Unified Framework for Integrating Blockchain into Supply Chain Systems

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Abstract: The process of integrating blockchain for supply chain systems is generally viewed as a complex process, due to a combination of technical and social factors involved. To ensure undisrupted operations during the integration process, supply chain systems require support from a host of interconnected stakeholders due to the transactions involved and economic cost incurred from delays. To address the challenges that hinder the success of blockchain integration, this study proposes using a modified MOHBSchain framework along with the adoption of agile model of project management, to allow for incremental improvements to the system. This unified supply-blockchain framework serves as a solution to address the dynamic needs of supply chain systems, as it helps improve adoption by focusing on the necessary components to allow blockchain integration with various supply chain system frameworks in the shortest possible time. By prioritizing key features rather than simultaneously developing various areas for improvement, the proposed framework would be able to sustain stakeholder support, as benefits are realized immediately rather than being restricted by project schedules and deadlines. The proposed framework is then applied to a real-world case study, wherein project flow and implementation strategies are recommended to overcome challenges faced. Theoretical application of the framework does have limitations, as geopolitical, administrative, and logistical challenges are not considered.

Keywords: agile model, blockchain integration, MOHBSchain framework, supply chain systems

1. Introduction

Supply chain systems are inherently dynamic due to the combination of regulatory, economic, and logistical environments that shape the efficiency and methods used for operational tasks. Changes occur frequently and sporadically, which leads to routine decision-making being subjected to updates on a regular basis. The myriad of changes within the system, due to the inherent nature of the industry, tends to cause automation to be difficult to implement due to the need for reconfiguring various components in a timely and accurate manner. Regulations are tied to the political landscape of involved countries and their respective government agencies, which tends to directly impact documentary requirements and leads to sweeping reforms to existing protocols and processes. Economic environments impact the supply and demand of goods and are also interrelated with logistical environments as it affects the flow of goods from one location to another.

Human intervention remains to be one of the biggest bottlenecks in supply chain systems, as most procedures emphasize the need to verify documents to avoid any additional inconvenience caused by human error in checking paperwork or implementing policies. By extension, this also serves as a strong motivation to avoid any automated system that still requires human intervention as unintended results may occur, which are difficult to rectify due to multiple transactions being processed within supply chain

systems every minute. Keeping personnel updates with the latest policies, assuring accuracy in checking provided paperwork, and creating systems that would be able to address sudden increases in the volume of processed documents form part of the current context of supply chain systems.

The adaptability of blockchain technology is also a major factor that influences its framework. The necessity to simplify the processes for handling transactions within supply chain systems remains crucial, and blockchain is viewed to be one of the more reliable and secure means of addressing the issue. However, there is direct conflict with this view of developing and adopting blockchain technology vis-à-vis its practical application that involves working around existing technologies. Currently, the blockchain framework used and incorporated within supply chain systems remains more of an accessory to previous technologies applied within the industry rather than becoming the central basis for developing a comprehensive framework together with Internet of Things (IoT) devices and Radio Frequency Identification (RFIDs). Despite the demand, blockchain adoption levels remain limited, which is why the preferred mode of integration is a modular approach based on existing needs.

The adoption of blockchain is still in its early phase as its utilization is more geared towards exploring its potential use. The current focus involves transparency to ensure that various involved parties can act accordingly and hold others accountable for any anomalous activity or delay. However, there have also been attempts to utilize smart contracts to develop reliable automation within blockchain frameworks. The growing demand for the use of blockchain technology and its benefits continue to fuel interest and adoption, but this has also led to difficulties in developing comprehensive frameworks that would cater to various and often-changing requirements.

2. Research Objectives

This research intends to propose a unified framework for integrating blockchain into supply chain systems using a modified MOHBSchain model together with adoption of agile model of project management. The new proposed Supply-Blockchain framework will focus on the necessary components to allow blockchain integration with various supply chain system frameworks in the shortest possible time. This will serve as a direct solution to the dynamic nature of supply chain system and help improve the adoption process. The proposed model will also simplify the introduction of incremental updates to the blockchain framework by creating a modular approach for implementing features.

3. Related Work

3.1.1. Essential Requirements and Specifications

The continuous operations required of supply chain systems create multiple limitations that need to be addressed as the development of any new feature or framework is forced to be compartmentalized to be able to meet the constant demand for processing documents while also introducing innovations and features [1]. Supply chain systems require a modular approach rather than a complete overhaul of the existing system [2], as the acceptance of sudden changes is very unlikely across various involved parties. Integration of changes tends to take time across different segments due to the complexity of relationships and procedures. More often than not, change is introduced slowly to allow regulators, suppliers, and other users to adjust to new policies and ensure that the documents of products already in transit are still acceptable within the currently transitioning system. In addition, existing frameworks also need to be tested as it is being modified to ensure that changes produce only the intended results [3]. Deviations from standard procedure and updated policies, particularly for regulatory functions within supply chain systems, create a domino effect throughout the system. Hence, frameworks that are adopted are ideally made to maintain a standard procedure to ensure predictability during operations.

The essential requirements and specifications of blockchain frameworks stem from the context of their priority functions, which are defined by a combination of the identified case's technological need, current operational framework, political climate, existing regulations, and intended purpose [2]. The development of blockchain frameworks requires an analysis of these factors to identify the exact specifications required to address both the existing issues of supply chain systems and the blockchain architecture needed to address future development. Technological needs and operational framework are particularly important as they highlight how the blockchain could be integrated with various existing technologies, such as IoT and RFID. On the other hand, certain specifications are often dictated based on the political climate and existing regulations as these involve embargos, trade restrictions, product quality specifications, identification of the origin of goods, and other limitations or requirements for handling logistics within the supply chain system.

3.2. Managing Risk within Supply Chain Systems

Risks in implementing and adopting blockchain frameworks impact the sustainability of the supply chain systems due to their inherent capacity to stall the transport of goods and potentially lead to spoilage or damage [4]. Sweeping changes are likely to cause confusion and disrupt the operations of supply chain systems. Avoiding risks is considered to be a necessary step in blockchain framework development, as the severity and volume of transactions handled are likely to cause a significant impact on day-to-day functions. Mitigation is conducted by pursuing framework development that not only fits the context of supply chain management but also builds upon features that fit the particular needs of various stakeholders [5]. The overall approach to mitigating risk would be to ensure stability and regularity of operations even as changes within the system occur.

To initiate the process of integrating blockchain frameworks without disrupting the existing system, it is found that the approach should gradually transition the current operations while maintaining a fully functioning system that provides day-to-day service. New features are then tested before being released once the migration process to a new framework has been completed [1]. In developing these new features, the goal is to ensure that these are complementary to the existing supply chain environment and industry needs otherwise, it leads to unnecessary risks that could disrupt the system. Furthermore, the preservation of continuous service allows for greater flexibility in realigning proposed changes as each component that is sought to be integrated is tested for a limited period of time, which enables adjustments to be made in comparison to previous performance or operations.

A system of checks and balances is necessary to proactively mitigate risk within the supply chain system due to its complex nature resulting from various roles, processes, and transactions involved. Hence, the development of a secure consensus mechanism is found to be critical in ensuring data transparency and validity [5]. While trust within the digital ledger is acquired through the reduction of uncertainty, there must still be extensive measures to ensure that hashes are not vulnerable to tampering across all data points. Therefore, it can be said that blockchain frameworks enable regulations to be more predictable, but only for as long as the system remains reliable for all involved parties.

3.3. Value of Transparency in Framework Development

Integrated blockchains have generally been adopted due to their capacity to promote transparency within the system [6], particularly due to the nature of logistics and supply chain systems that seek to provide pertinent data to respective users in a timely and accurate manner. Transparency is viewed as a means to create predictability across multiple regulatory bodies that a parcel may pass through. Hence, its reliable implementation through blockchains has attracted attention to how existing frameworks could incorporate strategies that maximize such benefit [7].

As a core feature of blockchain frameworks, transparency builds trust among users that data remains immutable. Users of varying roles and authority are able to monitor transactions and access role-relevant data to aid in decision-making and enable the predictability of conducted processes [8]. In cases wherein automation is sought, transparency also serves as a means of audit without interference, as data could not be scrubbed from ledgers within a blockchain's secure system [3]. End-users, such as businesses that import or export their goods, are examples of stakeholders that benefit from transparency as they are able to hold government agencies accountable for delays. Another benefit of transparency is that it allows for accurate forecasting as data involving approval of transactions, time taken to deliver goods, and other relevant data are accessible.

Transparency also promotes accountability within the blockchain framework as it allows irregularities or loopholes to be detected based on the visibility of all conducted transactions. As supply chain systems tend to deal with various roles and levels of authority, then it would be practical to have backup systems that are used to validate existing data [9]. Moreover, increased protection also enables the system to be adopted or bridged with other existing platforms or networks with minimal issues as any irregularity to the data could be addressed by the system regardless of its source or reason for occurring.

3.4. Approaches towards Blockchain Framework Development

Project management has been a necessary component in the approach toward implementing a blockchain framework. The process of integrating a new framework and replacing the old system or merging both systems into a single framework requires proper allocation of resources and prioritization of tasks [10]. The purpose of project management is to ensure that goals are being met during the adoption phase without

any additional implications to time, cost, and quality. In blockchain framework development, the same principles apply as multiple external factors could impact the completion of the project, particularly in supply chain systems that encompass a multitude of geopolitical and logistical aspects.

There are three main phases to be considered for blockchain framework development in the context of supply chain systems, namely: framework creation, framework integration, and framework adjustment [11]. Creation focuses on the development of architecture, data structuring, and intended dependency across various systems that would be involved with the blockchain framework. Integration focuses on the concessions made to the architecture to fit the needs of the system as well as, the adjustments needed to be implemented during the course of blockchain adoption [12]. Lastly, adjustment is made based on how goals and standards are met to be able to realign the purpose and function of the created and implemented blockchain to fit the needs of the supply chain system, including any optimizations or calibrations required as the framework expands or changes its overall structure [13].

3.5. Integrating Change Management for Blockchain Adoption

The process of integrating change management into existing systems has been characterized by the numerous online platforms that are present across various supply chain systems [14]. Change management, in the context of blockchain integration, involves pursuing strategies and building architecture that is more acceptable to involved parties by either minimizing changes or improving the quality of life across different sectors.

Resistance from various stakeholders has to be expected as supply chain systems revolve around transparency, accountability, and stability [15]. Risk is also incurred whenever changes are made, particularly due to unforeseen results and unfamiliarity with the technology. Hence, the process of creating and integrating the blockchain framework tends to require a buy-in period wherein stakeholders are made aware of how the framework's technology operates.

One of the biggest factors affected by risk would be the presence of strict policies within supply chain systems, which would have accompanying sanctions when specifications are not met [13]. In this regard, change management needs to follow strict adherence to the core principles and specifications while also ensuring that the process of integration would remain stable throughout the integration process.

4. Proposed Framework

Developing a unified supply-blockchain framework for integrating blockchain into supply chain systems will help address several issues such as the lengthy period before perceived benefits are enjoyed and the costly transition towards blockchain. In addition, DevOps practices are properly introduced by the unified supply-blockchain framework as it fosters a more modular approach toward developing multiple features.

The framework involves integration of the following:

- Agile model of project management
- Core integration framework adapted from MOHBSchain model

4.1. Agile Method of Development

The agile method of development is ideal for addressing supply chain system software as it enables modular improvements to the existing system while also enabling a secured environment for testing before changes are pushed into the live service [16]. In the context of supply chain systems that are likely to run non-stop, the use of the agile method is crucial as it allows for continuous servicing that mitigates the risk of backlogs due to delayed processing of documents and system downtimes. The approach toward adopting the agile method involves the ability to simultaneously test introduced features at the cost of higher resources for troubleshooting and bug-fixing [17]. While beta testing and quality assurance are possible strategies before committing changes to the live service, there is still an expectation that costs will be incurred for addressing any unforeseen issues that may arise.

As a form of project management, the agile method also allows for the prioritization of key features based on existing needs and demands [18], which leads to effective incremental progress as main issues are partially or fully resolved within sprints. Unlike other project management strategies, the agile method allows feedback loops to be faster to roll out improvements quicker. In the process of integrating blockchain into supply chain systems, the agile method enables blockchain technology to be utilized to address primary issues, which builds up the impact of the technology and its features on the identified project.

4.2. Development of a Core Integration Framework

The unpredictability of political and economic conditions requires that framework development be suited for multiple types of scenarios that could be encountered. While blockchain is inherently flexible due to its large capacity to handle multiple functions, it also needs to be guided by key features that enable it to perform its intended role and purpose [19]. To ensure that blockchains remain useful while also being adaptable to various changes, developing a core framework is viewed as ideal for enabling greater flexibility as it allows features, policies, and other related systems to be repurposed whenever sweeping changes are implemented. The main benefit of this approach is that it enables scalability for supply chain systems that are likely to constantly develop and adapt to their external environment.

A core framework also limits issues regarding transferability and compatibility when new technology is expected to be implemented, as it enables a modular approach to be incorporated that is likely to be able to accept multiple features and allow modification of each one separately [20]. Lack of interdependence among the features also allows the developed framework to function more consistently as the inclusion, revision, and removal of features would have minimal impact on the overall operations.

The core integration framework has been adapted from the MOHBSchain model that is intended for use in logistics and supply chain systems, due to its simplified centralized architecture that enables multiple connections with various external devices [21]. MOHBSchain provides the advantage of maintaining security and combining it with functionality to meet the stringent demands of supply chain systems brought about by an ever-changing environment and strict requirements to meet regulations and specifications.

From a functional perspective, the MOHBSchain model's advantage is that it clearly delegates and clusters trusted and non-trusted devices to funnel interactions into certain layers wherein security can be strengthened while maintaining the accessibility of the system to external devices [23]. The delineation between each segment of the framework also identifies key points where security needs to be improved to ensure that data is immutable and reliable [21]. Moreover, the MOHBSchain model also enables an easier way of monitoring operations and identifying errors within the system by allowing transactions to be compartmentalized and limited within each respective portion. This allows hotfixes to be more reliable and effective as portions of the system are segmented and easily identifiable, which benefits the agile method as it allows for shorter testing periods before the actual release of changes [22].

While MOHBSchain model has many advantages, it is also quite complex to implement. Therefore, the core supply-blockchain framework developed in this research only utilizes MOHBSchain model's core features. Figure 1 presents the proposed framework, the core blockchain ecosystem is surrounded by two layers. The first layer provides services such as storage and retrieval, processing of the transaction, operation of the consensus mechanism for verification, and processing of blockchain transactions through the use of smart contracts. The first layer is patterned in a way that it contains the core functions needed for the blockchain to operate. This is also the reason why the first layer is prioritized in terms of development and integration.

The second layer involves additional features that improve the security and functionality of the framework, while still retaining core features necessary to operate and maintain the blockchain network. Thus, prioritization of new features implementation can depend on the changings needs of a supply chain organization. For example, if security is the main concern, then developing dynamic encoding and control of access for regulators and other users can be prioritized over other updates. But, if the focus is on end-user experience, then developing access channels for viewing transactions and automating purchases through an app or website linked to the blockchain network can be prioritized. Development of channels to connect with external devices improves accessibility, while a backup server helps to strengthen the reliability of processed data. These components are less prioritized, as they involve expanding the framework to other connections, which not only increases security risks but also requires more resources to complete.

The particular model is identified to be beneficial to an agile method of development as it fills the gaps in security that are expected to occur as incremental changes may inadvertently result in security loopholes within the system. Moreover, it also establishes a clear hierarchy of prioritization among the different components of the system that should be developed, which allows for a clear pathway toward assigning sprints for each time period [22]. The hierarchy serves an important role as it is a way to be able to inherently structure data that would be processed, stored, and accessed from the central blockchain and its various layers.

5. Application of Proposed Framework to Case Study

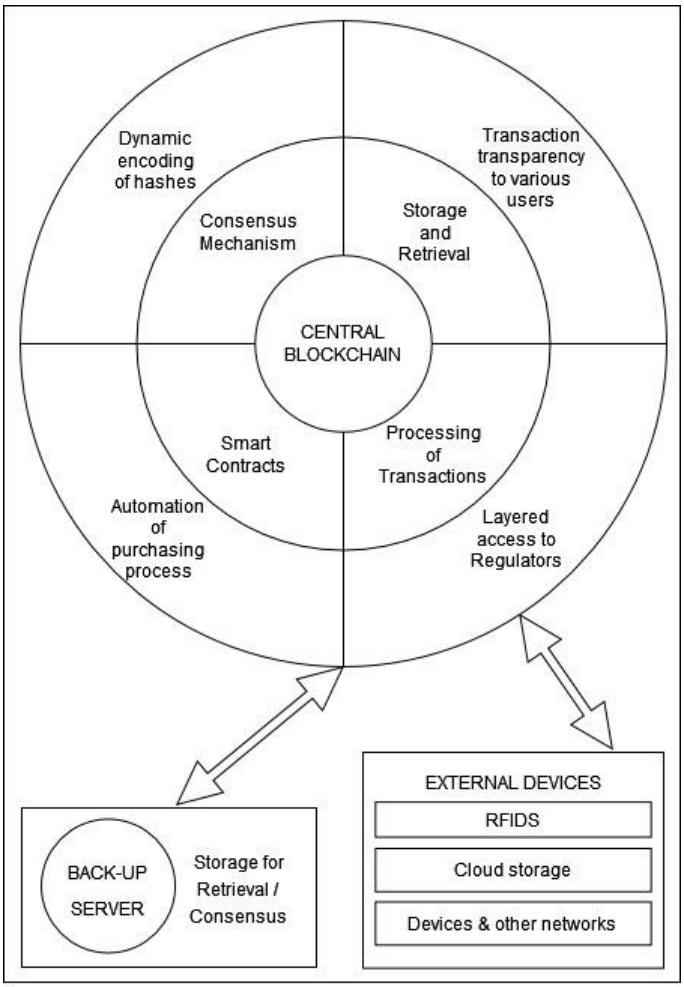

Fig. 1. Proposed supply-blockchain framework.

To identify how the framework operates and differs from existing strategies, it would be important to test the provided example with an actual scenario. The case study used for the application of the proposed framework is Sternberg, Hofmann, and Roeck's "The Struggle is Real: Insights from a Supply Chain Blockchain Case" [24]. The case study's scenario involves a contemporary situation wherein the application of blockchain theory is sought for a specific project but social and systemic factors, such as an inter-organizational structure, a distortion in the cost-benefit analysis, and the strong presence of tension throughout the internal and external environment, are found to hinder the implementation of blockchain frameworks. In this case, the proposed framework seeks to address resistance and tension toward the adoption of blockchain technology by making the benefits more prevalent. Moreover, by following an agile project model, most of the issues provided in the case study could be addressed in a timely manner, which are further discussed in the latter portion of this study.

5.1. Proposed Project Flow

In the proposed project flow, the main focus is to integrate the blockchain into the supply chain system while also adding greater priority to both feature development and correction of system requirements to meet set standards. The triggers for developing new features involve interventions from any stakeholder, existing systems not meeting the expected results, and seeking improvement to the supply chain system operations [25].

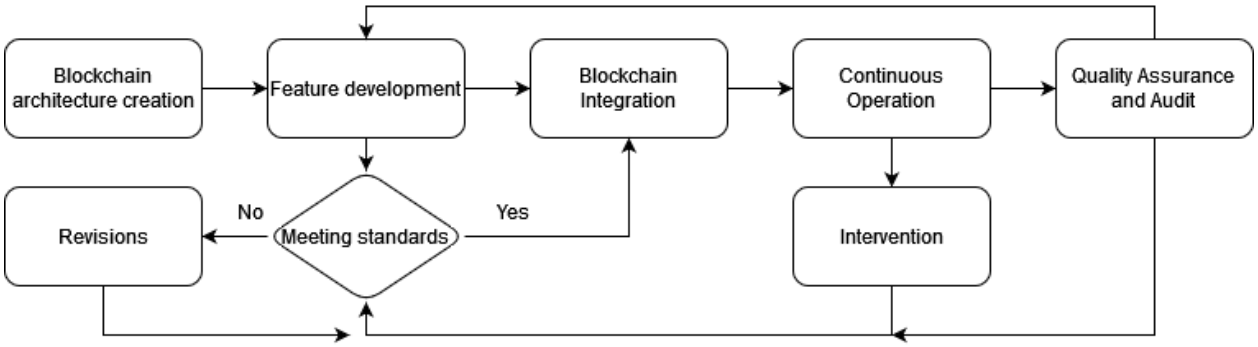

Fig. 2. Block diagram of the proposed project flow.

The blockchain architecture creation starts the process as it involves the most planning among the different steps of the project. The data structure, the interconnection between different networks, the security measures for encrypting hashes, and the method for the consensus mechanism are all prepared during this phase as these are the rudimentary steps needed to operate the blockchain framework [26].

Afterward, the project would then follow development cycles wherein sprints would be conducted to prioritize tasks based on current conditions. These features are then integrated into the blockchain system after pre-testing to ensure that the features are in line with the project specifications and standards. However, alternative solutions arising from interventions and quality assurance may lead to revisions of existing or proposed features within the blockchain to ensure that the supply chain system is able to adapt to its conditions.

In this case, the rationale for following the proposed project flow would be to ensure regularity during actual operations. Blockchain would serve as a means to improve security and reliability throughout the supply chain system, but its features are incrementally introduced to ensure that the integration process does not disrupt daily processes, transactions, and operations [27]. Ideally, the gradual integration of the blockchain and its new features would serve as a means to reduce tension by allowing the stakeholders to familiarize themselves with the new system at a slower pace [28].

5.2. Key Implementation Strategies

The project would be implemented in three main phases, which involve conceptualization, integration, and adaptation. The three phases follow the pattern provided in the proposed project flow.

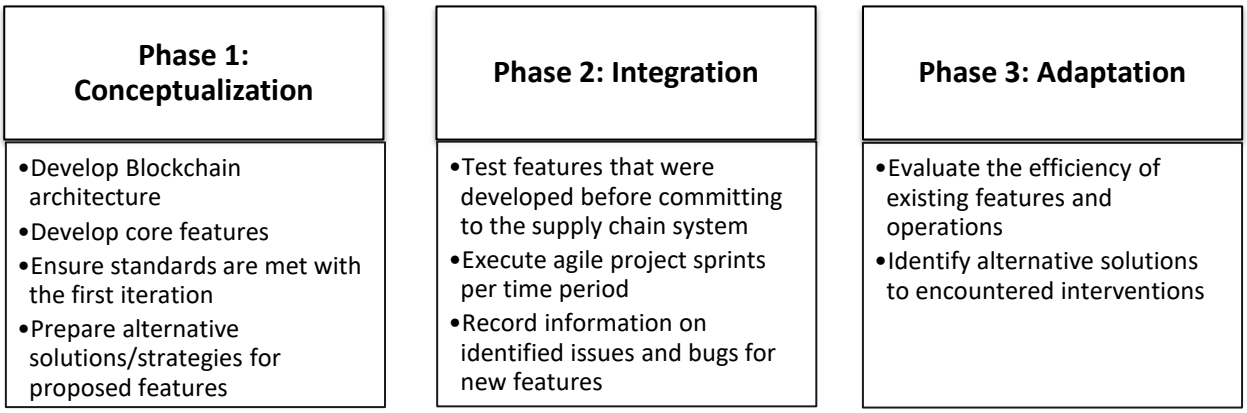

Fig. 3. Proposed project phases

Conceptualization involves all the planning tasks that enable the creation of the blockchain architecture and its initial features. In this phase, the overall idea of how the blockchain framework would fit the supply chain system is already prepared. This phase is meant to ensure that all aspects of the blockchain framework are in line with the necessary requirements and specifications before they are integrated into the current system [29]. Moreover, any contingency plans and foreseen issues are also discussed and identified in this phase.

Integration involves the incremental process wherein the project follows the agile method as changes are

slowly introduced into the system. The Supply-Blockchain model shall slowly be implemented during the integration phase, which may also involve major changes to the current system used for operations. However, the main focus of this phase is not only to integrate the project into a new system, but also to allow various stakeholders to be more accepting of the change. Transitions are aimed at giving more time for stakeholders to familiarize themselves not only with the new system but also with its accompanying features [30].

Adaptation involves the continuous development process that will maintain the quality of the whole system and ensure that any internal and external changes are correctly responded to. The adaptation phase is a response to the issues in the case study that were not addressed by having a more proactive stance on possible changes that impact the supply chain system. In relation to continuous development, prioritization is also part of the adaptation phase, which is tied to the goals of the implemented blockchain framework. To ensure that the system would have minimal issues regarding prioritization, the MosCoW method is used as a means to identify the greatest to least priority features and components for the blockchain system [31].

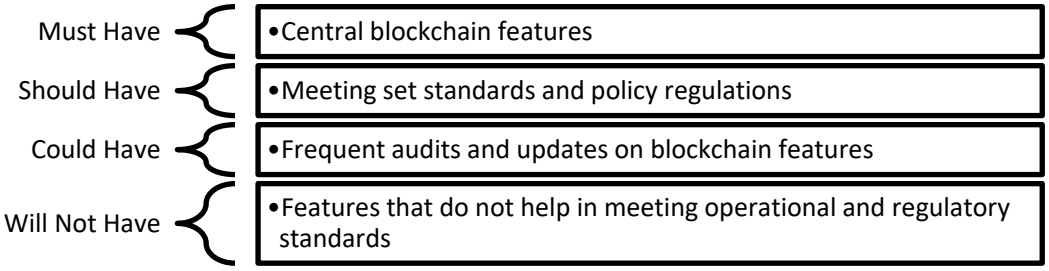

Fig. 4. Application of MoSCoW method to case study

As the case study involves numerous issues during and after the implementation of the blockchain framework, the proposed strategy would be to maintain focus on the central blockchain system and develop external linkages to expand the network, similar to how the MOHBSchain model operates. In this way, the blockchain architecture is clearly determined and would remain intact even after new features are introduced as a response to various needs and demands. This system would also allow agile sprints to be more targeted as to what features and changes should be prioritized.

5.3. Difference in Approach

The method of solving the problems in the identified case study would be through the revision of how the project is managed and how blockchain is introduced and integrated with existing supply chain systems. The proposed project framework emphasizes the timeliness of updates and the gradual process of blockchain adoption to mitigate tension with existing and future stakeholders within the supply chain system as these are viewed to be among the main reasons why blockchain frameworks tend to have issues and lead to having less impact than expected [32].

One of the main differences in approach would be the focus on building upon the central blockchain and its features, which aims to address organizational immaturity. A central blockchain reduces overall complexity during the start of the implementation phase as it is designed to allow fewer disruptions and minimal transition needed from the old to the new system. Moreover, urgent issues involving lack of knowledge or training on the use of the new system could immediately be added as a priority task in the agile method as sprints are conducted during set periods but are open to being changed depending on the immediate needs [33]. Compared to the original approach used in the case study, the use of a central blockchain limits the immediate need for additional infrastructure as it allows the system to operate with the least possible resources needed for the blockchain framework to function. As a result, dependencies are limited during the implementation phase, which also limits the overall complexity of the project and allows for greater focus on improving key features in the early stages and slowly building improvements after the central blockchain has been integrated into the system.

External resistance is considered to be a constant threat to the implementation and operation of blockchain integration into supply chain systems due to its large scope and impact. In the case study, the focus on external resistance involved industry stakeholders, rival businesses, and an overall lack of commitment, which are often considered to be behavioral in nature but could be addressed through the use of direct involvement in the intervention step as well as the quality audits that force new specifications to

be made in relation to the supply chain system's operation [34]. The introduction of a new step as a part of the integration process as well as, the operations of the supply chain system is viewed to be integral in reducing tension from external resistance by building trust through continuous engagement. Unlike the approach in the case study, this proposed strategy of including interventions across different stages allows for active participation and the provision of insights from various stakeholders to maintain a clear goal for the project's direction as it matures over time. Lastly, the perceived obstacles are handled directly through the agile method as operational efficiency can be improved through prioritization of key features and tasks while increasing complexity is addressed by the incremental growth of the project and its required technology. The project phases are meant to allow for proper planning of requirements before blockchain integration, reassessment of priorities during the blockchain implementation phase, and reassessment of goals during the adaptation phase to allow the various stakeholders to have ample opportunities to intervene and ensure that expectations are being met.

6. Implications and Limitations of Proposed Framework

The proposed framework intends to provide an improved experience to supply chain companies while handling a blockchain integration project, leading to multiple implications related to improved timeliness and availability of resources to address obstacles encountered. The proposed framework utilizes the agile model for project management, thereby serving as a timely response to the common issues identified and experienced during blockchain integration. Through the use of the proposed framework, there would be a better understanding of how entry-level barriers to blockchain adoption could be addressed based on an understanding of the technological, managerial, and behavioral aspects involved during the process. While the proposed framework does not guarantee to be a panacea that would resolve all issues, it is viewed as a means to delve further into the process of increasing both blockchain adoption and blockchain integration effectiveness within supply chain systems.

The limitation of the study is that it involves the theoretical application of the Supply-Blockchain framework to the identified case study. In practice, it is expected that multiple other factors such as geopolitics, administrative and logistical challenges would have a significant impact on an operational level, particularly when proposed changes are introduced. Moreover, each case study is viewed to be unique and independent of the other hence, there are multiple scenarios that could not be covered by the study. The focus on identifying each factor would not be possible without a significant amount of data for further analysis, which is not part of the scope of this study, but is deemed to be relevant nonetheless.

7. Conclusion and Future Work

The proposed framework explores the idea of standardizing how blockchain integration and adoption could be conducted not only for supply chains but also for other industries. The focus on addressing issues from a holistic perspective can be seen as an important aspect of capturing attention and building trust toward blockchain technology, particularly for industries that need to heavily commit to changes for the transition to be successful. By providing both project management strategies and proposed blockchain architecture to support the implementation process, the proposed framework could provide an initial blueprint as to the other unexplored factors that need to be taken into consideration for blockchain technology to be more accessible to industries that are likely to become late adopters. Integrating agile approach into the unified framework helps improve efficiency of blockchain integration, particularly for shortening the period needed to enjoy the perceived benefits.

Future studies may focus on the impact of the proposed framework for blockchain integration, particularly during integration and implementation. While the unified framework helps with integration, it does not particularly focus on key features needed for integration to be more effective and have a greater impact. Once the initial success rate for blockchain integration increases due to common issues being resolved more often, certain complex issues are expected to arise during deployment, which would require further improvements to the core framework to adapt to changing needs and demands of the supply chain environment.

Conflict of Interest

The authors declare no conflict of interest.

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