THE JBBA

PEER-REVIEWED RESEARCH

OPEN ACCESS
ISSN Online: 2516-3957
ISSN Print: 2516-3949
https://doi.org/10.31585//jbba-8-1-(1)2025

Blockchain-as-a-Service (BaaS) Empowered Vendor-Managed Inventory (VMI): A Paradigm Shift in Supply Chain Efficiency

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Received: 22 February 2024 **Accepted**: 29 April 2024 **Published**: 11 November 2024

Abstract
This article explores how Blockchain-as-a-Service (BaaS) can revolutionise Vendor-Managed Inventory (VMI) models. VMI is a supply chain approach where vendors manage customer inventory levels. However, traditional VMI models face challenges in data sharing, integration, real-time access, security, and enforcing service agreements. To overcome these limitations, this paper suggests using BaaS to implement VMI with blockchain technology.

The utilisation of BaaS in VMI processes allows organisations to utilise blockchain's attributes, including trust-less collaboration, real-time data access, heightened security, data integrity, immutability, and automation through smart contracts. The article explains how BaaS platforms offer streamlined provisioning, easy configuration, rapid member onboarding, and seamless integration with existing systems. Furthermore, it highlights the benefits of using BaaS to enhance supply chain efficiency by facilitating smooth collaboration among VMI stakeholders.

In addition to these benefits, the proposed solution emphasises the use of built-in functions within each partner's ERP/supply chain/enterprise applications, combined with blockchain integration capability, to establish a comprehensive end-to-end VMI solution. Moreover, the article provides a conceptual model of the solution that covers an end-to-end VMI process. It also provides guidelines for selecting a suitable BaaS provider tailored to VMI implementation.

Through these contributions, the article proposes an innovative VMI model built upon BaaS foundations, effectively addressing the inefficiencies of traditional VMI, and ushering in a new era of optimised supply chain performance.

Keywords: *API, Blockchain, Supply Chain, dApps, Vendor-Managed Inventory, Smart Contracts, Channels, Bullwhip Effect, BaaS*
JEL Classifications: *O33,O32,M15,L86,K20,L21,D24*

1. Introduction

Importance of Collaboration in Supply Chain Management

Efficient supply chain management hinges on the foundation of effective collaboration among its various stakeholders. Organisations increasingly recognise the indispensability of collaborative approaches in an era marked by volatile demand patterns, stringent timelines, cost-saving imperatives, and the pursuit of streamlined supply chain efficiencies. One such paradigm that embodies the spirit of collaboration is Vendor-Managed Inventory (VMI) [1].

Background of VMI

In supply chain management, balancing inventory carrying costs and achieving desired customer service levels are crucial for the success of efficient operations. VMI is a collaborative model where the vendor manages the customer's inventory and performs replenishments [1]. It has gained popularity due to benefits such as reduced stock-outs, increased inventory turnover, reduced bullwhip effect, and improved customer satisfaction. However, traditional VMI models face challenges that can be addressed through technological advancements.

Motivation for Using Blockchain in VMI

As VMI strategies continue to evolve, the demand for advanced technological solutions to enhance collaboration, streamline data sharing, and automate processes becomes increasingly pronounced. Amid this backdrop, blockchain, a distributed ledger technology, emerges as a transformative enabler for implementing VMI strategies. Its inherent attributes of secure and transparent transaction recording eliminate the necessity for intermediaries, thereby safeguarding data integrity while facilitating real-time data accessibility [2].

The integration of smart contracts further enhances the efficiency of VMI activities, effectively automating processes

within the supply chain. While emphasising the revolutionary impact of blockchain in VMI, it is important to stress the significance of middleware technology, APIs (Application Programming Interfaces), and services development, along with the seamless integration capabilities with enterprise applications such as ERP [3].

Being fundamentally collaborative, VMI aligns naturally with blockchain's potential to facilitate processes among external trading partners. This implies that the realm of inter-organisational communication and collaboration stands as a crucial focal point, deserving prominent emphasis. By amalgamating blockchain technology within the VMI landscape, supply chain processes stand to be revolutionised, cultivating efficiency, trust, and transparency across all facets of collaboration and trade.

2. Literature Review

Several research studies have investigated the potential of incorporating blockchain technology in supply chain management, specifically in the context of VMI. For example, a proposal put forth [4] suggests a VMI model that utilises smart contracts to automate the inventory replenishment process. The findings of the study demonstrate that this model effectively minimises the bullwhip effect and enhances overall supply chain performance and effectiveness.

Another study conducted [5] put forward a blockchain-based VMI model as a solution to the limitations of traditional VMI methods. The model utilises blockchain technology to improve VMI systems through decentralised data exchange, increased transparency and trust, automated processes with smart contracts, and integration with existing ERP systems [6]. This eliminates the need for significant initial investments, addresses issues with data silos, and replaces trust with unalterable and verifiable data records. Additionally, it enables direct and automatic payments, reduces transaction costs, and streamlines the inventory management process.

Furthermore, a study [7] proposes the challenges of scalability and privacy of blockchain networks through the concept of off-chaining. Off-chaining involves moving computations and data off the blockchain while maintaining its key properties, such as immutability and decentralisation. This technique reduces the workload on the blockchain, which improves scalability and enhances transaction throughput by reducing redundancy. It also ensures privacy by avoiding the disclosure of sensitive data on the blockchain. VMI models utilising blockchain technology have a great capacity for incorporating these methods.

Overall, these studies demonstrate the potential of blockchain technology in enhancing the efficiency and transparency of VMI processes. The proposed blockchain-based VMI models offer several advantages such as automation, real-time data access, heightened security, and increased collaboration among supply chain stakeholders.

3. Statement of Problem

Challenges in Traditional VMI Models

The conventional VMI models grapple with a multitude of challenges that hinder their efficiency and effectiveness. These challenges encompass various aspects of the VMI process and include:

Sharing Sensitive Data Between Trading Partners: In the realm of VMI, the seamless exchange of sensitive data between vendors and customers poses a significant challenge [8]. The vendor requires access to the customer's inventory, sales, and forecast data to effectively plan and execute replenishment orders. Conversely, the customer needs to receive information from the supplier regarding delivery, invoice status, and inventory updates to monitor and evaluate VMI performance [9]. Ensuring the security, accuracy, consistency, and timely updating of this data is vital to avoid errors and discrepancies.

Establishing Reliable Data Exchange Systems: Establishing a reliable and secure data exchange system between suppliers and customers is crucial for successful VMI implementation [10]. The traditional methods of data transfer, such as manual uploading or transmission through Electronic Data Interchange (EDI), often prove cumbersome and time-consuming. A shared platform or technology that facilitates seamless data integration and communication can streamline this process and enhance data accuracy and accessibility.

Real-Time Access to Data: Timely access to accurate and up-to-date data is pivotal for effective VMI management [11]. Traditional VMI models often suffer from delays in data availability, making it challenging to make informed decisions and respond promptly to changes in demand or inventory levels. Real-time data access is crucial for agile decision-making and proactive inventory management [12].

Collaboration among All Trading Partners: Modern VMI models emphasise collaboration not only between suppliers and customers but also among all trading partners involved, including manufacturers, distributors, and logistics service providers [13]. Achieving successful collaboration necessitates the exchange of tactical and strategic plans, fostering integrated supply chain processes [14]. Enterprises seek technological solutions that enable seamless collaboration among diverse partners.

Cumbersome Integration between ERP Systems: Effective VMI requires integration between the ERP systems of the supplier and the customer. However, existing integration approaches tend to be complex and require ongoing effort to maintain. Typically, one-to-one integrations are established between partners in the supply chain, adding to the complexity and potential inefficiencies [6].

Enforcing and Assessing Service Levels: Once a VMI program is implemented, customers often face challenges in evaluating

the real-time performance of the model and making necessary adjustments. Key performance indicators (KPIs) [15] such as fill rate, on-time delivery, stock-out frequency, inventory carrying cost, and warehouse usage need to be measured accurately to assess the efficacy of the VMI model.

Invoice Reconciliation and Financial Management: Efficient invoice reconciliation and financial management are crucial aspects of the VMI framework. Manual reconciliation processes can introduce errors and inefficiencies, disrupting the streamlined flow of financial operations [16]. The adoption of an automated approach for invoice reconciliation is imperative to ensure the accuracy and efficiency of financial transactions. This automation not only minimises discrepancies but also optimises the overall financial management process [17], fostering greater reliability and effectiveness within the VMI model.

Limitations of Existing Technology Solutions: The existing technology solutions employed in VMI, such as EDI, exhibit certain limitations that hinder the seamless execution of VMI processes. While EDI enables data integration to some extent, it lacks real-time data access and automation capabilities [18]. Direct function calls between applications require additional effort and often lack standardisation, impeding seamless communication between systems. The reliance on manual processes for invoice reconciliation introduces delays, potential discrepancies, and disputes, impacting overall supply chain efficiency.

The Need for a Secure and Efficient VMI Framework: Given the challenges faced by traditional VMI models and the limitations of existing technology solutions, there is an evident need for a secure and efficient VMI framework. This framework should facilitate real-time data sharing, promote collaboration among trading partners, enable automation, ensure accurate assessment of service levels, and streamline the overall VMI process [19]. Blockchain technology presents a promising solution that has the potential to transform VMI, addressing these challenges and driving enhanced efficiency and effectiveness in supply chain management.

4. Blockchain Technology for VMI

Understanding Blockchain from a Supply Chain Perspective

Gaining insights into blockchain through the lens of supply chain management reveals its transformative impact on traditional supply chain practices. At its core, blockchain, a distributed ledger technology, revolutionises the way transactions are recorded, verified, and stored within the supply chain ecosystem [20].

The essence of blockchain's functionality lies in its ability to structure transactions into unchangeable blocks, forming an immutable chain interconnected through sophisticated cryptographic algorithms. Within the context of supply chain dynamics, each block contains a spectrum of transactions, ranging from the movement of goods to financial exchanges and information sharing. This unalterable chain, referred to as the blockchain, is replicated across numerous nodes, ensuring redundancy and resilience across the network [21].

A prominent strength that blockchain bestows upon the supply chain domain is heightened traceability. Capitalising on blockchain's transparency and immutability, supply chain participants can meticulously trace the entire trajectory of goods, encompassing their origin, journey, and transformations throughout the supply chain lifecycle. This amplified traceability holds particular significance in sectors where authenticity, provenance, and regulatory compliance carry paramount importance, such as pharmaceuticals, luxury goods, and food supply chains [22].

Moreover, blockchain reinforces data integrity within the intricate web of supply chain activities, addressing the challenges posed by fragmented traditional supply chain models [23]. By granting all stakeholders access to a shared, unchangeable ledger, blockchain ensures the precision and uniformity of information. This transparency and integrity cultivate trust among trading partners and streamline operations, paving the way for effective supply chain management [22].

Collaboration, a pivotal pillar of efficient supply chain orchestration, experiences a substantial boost through blockchain technology. With intermediaries eliminated from the equation, blockchain facilitates direct peer-to-peer interactions, nurturing seamless collaboration among supply chain participants. This direct engagement accelerates decision-making, curbs communication obstacles, and amplifies overall efficiency within the supply chain. Furthermore, blockchain's transparent and unchangeable records incentivise accountability and ethical practices among participants, fostering robust collaboration and trust.

In the realm of collaborative operational models, blockchain emerges as an ideal technological solution. Its capacity to establish a trustless environment, fortified by smart contracts, empowers autonomous processes that are triggered by predefined conditions or events. Rather than maintaining duplicative copies of diverse supply chain documents, blockchain provides a single source of truth, accessible to all stakeholders, streamlining asset management, procurement, logistics, provenance, and fraud detection [24].

A comparison between conventional information-sharing approaches and blockchain underscores the manifold advantages the latter brings to the forefront [25]. By obviating intermediaries and furnishing a singular source of truth for supply chain activities, blockchain reduces delays, augments transparency, and heightens data security. Embracing blockchain within collaborative supply chains unleashes unprecedented efficiency, trust, and reliability in the

cooperative operational model, thereby redefining the terrain of supply chain management [26].

Advantages of Blockchain in VMI

Blockchain technology brings forth a multitude of advantages that revolutionise the implementation of VMI. These advantages encompass various aspects of VMI and contribute to its overall efficiency and effectiveness. The advantages of blockchain in VMI are as follows:

Trustless Collaboration: One of the fundamental advantages of blockchain technology is its ability to facilitate trustless collaboration among trading partners. By leveraging blockchain's decentralised and distributed nature [4], VMI participants can engage in direct interactions without relying on intermediaries. Traditional VMI models often involve multiple parties, including vendors, manufacturers, logistic service providers, and retailers, which may introduce complexities and potential trust issues. Blockchain eliminates the need for trust between parties by providing a transparent and immutable record of transactions. The shared ledger ensures data accuracy and consistency, reducing the risk of errors, disputes, and misunderstandings among trading partners.

Real-time Data Access: In the context of VMI, timely access to accurate and up-to-date data is of paramount importance. Blockchain technology enables real-time data access for all participants within the VMI network. Trading partners can securely access critical information, such as inventory levels, sales data, forecasts, and order status, without the need for manual data exchanges or delays. Real-time data access empowers stakeholders to make informed decisions based on the latest information, enhancing demand planning, inventory management, and replenishment processes. By eliminating delays in data availability, blockchain contributes to agility and responsiveness in VMI operations [12].

Enhanced Security and Data Integrity: Security and data integrity are critical considerations in VMI, as sensitive information is exchanged among trading partners. Blockchain addresses these concerns through its inherent security features. The technology employs advanced cryptographic algorithms to protect data, ensuring confidentiality, integrity, and authenticity. Transactions recorded on the blockchain are tamper-resistant, making it exceedingly difficult for malicious actors to manipulate or alter the data. The decentralised nature of blockchain adds an extra layer of security, as the data is stored across multiple nodes in the network. This distributed architecture reduces the vulnerability to single points of failure or attacks, enhancing the overall security posture of the VMI ecosystem [27].

Automation and Smart Contracts: One of the most transformative aspects of blockchain technology in VMI is its ability to automate processes through smart contracts. Smart contracts are self-executing agreements with predefined rules and conditions encoded on the blockchain. These contracts automatically execute actions and trigger events when specific conditions are met. In the context of VMI, smart contracts enable the automation of various business processes, streamlining operations and reducing manual intervention [28]. For instance, smart contracts can automate order generation based on predefined inventory thresholds, trigger invoice payments upon successful delivery, and facilitate automatic performance evaluation based on predefined metrics. By automating these processes, blockchain enhances operational efficiency, reduces human errors, and minimises the need for manual reconciliation and communication between trading partners.

Data Privacy: In the context of VMI blockchain implementation, ensuring data privacy is paramount. Some blockchain protocols feature channels, enabling data segregation for specific participants or groups [29]. Channels partition and isolate data, allowing private and confidential transactions. However, this introduces administrative complexities. Private data collection (PDC) offers an alternative by allowing selective data confidentiality, addressing cases where most information is transparent while specific parts remain private [4]. Architects establish policies to govern data treatment, determining access and storage rules. Given the sensitive nature of VMI agreements, enterprises might utilise channels or PDC to restrict access to agreements between suppliers and customers, ensuring that only involved parties can access these confidential records.

In summary, blockchain technology brings forth a myriad of advantages for VMI implementation. It enables trustless collaboration, provides real-time data access, enhances security and data integrity, and facilitates automation through smart contracts. By leveraging these advantages, VMI stakeholders can unlock new levels of efficiency, transparency, and effectiveness in their supply chain operations.

5. Blockchain-as-a-Service (BaaS)

Introduction to BaaS

BaaS is a cloud-based service that provides infrastructure and tools for developing, deploying, and managing blockchain applications. It offers convenience, scalability, and cost-effectiveness by eliminating the need for organisations to build and maintain their blockchain infrastructure.

Benefits of BaaS for VMI Implementation

BaaS platforms offer a range of benefits for organisations looking to implement blockchain technology in their VMI processes. These benefits streamline deployment, enhance security, and improve overall supply chain efficiency. Let's delve deeper into the advantages that BaaS brings to VMI implementation:

Fast Provisioning: One of the key benefits of BaaS is its ability to provide rapid provisioning of blockchain networks. BaaS platforms offer pre-configured environments that eliminate the complexities associated with setting up a blockchain infrastructure from scratch. With ready-to-use templates and intuitive interfaces, organisations can deploy a functioning blockchain network quickly, saving valuable time and resources [2].

Ease of Configuration: BaaS platforms simplify the configuration process by providing user-friendly tools and interfaces [2]. These tools abstract the underlying complexities of blockchain technology, enabling organisations to focus on tailoring the network to their specific VMI requirements. With easy configuration options, organisations can define parameters such as consensus mechanisms, data access controls, and network governance models [30], ensuring seamless integration of blockchain into their VMI processes.

Quick Onboarding of Members: Collaboration is at the heart of VMI, and BaaS platforms facilitate the efficient onboarding of trading partners. BaaS solutions provide identity management tools and secure digital certificates, streamlining the process of adding new members to the blockchain network [31, Fig. 1, Fig. 2]. By simplifying the onboarding process, organisations can foster collaboration and ensure the smooth integration of trading partners into the VMI ecosystem.

Embedded Identity Management: BaaS platforms offer robust identity management capabilities, ensuring secure access and authentication for network participants [2]. These platforms enable organisations to establish trust among participants by verifying their identities and ensuring that only authorised entities can interact with the blockchain network [31]. With embedded identity management features, BaaS platforms provide an additional layer of security and integrity to VMI processes[Fig. 2].

Enhanced Security and Confidentiality: Security is paramount when dealing with sensitive VMI data, and BaaS platforms address this concern through advanced security measures. Encryption, access controls, and permissioned blockchain networks are commonly implemented by BaaS providers to protect data confidentiality and integrity [32]. By leveraging these security features, organisations can conduct confidential transactions and share sensitive information securely within the VMI ecosystem.

Efficient Development and Testing: BaaS platforms offer a suite of development tools, software development kits (SDKs), and testing environments tailored to blockchain development [30]. These resources streamline the process of developing and deploying smart contracts, which play a crucial role in automating VMI processes. With BaaS, organisations can iterate rapidly, reducing development cycles and accelerating the integration of VMI processes with the blockchain network.

Enhanced Integration with Processes and Applications: Seamless integration with existing enterprise applications and systems is essential for VMI implementation [6]. BaaS platforms provide robust APIs and integration capabilities [32], enabling smooth data flow between VMI processes and the blockchain network, ensuring that a single end-to-end process can be implemented even if it transcends into multiple business entities, applications, and data sources.

Better Performance and Scalability: BaaS platforms offer scalability features that allow blockchain networks to handle a significant volume of transactions and accommodate the growing needs of VMI processes. With efficient consensus algorithms and distributed infrastructure, BaaS providers ensure that the blockchain network can scale seamlessly while maintaining optimal performance [32].

High Availability and Operational Resilience: BaaS platforms implement redundant infrastructure and fault-tolerant mechanisms to ensure high availability and operational resilience [33]. By leveraging distributed architecture and data replication techniques [33], these platforms minimise downtime and maintain the integrity of VMI processes. This ensures that critical VMI operations continue without interruption, even in the face of potential

Decoupling Infrastructure from Legacy Systems: One of the notable advantages of BaaS is its ability to integrate blockchain technology into existing VMI processes without requiring significant modifications to legacy systems [30]. BaaS platforms provide a flexible and non-disruptive approach to blockchain adoption, enabling organisations to leverage the benefits of blockchain while preserving their investment in legacy infrastructure. This decoupling allows for seamless integration of blockchain into VMI processes, unlocking the full potential of blockchain technology without causing operational disruptions.

6. Proposed Solution-Implementing VMI on a BaaS Platform

In the rapidly evolving landscape of supply chain management, the convergence of VMI principles with cutting-edge technology offers unprecedented potential. Among these transformative technologies, BaaS emerges as a beacon of innovation, promising enhanced collaboration, transparency, and data integrity. This section unveils the blueprint for implementing VMI on a BaaS platform, encompassing the technical architecture, smart contract automation, partner onboarding, execution automation, transportation planning, payments automation, and a comprehensive discussion on the revolutionary impact of blockchain and BaaS on traditional VMI models.

a) Technical Architecture for VMI on BaaS

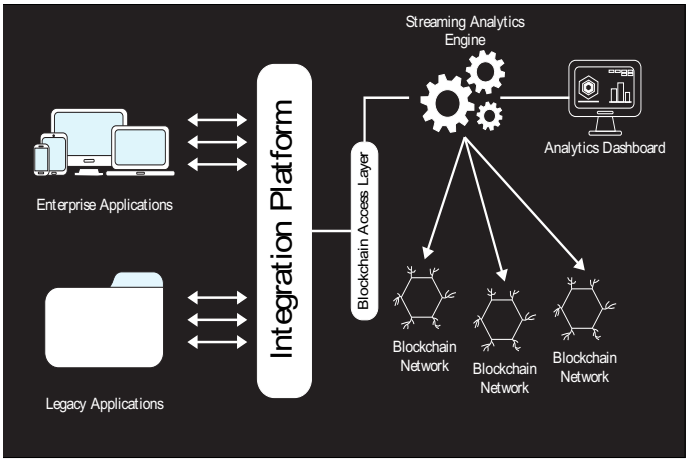

Fig. 1 Technical Architecture [34]

In the context of VMI on a BaaS platform, the technical architecture plays a vital role in establishing a secure and efficient network. The BaaS platform enables the creation of a private blockchain network [Fig. 1] where trading partners, including suppliers, customers, manufacturers, distributors, and transporters, can participate. The BaaS platform's robust integration capabilities allow major ERP vendors such as Oracle, SAP, and IBM to seamlessly connect their application software with the blockchain [29, Fig. 1].

By integrating ERP systems with the blockchain through RESTful APIs, real-time data sharing becomes possible [35]. Each participant gains access to VMI-related information concurrently, ensuring a synchronised and transparent flow of data.

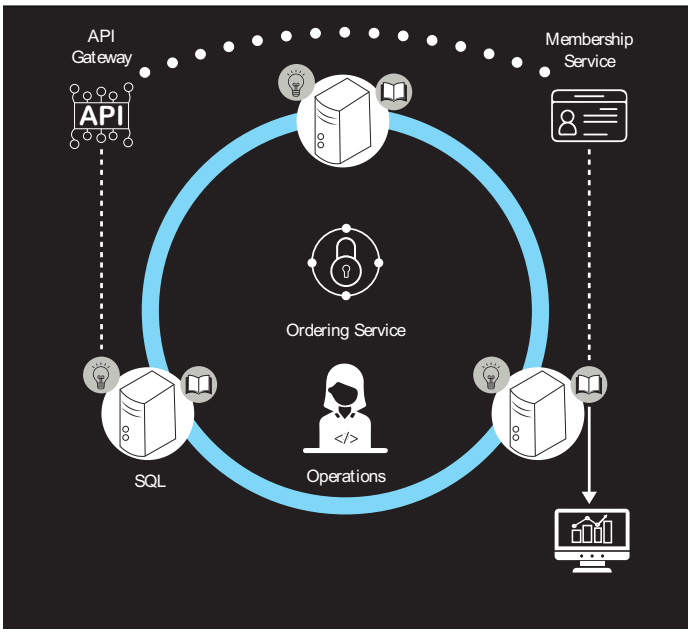

Fig. 2 Technical Architecture [3]

b) Figure 3 represents the 'Conceptual VMI Process Model' utilising BaaS

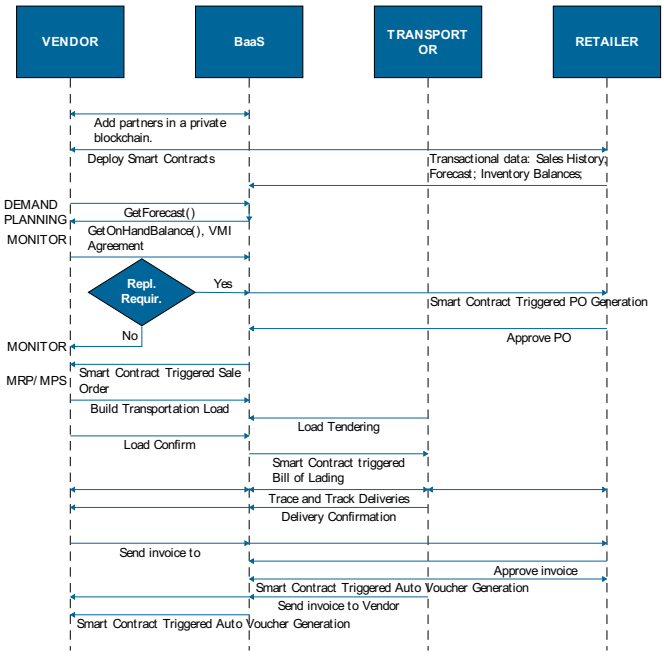

Fig. 3 Proposed VMI Model

Onboarding Partners and Integration Services

To initiate the VMI process on the BaaS platform, organisations must create a private blockchain network and invite vendors, customers, manufacturers, and other stakeholders as participants. BaaS providers offer tools and SDKs to develop client applications and smart contracts, facilitating the integration of business entities with blockchain technology [35]. Integration services provided by the BaaS platform enable seamless connectivity between various ERP systems, ensuring data exchange and communication among trading partners. By embracing interoperability and data consistency, the VMI ecosystem becomes more efficient and collaborative [35].

Developing Smart Contracts for VMI Automation

Smart contracts are the cornerstone of automating VMI processes on the blockchain. These self-executing agreements with predefined rules and conditions are encoded on the blockchain. Organisations need to develop and deploy smart contracts that govern various activities within the VMI ecosystem.

For instance, smart contracts can automatically generate purchase orders when inventory levels fall below a specified threshold, initiate delivery confirmation and acceptance based on predefined criteria, and facilitate invoice reconciliation by verifying the accuracy of received goods. By leveraging smart contracts, VMI operations become streamlined, reducing manual intervention, and enforcing compliance with predefined rules and service-level agreements.

Planning: Enhancing VMI Efficiency through Data-Driven Strategies

In pursuit of a streamlined VMI, effective planning emerges as a crucial factor. Vendors can boost efficiency by integrating historical sales and forecasting data from customers into their demand management systems. Modern BaaS platforms facilitate this process by exposing functions for data retrieval through REST APIs [36]. This data-driven approach replaces traditional methods, such as manual uploads or EDI, providing real-time data accessibility and reducing administrative overhead. With accurate insights at hand, vendors can formulate well-informed tactical and strategic plans, optimising inventory management and decision-making.

The integration of historical sales and forecast data into demand management systems through BaaS platforms streamlines the planning process [37, 38]. Real-time access to stock figures at customer locations, enabled by blockchain's REST APIs, enriches decision-making. By eliminating manual data transfers and improving accessibility, partners enhance their planning strategies, ensuring precision and agility in VMI operations. The synergy between blockchain technology and data-driven planning accelerates the efficiency of VMI processes, fostering collaborative and informed decision-making across the supply chain.

Monitoring: Ensuring Timely Stock Management through Blockchain

In the context of VMI, maintaining optimal stock levels and adhering to service agreements is paramount. To achieve this, vendors must continuously monitor their customers' inventory levels [37, 38]. Blockchain technology provides a robust solution by enabling real-time sharing of inventory-related transactions across the network. This seamless information exchange ensures that both vendors and customers are updated about stock changes on time.

Blockchain's architecture facilitates the creation of automated monitoring mechanisms within the ecosystem. Through the implementation of recurring, time-triggered smart contracts, the monitoring process becomes efficient and accurate. These contracts are initiated by external triggers, allowing tools like 'Chainlink Automation' to periodically evaluate customer stock levels. By incorporating such automation into the blockchain infrastructure, VMI participants can proactively manage inventory, prevent stock-outs, and enhance supply chain visibility.

Automating VMI Execution and Order Generation

Smart contracts, powered by the blockchain, enable the automation of VMI execution. Vendors continuously monitor customer's stock levels through time-triggered smart contracts. The smart contracts, designed to trigger automatic actions when predefined conditions are met, generate purchase orders on the customer's side and sales orders on the supplier's ERP system. This autonomous process eliminates the need for manual intervention, ensuring the seamless execution of VMI agreements and minimising stock-outs.

Transportation Planning and Delivery

Blockchain facilitates load tendering processes, where load information is shared within the network between transport and logistics service providers. Any changes to the load get reflected on the blockchain and are visible to all partners in real time. The smart contracts verify load approvals, generate transportation documents like bills of lading, and automate invoice generation after delivery confirmation [38].

Billing and Payments Automation

The blockchain's single source of truth streamlines billing and payments in the VMI ecosystem. Smart contracts facilitate the automation of matching purchase orders with invoices raised by suppliers [39]. Automated vouchers are generated and processed in the customer's ERP, while banks participating in the blockchain network can trigger automated payments based on predefined conditions. By leveraging smart contracts and blockchain technology as a service, VMI billing and payments become faster, more transparent, and more efficient.

7. Case Study

A global manufacturer of household electrical appliances initiated a strategic plan to improve the efficiency of its supply chain by implementing VMI. The key goals were to accurately calculate the replenishment quantities for its components and finished goods based on actual sales data and inventory levels, and efficiently coordinate the logistics of product distribution to meet replenishment requirements. This initiative required the collaboration of multiple business entities, such as sales companies, distributors, manufacturing plants, suppliers, and transportation companies. Although the company moved from a traditional replenishment system to a VMI model, it encountered some operational and technical challenges, such as integration with partners, accuracy of shared data, delay in sharing real-time data, data privacy concerns, use of EDI and Extranet for information sharing, complexities in managing and sharing multiple data types (short, medium, and long term), manual adjustments to the billing details, reluctance by trading partners in technological investments, and measuring KPIs for improvements.

A VMI model based on BaaS has the potential to address all the above inefficiencies with traditional VMI. The model would enable real-time data sharing, resulting in a more accurate Target Stock (TAS). The platform's inherent data privacy features would encourage partners to participate in the process. Both process and technology integration with partners can be addressed by utilising the API and integration capabilities offered by various BaaS vendors. The use of DLT in exchanging information could replace the cumbersome EDI process. Trading partners would be motivated to

participate, as the technological investments required would be low, and minimal changes would be needed to align their in-house legacy IT applications with the process. Further analytics capabilities offered by BaaS vendors would help measure the performance of VMI, along with prescriptions to improve processes.

8. Discussion

Blockchain technology offers a promising solution to transform traditional VMI models into efficient and secure supply chain ecosystems. Unlike conventional VMI models that rely on technologies like EDI, blockchain's decentralised and transparent nature ensures real-time data access and collaboration among multiple trading partners.

By implementing VMI on a BaaS platform, organisations can unlock a myriad of benefits, propelling their supply chain operations to new heights. This collaborative approach empowers participants with valuable insights, optimising inventory management, and streamlining transactions throughout the entire VMI journey.

The key advantages of implementing VMI on a BaaS platform are as follows:

Greater Efficiency: Blockchain's real-time data access and smart contract automation eliminate manual interventions, reducing delays and human errors in inventory management. Trading partners can access synchronised data, enabling faster decision-making and proactive responses to changes in demand.

Reduced Operational Overheads: By eliminating the need for intermediaries and streamlining processes, VMI on a BaaS platform reduces operational costs. The transparent nature of blockchain simplifies reconciliation processes, minimising disputes and associated expenses.

Enhanced Data Privacy and Security: BaaS platforms offer robust encryption and access control mechanisms, ensuring that sensitive VMI data remains confidential and accessible only to authorised participants. The temper-resistant nature of blockchain ensures the integrity and authenticity of the shared data.

Improved Supply Chain Performance: With blockchain's transparency, organisations can monitor KPIs in real time. This visibility allows for better-informed decisions, optimising supply chain performance, and fostering continuous improvement initiatives.

9. Selecting the Optimum BaaS Provider for VMI

When it comes to choosing the right BaaS provider for implementing VMI, several critical factors demand consideration. These aspects are pivotal in ensuring the seamless integration of blockchain technology into the VMI framework, optimising supply chain operations while maintaining data security and accessibility. Key points for assessing the suitability of a BaaS provider include:

Blockchain Protocol Selection: Diverse blockchain platforms offer varying levels of access control and decentralisation. For VMI, which involves confidential agreements between trading partners, the provider's support for permissioned blockchain platforms becomes crucial. Permissioned blockchains allow for controlled access, ensuring that only authorised members can participate [Fig. 2]. The provider should offer features to facilitate the easy addition of network participants and client-only members, safeguarding the confidentiality of sensitive information within the VMI network.

Consensus Mechanism Flexibility: The consensus mechanism governs how transactions are validated and added to the blockchain. Enterprises implementing VMI may prefer flexibility in choosing or even designing their consensus algorithm, given that network members operate under known identities. BaaS providers offering adaptable consensus mechanisms align with organisations' preferences seeking tailored approaches to consensus within their VMI ecosystem.

Support for Off-Chain Applications: VMI processes involve large amounts of data, from monitoring inventory levels to collaborative planning. To ensure efficient operations and address throughput requirements, a BaaS architecture should support off-chain applications. This capability enables certain functions, like monitoring inventory levels, to be performed off the blockchain, enhancing scalability and efficiency in executing smart contracts [40].

Seamless Integration Services: In the intricate VMI landscape, partners often operate with diverse ERP systems and enterprise applications. The selected BaaS provider should offer integration services that enable smooth connectivity between different ERP systems and blockchain technology. This integration streamlines data exchange and communication among trading partners, ensuring interoperability across the VMI network [2, 3].

Development Tools for Client Applications and Smart Contracts: An effective BaaS platform should provide user-friendly tools and SDKs for crafting both client applications and smart contracts. This empowers organisations to build and deploy tailored solutions that cater to their unique VMI requirements. Additionally, the BaaS platform should offer capabilities to interact with smart contracts and query ledgers through RESTful APIs [2, 3, 41].

Analytics-Ready Transaction Mirroring: An often overlooked aspect is the ability to mirror blockchain transactions to a data warehouse for advanced analytics. This feature enables enterprises to glean insights from the transactional data

generated within the VMI ecosystem, fostering informed decision-making and continuous improvement [3].

10. Conclusion

By embracing blockchain technology and implementing VMI on a BaaS platform, organisations can transform their supply chain management, fostering trust, efficiency, and collaboration among all trading partners involved [42]. This innovative approach opens new possibilities for streamlined inventory management and sets the stage for the future of VMI in the ever-evolving global market.

Summary of Benefits of Blockchain BaaS in VMI

Blockchain technology offers significant benefits for VMI implementation. According to Chris Fabre, it enables trustless collaboration, real-time data access, enhanced security and data integrity, and automation through smart contracts. By leveraging BaaS, organisations can achieve faster provisioning, ease of configuration, quick onboarding of members, enhanced security, data privacy, and seamless integration with existing processes and applications [35].

Potential Challenges and Mitigation Strategies

Implementing blockchain in VMI may come with challenges such as resistance to change, integration complexities, and the need for industry-wide standards. Organisations should address these challenges through change management strategies, thorough testing and validation, and active participation in industry consortium and standardisation efforts.

Future Directions and Research Opportunities

The adoption of blockchain in VMI is still in its early stages, presenting numerous research opportunities. Future research could focus on exploring interoperability between blockchain networks, investigating privacy-preserving techniques, and developing analytics frameworks for extracting valuable insights from blockchain data. Performance optimisation of smart contract execution, on-chain/off-chain data/decentralised storage, and automated/autonomous financial transactions.

Final Remarks on the Role of Blockchain in VMI

Blockchain technology has the potential to revolutionise VMI by improving collaboration, data integrity, automation, and supply chain performance. Organisations that embrace blockchain and choose the right BaaS provider can position themselves at the forefront of supply chain innovation, gaining a competitive edge in the marketplace. By overcoming the challenges of traditional VMI models and harnessing the power of blockchain, organisations can achieve greater efficiency and customer satisfaction in their supply chain operations.

Competing interests:
None declared.

Ethical approval:
Not applicable.

Author's contribution:
SVM conceptualised the research, developed the methodology, collected data, drafted the initial manuscript, and coordinated the revision process.

Funding:
None declared.

Acknowledgements:
None declared.

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