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Blockchain Technology to Improve Aerospace Supply Chains

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Abstract:
Purpose: Traceability in aerospace industries starts from procuring raw materials until the final assembly part of the aircraft. These processes involve different parts of the supply chain network, including raw material suppliers, manufacturers, and original equipment manufacturers. Due to the complexity of the supply chain process in aerospace industries, robust technologies such as blockchain technology are required to assist the supply chain process, which can lead to a company's operational excellence. The purpose of this research is to look at the existing practice of aerospace supply chain management and to identify the concerns and challenges that impede the use of blockchain technology in the management of aerospace supply chains.
Design/methodology/approach: The qualitative research method was chosen, and an online interview was conducted to collect the information from informants.
Findings: The findings reveal that the main challenges to blockchain adoption in the aerospace supply chain are cost and lack of knowledge. The outcome of this study presents significant theoretical and managerial implications and a deep understanding for practitioners who plan to develop blockchain technology in the aerospace supply chain.
Research limitations/implications: The scope of this research is limited to the usage of blockchain in the aerospace industry's supply chain. It would be beneficial to broaden the scope of this research to include a comparison of the applications of blockchain technology in different industries.
Practical implications: The successful implementation of blockchain technology in managing the aerospace supply chain can strengthen the manufacturing sector. It helps achieve sustainability by bringing transparency to the system and enhancing the market position. The emphasis on blockchain technology also helps take organizational practices toward achieving a competitive advantage by generating new operational excellence in the current complexity of the supply chain landscape.
Originality/value: The results can be used as the framework to foresee the successful implementation of blockchain technology in managing an aerospace supply chain.

Keywords: Blockchain Technology, Qualitative Research, Aerospace Supply Chain, Supply Chain Management, Operational Excellence

Introduction

Supply chain management (SCM) practitioners are being compelled to create distinctive business strategies that include the nascent industry 4.0 technology. Blockchain technology (BCT) is one of the most promising technologies in managing supply chains (SC) because its warrants efficiency, accuracy, and quicker information sharing (Ahmad et al., 2021; Kumar et al., 2022). Further, there is a rapid acceptance of BCT in various industries. It will help the company manage a huge number of assets and distributed processes (Dutta et al., 2020) and convert the current business process to be more efficient, transparent, and ethical. The BTC adoption has occurred due to recent advancements in digital technologies (Javaid et al., 2021). Several industries benefited from blockchain-based solutions, including shipping, manufacturing, automotive, aviation, finance, technology, energy, healthcare, agriculture, food, logistics and transportation, and education (Jadhav & Deshmukh, 2022). A distinct SC system or network exists for each of these sectors. The SC is plagued by several issues, including the bullwhip effect (Zhu et al., 2022), information asymmetry, and the difficulty of satisfying customer demand (Li et al., 2022).

Traditional SCM procedures rely heavily on a centralized entity or third parties, such as banks, to validate or store all the transactions that occur. However, this situation is facing a high risk in terms of information leaking, cyber security issues, and other attacks that may lead to confidentiality, traceability, and integrity issues among the parties involved. The use of BCT eliminates the need to rely on third parties by providing decentralized processes. This opens the door for peer-to-peer (P2P) transactions and exchanges, which don't need the involvement of any centralized authority. In addition, this decentralized system offers the possibility of a trustworthy working environment.

Regulated industries, such as aerospace manufacturing, need to adhere to government laws, rules, policies, and governance. Further, the business is fully government-controlled and aerospace manufacturing companies need to comply with good manufacturing practices and certain quality requirements (Liangrokapart & Sittiwatethanasiri, 2022; Stosic et al., 2022). This tight control aims to safeguard the well-being and safety of those who use the services. In the aerospace industry, parts and products are traceable from procurement until the end of aircraft life. Traceability is of major importance to ensure important product characteristics, such as safety issues, reliability, and efficiency. Aerospace manufacturing is considered a highly regulated industry because any failure that occurs may lead to irreversible harm such as death.

Furthermore, aerospace industries can be categorized into several, and they involve different supply chain tiers, starting from designing the aircraft, procurement activities, production process of aircraft parts, final assembly and maintenance, and repair and overhaul (MRO). These processes are supported by logistics activities such as warehousing, shipping, inventory management, customer services, and many more. To ensure the process goes smoothly, all these activities require information to be transferred in a timely manner and in very high transparency. In addition, aircraft panels are manufactured in many countries worldwide and sent to one country for the final assembly of aircraft. These SC networks are complex and involve different parties in different geographical areas. Further, the aircraft's lifetime can last several decades (Dolganova et al., 2022), making traceability issues very important and leading to worsening scenarios if they cannot be controlled properly.

Traceability in the SC aerospace industry is strictly enforced, in contrast to the food industry and other SC. In the first place, the SC of the aerospace industry necessitates the purchase, production, trade, installation, and maintenance of tens of thousands to hundreds of thousands of unique raw materials and components. The history of each component's origin should be kept, especially in aerospace-related fields. It needs to be in a complete trace. Thirdly, the market structure is distinct because participants in regulated sectors are frequently certified, audited, and constrained by exclusive contractual agreements. Fourth, while the product is susceptible to spoiling as a result of outside influences, the regulated components are frequently less impacted, giving the traceability information long-lasting validity and value. To retain and maintain records in accordance with compliance regulations, the aerospace industry heavily relies on manual procedures and paper-based documentation. But it's hard to keep track of and accurate when paperwork is done manually. Data duplication is another major concern with this kind of storage since it requires several parties to process and update the data entries simultaneously. As a decentralized ledger system, BCT's advantages lie in the reliability, transparency, and permanence of the data it stores (Ahmad et al., 2021). Because there is no longer any need for third parties to delegate the power to carry out the transactions, it is also a cost-effective choice.

Inspired by the fact that BCT is a possible prospect and becomes an increasingly significant contributor to managing the SC aerospace industry in more depth, the followings are the research questions to be investigated:

• How does the blockchain technology support supply chain process in producing aircraft panels?

• What issues and challenges impede the adoption of BCT in managing aerospace SC?

The rest of the paper is organized as follows: Section two presents the background on BCT. Section three elaborates on various applications of BCT and supporting features including smart contracts and radio frequency identification (RFID) in managing SC. Section four presents a result and case study of various BCT platforms or usage for SC aerospace, and in section five, we provide some closing observations as well as some ideas for future research.

Literature Review

Features of Supply Chain in the Aerospace Industry

Passenger air traffic and associated aerospace demand are predicted to increase dramatically by 2037 (Hu et al., 2022), leading to a corresponding increase in aircraft manufacturing by an average of 4.7% yearly (Dolganova et al., 2022). Further, due to the rise in e-commerce nd globalization, cargo aircraft have a significant increase in demand by airlines. As a result of this increase, there will be an enormous demand for additional flight carriers; consequently, the SC needs to run in the correct sequence without any mistakes. To accommodate the demand increase in passenger and cargo aircraft, the leading aircraft producer must ensure aircraft orders and deliveries are achieved with a minimal backlog if any. Increased demand has put stress on the SC, which in turn causes bottlenecks and breakdowns. For example, this unavoidable circumstance may arise at any stage of the SC when a supplier cannot meet customer demand because of stockouts at a different tier. Behind every final product is a long chain of assembly, which is primarily divided into multiple levels, which produce for OEMs, and three key tiers of the supply (Supply Chain Features of the Aerospace Industry Particular Case Airbus and Boeing):

Tier 1: This level directly works for Boeing and Airbus, creating aircraft wings, fan cowls, and other components; they are the initial suppliers to the assemblers.

Tier 2: They are the suppliers for tier 1, providing manufactured items using their own productions. For example, different components of an aircraft wing.

Tier 3: These vendors provide raw materials such as carbon fiber, honeycomb core, chemicals, metallic, plastics, and so on.

Aircraft Composites Company is shown as an example in Figure 1 below; nevertheless, this firm would serve at some tier for other "Originating Buyers," illustrating that any component of any SC, at any tier, would have its tier of suppliers.

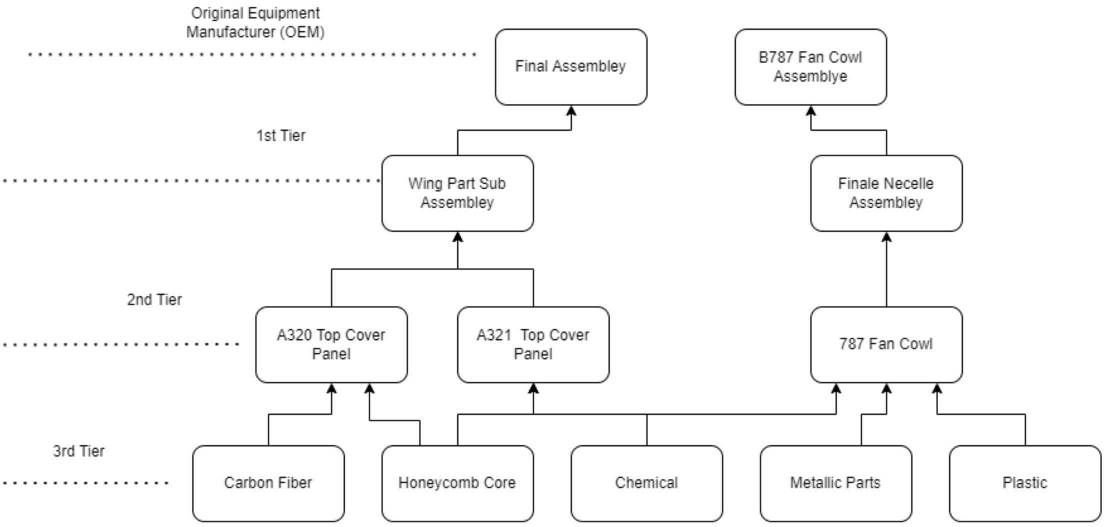

Figure 1: The aircraft's wing and nacelle Supply Chain Management

Source: Adapted from Ahmad et al., (2021)

While Figure 2 shows the data on orders and deliveries from one of the leading world aircraft producers, Boeing. Models of aircraft that will be produced represent a different supply chain process and uniqueness of SC network.

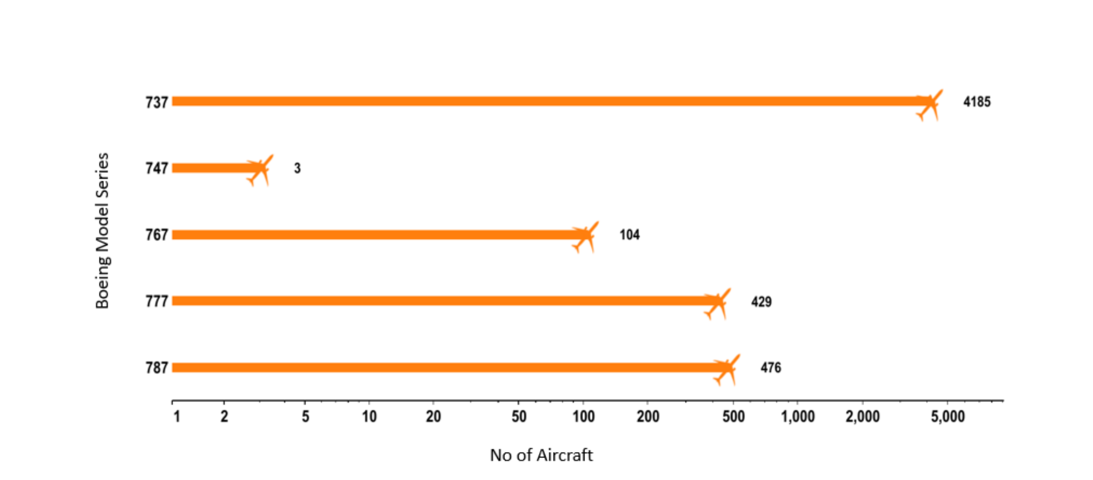

Figure 2: Boeing Airplane Orders and Deliveries (Boeing Commercial Aviation, 2022)

A general view of aerospace SCM is illustrated in figure 3. The method of creating an aircraft panel is shown in the diagram. It began with obtaining a supply of raw materials. The supplier then sent the ordered supplies to the manufacturer in accordance with the order's specifications. The company began production as soon as they received the orders and sent them to the ultimate buyer. Reverse logistics are also a part of the process and become very important when handling an aerospace SC where return or defective panels or raw materials from the customer to the manufacturer or from the manufacturer to the supplier need to be handled quickly as it incurs a cost (Liangrokapart & Sittiwatethanasiri, 2022). All the processes involved, from the raw material supplier to the end customer, require each party to follow certain requirements including traceability, compliance, flexibility, and stakeholder management.

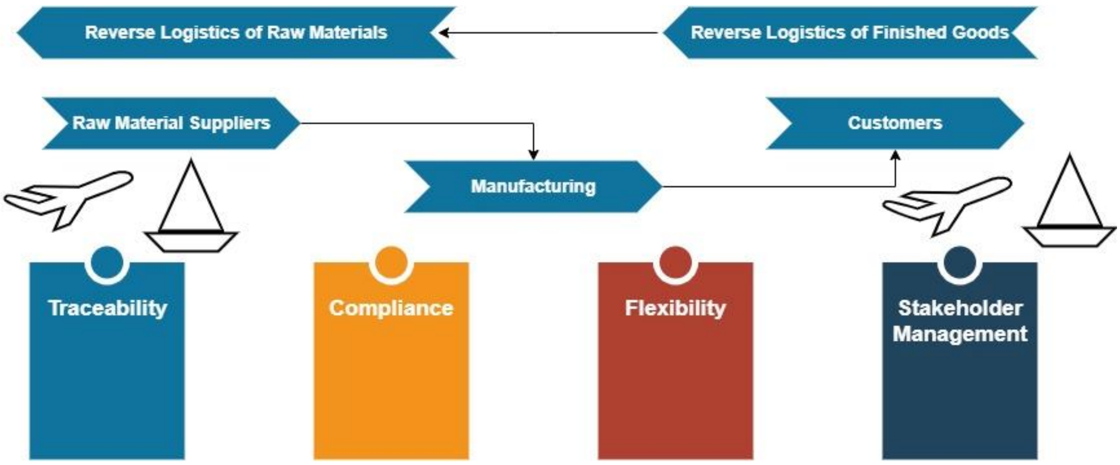

Figure 3: Overview of aerospace SCM

Source: Adapted from Yang et al. (2019)

Blockchain Technology

To resolve disputes amongst stakeholders, a typical business model heavily relies on a centrally contracted third-party service. However, a third party-focused reconciliation is significantly slower and more expensive. As an alternative, BCT does away with the need for reconciliation services provided by third parties. It allows trustless entities to transact with each other in a much faster and more economical way. The smart contract is a self-executing code that executes when pre-defined conditions are met. As a result, in BCT, no one is entitled to control the data. All the data are visible to everyone who is involved in the transactions. Furthermore, BCT does not allow unauthorized access or manipulation against the blockchain ledger; therefore, data involved in such transactions can be secured effectively (Wang et al., 2019). Technically, the BCT is referring to a data infrastructure that allows either for the distribution of data or methods of data recording through a crypto-analytic hash function. BCT is made up of nodes spread out throughout a communication network and has a standard protocol for exchanging information. BCT is a digital ledger that can be kept on multiple computer devices in public and private networks.

Based on the decentralization principle, in which intermediaries can be eliminated, the smart contract is an essential blockchain application that works automated to transfer assets when a determined condition is satisfied. Thus, smart contracts are reconfiguring several business models, in which producers and consumers can trade without an intermediary. Consequently, blockchain decentralization and disintermediation features can lead to disruption and support SCM innovation and reconfiguration in the digital age. The automation process significantly boosts the performance of a business. Moreover, the immutable transaction records can be used to resolve potential conflicts (if any) among business parties in a much faster way.

Opportunities of Blockchain in the Supply Chain of Aerospace Industries

Although (Zhu et al., (2022) recognized that the bulk of present BC applications are in the financial sector, they added that more uses were starting to emerge in the process. The authors proceeded by suggesting that established sectors may be able to benefit from BCT by integrating BCT into their existing infrastructure. BCT can transform the aerospace SC, including procurement, inventory management, and warehousing to digital transactions. A distributed ledger that stores immutable digital transaction information and related applications may lead to a new age of productivity in the aerospace SC and purchase phase. BCT in the aerospace SC could deliver a new level of trust and transparency, from payments and audits to inventory and asset tracking, while enabling the purchasing process to achieve enormous productivity gains (Wang et al., 2019). BCT can be implemented to control the finished parts of an aircraft panel and assist in managing a SC of raw materials to make an aircraft panel. Through BCT there is no intermediaries resulting from smart-contract adoption thus contributing to numerous improvements such as increased responsiveness, reduction in lead time, transaction cost, improved companies' flexibility and agility, and more trust, security and transparency in the network (Eryilmaz et al., 2020). For instance, BCT enables improved traceability by tracing and monitoring the items in real-time from their places of origin to their points of consumption. Due to the importance of traceability issues in the aerospace industry, BCT makes it possible for all parties involved in a transaction to understand who is doing what and when by providing all the relevant information. In addition, the use of BCT can support the prevention of process in unauthentic and legitimacy raw material fakes across the aerospace SCM.

Integrated with other technologies, such as Internet-of-Things (IoT), for instance, these BCT can enhance their applications for other SC networks in aerospace industries. For example, in the procurement or purchasing of raw materials to produce aircraft parts, transparency in product certification is crucial followed by production planning, where all related matters concerning production planning need to be authentic to avoid a major disruption on both sides either the manufacturing or supplier side (Dutta et al., 2020). In addition, using RFID helps in inventory management, warehouse management (Kumar et al., 2022), logistics and shipping activities (Chen et al., 2022; Yang et al., 2019).

Issues and Challenges of Blockchain Adoption in the Supply Chain of Aerospace Industries

Application Barriers

A lack of representative projects since BCT is still in its early stages, implying that additional research and development are required, particularly in aerospace SCM. Other fields like the services and banking industry are similarly at a pre-mature stage of BCT development (Saberi et al., 2019), making it difficult to find persuasive examples and practices for regulated companies to apply the BCT in controlling SC (Vaghani et al., 2022). In addition, there is a lack of clarity on the benefits. Because there are not a lot of firms that employ BCT in the integration of aerospace SCM, applications that make use of BCT are not being prioritized. As a result, it was difficult to assess such initiatives comprehensively, particularly in terms of their economic and social advantages.

Technical Barriers

It is argued that technical barrier has high requirements for computing performance and hardware. To facilitate data transmission and verification between many nodes, strong processing performance and operational efficiency are required. This procedures frequent data transfer and verification across many nodes, with exceptionally large calculations and frequent transactions that may impact the BCT application if a system transaction were to be delayed (Zhou et al., 2021).

Regarding threat to the confidentiality of data, the technical barriers have several points need to be considered. Due to advancements in areas such as mathematics, cryptography, and computer technology, the BCT technique has grown more vulnerable. This situation leads to the risk of being maliciously controlled by hackers. It is difficult to determine the legitimacy and purpose of the instruction task. Additionally, one of the high-risk categories that attackers may use to launch a similar assault is human incompetence (Guo & Yu, 2022).

Policy and Legal Barriers

Because there is currently a lack of clarity in governmental legislation and regulations regulating the application of BCT, the industry has not been able to fully implement BCT (Kouhizadeh et al., 2021). The adoption of BCT is hampered by several legislative and legal impediments, including a lack of legal security, corporate governance, and law regarding the BCT applications.

Methods

Research Design

The purpose of this study was to investigate the actual SC process in aerospace industries and the challenges of BCT in enhancing the SC of the aerospace sector. Because BCT topics are still relatively new in Malaysia's aerospace industry, they demand an in-depth investigation. As a result, a qualitative research method was chosen for this study for the following reasons. First, BCT adoption is still in its infancy for the Malaysian aerospace sector in managing the

SC, necessitating a thorough assessment. A qualitative research method can provide a deeper insight, resulting in greater external dependability and validity.

Sampling Design

The purposive sampling technique was used in the data collection to gain greater insights on the phenomenon. Purposive or judgemental sampling technique was selected with some justification. Firstly, because BCT topics are early stage in managing aerospace industry SC especially in Malaysian context, and secondly this sampling technique is often used when working with very small samples such as in case study research (Saunders et al., 2009; Yin, 2018). The informant was from middle and top management positions in SC department including, warehouse manager, supply chain manager, project manager, and senior executive. Although the reason for interviewing staff at managerial levels was to ensure that the informants had pertinent and salient information and knowledge regarding BCT and supply chain, before the interview session, the nominated respondents were queried to confirm their availability and willingness to participate in the interview. As a result, five key informants are willing to participate in the interview.

Data collection

This qualitative research focused on enhancing the SC capabilities of the aerospace sector by utilising BCT. The respondents to this interview came from managerial levels inside the organisation they represented to answer the survey questions. The selection of managerial levels was done with the intention of ensuring that the informants have relevant and important information and knowledge regarding BCT. In addition, the informants selected were staff members who were actively involved in the company's strategies and who had previous experienced with the SC process. The meeting lasted an average of 15 to 35 minutes and was held via online interview. Each interview was digitally recorded and transcribed for coding and analysis purposes.

Procedure

Before conducting the interview, the informants were contacted by human resources for approval. Invitation letters explained the relevance of the informant's participation in this study and that it was for academic research purposes only. The data collecting guide and interview information were emailed to the informants before the interview to ensure they were prepared. The interviews were performed during working days through phone and online meeting. The researcher told the interviewee that the HR manager approved the interview. The researcher explained the study's aim. The names of the informants were kept confidential to improve the chance of information during the interview. In addition, a sequence of questions was altered, or probing questions were asked. Before the interview, each company's website, portal, and magazines were thoroughly scrutinised to gather information or activities related to BCT or digital innovation.

Data Analysis

The acquired data were thoroughly evaluated to uncover common patterns, which were then summarised to address the research objectives. The analysis procedure begins with a transcribing process, which is then followed by a coding process. Line-by-line, the transcribed document was read and coded. This was while comprehending the transcript's meaning and recognising its essential difficulties. The codes are primarily derived from transcript data.

Findings

Table 1: Sample 1

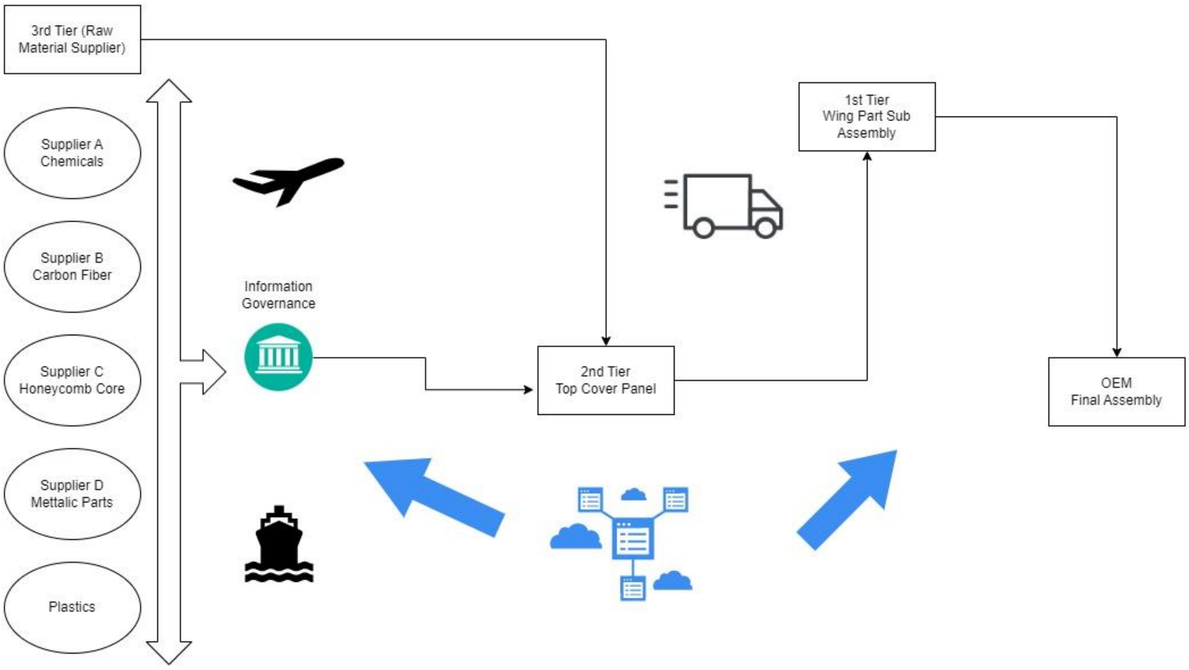

Figure 4: Overview of current practices in purchasing raw materials

Let us begin at 2nd tier as a manufacturer of the top cover panel for the A320 Aircraft part. The reasons why the 2nd tier was chosen are due to the crucial situation for the company in controlling and planning their raw material suppliers, customers, and OEM. In addition, the raw materials that are purchased are numerous and varied, and suppliers are overseas based. The features of raw materials and aerospace industries itself have caused the 2nd tier to be very important compared to other tiers, specifically in the aerospace industries. This is because failure from the 2nd tier in the delivery of the aircraft parts will jeopardize the final assembly of one aircraft. Another reason why the 2nd tier is chosen is to minimize the bullwhip effect. To mitigate the bullwhip effect is thru better supply chain management by using a visibility tools and technology (Sarfaraz et al., 2022).

Procurement/Purchasing Activities - An overview of current practices in purchasing of raw material to produce an aircraft part is shown in figure 4. In this hub, the companies buy diverse raw materials from different suppliers from overseas. This 2nd tier hub is one of the individual companies who has been granted to produce different parts of aircraft from the different customers such as Sprit Aero Systems and Airbus, respectively. When purchasing activity starts, the purchaser sends the information regarding order details through a purchase order (PO) to the supplier and updates the logistics service provider for the shipping arrangement. These events involved two distinct forms of information exchange, which necessitated the maintenance of two sets of transaction records, which is a tedious, inconvenient, and error-prone process. However, this hassle can improve by using BC smart contract in procurement activities, resulting in enormous productivity gains in procurement processes such as improving the flow of information between SC networks and aiding access to financing (Raj et al., 2022).

Inbound Logistics Activities - When the supplier receives the PO, all necessary arrangements must be made since some of the materials are controlled temperature products. The shipping activities need to be supported with a special requirement such as refrigerated container if using sea freight. While if the arrangement using an airfreight the consignment need to be added with temperature recorder and dry ice to ensure the temperature are within the specification. Once material is picked up from the supplier facility, the appointed forwarder is responsible for providing the shipment details to the consignee once the booking is secured. Important information including estimated time departure, estimated time of arrival, and other important documentation are sent through email. Forwarders need to update the shipment throughout the journey in a timely manner, especially if shipment delays happen. To prevent production from being jeopardized, delivery information from the forwarder to the consignee must be sent promptly. All the delay information gathered from the forwarder needs to be shared with their customer either 1st tier or with the original equipment manufacturer (OEM) in this case Spirit and Airbus respectively. This is because the assembly of airplanes is like a chain that involves different manufacturers worldwide. Visibility in inbound logistics is challenging especially involving various activities starting from point of origin to point of consumption. This complex transaction requires fasters delivery of products and information, coordination, and integration among SC networks. Utilizing RFID and integration with BC technology helps sync all the information regarding orders, shipments as well as payment, hence enables companies' improving operational excellence such as reducing operational cost, energy efficiency, flexibility, and agility in responds to the current business scenario. By combining IoT and BCT help in providing an intelligent transportation logistics by allowing parties to verify the history of locations, temperature data that collected and stored in BC which can help to improve companies overall operational excellence (Chen et al., 2022).Warehouse Activities - Once raw materials are received in the consignee facility, warehouse personnel will receive the shipment and check the physical versus the document. When all the requirements are met then these goods will be sent to supplier quality assurance personnel for quality-checking purposes. After quality checking, this material will be transferred to the warehouse for storage purposes. Different materials have different locations inside the warehouse. Once everything meets the material specification, such as material shelf life, all the information will be transferred into the system. This has been done manually by data entry. In the system, information like quantity available, shelf life, and expiry date is very important for the planner before they start production. This information needs to be updated from time to time and authenticity and transparency are very important. In the aerospace industry, traceability and process legitimacy are very important to avoid unnecessary things happening, especially during production and customer audits. As mentioned by informants, capturing real-time information accurately and securely is crucial to avoid any circumstances unwanted event happening, especially during material receipts, storage, and picking activities in the warehouse. The integration of BCT together with IoT and RFID helps to improve SC transparency. Utilising BCT together with other emerging technologies such as IoT and RFID as a viable solution for enhancing product traceability, transparency, visibility and auditability (Ahmad et al., 2021).

Production Activities - Once production planning is in place; the material planner starts the issuance of raw materials. Issuance of material from warehouse to the production line will take place one day ahead from production layup to start. Advance issuances are needed especially for freezer material because they need a special process known as the thawing before being sent to production line for layup. Information regarding thawing time and person handling this process must be recorded to ensure the material still has a shelf life during a layup process. Other materials sometimes are issued from the warehouse to production simultaneously and some of them need to follow a sequence according to which and when the process will occur. For example, chemical products are issued when the panel is ready for the last process, which is the painting process. According to the informant, the transfer of ownership of materials begins when they are issued from the warehouse to the production area. These processes sometimes may not sync up neatly because of incomplete work order issues, which are prone to miscellaneous problems later. Therefore, the execution of BCT allows internal SC tiers to be linked and the records are changeless in the chain. These unique features are fit for managing aerospace SC. Visibility, traceability, and authenticity elements, either products or information are very paramount to aerospace SC. Execution of BCT allows internal SC tiers to be linked and the records are changeless in the chain. These unique features are fit in managing aerospace SC. Combining RFID for data capture and making use of BCT for the authentication and dissemination of these data throughout internal SC tiers. Based on this connection, BCT permits the swift information spreading of RFID facts and figures simultaneously in SC tiers (Zelbst et al., 2020). Outbound Logistics Activities - The last process is shipping activities. Once the panel is ready to be shipped either to 1st tier or OEM, the project leader needs to send all the shipment details to the logistics department. Export logistics personnel will start communicating with appointed forwarders for booking and shipping arrangement purposes. Information such as pick-up time, box dimensions or any special equipment needed during the journey needs to be informed to the forwarder. Once everything is ready, the customer's notification on the shipment needs to be sent immediately through email. Referring to the informant, cross-border management is among the most complicated processes to manage because it involves various transactions and data exchanges and compliance with international transportation standards. They are using BCT in logistics activities assists in fabricating intelligent transportation logistics, especially when multiple transport modes, logistics services, and companies are involved. BCT magnifies customers' confidence and trust because this emerging technology enables customers to inspect the whole journey of goods in all SC tiers.

Table 1: The summary output issues and challenges in implementing blockchain technology in aerospace supply chain.

Informant	Position	Remarks
Informant A	Supply Chain Manager	There are several primary challenges in implementing BCT in improving the SC of aerospace. Lack of knowledge and awareness, high cost and data privacy
Informant B	Project Leader (A320 Top Cover)	Cost, complexity in global collaboration, top management support, knowledge of BCT
Informant C	Logistics Assistant Manager	Knowledge and awareness towards BCT in logistics management, lack of technological equipment, cost
Informant D	ICT Manager	High-cost BCT involved technological equipment, process, and infrastructure. Legal issues related to the BCT application
Informant E	Supplier Quality Engineer	Data security issues, lack of knowledge of the BCT application in aerospace SC, lack of expertise

The main challenges that impede the adoption of BCT in managing aerospace SC is cost, lack of knowledge and awareness, data privacy and security. All the informant is frequently highlighting cost. That’s the reason that hampers the adoption of BCT in their SC process. According to informant A, adopting BCT in SC process requires a high cost of investment because BCT comprises of technological equipment, process, and infrastructure. Similarly, according to Project Leader (A320 Top Cover), to informant B, the company's main challenges is a high-cost involvement. From the perspective of the project leader, high-cost involvement is due to the purchasing of new software and hardware needed. According to both informant’s costs incurred can be categorised as internal barriers where substantial amount of money is needed to implement BCT in SC process. This finding is like the study done by (Govindan, 2022; Kumar et al., 2022) where high technology costs are involved when implementing digitalise technologies such as BCT and IoT. Different from the assistant logistics manager, where the mentioned cost is related to the other parties. Since BCT involves a collaboration between several parties, some small-scale companies like a logistics service providers are reluctant to invest a huge amount of money towards BCT due to financial constraint. The all informants emphasise the perceived knowledge of the deployment of BCT in managing aerospace SC. Since BCT technology is still in the infant stage, the lack of human resources that are expert in this BCT are limited. This finding is corroborated by (Saberi et al., 2019; Upadhyay et al., 2021) who point out that limited technical know-how and understanding of using BCT in managing SC turn a hurdle to adopting this new advanced technology and become a challenges to them.

Discussion and Conclusion

Traceability is crucial in managing aerospace SC. All nodes in aerospace SC need to be informed with the right and timely information throughout the SC process. Furthermore, the authenticity of the information as well as the raw materials purchased became a priority in the SC members, which makes BCT play a vital role in improving visibility in aerospace SC. The use of BCT in aerospace SC management has the potential to optimize the overall operational excellence situations in the aerospace supply chain. This applies not only to aircraft manufacturers but also to the supporting units of the industry, such as logistics and suppliers. This will be the most effective and open manner of doing business, which will ultimately improve both the result and performance. Accessing all the relevant information in a real-time lead to planning ahead to curb the effect of a bullwhip in aerospace SC whereby an increase in demand will not have a huge impact on other SC networks. On the other hand, implementing a smart contract can reduce unethical practices such as corrupt practices because it would do away with the need for a third party, ensuring the authenticity of the data being shared among SC networks.

Further on this, the data information is dispersed widely and in real-time lead to the overall company operational excellence. The aerospace industry's main challenges are high cost and lack of knowledge on BCT in managing their SC process. These challenges can be overcome by the government sector which can provide an incentive for companies who are interested in transforming their current conventional SC to digitalization including BCT. In addition, the lack of human resources such as a lack of technical expertise in using BCT in SC can be resolved by having a program technology know-how transfer with the industries that are leading in utilizing the BCT or with other developed countries that have succeeded in BCT applications. Overall, it can be concluded that the implementation of BC helps achieve sustainability by bringing transparency to the system and enhancing the market position. The emphasis on BCT also helps take organizational practices toward achieving a competitive advantage by generating new operational excellence in the current complexity of the supply chain landscape.

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