'military OR army OR defence AND supply chain' refines the search, narrowing down the results to Article Title, Abstract, and Keywords. Filtering these results to articles in journals ensures high research quality and relevance, aligning with the review's objectives.

3. **Bibliometric Analysis:** A pivotal phase involves employing bibliometric analysis techniques to quantify the impact of published documents, identify research themes, and establish correlations among co-occurring keywords. Citation analysis using co-citation and bibliographic coupling uncovers frequently cited papers, like 'Ensuring Supply Chain Resilience,' signifying significant contributions in this domain. These analyses, visualized through VosViewer and further examined through volumetric analysis in Excel, aid in recognizing research trends, influential papers, and prevalent research gaps.

4. **Comparative Analysis of Technologies:** The review integrates a comparative assessment of technologies pertinent to military supply chain security – Digital Twins, Blockchain, RFID, and GIS. Evaluating their diverse capabilities, security features, scalability, interoperability, and vulnerabilities provides insights into their applicability and suitability within this domain.

5. **Challenges and Limitations:** Challenges encountered in the review process include limited access to classified information, scarcity of available research, and the evolving nature of technologies like blockchain within military contexts. These constraints impede a thorough examination and necessitate meticulous sourcing and evaluation of available unclassified data while balancing the dissemination of valuable insights and the confidentiality of sensitive information.

6. **Significance and Implications:** The offer a methodical and insightful analysis of military supply chain security, employing bibliometric analysis and comparative assessments to navigate challenges and shed light on pertinent research trends and technological implications.

3.5. Design Selection

In this study examining blockchain's potential in military supply chain security, key features have been analysed. The focus centers on blockchain technology, known for its decentralized ledger, cryptographic security, and smart contracts. Other methodologies like centralized databases and cryptographic security protocols are also compared against blockchain. Evaluation against objectives scrutinizes blockchain's effectiveness in addressing security challenges within military supply chains, emphasizing transparency and data integrity. Strengths (immutability, traceability) and weaknesses (scalability, regulatory complexities) of blockchain and alternative methodologies are highlighted. Alignment with constraints such as data confidentiality and interoperability is assessed. A comprehensive comparative analysis delineates strengths, weaknesses, and applicability of blockchain and other methodologies in the military context. Constraints affecting selection or implementation, like security clearance and regulatory compliance, are outlined, detailing their impact on technology integration in military supply chain security.

3.6. Implementation Plan/ Methodology

This paper follows a systematic approach to conduct literature review using bibliometric analysis wherein bibliographic data is analysed using various parameters to establish correlations through quantitative analysis. Such an approach aids in evaluating the performance of articles within a specific field of study, identifying central research themes, and finding potential research gaps that could steer future investigations.

1. **Data Collection:** To initiate the research process, the data collection phase involves exploring earlier publications that advocate for securing military supply chains and utilizing emerging technologies such as blockchain, DLT, and digital twin. Given the covert nature of military operations and the relatively nascent use of recent technologies like blockchain, available online research within this domain is notably scarce compared to other fields of study. To broaden the scope of the study, the search process commences by identifying related papers using Google Scholar and Litmaps. Furthermore, to enhance the depth and breadth of the study, a comprehensive multidisciplinary scientometrics database known as Scopus was utilized to export papers obtained using Litmaps and Google Scholar. These papers are then mapped using VosViewer, a bibliometric analysis tool, to establish correlations among co-occurring keywords within these documents yielding additional keywords to further search for articles online, enriching the breadth of literature considered in the study for a thorough examination and a more nuanced understanding of the research landscape in the context of military supply chain security and emerging technologies.
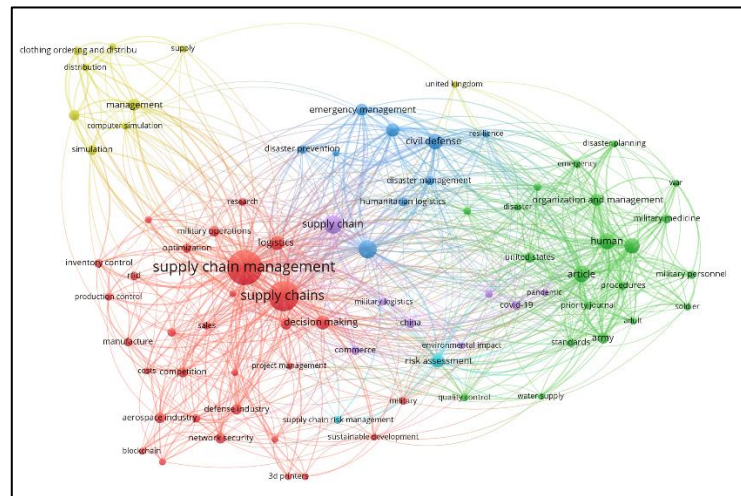

Fig. 8. Mapping of co-occuring keywords using VosViewer

Utilizing Boolean operators such as 'military OR army OR defence AND (supply AND chain) OR (supply AND chain AND management) OR transport OR mobility' in query strings helped

extract a substantial number of articles. To further refine the results, the scope is limited to Article Title, Abstract and Keywords. Thereafter, the articles are filtered based on several parameters to align the results with the objective and domain of the review. Limiting the results to only 'Articles' published in 'Journals' helped in refining the results to ensure high peer review and research quality for relevancy and accuracy. The resulting documents are further analysed bibliographically to identify the research gaps prevalent in the research field of military logistics.

TABLE III.   REVIEW FILTERING PARAMETERS

Filtering Parameters	Action	Results
String Query	Using Boolean operators and related keywords obtained by VosViewer Text Data Map	36,475
Scope	Searching within Article Title, Abstract and Keywords	959
Document Type	Filtering the review to only Articles	747
Source Type	Limiting source to only Journal	366
Keyword	Limiting the search to particular keywords that are relevant to the study	231

2. Bibliometric Analysis: The bibliometric analysis is a quantitative analysis used to measure the level of impact of the published documents and the find the correlation among these documents to identify patterns and reveal trends.   Initially, a citation analysis is performed using co-citation and bibliographic coupling. These graphical representations depict the backward and forward citation analysis and the authors that are frequently cited together. The most cited papers related to this domain turned out to 'Ensuring Supply Chain Resilience: Development of a Conceptual Framework'. The data obtained by the bibliometric analysis is further utilized in excel to obtain a volumetric analysis based on total citations and no. of publications.
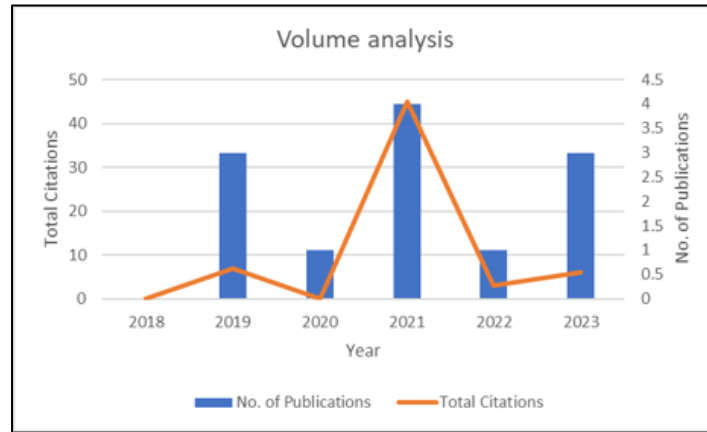
Fig. 9.   Volume analysis based on total citations and no. of publications

3. Comparative Analysis:

TABLE IV.   COMPARATIVE ANALYSIS

Parameters	Digital Twins	Blockchain	RFID	GIS
Working	Virtual replicas of physical assets or systems and dynamic digital representations used for analysis	Decentralized, distributed ledger technology for recording and validating transactions.	Wireless technology using electromagnetic fields for automatic identification and tracking of tags attached to objects.	Framework for collecting, storing, analysing, and managing geographical data, visualizing spatial information, and performing spatial analysis.
Technology	Simulation and modelling technology	Distributed ledger technology	Wireless technology for identification and tracking through tags.	Geospatial software and tools enabling data visualization and analysis based on geographic coordinates.

Functionality	Simulation, predictive analysis, monitoring, predictive maintenance	Secure, immutable record-keeping of transactions, transparent, and tamper-resistant.	Automatic identification, real-time tracking, and inventory management.	Spatial data analysis, visualization, mapping, and decision-making based on geographical data.
Data representation	Real-time representation of physical assets	Cryptographic hashing and linking of data blocks	Identification and transmission of data through tags	Visualization of spatial information, maps, and geographic features.
Scope of application	Predictive analysis, operational optimization, real-time monitoring, maintenance	Secure data sharing, traceability in supply chain, smart contracts execution.	Inventory management, asset tracking, authentication.	Military asset tracking, terrain analysis, situational awareness, route planning.
Security Features	Limited security features; focused on data access control and monitoring.	High security through cryptographic mechanisms, immutability, consensus mechanisms.	Limited security features, potential vulnerability to interception or cloning.	Provides data security through access control, encryption, and secure data storage.
Consensus Mechanism	Not applicable; reliant on data analysis and model simulation	Consensus protocols (e.g., Proof of Work, Proof of Stake) ensure agreement on transactions.	Not applicable; operates through read/write operations without a decentralized ledger.	Not directly related to consensus mechanisms but may integrate with distributed systems.
Scalability	Scalable for simulations and models	Scalability challenges with increased transaction volume	Scalability limitations in handling large-scale operations.	Scalable for managing large volumes of spatial data and conducting complex analyses.

Interoperability	Potential interoperability challenges with various systems and platforms	Potential interoperability issues between different blockchain networks or protocols.	Compatibility concerns between various RFID systems and frequency ranges.	Interoperability with various data formats, data sources, and software systems.
Vulnerabilities	Vulnerable to cyber threats due to reliance on digital infrastructure and data integrity	Susceptible to 51% attacks, private key compromises, and smart contract vulnerabilities.	Vulnerable to interception, data alteration, and unauthorized cloning.	Vulnerable to cyber threats, potential data breaches, and privacy concerns.

The above stated comparative analysis signifies:

1. **Diverse Capabilities:** Each technology offers distinct functionalities. Digital Twins excel in simulation and predictive analysis, Blockchain ensures secure and transparent transactions, RFID provides real-time tracking, and GIS facilitates spatial data analysis and visualization.

2. **Security Features and Vulnerabilities:** There's a spectrum of security features and vulnerabilities. Blockchain provides high security through cryptographic mechanisms but faces vulnerabilities like 51% attacks, while RFID has limited security features, making it susceptible to interception or cloning.

3. **Scalability Challenges:** Scalability limitations are evident across these technologies. Blockchain faces challenges with increased transaction volume, while RFID has limitations in handling large-scale operations.

4. **Interoperability and Integration:** Each technology poses interoperability challenges with different systems or protocols. However, they also exhibit potential for integration within existing infrastructures.

5. **Vulnerabilities and Cyber Threats:** There's an acknowledgment of vulnerabilities and susceptibility to cyber threats across these technologies, which emphasizes the importance of robust security measures in their deployment within military contexts.

RESULTS ANALYSIS AND VALIDATION

4.1. Solution Results

The comprehensive review and comparative analysis of various technologies, including Digital Twins, RFID, GIS, and Blockchain, within the realm of military supply chain security, emphasize the superiority of Blockchain technology due to its exceptional security attributes and multifaceted applicability.

While RFID excels in real-time tracking and GIS aids in spatial data analysis, Blockchain's versatility enables multifaceted applications within military supply chains. Its smart contract functionalities allow for automated and self-executing agreements, streamlining procurement processes, ensuring contractual compliance, and enabling secure and transparent communications between various stakeholders.

Furthermore, Blockchain's potential for secure data sharing, traceability, and inventory management transcends the conventional boundaries of supply chain logistics. It facilitates enhanced provenance tracking, real-time visibility into inventory movements, and optimization of logistics operations. Its decentralized architecture enables seamless collaboration among authorized participants while maintaining data privacy and confidentiality, a vital aspect in military operations where data security and secrecy are paramount.

Beyond logistics, Blockchain's integration potential in maintenance management, repair parts tracking, and secure communication channels within military operations signifies its adaptability across multiple domains. Its decentralized nature allows for increased data exchange, facilitating efficient decision-making processes and ensuring the authenticity and reliability of information shared across diverse military units.

CONCLUSION AND FUTURE WORK

5.1. Conclusion

In conclusion, this review identified critical gaps and practical observations within the realm of blockchain application in military supply chain management (SCM). Firstly, a prominent gap exists due to the scarcity of empirical studies specifically focusing on blockchain-based SCM models for logistics. This scarcity contrasts with the presence of some empirical analyses focusing on surveillance technologies in similar contexts, indicating a discrepancy in the depth of research within these related fields.

Secondly, an evident disparity emerges regarding the integration of RFID (Radio Frequency Identification) technology within blockchain-enabled military supply chain models. Disagreements and varying viewpoints among experts regarding the seamless integration and utilization of RFID within the blockchain framework pose a noteworthy gap, signifying a lack of consensus or standardized approach in this aspect.

Moreover, a practical gap is discernible between the extensive academic study and the actual implementation of blockchain technology in defence logistics. Despite substantial scholarly attention and research dedicated to exploring blockchain's potential in military supply chains, the real-world implementation remains limited. Notably, while studies and discussions around blockchain's application are prolific in academic and research circles, its adoption and utilization in defence logistics lag behind. An additional observation highlights that while there's minimal implementation in defence logistics, Chinese commercial logistics have already begun incorporating blockchain technology, marking a practical gap between different sectors' adoption rates.

These identified gaps – the dearth of empirical studies, discrepancies regarding RFID integration, and the disparity between academic exploration and practical implementation – underscore critical areas that warrant further attention, collaboration, and focused initiatives. Addressing these gaps may involve fostering more empirical research, fostering consensus among stakeholders, and promoting greater practical deployment of blockchain technology within defence logistics, aligning academic exploration with real-world adoption to bridge these gaps effectively.

5.2. Future Work

In the realm of military supply chain security, the future horizon holds promising avenues for blockchain technology's application, coupled with a need for further empirical studies and strategic advancements. Primarily, there's a critical call for more empirical research centered explicitly on blockchain's implementation within military supply chains. These studies would offer invaluable insights into the practical implications, challenges, and advantages of integrating blockchain technology in real-world defence logistics scenarios. Simultaneously, there emerges a prospect of merging digital twin technology or other simulation techniques with blockchain systems. This integration promises a transformative impact, streamlining tracking processes and enhancing operational efficiency. However, this prospective advancement might also witness a re-evaluation of RFID (Radio Frequency Identification) use within military operations due to lingering security concerns. While RFID allows real-time tracking capabilities, its susceptibility to security breaches may prompt a shift towards alternative, more secure tracking technologies. Looking forward, the future scope also revolves around fortifying security and privacy measures within blockchain-based military supply chains. Intensified efforts in cryptography, permissioned access controls, and privacy-preserving techniques aim to solidify data integrity and confidentiality. Moreover, the roadmap ahead involves establishing standardized protocols tailor-made for blockchain's deployment in defense logistics, ensuring interoperability and seamless integration across military infrastructures. Overall, the future direction entails a blend of empirical studies, innovative integrations, security enhancements, and standardized frameworks to augment the resilience and efficiency of military supply chains leveraging blockchain technology.

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