The Application of Blockchain Technology to Optimize Supply Chain Transactions

DIEGO TORRES MARTÍN, University of Twente, The Netherlands

Modern supply chains must adapt and innovate to remain agile in this ever-changing market. In the existing literature, many supply chain management methodologies have been proposed to achieve efficiency, while few technologies have actually been discussed. This research paper aims to explain how supply chains can benefit from incorporating blockchain technology to optimize their daily business transactions. It is through smart contracts within blockchains that supply chain transactions can become efficient and robust by providing trust, transparency, and accountability for the network. The approach follows an in-depth multi-analysis that evaluates the stakeholders involved, along with the driving and restraining forces, followed by the the strengths, weaknesses, opportunities, and threats of implementing blockchain technology in supply chain networks. With these conclusions and further research, the authors have developed a detailed framework (validated by three field experts) that serves as a guide for management practitioners and researchers considering the implementation of blockchain technology to optimize supply chain transactions.

Additional Key Words and Phrases: Blockchain Technology, Supply Chain, Smart Contracts, DLT, SCM, BCT, FBCTSCM

1 INTRODUCTION

Currently, studies show how inefficiencies and fraud in supply chains cause losses of more than $1 trillion across industries, each year, around the world [30]. Blockchain technology emerges as the solution to mitigate 70% of these losses in supply chain operations [3]. The World Economic Forum (WEF) states that "Reducing supply chain barriers to trade could increase GDP by nearly 5% and trade by 15%" [62], and such can be done via IT technological solutions like blockchain and smart contracts, as pointed out by [34]. Furthermore, as claimed by Harvard Business Review: "Blockchain could dramatically reduce the cost of transactions and, if adopted widely, reshape the economy" [37], thus enabling the optimization of supply chain transactions through the application of blockchain technology.

Blockchain technology can be defined as a decentralized digital, secure, immutable, and transparent ledger that allows for the recording of transactions within a network of parties [57]. Each transaction is approved through consensus mechanisms and added to the bookkeeping ledger as a block, creating a digital chain of transaction blocks. By remaining tamper-proof, it ensures trust, transparency, and security without relying on third-party intermediaries [2]. This allows blockchain to gain popularity as the way to go for different industries and applications, e.g. supply chain management.

Supply chains can be defined as the interconnected journeys from raw materials extraction and collection to manufacturing and assembly of goods to the sale and distribution of end products to customers [1]. In addition, all the processes, resources, and stakeholders involved must be managed accordingly to ensure effective supply chains; known as supply chain management (SCM). Its main goal is to optimize the coordination of the network within and across companies [32]. In this way, SCM continues to innovate through new technological integrations such as blockchain, to achieve the full optimization of supply chain (global) networks.

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2 PROBLEM STATEMENT

Traditional supply chain transactions suffer from a lack of efficiency and optimization as they struggle to ensure trust among the different parties involved, as they lack transparency and information-sharing, while relying on processes filled with bureaucracy, making it costly and time-consuming for all.

Dilemmas such as prepayment versus postpayment in supply chains exemplify the complexity and pitfalls of traditional supply chain transactions. This dilemma questions whether the resources and goods demanded should be delivered by the supplier (seller) before or after the payment is completed by the buyer. In fact, this is a challenge of trust with respect to who makes the first move. Solutions to this dilemma have been examined and tested, yielding positive results only for specific conditions, hence creating restrictions for its applicability in limited contexts and situations. Trade credit is one of these solutions as proposed by [19] where the supplier takes the risk of allowing for the delivery of goods on credit to the buyer [38]. With this approach, risk and liquidity trade-offs are present along with uncertainty. Different challenges remain to ensure trust and to fulfill the interests of both parties.

Transparency and information-sharing also become important concerns and challenges for traditional supply chain transactions. Studies by Harvard Business Review Analytic Services [48] who have surveyed 779 global executives, have shown that 90% claim that increasing business transparency leads to better informed decision making, 55% claim that ethical and commercial considerations are key when evaluating different suppliers, and 26% claim that transparent finance and procurement leads to 11% to 20% cost savings. Furthermore, the survey demonstrates how executives and professionals that have already applied this transparency and visibility are already benefiting from greater employee engagement, better reputation, and higher revenue growth [10]. Furthermore, 60% also stated that lack of transparency and visibility is a significant source of risk [10, 48]. In this way, a direct correlation exists between an organization's transparency and success. Therefore, research shows that transparency and information-sharing are key to remain competitive and resilient in supply chain management.

The high levels of inefficiencies in traditional SCM practices are also growing, as is the complexity of such practices. These traditional supply chain processes suffer from manual work, endless bureaucratic procedures, long lead times, risk management challenges, and limited use of technologies, making transactions time consuming and costly [27]. According to the Harvard Business Review executive survey, 45% of executives revealed that their manual processes lead to incomplete data entry with negative results and consequences [48]. In this way, it is essential to transition to modern supply chain management techniques to remain competitive, reduce waste and costs, and grow in a highly demanding supply and demand market.

2.1 Goals:

Taking the problem statement as the basis, we formulate the following two goals for our research:

(1) **Goal 1**: Develop a complete framework for enterprises to implement blockchain technology to optimize their supply chain operational transactions.
(2) **Goal 2:** Exemplified the driving and restraining forces, along with the strengths, weaknesses, and opportunities of implementing blockchain technology in supply chain networks.

2.2 Research Questions

Following the problem statement and goals, we formulate two main research questions for our research.

(1) **Primary RQ:** How can the application of blockchain technology in business operations serve to effectively optimize day-to-day supply chain operational transactions?
(2) **Secondary RQ:** To what extent do strategic and operational values and outcomes, as a result of the application of blockchain technology in optimizing supply chain transactions, outweigh both business risks and technological risks derived from the novelty of this technology?

3 PRACTICAL CONTRIBUTION

The two main takeaways from this thesis research paper are the following: First, blockchain technology can optimize supply chain transactions due to the benefits outweighing the challenges involved. Second, the implementation of blockchain technology to optimize supply chain transactions can be accomplished through the proposed theoretical framework, FBCTSCM (Framework for Blockchain Technology and Supply Chain Management). In this way, this research paper should serve as guide for management practitioners and researchers in the fields of blockchain and supply chain who are considering the implementation of blockchain technology to optimize supply chain transactions.

4 METHODOLOGY

For this research, we have applied different methods: First, we have designed diagrams and analyzes to illustrate the stakeholders involved in supply chains, along with the driving and restraining forces for the adoption of blockchain technology, and without overlooking the strengths, weaknesses, opportunities, threats, and internal potential drawbacks of such a technological implementation. Second, we have developed a well-governed, highly agile, multi-stakeholder collaborative hybrid framework based on blockchain technology, supply chain management, and IT project management to guide the implementation of blockchain in supply chains. All of these methods have been applied to answer the research questions and fulfill the established goals by exemplifying the application of blockchain technology to optimize supply chain transactions.

4.1 Framework Development

The primary research question was answered by developing an extensive and in-depth framework in which steps to implement blockchain technology in supply chain networks were laid out to optimize daily business transactions. This framework was then theoretically validated by three field experts through semi-structure interviews. The framework considers three aspects: blockchain technology, supply chain management, and IT project management. This way, the well-governed, highly agile, multi-stakeholder collaborative hybrid framework focuses on the adoption of blockchain technology and smart contracts for the optimization of supply chain transactions.

4.2 Diagrams & Analysis

The secondary research question was answered by conducting a triangulation literature review consisting of the analysis of scientific and academic publications in a structured way through queries, then with a cross-industry scattered approach, and finally with a focused approach for real life case-studies and simulations. These triangulation literature review has helped to develop a Stakeholder Analysis, a SWOT Analysis, and a Force-Field Analysis to showcase the stakeholders involved along with the driving and restraining forces, in addition to the strengths, weaknesses, opportunities, and threats of implementing blockchain technology in supply chain networks.

5 RELATED WORK AND ADDITIONAL KNOWLEDGE

Taking into account the problems outlined in section 2, research conducted has not only proven the existence and consequences of the problem, but also aimed at solving these problems through different methods and approaches. However, this research is currently independent and scattered.

SCM has been extensively reviewed and with different suggestions for improvement ranging from implementing roadmaps [19] to innovating through the implementation of technology [27]. It is one of these niche technologies that researchers are starting to focus on due to its positive benefits; blockchain. Although new, a great deal of research has been conducted on blockchain and its potential in different fields, mainly crypto. Few research has been oriented towards the application of blockchain to supply chains, and even less into the actual business transactions within supply chains. Interestingly, research demonstrates how blockchain applications (especially in supply chain contexts) remain at an 'infancy' stage [23]. This fact is supported by the data analysis conducted by [14] that revealed that by 2023, only 15 % of global supply chains had implemented blockchain-based smart contracts.

In addition, smart contracts serve as the bridge between supply chain transactions and blockchain-integrated technology. Smart contracts can be defined as digital agreements written in code, with predefined terms that enable autonomous execution once the conditions are met and verified [4]. In this way, blockchain and smart contracts have the potential to replace traditional bureaucracy, leading to efficient supply chains with optimized business transactions.

Further research shows how the application of blockchain-based smart contracts has a negative correlation with supply chain (administrative) inefficiencies [14]. The analytical results demonstrate how the adoption of smart contracts within supply chain blockchains reduces the delay and processing times of transactions by 40% [14]. In addition, compliance costs for companies drop by 25%, resulting in significant cost savings [14]. Furthermore, such adoption leads enterprises to reduce their fraud-related losses by 30%, thus effectively mitigating fraud [14]. In this way, the application of blockchain-based smart contracts within supply chains can effectively optimize business transactions. This is accomplished by ensuring trust among the different parties involved, with full transparency and legitimate information-sharing, while significantly reducing the (traditional) bureaucratic processes, allowing for cost and time savings in supply chain transactions.

6 FINDINGS

This section covers the findings of subsection 4.1, subsection 4.2 outlined in section 4. The steps taken in each subsection as well as the findings are explained in more detail, including an overall discussion.

6.1 Triangulation Literature Review

The triangulation literature review consisted on analyzing 27 scientific and academic publications (found in subsection 9.3) in a structured way searching for keywords in Scopus, Web of Science, and Google Scholar, with queries such as TITLE-ABS-KEY (("Blockchain" AND "Supply Chain*") AND (benefits AND challenges OR obstacles OR challenges OR opportunities OR drawbacks OR enablers OR advantages OR barriers OR limitations)) and reviewing the publications with the highest number of citations. Then, a scattered research was conducted investigating the relationship between blockchain technology and supply chain management in different SCM industries. Lastly, a case-study research was conducted, where real-life applications and simulations of blockchain technology application in supply chains were evaluated highlighting positive and negative process implementation outcomes. With this triangulation literature review, insights into the Stakeholder Analysis, full development of the Force-Field Analysis, and further breakdown of the SWOT Analysis were able to demonstrate how strategic and operational values and results, as a result of the application of blockchain technology in optimizing supply chain transactions, outweigh both business risks and technological risks derived from the novelty of such technology.

6.1.1 *Stakeholder Analysis*

A Stakeholder Analysis [44] was developed to show who are the stakeholders typically involved in a supply chain and what their power and interests are on it. The evaluation of strategic and operational values and results, along with the business and technological risks derived from such an adoption, can only be understood by first understanding the key players who benefit and suffer from such a complex technological implementation. In this way, the following stakeholder mapping (see Figure 1) helps visualize the stakeholders with whom negotiations must be performed and agreements signed for a successful blockchain implementation for a supply chain transaction optimization.

The Stakeholder Power-Interest Matrix (see Figure 1) exemplifies the classification of each stakeholder in the supply chain based on their power and interest derived from the insights gathered from the triangulation literature review in (subsection 9.3) and [15, 16, 21, 52]. Depending on how much power or influence they can exercise in the supply chain, along with how much interest they have in their participation, they are placed in one of the four quadrants; drivers, blockers, defenders, and bystanders (as identified by [46]). Each quadrant suggests different management and communication approaches that must be established to ensure proper collaboration.

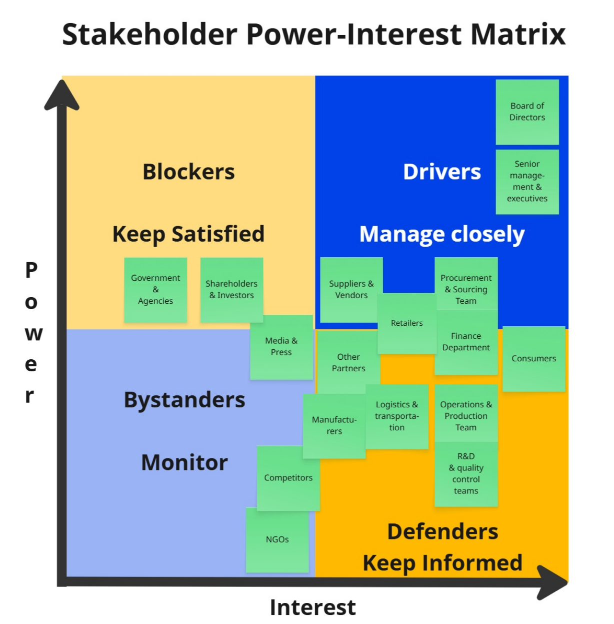

Fig. 1. Stakeholder Power-Interest Matrix Analysis in Supply Chains

Drivers (upper right quadrant in Figure 1) tend to have high levels of power and high levels of interest in the supply chain. In this way, they are required to be closely managed as they are considered influential and important players for collaboration. Their expectations must be met, as they tend to be key decision-makers with a great impact on the success of new (technological) project implementations, such as blockchain technology in supply chains.

Blockers (upper left quadrant in Figure 1) also tend to have high levels of power, but their interest in the supply chain tends to be low. Due to their influence, their needs and expectations should be met, even if they're not actively engaged. When their needs are satisfied,they can positively use their power to benefit and support the entire supply chain network. At the same time, if their needs are ignored, they can become serious obstacles, causing disruptions in the supply chain.

Defenders (bottom right quadrant in Figure 1) tend to have low power but high interest, requiring an effort to keep them well informed. Although their power is not high, their high interest can be leveraged for good as they can become helpful throughout new (technological) project implementations. In this way, it is recommended to keep them actively engaged and informed, by setting meetings where their main issues can also be communicated and dealt with to ensure effective collaboration.

Bystanders (bottom left quadrant in Figure 1) tend to have low power and low interest in the supply chain, which requires periodic monitoring. Due to their low interest and low power status, they do not suppose a main threat at a first glance, but their actions can become radical and have consequences for the supply chain over time. In this way, they must be periodically monitored with some information sharing to keep them informed of their role in the supply chain and ensure the necessary collaboration when needed.

The Power-Interest Stakeholder mapping along with their role description found in subsection 9.5 helps to understand who are the key players in a supply chain and what their roles encompass. In this way, when a new (technological) project is performed, such as implementing blockchain technology to optimize supply chain transactions, their collaboration and commitment are essential for success. Therefore, actively communicating with them and involving them (based on their power and interest) in the project development journey can contribute to leveraging the strengths and opportunities, while mitigating the weaknesses and avoiding threats. In addition, a blockchain implementation would require a change and adjustment of their role in the supply chain. Therefore, prior communication with respect to changes in dynamics would help them understand and adapt to their new roles, always considering their valuable input. With this, effective collaboration could be achieved, aiding in the successful implementation of blockchain ecosystems in supply chains.

6.1.2 *Force-Field Analysis*

A Force-Field Analysis [59] was developed to quantitatively demonstrate how the adoption of blockchain technology in supply chains can help optimize transactions, as great benefits can be obtained, while challenges remain to be tackled. In general, despite the identified business and technological risks when adopting blockchain technology in supply chains, the strategic and operational values, outcomes, and benefits to be achieved, significantly outweigh the risk and challenges, hence driving such technological implementation for achieving the desired optimization.

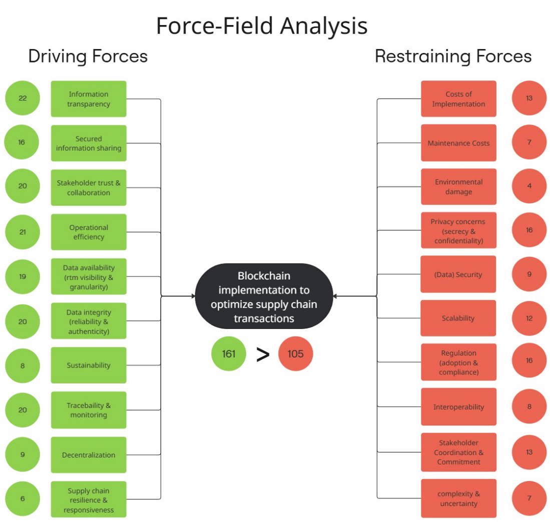

Fig. 2. Blockchain implementation for optimization of supply chains Force-Field Analysis

The Force-Field Analysis (see Figure 2) conducted via a triangulation literature review (explained in subsection 6.1) quantitatively presents the identified driving forces and the restraining forces currently found in the implementation of blockchain technology within supply chains. The driving forces are composed of the enablers, benefits, opportunities, and advantages that drive the implementation of blockchain in supply chains. At the same time, on the opposite side, the restraining forces are composed of challenges, drawbacks, limitations, and barriers that restrict the implementation of blockchain technology in supply chains. In this way, the Force-Field Analysis exemplifies how a greater number of scientific and academic publications, as well as case-studies, agree on the key elements that drive the blockchain implementation in supply chains, while fewer and more scattered publications exemplify the constraints for implementation. Hence, quantitatively demonstrating how the driving forces are considerably greater than the restraining forces for implementing blockchain technology in supply chains. In this way, based on literature, it is evident that the benefits, enablers, opportunities, and advantages of implementing blockchain in supply chains are much more discussed and examined, proving that the implementation of blockchain technology in the supply chain is becoming a prominent topic with more drivers and positive outcomes identified than challenges or obstacles.

By diving in detail into the Force-Field Analysis, a set of ten main driving forces and another set of ten main restraining forces were identified. Each unique force was assigned a number corresponding to the number of examined publications that agreed and mentioned such force. In this way, in the driving forces category, the main positive forces (the highest number of publications mentioning such) driving the implementation of blockchain in supply chains (detailed in subsubsection 9.6.1) were: information transparency, operational efficiency, stakeholder trust and collaboration, traceability and monitoring, data integrity (including reliability and authenticity), data availability (including real-time visibility and granularity), secured information sharing, decentralization, sustainability, and supply chain resilience and responsiveness, respectively. Similarly, in the category of restraining forces, the main negative forces (the largest number of publications that mention such) that restrict the implementation of blockchain in supply chains (detailed in subsubsection 9.6.2) were: regulation (including adoption and compliance), privacy concerns (including privacy and secrecy of data), stakeholder coordination and commitment, initial implementation costs, scalability, (data) security, interoperability, costs of maintenance, complexity and uncertainty, and environmental damage, respectively. This way, the force-field analysis shows how the driving forces outweigh the restraining forces by 56 points (161 to 105 respectively) where the point system makes reference to the aggregation of publications mentioning driving or restraining identified forces. With this, future research and analysis can be performed to determine the impact of each driving and restraining force in each independent industry.

Understanding the driving and restraining forces in the implementation of blockchain technology to optimize supply chain transactions can help managers understand and evaluate the main benefits and challenges of such technological implementation, identified in this Force-Field Analysis. With these considerations, they can approach the FBCTSCM in a more considerate way.

6.1.3 *SWOT Analysis*

A SWOT Analysis [28] was developed to exemplify the strategic and operational values and outcomes, along with the business risks and technological challenges derived from the implementation of blockchain technology in supply chains. Through the triangulation literature review, these values, outcomes, risks, and challenges were identified through the strengths, weaknesses, opportunities, threats, and internal potential drawbacks derived from such technological implementation. From this analysis, based on the individual organization's considerations, a further internal evaluation of each identified factor of the five SWOT dimensions could be performed as a form of cost-benefit analysis to determine if the strengths and opportunities actually outweigh the weaknesses and threats of implementing a blockchain ecosystem in the respective supply chains.

Fig. 3. Blockchain implementation for optimization of supply chains SWOT Analysis

The SWOT Analysis (see Figure 3) displays a further breakdown of the Force-Field's driving and restraining forces into four categories: Strengths, Weaknesses, Opportunities, and Threats. This breakdown allows organizational management to clearly distinguish each individual force and categorize it in its appropriate quadrant. Moreover, the findings of the triangulation literature review suggested the introduction of an additional quadrant denoted Internal Potential Drawbacks as part of this SWOT analysis.

The strengths quadrant within the SWOT Analysis (further explained in subsubsection 9.7.1) is composed of: information transparency, secured information sharing, improve stakeholder trust, better operational performance, data availability, data integrity, traceability, and decentralization. These strengths can be leveraged by organizations through the effective implementation of blockchain technology in supply chains, thus optimizing transactions and generating added value as benefits.

Then, the weaknesses of such implementation must also be considered to properly balance-out the positive and negative advantages and challenges that come with it. These weaknesses (detailed in subsubsection 9.7.2) include: high initial investment costs, maintenance and operational costs, privacy concerns for stakeholders involved, environmental damage, IT infrastructure complexity, interoperability with legacy systems, technology immaturity, and scalability. By properly understanding the weaknesses in advance, organizations can take proactive measures to address them effectively, reducing the risk of disruption, and improving overall performance. In this way, by understanding the strengths and weaknesses involved in the implementation of blockchain technology in supply chains, strategic clarity can be derived to leverage advantages and address shortcomings.

In addition, opportunities and threats also play a role in the implementation of blockchain technology in supply chains. The opportunities that can be achieved from this implementation (detailed in subsubsection 9.7.3) are: learning from pilot programs, digitalization, fraud and counterfeit elimination, disintermediation, integration with regulatory bodies, common standards and protocols, positive sustainability impact, and stakeholder commitment. These opportunities would help achieve a smoother implementation, while contributing to the overall global growth of the blockchain in the supply chain.

Then, considering possible threats is key to ensure proper risk management and, if necessary, mitigation, to avoid negative repercussions, even after a successful implementation. The identified threats (detailed in subsubsection 9.7.4) are the following: stakeholder commitment, negative sustainability impact, lack of specific regulation, lack of technological standardization, resistant culture to change, data accuracy due to (human) error, lack of technological knowledge, and cyberattacks. By identifying these threats, management can proactively develop risk management plans to mitigate any potential risks arising from these threats in the implementation of blockchain technology in supply chains.

Lastly, internal potential drawbacks must also be taken into consideration as potential limitations for the implementation of blockchain technology in the supply chain due to the organization's (wishing to perform such implementation) current nature. These internal potential drawbacks (detailed in subsubsection 9.7.5) include: organizational immaturity, organizational readiness, financial resources, technological know-how, necessity, and confidence. By properly considering whether these drawbacks are or are not applicable, organizations can make better decision-making when learning about what it takes to implement blockchain technology to optimize supply chains.

With this in mind, the SWOT Analysis conveys a clear picture of the categorization of strengths, weaknesses, opportunities, threats, and internal potential drawbacks for the implementation of blockchain technology in supply chains. With such a comprehensive view, better informed decision-making can be achieved before, during, and after the implementation of blockchain technology to optimize supply chain transactions.

6.2 Framework: FBCTSCM

As identified and pointed out in the Force-Field Analysis as well as the SWOT Analysis, the complexity and uncertainty along with the lack of standardization supposes important barriers for the implementation of blockchain technology in supply chains. Therefore, a novel, well-governed, highly agile, multi-stakeholder collaborative hybrid framework was developed to become part of the few early theoretical standards to be applied for the implementation of blockchain technology in supply chain optimization.

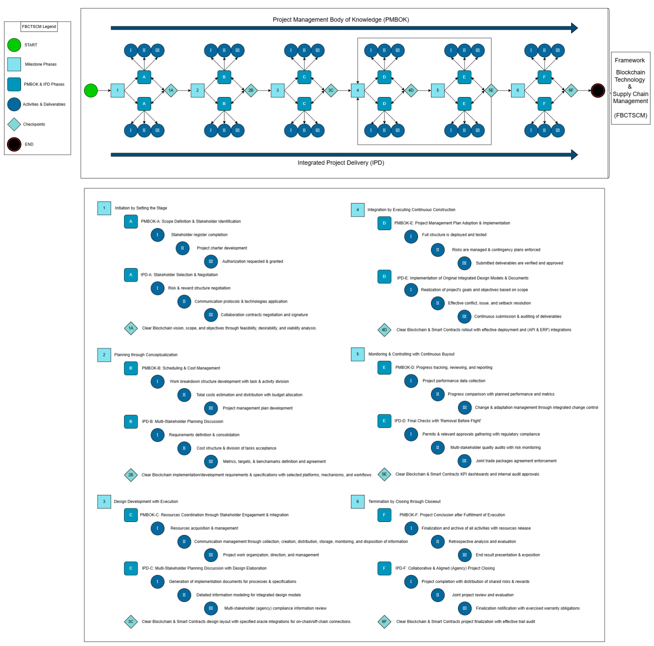

Fig. 4. FBCTSCM Framework

In this paper, we have developed the FBCTSCM (Framework for Blockchain Technology and Supply Chain Management), (see Figure 4). A well-governed, highly agile, multi-stakeholder collaborative hybrid framework focused on the adoption of blockchain technology and smart contracts for the optimization of supply chain transactions. The framework considers both the traditional standard Project Management Body of Knowledge (PMBOK) Framework [24, 47] and the lean Integrated Project Delivery (IPD) [7, 58] collaborative project delivery model. It is designed to effectively and efficiently guide enterprises through the different steps and considerations required to implement modern technologies such as blockchain and smart contracts into their respective industry to optimize their business transactions arising from the established supply chain network. We believe this approach combines the best of both project development and integration worlds that blockchain technology adoption requires due to its complexity and multi-party involvement arising from today's global supply chain management.

The FBCTSCM was designed to accommodate the best of both project management approaches, the traditional PMBOK and lean IPD. The end goal of this framework is to help enterprises looking to adopt blockchain technology to optimize their supply chain transactions, implement this technology through a robust and lean project management approach, meeting specific business goals and constraints such as scope, budget, schedule, and quality. The framework is further structured with the intention of being applied at all management positions, irrespective of the enterprise's organizational structure (hierarchical, flat, hybrid). For each management position, the framework shines light in a strategic, tactical, and operational way.

Strategical management positions benefit by looking at the blockchain implementation from a long-term perspective on the organizational changes that would happen along with the derived growth and benefits that will come with it to fulfill the organization's overall mission and vision. Hence, their commitment for taking the initiative and allocating the necessary organizational resources to the project throughout the different implementation and adoption phases is crucial. Then, tactical management positions benefit by understanding the coordination required for the successful blockchain implementation. By linking top-level organizational strategies with specific day-to-day development operations, they are capable of aligning the resources provided with effective planning for goal achievement through continuous project monitoring and stakeholder communication. Lastly, operational management positions benefit from understanding the required deliverables in every phase, thus focusing on their delivery through team management, productivity, and efficiency for the successful execution of daily operations.

The synergy of the PMBOK and IPD approaches in one allows for the optimal division of work using the specialized skills and experience of multiple project stakeholders who share responsibilities, risks, and rewards. This is achieved through the continuous involvement of all project stakeholders at all stages of development, from planning to design, to execution to completion. The framework is considered disciplined as each project stakeholder knows their role but contributes to the overall decision-making processes through joint project control mechanisms.

The nature of such a framework reveals how all involved stakeholders follow the same general goals of the project, as such goals take precedence over individual interests. It is through the limited but shared liability that all project stakeholders feel the need and responsibility to collaborate and work together for common goals to unlock the common benefits and mitigate mutual risks. The establishment of continuous and open communication through defined communication channels allows optimal use of the resources and capacities involved, allowing the right materials to be with the right person for the right job at the right time and place. The optimization of these resources belongs to the greater focus of this project management approach, by integrating people, systems, and business structures and practices altogether for optimal project success. By considering everyone's perspectives and through open but focus dialogues, project waste is removed from all phases and stages, leading to efficiency and lean optimization.

Safety, fairness, and respect are key cultural elements that apply to all stakeholders involved in ensuring trust in a positive workplace environment. Furthermore, the established open contribution culture not only allows for optimal planning and execution but also for optimal morale so that continuous optimal progress is achieved. In addition, an atmosphere with efficient communication and collaborative safe space environment allows for a flexible change management culture where necessary changes are proposed, discussed, and accepted or rejected, always following the best-for-project approach.

Therefore, with an appropriate implementation of the well-governed, highly agile, multi-stakeholder collaborative hybrid FBCTSCM, the common project management pitfalls are avoided, leading to successful blockchain and supply chain technological implementations. The careful and considerate project planning and design phases that involve all project stakeholders avoid missing deadlines along with failing to achieve the objectives for which the project was undertaken. The flexibility involved with the risk and reward mechanisms avoids cost overruns along with unnecessary and wasteful reworks. Then, the continuous collaboration of multidisciplinary stakeholder groups with the integration of people, systems, and business practices along with robust metrics, tools, and audits leaves no space for poor quality or unsatisfied stakeholders. In this way, the FBCTSM is ideal for technological projects such as blockchain and smart contracts adoption for supply chain optimization due to its multi-stakeholder collaborative environment and its risk diversification mechanisms, ensuring a successful technological project implementations within scope, schedule, budget, and quality.

7 DISCUSSION

7.1 Triangulation Literature Review

Learning and understanding the benefits of undergoing blockchain implementation in supply chains, along with familiarizing oneself with the technology, eliminates one of the most influential sets of barriers as claimed by [37, 41], technological unfamiliarity with an unclear perception of benefits. Therefore, the exemplified Stakeholder Analysis, Force-Field Analysis, and SWOT Analysis provide a strong basis for the implementation of blockchain technology to optimize supply chain transactions. However, the identified stakeholders, driving and restraining forces, strengths, weaknesses, opportunities, threats, and potential internal drawbacks are general and not industry or organization specific. They were obtained by comparing sets of scientific and academic literature from different industries and organizations. In this way, an organization wishing to implement blockchain technology in their supply chain must consider these analyses and develop their own, customized to their own specific industry, needs, and nature. Moreover, Table 9.5 helps to understand how stakeholders would have to undergo a shift in their roles as part of the blockchain implementation, which would affect all stakeholders in different ways.

Furthermore, a Cost-Benefit quantitative analysis is suggested to compare the organization's specific costs and benefits of undergoing such a technological implementation. The Cost-Benefit analysis to be performed can follow the step-by-step guide suggested by Harvard Business School [55] to determine whether or not specific perceived benefits significantly outweigh overall costs. Moreover, if the Cost-Benefit Analysis yields positive results toward the adoption of blockchain, a Risk-Assessment Analysis is recommended to outline the potential risks associated with the implementation of blockchain technology in supply chain optimization. A guideline with principles and frameworks is exemplified by the ISO-31000 international standard [33]. Subsequently, a contingency plan incorporating a clear mitigation strategy should be developed to ensure effective management and minimize potential impacts and consequences. Thus, a Cost-Benefit Analysis along with a Risk-Assessment Analysis serves as valuable additional tools to evaluate and manage the risks involved in adopting blockchain technology to optimize supply chain transactions.

7.2 SWOT Analysis

Interestingly, the first four threats of the SWOT Analysis can be combatted by the last four opportunities. Achieving multi-stakeholder commitment for the full implementation of blockchain in supply chains requires many upstream and downstream organizations and individuals to commit to such a project with purpose and shared goals [11, 54]. In the same way it can be considered a major threat if their commitment is negligible, it can also be considered a huge opportunity with many diverse benefits if their commitment is actually achieved [51, 65]. Therefore, depending on how it is handled and managed, it can serve as a threat or an opportunity.

Moreover, the implementation can have a negative sustainability impact due to the high levels of energy consumption required to run all the servers and machines in which the blockchain is deployed [20]. Hence, this adoption can be considered a significant environmental threat when implemented on a full scale. At the same time, the implementation can have a positive impact on sustainability by creating a positive social and sustainable organizational awareness when exemplifying innovation, digitalization, and traceability of goods through proven sustainable practices [26]. In this way, such an implementation can be regarded as both a positive and negative practice from a sustainability perspective.

Moreover, the absence of specific regulations poses a significant risk, as outdated or irrelevant legislation may be applied to blockchain implementations in the supply chain, potentially limiting their full potential [5, 6]. Therefore, to mitigate such threat, it is essential to collaborate with regulatory bodies to co-develop tailored legislation that supports innovation. Such partnerships could even be perceived as opportunities, by integrating regulators into the blockchain ecosystem itself, enabling shared benefits and fostering mutual trust [6, 17].

Furthermore, the lack of technological standardization of blockchain adoption and implementation can suppose a threat as mistakes and issues are certain to arise when testing multiple implementation methodologies, leading to higher project costs [39, 60]. Therefore, the opportunity to create common standards and protocols for the implementation of blockchain in supply chains can contribute to the development of best practices and support the advancements of this technology [17, 35]. An example of such an approach is the FBCTSCM.

7.3 FBCTSCM

Throughout the blockchain implementation for the optimization of supply chain transactions, the FBCTSCM covers and acknowledges the risk & reward sharing program explained in subsection 9.2. In this way, it is highly interesting to notice how an additional blockchain ecosystem can be implemented along with smart contracts in the actual blockchain implementation process. This external blockchain can help in effectively managing the risk & reward sharing program by tracking in real-time all the cash inflows and outflows of funds, while automating the payouts or penalties at the end of the implementation, ensuring transparency, automation, and real-time monitoring. Furthermore, there exist several academic and scientific publications where such a concept was discussed through in-depth literature reviews with multiple framework developments and use-cases [18, 31, 53]. This way, interesting enough, blockchain technology can be applied to implement blockchain technology as part of the risk & reward sharing program.

Upon completion of the FBCTSCM framework, three formal interviews with three different research experts in the fields of blockchain, supply chain, and IT project management were conducted to validate from a theoretical point of view, the clarity, completeness, usefulness, usability, applicability, adaptability, and effectiveness of this framework for the implementation of blockchain technology to optimize supply chain transactions. In general, positive feedback was received with new insights and suggestions for further improvements in the next upcoming versions of the FBCTSCM.

8 CONCLUSION

In conclusion, blockchain is a growing technology with the potential to optimize supply chain transactions. Among its many benefits, there also exist challenges that need to be overcome to achieve successful implementation. The multi-analysis performed in this research paper through a triangulation literature review has yielded both qualitatively and quantitatively results. First, it has shown who are the stakeholders involved in supply chains and how they relate to each other based on their overall power and interest in the supply chain, which demands new shifts in their current roles due to the characteristics of blockchain and smart contracts. Second, the main driving and restraining forces for the implementation of blockchain in the supply chain have been identified, along with their importance and relevance. Third, the forces have led to further identification of the strengths, weaknesses, opportunities, threats, and potential internal drawbacks commonly encountered in the adoption of blockchain technology in supply chains. In this way, the triangulation literature review has served as a basis for developing a Stakeholder Power-Interest Analysis, a Force-Field Analysis, and a SWOT Analysis which have successfully answered how strategic and operational values and outcomes, as a result of the application of blockchain technology to optimize supply chain transactions, outweigh both the business and technological risks derived from the novelty of blockchain technology.

Furthermore, the development of a novel, well-governed, highly agile, multi-stakeholder collaborative hybrid framework, FBCTSCM, provides a theoretical foundation as a potential standard to be applied for the implementation of blockchain technology in supply chain optimization. It provides a visual representation of the project management steps to be followed to achieve a successful implementation by understanding and following the milestones, phases, activities, deliverables, and checkpoints outlined in the framework. In this way, FBCTSCM can be used as a powerful tool to achieve the successful implementation of blockchain technology in business operations to effectively optimize daily supply chain operational transactions, which, as claimed in the introduction, can even increase GDP and trade, while reshaping the economy.

8.1 Limitations and Future Research

The following research paper sets the ground for future research areas on the implementation of blockchain technology in supply chains. Due to the scope and time constraints, further suggestions and improvements are suggested. First, the literature review conducted could be expanded with a larger number of relevant publications. At the same time, the identified driving and restraining forces, strengths, weaknesses, opportunities, threats, and internal potential drawbacks could be further evaluated in a quantitative scale of importance and impact based on formal interviews with stakeholders who have already deployed blockchain technology in supply chains, in the form of (at least) pilot programs.

Second, the application of the FBCTSCM in new real-life blockchain implementations for supply chain optimization would validate and evaluate the practical usability, usefulness, applicability, adaptability, and effectiveness of the framework. These dimensions have been theoretically evaluated and validated through three formal interviews with three different research experts in the fields of blockchain, supply chain, and IT project management. However, a practical evaluation via a real-life implementation would highlight future improvements for different sectors of the supply chain industry, as claimed by [60].

With regard to future research outside of the scope of this research paper, different suggestions are proposed. First, consider the application of blockchain technology to optimize supply chain sustainability to leverage the circular economy. According to [8], blockchain has the ability to detail a product's five dimensions: the nature (what is it), the quality (how it is?), the quantity (how much of it is there?), the location (where is it?) and the ownership (who owns it?). In addition, various organizations have already started to implement blockchain in the supply chain for sustainable purposes. Examples are Coca-Cola's blockchain application for waste collection in Africa or Elelctrolux's initiatives to recycle refrigerator products with blockchain. According to [8], their results demonstrate significant savings in reuse and product collection costs as they become enabling factors for the implementation of blockchain.

Second, the implementation of blockchain in supply chains can yield even more benefits if combined with other technologies such as RFID, IoT, or ML as exemplified in the case studies of [12] and [34]. Therefore, although blockchain and smart contracts are a technology in itself, their integration with other technologies can unlock additional capabilities such as efficient tracking, forecasting, and advanced analytics, yielding better informed decision-making in SCM [50].

Third, regulation (including adoption and compliance) has been identified as one of the main barriers to the implementation of blockchain technology in supply chains (as exemplified in Figure 2). As new regulations regarding blockchain and smart contracts approach, debates and dilemmas arise on whether such regulation should be law- or code-based. Although the law tends to be intentionally ambiguous to allow for case-specific applications, including exceptions and limitations, code is extremely rigid and strict, as it automates the application of legal standards, leaving no room for ambiguity, while removing any bias or corruption from the system [42]. Although code might lead to greater legal efficiency and transparency, it might also reduce the autonomy and freedom of individuals as reported by [22]. Therefore, further research and pilot implementations between researchers, technologists, and regulators must be conducted to determine whether blockchain and smart contracts regulation should be enforced in terms of law, code, or a combination of both.

9 APPENDIX

9.1 AI Notice

During the preparation of this work, the author used:
- Overleaf assistant in order to fix spelling and grammar mistakes, yielding proper sentence formation.
- ChatGPT and Copilot to fact-check simplified explanations of complex topics written by the author.
After using this tool/service, the author reviewed and edited the content as needed and takes full responsibility for the content of the work.

9.2 Risk & Reward Sharing Program

The FBCTSCM includes the adoption of a risk & reward sharing program among all the involved stakeholders. This collaborative financial structure comes particularly from the IPD collaborative model with the aim of aligning the interests of all project stakeholders [13]. Such a program works by sharing the financial risks and rewards of the implementation project at hand among the stakeholders. In practice, all the stakeholders together agree on a fix target project budget known as target costs agreement. Then, they assign an extra contingency fund that can become part of the shared risk pool or the shared reward pool. The shared risk pool encompasses the contingency fund plus extra overrun costs after the target costs budget was exceeded, hence requiring the stakeholders to add more funds based on their fair share. Similarly, the shared reward pool includes the contingency fund that wasn't needed plus the remaining target costs budget after the successful completion of the project, hence sharing such reward accordingly based on the established fair share formulas. This way, throughout the entire project, all the stakeholders are incentivize to collaborate and work together towards the realization of the shared reward tool, while avoiding personal interests as those lead to undesired consequences from the shared risk pool. More information regarding blockchain's implementation in the risk & reward program can be found at Section 7: Discussion.

9.3 Triangulation Literature Review

Table 9.3 shows the different scientific and academic publications reviewed as part of the triangulation literature review (see subsection 6.1).

Authors	**Title**	**Category**	**Citation Reference**
Cai et al.	The Impact of Perceived Benefits on Blockchain Adoption in Supply Chain Management	Structured Search with Query	[11]
Wang et al.	Making sense of blockchain technology: How will it transform supply chains?	Structured Search with Query	[61]
Saberi et al.	Blockchain technology and its relationships to sustainable supply chain management	Structured Search with Query	[49]
Mahyuni et al.	Mapping the potentials of blockchain in improving supply chain performance	Structured Search with Query	[39]
Esmaeilian et al.	Blockchain for the future of sustainable supply chain management in Industry 4.0	Structured Search with Query	[20]
Abdul et al.	Navigating Blockchain's Twin Challenges: Scalability and Regulatory Compliance	Structured Search with Query	[5]
Azzi et al.	The power of a blockchain-based supply chain	Structured Search with Query	[9]
Dutta et al.	Blockchain technology in supply chain operations: Applications, challenges and research opportunities	Structured Search with Query	[17]
Tribis et al.	Supply Chain Management based on Blockchain: A Systematic Mapping Study	Structured Search with Query	[60]
Younis et al.	Revolutionizing supply chain management: a critical meta-analysis of empowerment and constraint factors in blockchain technology adoption	Structured Search with Query	[65]
Gonczol et al.	Blockchain Implementations and Use Cases for Supply Chains-A Survey	Structured Search with Query	[26]
Kumarsingh et al.	Blockchain applications for secured and resilient supply chains: A systematic literature review and future research agenda	Structured Search with Query	[35]
Mathivathanan et al.	Barriers to the adoption of blockchain technology in business supply chains: a total interpretive structural modeling (TISM) approach	Structured Search with Query	[41]
Kumari et al.	Designing Supply Chain Management System Using Blockchain: A Review	Structured Search with Query	[36]
Malyavkina et al.	Blockchain technology as the basis for digital transformation of the supply chain management system: benefits and implementation challenges	Structured Search with Query	[40]

Authors	Title	Category	Citation Reference
Sternberg et al.	The Struggle is Real: Insights from a Supply Chain Blockchain Case	Scattered Research for Industry Specific: Mobile Applications	[54]
Sharma et al.	Blockchain Technology Adoption: Multinational Analysis of the Agriculture Supply Chain	Scattered Research for Industry Specific: Agriculture	[51]
Hamledari et al.	Measuring the Impact of Blockchain and Smart Contract on Construction Supply Chain Visibility	Scattered Research for Industry Specific: Construction	[29]
Agrawal et al.	Blockchain-based framework for supply chain traceability: A case study of the textile and clothing industry	Scattered Research for Industry Specific: Textile & Clothing	[6]
Samatrai et al.	Blockchain-enabled secured supply chain for smart cities: A systematic review on architecture, technology, and service management	Scattered Research for Industry Specific: Smart Cities	[50]
Mishra et al.	Blockchain adoption in automotive supply chain: A systematic literature review amalgamated with bibliometric analysis technique and future research directions	Scattered Research for Industry Specific: Automotive	[43]
Negi	A blockchain technology for improving financial flows in humanitarian supply chains: benefits and challenges	Scattered Research for Industry Specific: Financial Humanitarian	[45]
Abdulsatar	Blockchain technology adoption in food supply chains: key factors, impacts and challenges	Scattered Research for Industry Specific: Food	[56]
Gazzola et al.	Using the Transparency of Supply Chain Powered by Blockchain to Improve Sustainability Relationships with Stakeholders in the Food Sector: The Case Study of Lavazza	Case Study Luigi Lavazza S.p.A.	[25]
Xia et al.	The Effect of Blockchain Technology on Supply Chain Collaboration: A Case Study of Lenovo	Case Study: Lenovo Group Limited	[63]
Yiu	An Empirical Analysis of Implementing Enterprise Blockchain Protocols in Supply Chain Anti-Counterfeiting and Traceability	Case Study: dNAS Wine	[64]
Jensen et al.	How TradeLens Delivers Business Value With Blockchain Technology	Case Study: A.P. Møller – Mærsk A/S	[34]

Table 2. Triangulation Literature Review Table.

9.4 Stakeholder Analysis

The Stakeholder Power-Interest Matrix (see Figure 5) exemplifies the classification of each stakeholder in the supply chain based on their power and interest with the necessary information gathered from the triangulation literature review (see subsection 6.1).

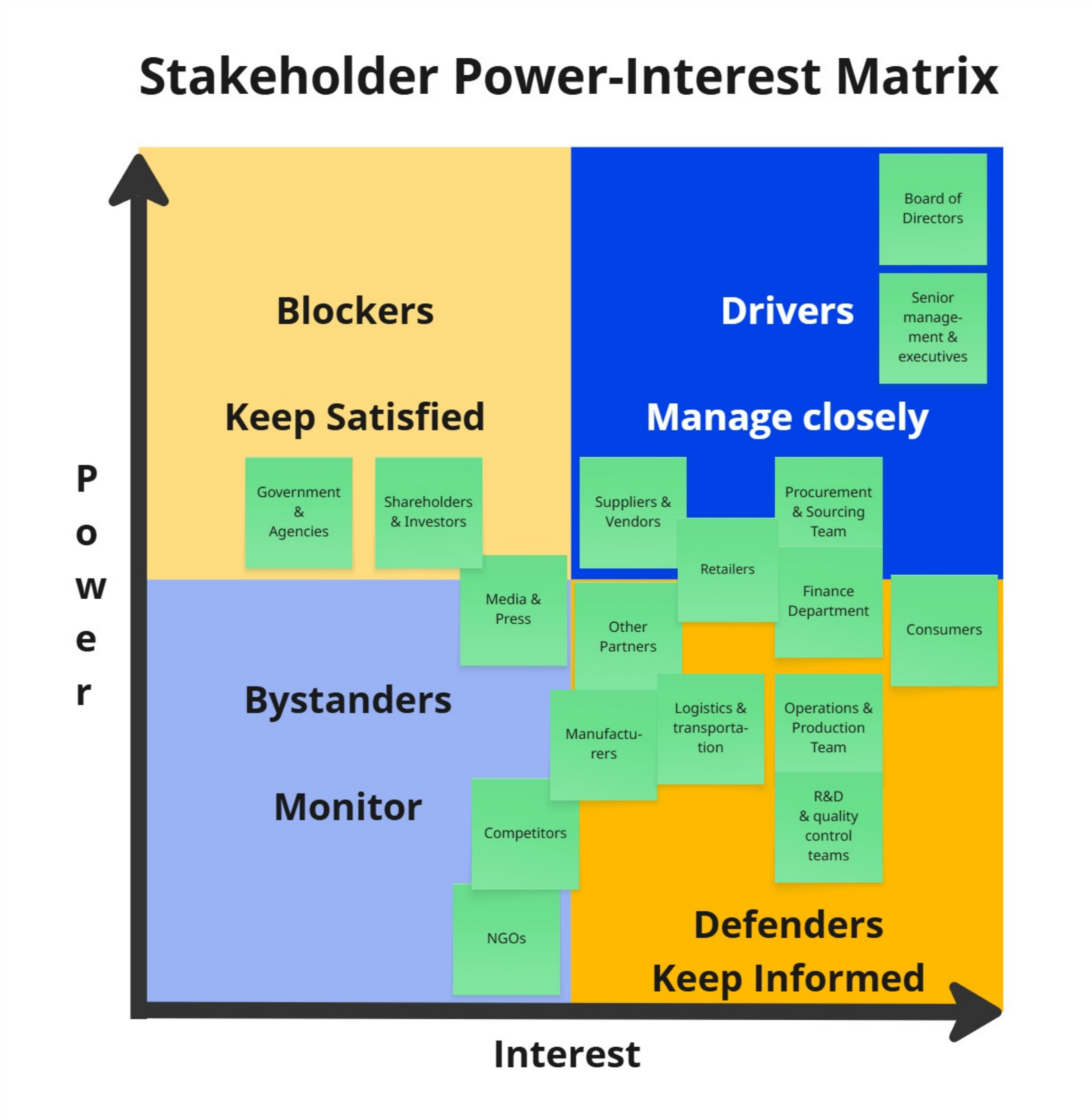

Fig. 5. Stakeholder Power-Interest Matrix Analysis in Supply Chains

9.5 Stakeholders' role division in supply chains

Table 9.5 exemplifies the role of each stakeholder in a supply chain context before and after the blockchain implementation. After such implementation, the role is adapted based on blockchain's requirements when optimizing supply chains with the necessary information gathered from the triangulation literature review (see subsection 6.1).

Stakeholders	**Role Description in Supply Chains**	**New Role after Blockchain implementation in Supply chains**
Board of directors	Hold meetings to discuss the strategic vision of the organization, while approving or disapproving investments in large projects.	Adapt current governance structures to also fit the needs of the blockchain implementation while overseeing blockchain's regulatory compliance and constantly defining risk management strategies due to the novelty of such technology.
Senior management and executives	Manage the resource allocation for every project, department, and division, while realizing the board's vision through clear KPIs and metrics.	Sponsor the implementation and adoption of pilot blockchain modules while managing performance dashboards, and facilitating training programs for technology usage and management.
Shareholders and investors	Their main role is to provide equity capital in return for dividends or shares that can the be sold as part of their return on investment (ROI) strategies as well as continuously evaluate investment opportunities.	In blockchain projects, they can financially support the project implementation and scale up based on their ROI assessments.
Procurement and sourcing team	They specialize in searching for the best suppliers as partners that offer the best competitive prices and contractual conditions, hence managing and monitoring the entire contractual and negotiation processes.	Leverage smart contracts design, signature, and execution through automation rules and off-chain negotiations.
Finance department	Manage the organization's accounts by processing invoices and payments.	Leverage smart contracts invoice validation and settlement through automation with real-time audits for potential required reconciliations.
Operations and production team	Manage production schedules via inventory planning and work-in-progress tracking.	Continuously manage production batches with automated hold or release orders via smart contracts automated ruling based on quality approvals or rejections.
R&D with quality control teams	Perform regular audits to certify the procedures for the testing of batches to ensure compliance with quality standards.	Record and publish the quality certificates on the blockchain, in a transparent and immutable way to ensure quality transparency.
Logistics and transportation	Manage and coordinate the entire distribution and shipping of materials and goods throughout the supply chain.	Record all the movement of goods throughout the supply chain in the blockchain ecosystem, while triggering automated payments and releases of goods based on smart contracts terms and conditions.
Manufacturers	Transform the obtained raw materials into actual goods and products while managing the manufacturing processes.	Record and link material processing and provenance certificates to ensure transparency, while sharing in real-time the production status for further partner's adjustments regarding inventory, ordering, shipping, and delivery.
Suppliers and vendors	Prepare and deliver upon the requested goods while tracking and forecasting.	Develop accurate predictive order forecasts based on on-chain transactional data while significantly reducing the bullwhip effect.
Retailers	Sell the end products upon delivery based on demand forecast and promotion planning.	Communicate and automate restocking accordingly via blockchain, while showcasing provenance and quality certificates to consumers.
Other partners	Provide additional services such as warehousing, IT, external audit and inspections, certification, etc.	Collaborate in the blockchain ecosystem by providing and recording audit results, certificates, and other records, while participating in automated smart contracts business settlements.
Consumers	Purchase the end products after considering necessity, urgency, pricing, quality, branding, etc.	Review quality checks, certificates, provenance, and environmental impact of products for informed purchasing
Government and agencies	Conduct inspections and audits to ensure compliance with regulations.	Access real-time data on the processes and state of goods to audit regulatory compliance in real-time.

Stakeholders	**Role Description in Supply Chains**	**New Role after Blockchain implementation in Supply chains**
Media and press	Perform reporting and research on sustainability claims, labor conditions, company disclosures, etc.	Fact check claims in real-time via the blockchain ecosystem while highlighting positive or negative practices and reducing misinformation.
Competitors	Compete for market share through pricing, quality, marketing, and service offering strategies.	Develop and respect agreed ethical best-practices through common standards for fair competition.
NGOs	Advocate for environmental protection, labour rights, ethical practices, etc. via audits, reports, and campaigns.	Verify and audit in real-time the business practices of organizations, suggesting improvements and collaborations for compliant certifications and credentials.

Table 4. Stakeholders' role division in supply chains before and after blockchain implementation.

9.6 Force-Field Analysis

Figure 6 exemplifies the Force-Field Analysis with (green) driving forces on the left hand side and (red) restraining forces on the right hand side, demonstrating how the driving force outweigh the restraining forces for the implementation of blockchain in supply chain based on the conducted triangulation literature review (see subsection 6.1).

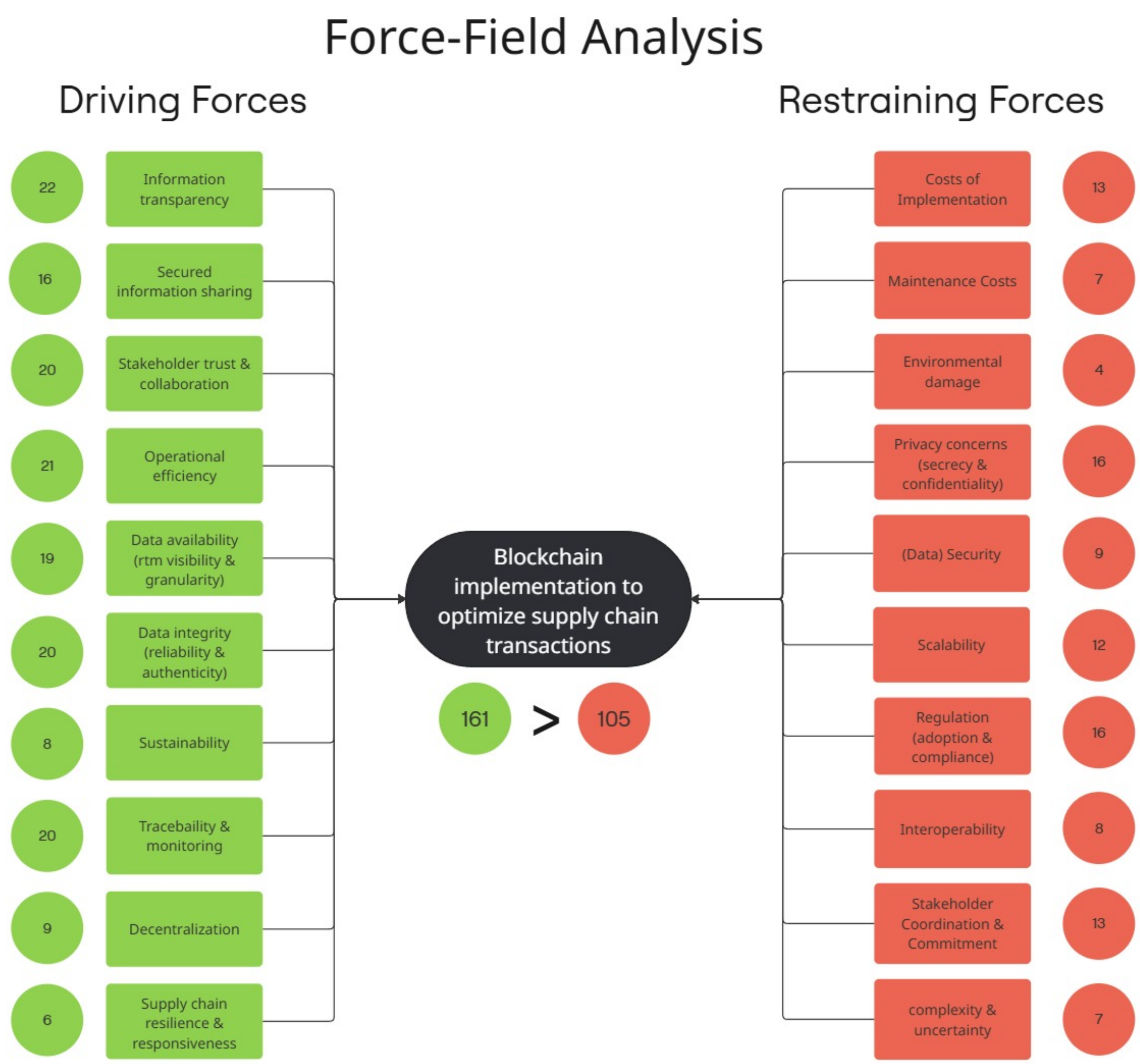

Fig. 6. Blockchain implementation for optimization of supply chains Force-Field Analysis

9.6.1 Driving Forces

Table 6 provides a description of each driving force identified in the Force-Field Analysis based on their relationship to the implementation of blockchain technology in supply chains with the necessary information gathered from the triangulation literature review (see subsection 6.1).

Driving Force	**Description**
Information transparency	The blockchain properties of shared and immutable ledger ensures that all stakeholders involved (with granted access) can follow the exact same real-time and unmodified (historical) transactional data, hence removing both information asymmetry and transactional data duplications providing clear and shared operations' oversight.
Operational efficiency	Achieved through the automation of contractual workflows through smart contracts that allow for the automated digitalization with a single source of truth allowing for efficient coordination and processes by significantly reducing lead times, eliminating manual routine paperwork, and resulting in significant reduction of costs.
Stakeholder trust and collaboration	The confidence on the authenticity and immutability of the transactional records due to the blockchain properties, leading to a higher number of shared data, such as inventory and demand forecasts, resulting in better coordination.
Traceability and monitoring	The end-to-end provenance tracking of transactional records and goods helps in detecting, attributing, and resolving faults, guaranteeing quality and compliance.
Data integrity (including reliability and authenticity)	The immutable nature of blockchain ensures that the data is properly recorded with cryptographic keys and algorithms and that every change or alteration is reflected and approved via the distributed consensus.
Data availability (including real-time visibility and granularity)	The replicated and distributed copies of the transactional ledger allow every involved stakeholder with permission to access at any-time the transactional history, and even integrate it with ERP systems for generating analytics and dashboards.
Secured information sharing	In supply chains, permissioned blockchains are the standard as they allow for role-based access control to ensure that the relevant data is only accessible to the relevant stakeholders, without limiting the quality of such data and its authenticity, as it can be verified through end to-end encryption, hashing, and other methods such as zero-knowledge proof.
Decentralization	Helps in ensuring that no central authority of control and failure exists, hence allowing for a shared and robust governance among the blockchain network.
Sustainability	Social and sustainable awareness is provided by sharing in a transparent way the proof or origin of goods, carbon-footprint records, eco-practices, and circular economy processes, which foster stronger relationships with the different stakeholders who aim for a greener future.
Supply chain resilience and responsiveness	The live visibility of all the transactions and actors helps in mitigating disruptions in real-time and providing alternatives through agile shifts due to the automation and efficiency of contractual arrangements through the smart contracts within the blockchain ecosystem.

Table 6. Force-Field Analysis Driving Forces for the implementation of blockchain technology in supply chains.

9.6.2 Restraining Forces

Table 8 provides a description of each driving and constraining force identified in the Force-Field Analysis based on their relationship to the implementation of blockchain technology in supply chains with the necessary information gathered from the triangulation literature review (see subsection 6.1).

Restraining Force	**Description**
Regulation (including the adoption and compliance)	The lack of specific regulation and legislation regarding blockchain and its implementation in supply chain makes it difficult to determine whether or not the adoption and implementation falls within the current regional, national, and international legislation, which often creates clashes and leads to uncertainty.
Privacy concerns (including privacy and secrecy of data)	Although transparency is one of the key drivers, an over-transparency risk also exists, leading the different stakeholders to question to what extent sensitive data must be made public in the shared ledger, as it can lead to secrecy exposure of which some stakeholders might take advantage when in comes to pricing or contractual arrangements.
Stakeholder coordination and commitment	The blockchain implementation only has an added value on the supply chain if the network joins and commits via a network inertia. Often, their exists differing incentives, interests, and risk appetites among the different stakeholders creating a barrier for the implementation.
Initial implementation costs	The costs of implementing such blockchain ecosystems tend to be really high, often requiring cost sharing mechanisms among the different involved stakeholders.
Scalability	The greater the number of actors and stakeholder involved from different countries, the more complex the supply chain is, hence requiring a global supply chain with recurrent transactions. This complexity becomes a burden to be managed without the correct people and infrastructure, along with technical challenges such as throughput limits.
(Data) security	Third party technological integrations can open doors for vulnerabilities and cyber-attacks, hence creating security risks to the whole blockchain ecosystem, including the data from all stakeholders, resulting in detrimental losses.
Interoperability	The lack of standards along with the (often) required integration with legacy systems, creates a barrier for the blockchain implementation, leading to improvisation and bridging solutions.
Costs of maintenance	Transactions are not free and hence result in added costs, on top of required software updates, security audits, and consortium governance meetings and reviews.
Complexity and uncertainty	The complexity lies on the IT infrastructure required along with the tailored and custom-made software to adapt to every supply chain industry and stakeholder. Moreover, the growth of blockchain novice platforms makes the choices of implementation uncertain.
Environmental damage	The power and electrical consumption to run the blockchain ecosystems results in detrimental effects for the environment.

Table 8. Force-Field Analysis Restraining Forces for the implementation of blockchain technology in supply chains.

9.7 SWOT Analysis

The SWOT Analysis (see Figure 7), provides a break-down of the Force-Field's driving and restraining forces into four categories: Strengths, Weaknesses, Opportunities, Threats, and an additional quadrant denoted Internal Potential Drawbacks with the necessary information gathered from the triangulation literature review (see subsection 6.1).

Fig. 7. Blockchain implementation for optimization of supply chains SWOT Analysis

9.7.1 SWOT Analysis Strengths

Table 10 provides a description of each Strength identified in the SWOT Analysis based on their relationship to the implementation of blockchain technology in supply chains with the necessary information gathered from the triangulation literature review (see subsection 6.1).

Strength	**Description**
Information transparency	The blockchain properties of shared and immutable ledger ensures that all stakeholders involved (with granted access) can follow the exact same real-time and unmodified (historical) transactional data, hence removing both information asymmetry and transactional data duplications providing clear and shared operations' oversight.
Secured information sharing	In supply chains, permissioned blockchains are the standard as they allow for role-based access control to ensure that the relevant data is only accessible to the relevant stakeholders, without limiting the quality of such data and its authenticity, as it can be verified through end to-end encryption, hashing, and other methods such as zero-knowledge proof.
Enhance stakeholder trust	The confidence on the authenticity and immutability of the transactional records due to the blockchain properties, leading to a higher number of shared data, such as inventory and demand forecasts, and resulting in better coordination.
Better operational performance	Achieved through the automation of contractual workflows through smart contracts that allow for the automated digitalization with a single source of truth allowing for efficient coordination and processes by significantly reducing lead times, eliminating manual routine paperwork, and resulting in significant reduction of costs.
Data availability	The replicated and distributed copies of the transactional ledger allow every involved stakeholder with permission to access at any-time the transactional history and even integrate it with ERP systems for generating analytics and dashboards.
Data integrity	The immutable nature of blockchain ensures that the data is properly recorded with cryptographic keys and algorithms and that every change or alteration is reflected and approved via the distributed consensus.
Traceability	The end-to-end provenance tracking of transactional records and goods helps in detecting, attributing, and resolving faults, guaranteeing quality and compliance.
Decentralization	Helps in ensuring that no central authority of control and failure exists, hence allowing for a shared and robust governance among the blockchain network.

Table 10. SWOT Analysis Strengths for the implementation of blockchain technology in supply chains.

9.7.2 *SWOT Analysis Weaknesses*

Table 12 provides a description of each Weakness identified in the SWOT Analysis based on their relationship to the implementation of blockchain technology in supply chains with the necessary information gathered from the triangulation literature review (see subsection 6.1).

Weakness	**Description**
High initial investment costs	The costs of implementing such blockchain ecosystems tend to be really high, often requiring cost sharing mechanisms among the different involved stakeholders.
Maintenance and operational costs	Transactions are not free and hence result in added costs, on top of required software updates, security audits, and consortium governance meetings and reviews.
Privacy concerns for stakeholders involved	Although transparency is one of the key drivers, an over-transparency risk also exists, leading the different stakeholders to question to what extent sensitive data must be made public in the shared ledger, as it can lead to secrecy exposure of which some stakeholders might take advantage when it comes to pricing or contractual arrangements.
Environmental damage	The power and electrical consumption to run the blockchain ecosystems results in detrimental effects for the environment.
IT infrastructure complexity	The complexity lies on the IT infrastructure required along with the tailored and custom-made software to adapt to every supply chain industry and stakeholder.
Interoperability with legacy systems	The lack of standards along with the (often) required integration with legacy systems, creates a barrier for the blockchain implementation, leading to improvisation and bridging solutions.
Technology immaturity	The limited toolchains, development tooling, debugging support, and frameworks result in careful blockchain implementations via experimental pilot projects.
Scalability	The greater the number of actors and stakeholder involved from different countries, the more complex the supply chain is, hence requiring a global supply chain with recurrent transactions. This complexity becomes a burden to be managed without the correct people and infrastructure, along with technical challenges such as throughput limits.

Table 12. SWOT Analysis Weaknesses for the implementation of blockchain technology in supply chains.

9.7.3 SWOT Analysis Opportunities

Table 14 provides a description of each Opportunity identified in the SWOT Analysis based on their relationship to the implementation of blockchain technology in supply chains with the necessary information gathered from the triangulation literature review (see subsection 6.1).

Opportunities	**Description**
Learning from pilot programs	They serve as testing environments where integration challenges are discovered and critical success factors identified for a lower future risk implementation.
Digitalization	Blockchain implementation can be a way of digitalization by providing a foundational layer supported with seamless connectivity between ERP integration, IoT devices, and even cloud platforms, supporting predictive analytics and even digital twin modeling. It further allows for automated documentation via smart contracts.
Fraud and counterfeit elimination	The blockchain nature combines immutability with traceability, allowing for tamper-proof transactional history that helps in authenticating product provenance, quality, and alteration, hence considerably reducing fraud and counterfeit.
Disintermediation	The act of eliminating unnecessary intermediaries, yielding positive results such as significant cost and price reductions as well as delays and lead times, hence empowering the relevant stakeholders resulting in higher operational efficiency.
Integration with regulatory bodies	The collaboration with regulators including governments and agencies optimizes the inspection and certification processes, as real-time compliance monitoring systems are in place with automated reporting , increasing data reliability, accuracy, and transparency.
Common standards and protocols	Shared standards create common data management processes and protocols that simultaneously comply with legislation and reduce frictions in the blockchain implementation due to better interoperability, leading to smoother and wider adoptions.
Positive sustainability impact	Social and environmental sustainable awareness can be spread through transparent carbon footprint accounting and circular economy mechanisms shared with the different stakeholders via the transparent data visualization in the blockchain ecosystem.
Stakeholder commitment	The blockchain implementation only has an added value on the supply chain if the network joins and commits via a network inertia. Often, their exists differing incentives, interests, and risk appetites among the different stakeholders that should be properly managed and aligned to ensure technological implementation success.

Table 14. SWOT Analysis Opportunities for the implementation of blockchain technology in supply chains.

9.7.4 SWOT Analysis Threats

Table 16 provides a description of each Threat identified in the SWOT Analysis based on their relationship to the implementation of blockchain technology in supply chains with the necessary information gathered from the triangulation literature review (see subsection 6.1).

Threats	**Description**
Stakeholder commitment	The blockchain implementation only has an added value on the supply chain if the network joins and commits via a network inertia. Often, their exists differing incentives, interests, and risk appetites among the different stakeholders creating a barrier for the implementation.
Negative sustainability impact	The power and electrical consumption to run the blockchain ecosystems results in detrimental effects for the environment.
Lack of specific regulation	The lack of specific regulation and legislation regarding blockchain and its implementation in supply chain makes it difficult to determine whether or not the adoption and implementation falls within the current regional, national, and international legislation, which often creates clashes and leads to uncertainty.
Lack of technological standardization	The different available options for implementing or adopting main blockchain platforms, data management models, consensus protocols, and APIs creates a wide variety that prevents common standard solutions, resulting in extra added costs for customization and integration that requires bridging solutions.
Resistant culture to change	The blockchain implementation in supply chains can be considered a radical technological shift that many risk-averse mindsets along with high dependency on legacy systems might create stakeholder resistance even before the implementation occurs.
Data accuracy due to (human) error	One the core features of the blockchain is the trust of data reliability and transparency that it provides. (Human) errors in data entry for transactions can cause mismatches and confusion that can be intensified by faulty off-chain input integrations.
Lack of technological knowledge	The complexity and infancy state of blockchain creates a blockchain shortage of architects, developers, and project managers, leading to longer implementation schedules with costs overruns.
Cyberattacks	Third party technological integrations can open doors for vulnerabilities and cyber-attacks, hence creating security risks to the whole blockchain ecosystem, including the data from all stakeholders, resulting in detrimental losses.

Table 16. SWOT Analysis Threats for the implementation of blockchain technology in supply chains.

9.7.5 SWOT Analysis Internal Potential Drawbacks

Table 18 provides a description of each Opportunity identified in the SWOT Analysis based on their relationship to the implementation of blockchain technology in supply chains with the necessary information gathered from the triangulation literature review (see subsection 6.1).

Internal Potential Drawbacks	**Description**
Organizational immaturity	The organization is not mature enough for such a radical innovation shift. Their governance structures might not yet be well-established, their decision-making processes might not be optimal, and a lack of cross-functional teams for the blockchain implementation might be lacking, creating difficulty in the implementation with unclear roles and slow approvals.
Organizational readiness	The organization is not ready yet to commit for such a complex and ambitious blockchain project. The internal working culture along with the established business processes might not be ready to accommodate such a shift, hence requiring previous restructuring to avoid vision misalignment along with strong resistance to change.
Financial resources	The organization might not have the required financial budget for the implementation or the organization might not be capable of raising such implementation budget from financing rounds, hence yielding insufficient funds that can result in a premature abandonment of the project, or an under-investment leading to lower quality and value.
technological know-how	The complexity and infancy state of blockchain creates a blockchain shortage of architects, developers, and project managers, leading to longer implementation schedules with costs overruns.
Necessity	A blockchain implementation to optimize supply chain transactions might not always be the right or best suitable technological solution for an organization. Many often perceive it as a need, instead of an actual "nice-to-have" solution, due to their characteristics and needs. Therefore, a detailed cost-benefit analysis for blockchain and other technologies is suggested to determine whether a necessity actually exists.
Confidence	A large and complex project such as the blockchain implementation in supply chains requires high levels of confidence from all involved stakeholders to avoid doubts in important decision-making processes, possibly creating undesired project sabotages.

Table 18. SWOT Analysis Internal Potential Drawbacks for the implementation of blockchain technology in supply chains.

9.8 Framework: FBCTSCM

The well-governed, highly agile, multi-stakeholder collaborative hybrid Framework (FBCTSCM) (see Figure 8) focusing on the adoption of blockchain technology and smart contracts for the optimization of supply chain transactions can be found below:

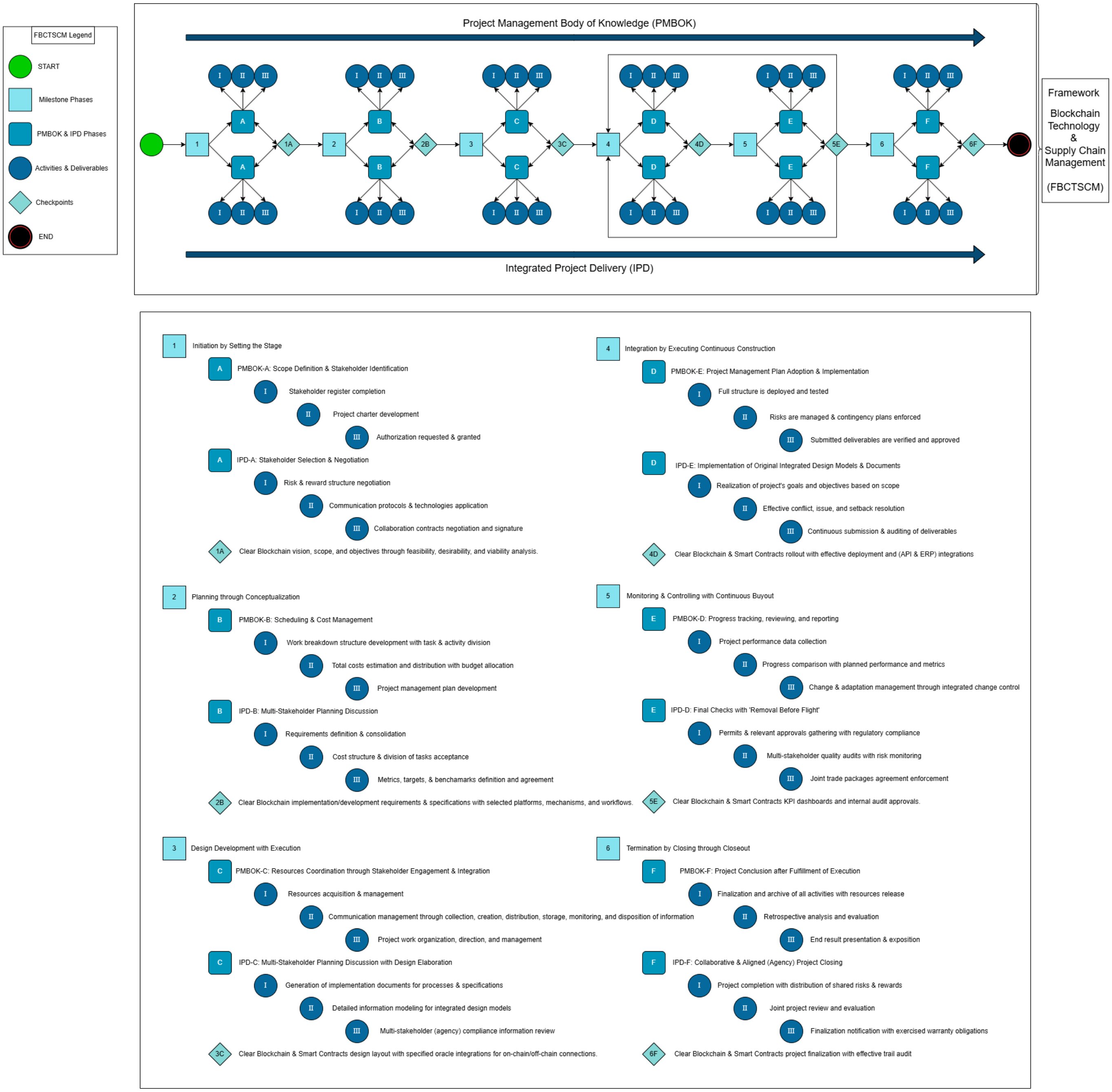

Fig. 8. FBCTSCM Framework

The FBCTSCM is structured into six different milestone phases numbered one through six with a squares shape. These phases are preceded and postceded by a start node(green) and an end node (black) with circular shapes respectively. Within each milestone phase, two new phases arise denominated by capital letters corresponding to the English alphabet and in the same index position as Arabic numerals count with rounded squared shapes. These phases are denominated PMBOK phase (top layer) and IPD Phase (bottom layer) as they make reference to each of the two frameworks in which the FBCTSCM is based upon. Following the PMBOK and IPD phases, the framework includes three main activities and deliverables per phase represented with circular shapes and chronological Roman numerals. Lastly, the integration of activities and deliverables within their respective PMBOK and IPD phases which are simultaneously integrated within the milestone phases conclude at their respective checkpoints denominated with rhombus shapes and the corresponding milestone phase Arabic numerals and PMBOK/IPD phases alphabetical English capital letters. The framework is complemented by two horizontal top and bottom arrows starting at the first milestone phase and concluding at the last checkpoint. They represent the flow of the framework by detailing how the top phases belong to the PMBOK based framework [47] [24], while the bottom phases correspond to the IPD based framework [58] [7]. Furthermore, it is important to notice how milestone phases four and five follow a chronological flow as the whole framework does but with the addition of an iterative added flow represented by the arrows originating at the fifth checkpoint and concluding at milestone phase two. This special combination of chronological flow and iterative procedure allows the fourth and fifth milestone phases to continuously build on each other as iterative loops due to the specific nature of such milestone phases. Finally, the FBCTSCM is complemented by a legend specifying the shape and naming convention of each framework element, and a rectangular container specifying the naming of each individual framework element, allowing for a clear and complete picture of the FBCTSCM.

9.8.1 *FBCTSCM Glossary*

Table 20 provides a description of each activity and deliverable within the PMBOK and IPD Phases, as well as checkpoints, as part of Milestone Phase One: Initiation by Setting the Stage.

Activity/Deliverable	Description	Phase
Stakeholder register completion	All the involved stakeholders are gathered together and a contract for participation is signed where their involvement and commitment to participate in the blockchain project implementation is clear.	PMBOK-A: Scope Definition & Stakeholder Identification
Project charter development	A formal document denoted as project charter is created by all the involved stakeholders outlining (but not limited to) the following aspects: project/implementation purpose, measurable objectives & success criteria, high-level requirements, description, boundaries, and deliverables, overall risks, milestone schedule, financial resources, key stakeholders list, project/implementation approval requirements & exit criteria, assigned roles and responsibilities, sponsors of the project/implementation.	PMBOK-A: Scope Definition & Stakeholder Identification
Authorization requested & granted	The stakeholders participating in the implementation ask and receive the authorization of their respective organizations to conduct and actively participate in the project providing the necessary resources based on their respective fair share.	PMBOK-A: Scope Definition & Stakeholder Identification
Risk & reward structure negotiation	Collaborative financial structure in which the financial risks and rewards of the implementation project are shared among the stakeholders. All the stakeholders together agree on a fix target project budget known as target costs agreement. Then, they assign an extra contingency fund that can become part of the shared risk pool or the shared reward pool. The shared risk pool encompasses the contingency fund plus extra overrun costs after the target costs budget was exceeded, hence requiring the stakeholders to add more funds based on their fair share. Similarly, the shared reward pool includes the contingency fund that wasn't needed plus the remaining target costs budget after the successful completion of the project, hence sharing such reward accordingly based on the established fair share formulas.	IPD-A: Stakeholder Selection & Negotiation
Communication protocols & technologies application	The different ways in which communication would be established throughout the project implementation are determined. This might include email, whatsapp, telegram, SMS, Slack, etc. along with how would meetings be set (weekly, monthly, physical, online, hybrid), and any other communication strategy and protocol required. Similarly, the technologies used would also be outlined, these include platforms and subscriptions for scheduling, communication, brainstorming, data sharing, etc.	IPD-A: Stakeholder Selection & Negotiation
Collaboration contracts negotiation and signature	All the involved stakeholders negotiate their fair share of their participation in the project implementation. The terms, conditions, risk, and rewards are discussed and negotiated until agreements are reached and the collaboration and commitment contracts are signed by all the parties.	IPD-A: Stakeholder Selection & Negotiation
Clear Blockchain vision, scope, and objectives through feasibility, desirability, and viability analysis.	Different analysis are conducted by all the stakeholders to determine whether the blockchain implementation is feasible in terms of resources and complexity, whether the implementation is desirable meaning if there is an actual need for it, and whether it is viable and the benefits outweigh the costs. Then, if this analysis proves to be positive, the blockchain implementation vision, scope and objectives are clearly laid down and agreed by every stakeholders involved.	Checkpoint

Table 20. FBCTSCM: Milestone Phase One: Initiation by Setting the Stage.

Table 22 provides a description of each activity and deliverable within the PMBOK and IPD Phases, as well as checkpoints, as part of Milestone Phase Two: Planning through Conceptualization.

Activity/Deliverable	**Description**	**Phase**
Work breakdown structure development with task & activity division	A planning for the project implementation is developed via tool such as Gantt Charts and Activity Work-down Diagrams where the different tasks, jobs, and activities to be performed throughout the implementation are laid down with their corresponding teams, time-frame, resources, and dependencies.	PMBOK-B Scheduling & Cost Management
Total costs estimation and distribution with budget allocation	A fixed budget is set upon discussion with all stakeholder based on the required costs to conduct the successful blockchain project implementation.	PMBOK-B Scheduling & Cost Management
Project management plan development	A project management plan is drafted among all the involved stakeholders with the following (but not limited to) details: scope, requirements, schedule, costs, quality, resources, communications, risk, procurement, stakeholder engagement, change management, configuration management, performance measurement, project life cycle, and development approach.	PMBOK-B Scheduling & Cost Management
Requirements Consolidation & definition	The requirements are drafted in the form of functional, non-functional, and quality requirements along with user stories, to outline and consolidate the necessary implementation project requirements.	IPD-B: Multi-Stakeholder Planning Discussion
Cost structure & division of tasks acceptance	The potential costs incurred in the project implementation are derived and estimated based on the desired scope, schedule, budget, and quality. The costs adapt to the allocated budget by all stakeholders, and not the other way around (this is due to the risk & reward mechanism explained in subsection 9.2). Furthermore, scheduling is conducted by creating tasks and assigning it to the different stakeholders to be accomplished throughout the project implementation.	IPD-B: Multi-Stakeholder Planning Discussion
Metrics, targets, & benchmarks definition and agreement	The previously defined costs and tasks must be continuously monitored via a set of established metrics with benchmarks as thresholds, and targets as motivators.	IPD-B: Multi-Stakeholder Planning Discussion
Clear Blockchain implementation/development requirements & specifications with selected platforms, mechanisms, and workflows.	The Blockchain requirements are clearly outlined and agreed upon all the stakeholders involved. The platforms to host the blockchain are selected. Along with this, the mechanisms and workflows that determine how the blockchain would be run and behave are decided and agreed upon for its next developments and implementation.	Checkpoint.

Table 22. FBCTSCM: Milestone Phase Two: Planning through Conceptualization.

Table 24 provides a description of each activity and deliverable within the PMBOK and IPD Phases, as well as checkpoints, as part of Milestone Phase Three: Design Development with Execution

Activity/Deliverable	Description	Phase
Resources acquisition & management	The previously outlined and agreed upon resources, necessary for the completion and implementation of the blockchain project, are acquired via deals and agreements. Then, they are set into motion with close management for their successful implementation and execution.	PMBOK-C: Resources Coordination through Stakeholder Engagement & Integration
Communication management through collection, creation, distribution, storage, monitoring, and disposition of information.	Clear and efficient predefined communication channels allow the information to flow through all involved stakeholders along the entire duration of the project implementation. This information is obtained and distributed by stakeholders via designated channels. Then, the information is stored and archived appropriately for future reference.	PMBOK-C: Resources Coordination through Stakeholder Engagement & Integration
Project work organization, direction, and management	After previously determining the roles and responsibilities of each involved stakeholder, the project work is further organized and manged via close monitoring and evaluation of the established metrics, by providing clear direction and further management.	PMBOK-C: Resources Coordination through Stakeholder Engagement & Integration
Generation of implementation documents for processes & specifications	The documents concerning the implementation with the appropriate designs and models are generated with the input of all the involved stakeholders. These documents also include diagrams to simplify and visualize concepts such as transactional processes, mechanisms, and specifications.	IPD-C: Multi-Stakeholder Planning Discussion with Design Elaboration
Detailed information modeling for integrated design models	The following integrated design models are collaborative and evolving digital representations of the end blockchain software to be implemented with its structured software, data flows, and management mechanisms and functionalities. They provide a sort of visual digital twin on how would the end-result look-like providing detailed information from different perspectives and allowing all stakeholders to contribute and collaborate on such design models.	IPD-C: Multi-Stakeholder Planning Discussion with Design Elaboration
Multi-stakeholder (agency) compliance information review	Once the designs and implementation documents are completed, they must be reviewed for compliance purposes. This review takes place in big rooms style discussion with representatives from external stakeholders affected by such blockchain implementation whose feedback and suggestions is well received. This way, the project ensures to bear internal and external collaborative compliance.	IPD-C: Multi-Stakeholder Planning Discussion with Design Elaboration
Clear Blockchain & Smart Contracts design layout with specified oracle integrations for on-chain/off-chain connections.	At the end of this milestone, the blockchain checkpoint ensures that the oracle integration has been discussed and planned in detail with a clear overview on who are going to be the assigned oracles and what are going to be their responsibilities. Furthermore, the information store on-chain versus the information stored off-chain is designed and greed upon with mechanism that allow for it such as external secure databases. This way, with the selected oracles in place along with the on-chain and off-chain designed connections, the monitoring and controlling phase along with the integration and execution phases can simultaneously begin.	Checkpoint

Table 24. FBCTSCM: Milestone Phase Three: Design Development with Execution

Table 26 provides a description of each activity and deliverable within the PMBOK and IPD Phases, as well as checkpoints, as part of Milestone Phase Four: Integration by Executing Continuous Construction.

Activity/Deliverable	**Description**	**Phase**
Full structure is deployed and tested	The physical project implementation actually takes place at this activity with the blockchain's full deployment. Moreover, phased testing is conducted to ensure that each deployed module works as expected and the full integration can later be successfully completed avoiding last minute costly errors and bugs that could have been detected earlier on through phased testing.	PMBOK-E: Project Management Plan Adoption & Implementation
Risks are managed & contingency plans enforced	As the project implementation and executions takes place, arising risks are monitored and managed accordingly, based on the established contingency plans and reserves to avoid as much delay, cost overruns, chaos, and disruptions as possible.	PMBOK-E: Project Management Plan Adoption & Implementation
Submitted deliverables are verified and approved	The different deliverables accomplished throughout the following phases based on the different tasks and activities, are completed and immediately submitted for peer revision by all relevant stakeholders to receive their proper sign-off based on the acceptance criteria drafted in the project management plan.	PMBOK-E: Project Management Plan Adoption & Implementation
Realization of project's goals and objectives based on scope	The following phases involves the actual fulfillment of the project implementation goals and objectives including technical, functional, and value-based as previously collaboratively designed and agreed upon based on the project implementation scope.	IPD-E: Implementation of Original Integrated Design Models & Documents
Effective conflict, issue, and setback resolution	Throughout the execution of the project implementation, different conflicts, issues, and setbacks might arise that require quick and effective collaborative resolution to avoid further negative consequences. Therefore, effective communication is key to resolve such arising conflicts in real-time with no delays and without compromising the project implementation goals.	IPD-E: Implementation of Original Integrated Design Models & Documents
Continuous submission & auditing of deliverables	Throughout the project implementation execution life cycle, the different deliverables are continuously and incrementally performed and submitted, reviewed, and further approved in a collaborative environment.	IPD-E: Implementation of Original Integrated Design Models & Documents
Clear Blockchain & Smart Contracts rollout with effective deployment and (API & ERP) integrations	This checkpoint assures that the blockchain implementation with smart contracts is incrementally rolled-out with appropriate testing and further integration with other platforms via secure API calls and ERP dashboards.	Checkpoint

Table 26. FBCTSCM: Milestone Phase Four: Integration by Executing Continuous Construction

Table 28 provides a description of each activity and deliverable within the PMBOK and IPD Phases, as well as checkpoints, as part of Milestone Phase Five: Monitoring & Controlling with Continuous Buyout.

Activity/Deliverable	**Description**	**Phase**
Project performance data collection	It involves gathering observations and measurements of the progress and state of affairs of the different activities and tasks of the implementation project, according to the schedule. It then helps to conduct further performance analytics to determine whether the project remains or not on track.	PMBOK-D: Progress tracking, reviewing, and reporting
Progress comparison with planned performance and metrics	After the performance data have been collected, it it is time to analyze it and gather further insights from it. This way, the progress data is compared to the the targets and goals established to determine whether the implementation project is going as planned or if some bottlenecks are arising. The pre-define metric help in objectively comparing such progress for further decision-making of the course of action.	PMBOK-D: Progress tracking, reviewing, and reporting
Change & adaptation management through integrated change control	Based on the performed analysis on project performance, new changes might be proposed and approved by all stakeholders regarding the implementation project's scope, schedule, budget, and quality. This changes are fundamental, and hence, require a detailed evaluation before approval.	PMBOK-D: Progress tracking, reviewing, and reporting
Permits & relevant approvals gathering with regulatory compliance	Due to the nature of such technological project implementation, regulation adoption and compliance is one the key critical areas. Therefore, the following activity focuses on acquiring and securing all the necessary legal and regulatory approvals and permits for a successful implementation. Compliance is key, and hence domestic and international regulation must be actively evaluated to ensure its full compliance.	IPD-D: Final Checks with 'Removal Before Flight'
Multi-stakeholder quality audits with risk monitoring	Collaborative reviews involving all relevant stakeholders are set in place to evaluate the quality and performance of the project from different project and stakeholder perspectives. Furthermore, with such evaluation, potential risks are detected and solutions drafted to mitigate such, before the implementation project is fully disrupted.	IPD-D: Final Checks with 'Removal Before Flight'
Joint trade packages agreement enforcement	The remaining stakeholders required to execute and finalize the implementation project (due to absence, sickness, and abandonment of previous ones) are looked for, while negotiation conversations take place to ensure their full commitment and participation in the implementation project by outlining individual as well as joint responsibilities.	IPD-D: Final Checks with 'Removal Before Flight'
Clear Blockchain & Smart Contracts KPI dashboards and internal audit approvals.	The following blockchain checkpoint deals with determining whether or not the different management dashboard have been properly established where analytics regarding the project implementation progress and metrics are outlined with the relevant KPIs. Furthermore, this checkpoint also evaluates whether or not internal audits have been successfully conducted and internal approvals have been granted for successful compliance. If the following is not the case, the another iteration is required to continue moving forward with the project implementation.	Checkpoint

Table 28. FBCTSCM: Milestone Phase Five: Monitoring & Controlling with Continuous Buyout

Table 30 provides a description of each activity and deliverable within the PMBOK and IPD Phases, as well as checkpoints, as part of Milestone Phase Six: Termination by Closing through Closeout.

Activity/Deliverable	**Description**	**Phase**
Finalization and archive of all activities with resources release	At this stage, the project implementation is completed and all essential records and documents from the project are properly archived for future reference. Furthermore, all the retained resources including people, materials, assets are officially release from the project due to its finalization.	PMBOK-F: Project Conclusion after Fulfillment of Execution
Retrospective analysis and evaluation	The retrospective session at the end of the project implementation, gathers all relevant stakeholders together to discuss and take note of the project's performance, decisions made, successes, and failures that happen throughout the project, with the objective of obtaining lessons learned for the future.	PMBOK-F: Project Conclusion after Fulfillment of Execution
End result presentation & exposition	At this point the final delivery moment comes, where the project implementation results, outcomes, and value-added elements are presented and showcased to all the internal and external stakeholders wishing for further commitment and collaboration in a near future.	PMBOK-F: Project Conclusion after Fulfillment of Execution
Project completion with distribution of shared risks & rewards	The project implementation ends, and the shared and reward contract is executed. This way, if the project implementation was successful and the scope, schedule, quality, and budget were met, then, the shared profits as part of the shared reward pool are release and shared proportionally among all the involved stakeholders, following the protocol and terms of the risk & reward sharing program. Otherwise, if at the end of the implementation project the scope, schedule, quality, and budget were not met, then, according to signed risk & reward sharing program, the accumulated overruns and costs must be shared among all the stakeholders based on their fair share. Furthermore, such process could potentially be automated via smart contracts. (For more information regarding the risk & reward program, see subsection 9.2).	IPD-F: Collaborative & Aligned (Agency) Project Closing
Joint project review and evaluation	The following activity encompasses a retrospective session with all the involves stakeholders throughout the project implementation where, looking back, the aspects of the project that did work, along with the ones that didn't are thoroughly discussed, along with team performance, communication protocols, workflows and further stakeholder relationships to note down lesson learned for future projects.	IPD-F: Collaborative & Aligned (Agency) Project Closing
Finalization notification with exercised warranty obligations	The project implementation has officially concluded and the transition to the warranty state is expected. At this point, the stakeholders involved define their new roles under the warranty contract, while detailing availability, responsibilities, and types of responses based on potential warranty claims or required support.	IPD-F: Collaborative & Aligned (Agency) Project Closing
Clear Blockchain & Smart Contracts project finalization with effective trial audit	The blockchain implementation project has concluded and now it is time to run the blockchain in an operational basis. For this, manuals of usage and training is given out by the respective stakeholders. Furthermore, a final test via a trial audit is performed with all stakeholders present to assure that the whole blockchain ecosystem works and functions as expected. From this point onwards, the blockchain ecosystem can run on its own while optimizing the supply chain transactions among the different stakeholders.	Checkpoint

Table 30. FBCTSCM: Milestone Phase Six: Termination by Closing through Closeout

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