A Proposed Framework to Implement Advanced Work Packaging (AWP) with the Support of Blockchain

Slim Rebai [1*], Olfa Hamdi [2], Zoubeir Lafhaj [1], Wassim AlBalkhy [1], Rateb Jabbar [3], Hamdi Ayech [1], Ahmed Moukhafi [1], Mohammed Chadli [1], Pascal Yim [1]

[1] Centrale Lille, CNRS, UMR 9013-LaMcube, Lille, France
[2] Concord Project Technologies, 1900 S. Norfolk St., Suite 350, San Mateo, CA, 94403, USA
[3] KINDI Center for Computing Research, College of Engineering, Qatar University, Doha, Qatar

*Corresponding Author: slim.rebai@centralelille.fr

Abstract

The construction industry faces persistent challenges around efficiency, transparency, and project performance. Advanced Work Packaging (AWP) offers a structured methodology to improve project outcomes through planning alignment and work packaging. However, AWP implementation itself encounters obstacles related to information security, access controls, and supply chain optimization. As an emerging technology with innate capabilities around decentralization, security, and transparency, Blockchain holds promise in addressing these barriers. This paper puts forth a framework for an integrated Blockchain-supported AWP system to enhance construction project delivery. The proposed three-stage framework maps key AWP activities in conceptual planning, detailed engineering, and site execution to Blockchain tools for strengthened information flows, analytics, and coordination. A case study of a firm's digitalization efforts provides real-world context. By bridging AWP and Blockchain, this research aims to spur innovation at the intersection of project management philosophies and next-generation technologies.

Keywords

Blockchain, AWP, Advanced Work Packaging, Construction Project Management, Framework

1 Introduction

1.1 Challenges in the Construction Industry

The global construction industry, pivotal to economic expansion, is experiencing unprecedented growth fueled by rapid urbanization and the increasing demand for infrastructure. However, this growth is hampered by persistent challenges such as cost overruns and pervasive corruption, which compromise the efficiency and integrity of large-scale construction projects[1][2][3][4]. These systemic issues highlight the critical need for innovative project management methodologies beyond traditional barriers to efficiency and transparency. These challenges indicate the necessity of integrating AWP with technologies capable of addressing these impediments.

1.2 Blockchain Technology: A Solution for AWP Challenges

Blockchain technology, characterized by decentralization, immutability, and enhanced transparency, presents a promising avenue to overcome these hurdles[7][8]. Integrating Blockchain with AWP can revolutionize construction project management, fostering greater efficiency, accountability, and trust among all stakeholders [9][10].

In addition to the benefits above, timestamps' immutability within the Blockchain is pivotal. This ensures that once a transaction or data entry is made on the Blockchain, the timestamp associated with this action cannot be altered, providing an unassailable record of every transaction. This permanence is crucial for construction projects where the timing of decisions, updates, and completions is vital for project scheduling, legal compliance, and dispute resolution. The Blockchain's ability to offer immutable timestamps enhances the reliability and integrity of project data, further solidifying the case for its adoption in managing and executing AWP workflows.

1.3 Synergistic Potential of AWP and Blockchain

This manuscript explores the synergistic potential of AWP and Blockchain within the construction industry, proposing a theoretical framework for their integration. It seeks to provide valuable insights for AWP practitioners, researchers, and Blockchain developers by examining existing applications, pinpointing challenges, and highlighting the transformative benefits of this integration. Ultimately, the paper advocates for adopting integrated AWP-Blockchain frameworks to significantly elevate industry standards, enhance project delivery outcomes, and usher in a new era of efficiency and transparency in construction project management.

The paper's structure articulates the fundamental principles of the AWP methodology, analyzes the advantages of Blockchain for construction project management, and provides a comprehensive overview of Blockchain's applications in the AEC (Architecture, Engineering, and Construction) field. It identifies specific AWP challenges that Blockchain can mitigate and proposes a framework for implementing Blockchain-supported AWP, underscoring the benefits of leveraging emerging technologies to refine and advance construction project management practices. The broader implementation of integrated AWP-Blockchain frameworks is a crucial strategy to enhance project efficiency, reduce costs, and build trust across the construction industry.

2 LITERATURE REVIEW

2.1 AWP

The AWP methodology originated from Workface Planning (WFP), one of the best practices developed to address challenges in oil and gas construction projects in Alberta, Canada[11]. The Construction Owners Association of Alberta (COAA) defines WFP as "the process of organizing and delivering all necessary elements, before starting work, to enable craft persons to perform quality work safely, effectively, and efficiently. This is accomplished by breaking down construction work into discrete work packages that fully describe the project scope to utilize resources and track progress efficiently" [11]. In 2011, a joint research initiative between COAA and the Construction Industry Institute (CII) aimed to review various methodologies including WFP to develop an integrated planning and execution model[12]. This research incorporated case studies, literature reviews, expert interviews, and experiential learning to create the AWP methodology[12][13].

The key principles of AWP include: collaboration between construction and engineering teams during planning to optimize project sequencing; breaking down overall project scope into construction work packages (CWPs) and engineering work packages (EWPs); early identification and removal of constraints; and integrated planning and work packaging over the entire project lifecycle[11][14]. The central AWP deliverable encompassing these tools is the Path of Construction (POC), prepared through multiple iterations of constraint analysis and sequencing reviews to determine optimal workflow. The POC guides the progression of construction activities from site preparation through mechanical completion and system turnover.

The AWP implementation process contains three main sequential stages:

1. **Conceptual planning** : to define work package deliverables at a high level and divide the project into CWPs aligned with overall execution strategy along with corresponding EWPs. This also involves charter alignment between all stakeholders.
2. **Detailed engineering** : to refine stage 1 work packages into detailed specifications, discipline-specific schedules, and multi-system integration alignment using three week lookahead processes.
3. **Construction planning and execution of installation work packages (IWPs):** issued 3 weeks before start and approved by frontline leads, with quality assurance by owner representatives throughout the build process.

While AWP significantly enhances project delivery outcomes, its broader application in the construction industry encounters several challenges. These include traceability issues, where tracking project progress and changes become cumbersome; security concerns related to safeguarding sensitive project data; and coordination difficulties among a wide array of stakeholders, leading to project inefficiencies [12][15]. These challenges not only hinder the optimal execution of AWP but also signal the need for innovative solutions to address these gaps.

2.2 Use of Blockchain in Construction

In response to these challenges, Blockchain technology emerges as a promising solution. Its features of decentralization, immutability, and enhanced transparency offer novel ways to address the critical issues identified in AWP implementations.

Recent research has examined the potential applications of Blockchain technology in the construction industry. Shojaei and San et al. initiated comprehensive inquiries into leveraging Blockchain for construction[16][17]. Nanayakkara et al.'s study provided insights into using Blockchain for smart contracts, supply chain management, and Building Information Modeling (BIM) systems, emphasizing Blockchain's ability to address persistent issues in construction like trust and transparency deficits and cumbersome administrative procedures[18]. Additional research by Kim et al. and Dakhli et al. examined Blockchain's profound influence on real estate dynamics and construction project management paradigms[19][20].

There has been growing advocacy for integrating Blockchain to improve engineering supervision information dissemination and data authenticity[21]. Zhao et al. emphasized the importance of offline functionalities and rapid synchronization in innovative frameworks like ChainPM for Construction Project Management Digital Twins[22]. Lu et al. proposed a pioneering trust-building Blockchain framework to facilitate technological and organizational advances in construction[23].

Through collective effort, research has revealed the symbiotic relationship between technological developments and supporting organizational frameworks. Table 1 proposes an overall overview of the potential application of the Blockchain in the construction industry.

Recent scholarship endorses Blockchain integration to enhance transparency, trust, data security, administrative efficiency, and information dissemination in the construction industry. Frameworks facilitating organizational change have been proposed to leverage technological capabilities fully. Continued cross-disciplinary collaboration is illuminating the immense potential of Blockchain applications in construction. Further research is needed to explore its applications in supply chain management, building information modeling, and contract management[24].

Blockchain's potential in construction extends beyond administrative efficiency to tackle AWP's challenges directly. For instance, its immutability and transparency enhance traceability, allowing for a secure and verifiable record of all project changes and updates. This directly addresses the traceability issue in AWP implementations. Furthermore, Blockchain's secure nature can significantly bolster information security, protecting against unauthorized access and data breaches. Lastly, smart contracts on Blockchain platforms facilitate improved coordination among stakeholders by automating and enforcing project agreements and tasks, thus addressing the coordination challenges within AWP frameworks.

Table 1. Use of Blockchain in Construction Industry

Year	Authors	Topic in Construction
2019	San et al.	Potentials, and Impacts for the Construction
2019	Nanayakkara et al.	Smart contracts, supply chain management, and BIM
2019	Dakhli et al.	Real Estate
2020	Kim et al.	Project Management Systems
2021	Akinradewo et al.	Applications for the construction
2023	Chen	engineering supervision information dissemination and data authenticity
2023	Zhao et al.	rapid synchronization in Construction Project Management Digital Twins
2023	Lu et al.	framework to technological and organizational advances in construction

Despite the theoretical benefits of integrating Blockchain within AWP practices, there is a notable gap in empirical research demonstrating this integration's real-world applications and benefits. The literature predominantly focuses on Blockchain's potential without providing detailed case studies or evidence of its practical application in overcoming AWP's specific challenges.

Therefore, future research should aim to bridge this gap by providing empirical evidence and detailed case studies on integrating Blockchain technology with AWP. Such research would validate the theoretical advantages discussed and offer practical insights into leveraging Blockchain technology to enhance AWP practices in the construction industry.

3 Proposed Solution

Blockchain technology has shown promise in addressing the myriad challenges faced by construction projects despite its early stages of development. This study proposes a flexible framework incorporating Blockchain technology into monitoring construction projects, utilizing the AWP methodology. A mixed-methods approach was employed to develop this framework, starting with a comprehensive literature review to identify the gaps in AWP practices. Successful implementations of Blockchain technology in similar industries were then analyzed, from which relevant strategies and technologies were extracted. Theoretical modeling was also utilized to tailor these findings to the specific needs of AWP in construction, ensuring that the proposed solution is both innovative and practical. This approach ensures that the framework is grounded in empirical evidence and is tailored to meet the unique challenges of the construction industry.

The Ethereum Blockchain was selected to develop the proposed framework due to its robust smart contract capabilities, widespread adoption, and active developer community. Ethereum's smart contract platform enables the automation of complex project management workflows, which is critical for implementing AWP effectively. The need for transparency and accountability in construction project management guided the decision to use a public versus private Blockchain architecture. Public Blockchains offer unparalleled transparency, allowing an immutable record of all transactions and interactions. However, considering the sensitivity of some project data, a hybrid approach was proposed, where Ethereum serves as the public layer for transparency, complemented by private, permissioned layers for sensitive information. This hybrid model ensures the security and privacy of critical project data while maintaining the benefits of transparency and immutability for auditability and trust.

Furthermore, the choice between permissioned versus permissionless systems was made to balance accessibility with control. A permissioned Blockchain layer, built on top of Ethereum's public network, allows project stakeholders to have controlled access and permissions tailored to their role in the project, enhancing security and efficiency in managing the supply chain and project workflows.

By integrating a hybrid Blockchain model combining Ethereum's public network with private, permissioned layers, this framework addresses the unique challenges of AWP implementation in construction projects. This approach leverages the strengths of both public and private Blockchain architectures, ensuring that the proposed framework is adaptable, secure, and capable of fostering trust among all project stakeholders.

As the AWP implementation encompasses three primary stages, this framework focuses on the initial and subsequent stages. It begins with receiving project confirmation from the client and initiating the project, as illustrated in Figure 1. The integration of AWP follows, involving the establishment of high-level work package deliverables through conceptual planning and dividing the project into Construction Work Packages (CWPs).

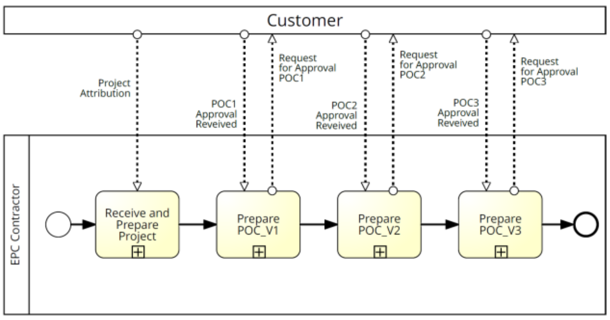

Figure 1: The principle of framework developed of the integration of the AWP by a support of Blockchain

In the conceptual planning stage, Blockchain technology can be applied to securely document and verify the establishment of high-level work package deliverables. Blockchain allows all stakeholders to access a tamper-proof and transparent record of the planning process, enhancing trust and accountability. For the division of the project into CWPs, Blockchain can facilitate real-time tracking and updates of work packages. Smart contracts automate the approval process of CWPs, ensuring that all relevant parties immediately reflect and approve any changes.

Detailed engineering then provides the specifications and discipline-specific schedules and aligns multi-system integration. The Blockchain is a decentralized repository for specifications and schedules during the detailed engineering stage. This secures the data against unauthorized changes and enables seamless multi-system integration, ensuring that all engineering work is accurately aligned with project requirements.

Termed collectively as the 'Path of Construction' (POC), this three-step process facilitates early contractor monitoring. The project manager manages multiple tasks, including data verification, risk assessment, internal departmental approval, regulatory/legal approval, and POC preparation over three versions. The 'POC' benefits from Blockchain through enhanced traceability and accountability. Each step of the construction process is recorded on the Blockchain, offering an immutable history of project progress. This facilitates early contractor monitoring and provides a reliable performance evaluation and dispute resolution basis.

This structured approach to detailing the implementation process will make the application of Blockchain technology within AWP more explicit, directly addressing the need for refinement and providing a comprehensive understanding of the proposed framework's benefits.

3.1 Current Scenario

The internal organizational procedures of the Project Design and Engineering department focus primarily on project management and oversight. Additionally, this department provides support services to other departments (Figure 1). When a project is transferred from a customer to the Project department, the customer also provides relevant inputs to facilitate the project workflow. The current workflow process relies heavily on manual email and physical document procedures. Each document possesses distinct properties and characteristics.

To critically evaluate this complex workflow and establish an improved framework, the Business Process Model and Notation (BPMN) 2.0 standard was utilized for modeling and visualization [25]. The analysis indicates substantial interconnections and integration challenges in terms of data management within the existing workflow process. Consequently, implementing a Blockchain-based platform could effectively digitize and streamline this process.

After outlining the existing project management challenges, including reliance on manual processes and the inefficiency of current digital tools, we propose specific Blockchain applications. For instance, Blockchain's decentralized nature allows for a unified platform that streamlines document management, risk assessment, and regulatory approvals, reducing reliance on manual email and document exchanges.

3.1.1 Receive and Prepare Project

Figure 2 illustrates that the study scenario commences with the Project Handover Phase. Upon project attribution, customers are notified and a Project Handover meeting is conducted, overseen by the Projects Sales Department (PSD). A well-defined handover format and a designated signatory for acknowledgment are established. The Project Manager (PM) emails the Project Handover meeting minutes in PSD format.

Upon receiving all project documents, the PM initiates the process of quantitative risk assessment. This evaluation considers technical, contractual, commercial, and environmental hazards. The risk assessment document is updated throughout the entire project, from execution to commissioning. The PM and the engineering team subsequently compile Pre-Qualification Submittals, Company Profile, Project Organization Chart, Professional License and ISO Certificates, QHSE documentation, Initial Design Drawings, and an updated Project Reference List.

The PM seeks internal verification from the Program Manager following the submission of Pre-Qualification Submittals. The Program Manager validates, reviews, and approves the Project Documents. Each revision incorporates additional Project Risk Assessments. Upon obtaining the customer's approval, the project manager proceeds to submit the Pre-Qualification documents to the third-party consultant responsible for issuing the legal Safety Authority Certificate required for Project Permit Approval.

All submitted documents undergo a thorough review process upon request for additional reviews. The Prime Minister collaborates with the consultant to make revisions until the Letter of Acceptance is received.

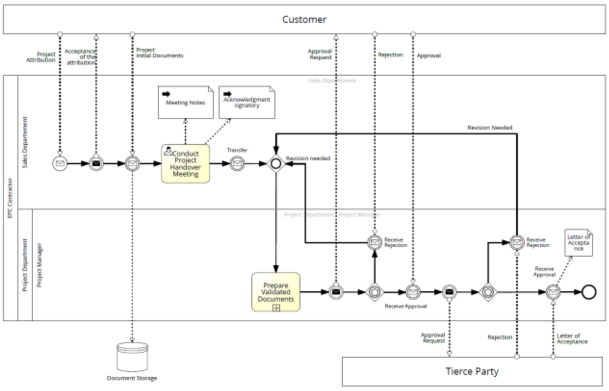

Figure 2: Receive and Prepare Project Process Modeling

3.1.2 Integrating AWP through POC

At this point, the process of integrating the AWP begins, focusing on its primary output, which is the Path Of Construction (POC). The POC will be developed in three iterations, each iteration providing an overview of the integration process and the necessary deliverables to achieve the desired outcome. The AWP Champion plays a crucial role in overseeing and coordinating all the processes at this stage of the AWP methodology implementation.

3.1.3 POC 1 : First iteration of POC

As depicted in Figure 3, the AWP Champion initiates the implementation of POC1 by requesting the Engineering Lead to create the conceptual drawings. Simultaneously, the AWP Champion commences three tasks:

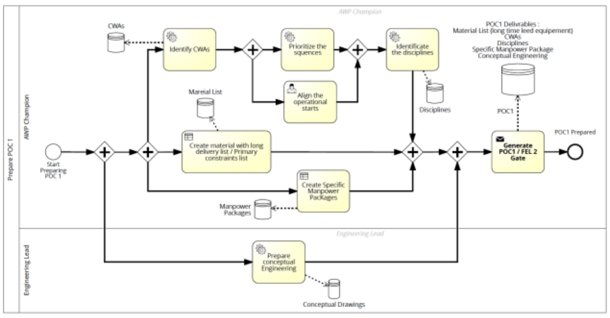

Figure 3: First iteration Prepare POC 1

1. Firstly, the identification of the Construction work areas (CWAs) allows for the prioritization of sequences and the simultaneous alignment of operational activities, facilitating the identification of different disciplines.
2. Compiling a list of materials with extended delivery periods, while considering the primary constraints list.
3. Subsequently, generating the necessary specialized workforce packages.

Upon completing this step, the Path of Construction 1 (POC 1) will be generated and assembled, incorporating the various deliverables produced in each task, and the customer's validation will be requested.

3.1.4 POC 2 : Second iteration of POC

The process to follow for preparing POC2 is illustrated in Figure 4. The AWP Champion will request the Engineering lead to commence work on the Basic Engineering. Simultaneously, the AWP Champion will prepare the Construction Work Packages (CWPs) while also identifying the Engineering Work Packages and the Procurement Work Packages (PWPs). This will enable them to work on preparing the turnover packages and identifying the operating systems concurrently. After completing these tasks, the AWP Champion will identify the testing packages and provide the commissioning packages.

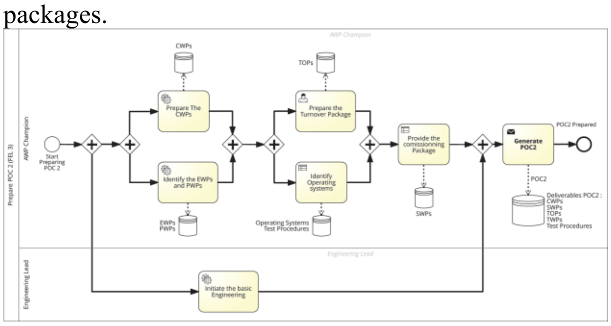

Figure 4: Second iteration to Prepare POC 2

After this step, POC 2 will be created and put together, integrating the different deliverables generated in each task, and the customer's validation will be sought.

3.1.5 POC 3 : Third iteration of POC

The current version of POC preparation incorporates the final set of tasks, as illustrated in figure 5, to fully integrate the AWP into the project monitoring process.

The Engineering Lead will now finalize the fundamental engineering tasks. Simultaneously, the AWP Champion will ensure a one-to-one relationship between the EWPs and PWPs, with regards to the CWPs, in order to guarantee their alignment. Subsequently, the AWP Champion was able to establish a connection between the System Work Packages and the CWPs.

These steps will enable the AWP Champion to develop a comprehensive schedule, assess its feasibility with the subcontractors responsible for different disciplines, and allocate resources accordingly to ensure the active participation of the subcontractors. These steps will result in the successful completion of preparing the deliverables for POC3 and obtaining customer confirmation.

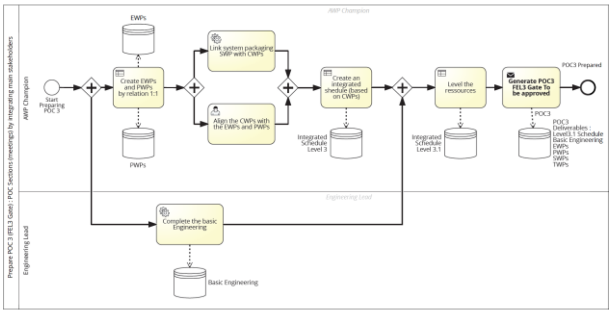

Figure 5: Third iteration Prepare POC 3

After outlining the application of Blockchain within the AWP framework, it becomes clear that there are potential implementation challenges, including technological readiness, stakeholder resistance, and regulatory compliance. Targeted training programs are essential to ensure all participants become well-versed in the functionalities and benefits of Blockchain, fostering a culture of innovation and acceptance.

Conducting empirical validation through pilot projects will be instrumental in demonstrating the practical viability and effectiveness of our proposed Blockchain-AWP framework. These pilots will enable adjustments based on real-world applications, ensuring the framework meets the diverse needs.

3.2 Case Study

3.2.1 Actual digitalization Actions

Various measures were taken to advance and improve the digitalization of this process. An Enterprise Resource Planning (ERP) System was implemented as part of a digitalization project aimed at encompassing all aspects of the company's EPC contractor process. The project is scheduled to be implemented and tested over a period of 4 years. Therefore, the project was divided into three main phases: firstly, the implementation and digitalization of the workflow process, which covers every stage from project attribution to project preparation, including instant notifications and an email system. Secondly, the system will be expanded to integrate the AWP across the three versions of POC. Finally, the success of this phase will lead to the inclusion of the integration of various departments throughout the company.

The study primarily focuses on the initial stage of the digitalization process, which commenced within the past 12 months. Additionally, tests of the implemented solutions have been conducted for a period of 3 months. The successful execution of this phase will serve as a catalyst for the company to proceed with the implementation of the remaining two phases. An analysis was conducted to assess the significance of the action taken and its financial and temporal impact on the organization.

3.2.2 Phase Analysis

According to table 2, the project cost for this phase was set at 80,000 USD, and the planned duration for the project's cost depreciation is 5 years. The organizations opted to procure its own dedicated server to store all data and essential information, along with implementing the necessary infrastructure system. The company oversaw a total of 40 projects annually, and the estimation for conducting and analyzing the digitalization processes was derived from the assumption that each managed project required approximately 150 interactions.

Table 2. Indicators about the digitized actions

Estimation	Amount
Phase 1 Digitalization Project Cost	80 000 USD
Depreciation Duration	5 Years
Projects managed per year	40 Projects
Interactions per project	150

The analysis primarily examines the duration of interaction to facilitate and improve the process of decision making, as well as the transaction cost required for furthering the interaction. As a central server, it efficiently handles data sharing, email communication, notifications, and real-time updates for new documents and steps in the process. It seamlessly involves various stakeholders. The transaction cost will be determined by dividing the total project cost by the depreciation period, and then dividing that by the number of projects managed annually, and finally dividing it by the number of interactions per project. After performing all the necessary calculations, the transaction cost for the digitalization solution amounted to 2.66 USD.

3.2.3 Proposed Approach

In order to enhance the company's digitalization efforts across its three process phases, a proposal is being put forth to adopt a comprehensive and cutting-edge solution utilizing Blockchain technology, as illustrated in Figure 6. This solution comprises four levels, spanning from level 0, denoting the starting point with no progress, to level 4, indicating a fully developed solution with multiple phases and the capability to assess transaction cost and time.

To advance from Level 0 to Level 1, a Blockchain framework was utilized in a comprehensive event-logging solution. The utilized Blockchain protocol is based on Ethereum technology. To advance from Level 1 to Level 2, integrating Smart Contracts enables the establishment of mappings and the specification of events in alignment with different BPMN Diagrams.

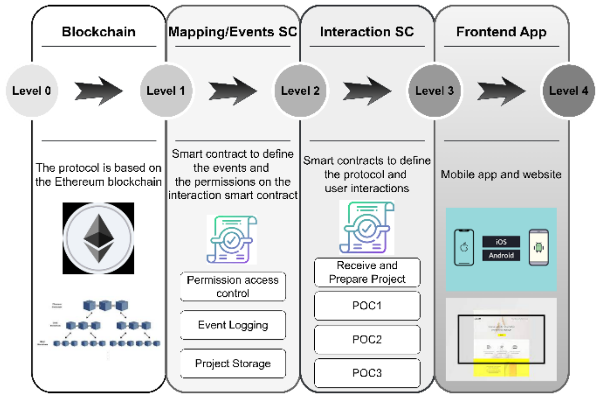

Figure 6: Second iteration to Prepare POC

Within this particular framework, Smart Contracts are responsible for overseeing various functions, including managing user access control, recording events, storing project documents and dates, and enforcing permissions for interactions between Smart Contracts. Consequently, advancement was made to the next level, precisely level 3. After the creation of all the smart contracts, the interaction between these contracts and users is governed by a specialized protocol that aligns with the different stages of the modeled process, starting from receiving and preparing the project up to POC 3.

Table 3. Cost Decomposition of the developed solution

Estimation	Amount
Ether Price	2047,07 USD
System total time response	9 Sec
Cumulative cost of transactions	145 USD
Deployment expenses	360 USD

The preceding work is commonly known as the backend of the developed solution. Hence, the task is to develop the user interface application, encompassing both the mobile application and website, to employ the solution effectively and attain Level 4. Upon examination of the implemented solution's transaction cost and response time, the transaction cost was quantified at 2.9 USD, accompanied by a total response time of 9 seconds. Consequently, this resulted in a cumulative cost of 145 USD. In terms of development, the associated cost stands at an unspecified value. Deployment expenses are explicitly stated at 360 USD. Furthermore, the operational cost is articulated through the formula: cost = 0.00000002 * eth_price * Number of gas The cost includes all expenses related to transactions, development, and deployments, as outlined in Table 3.

3.3 Comparison and Future Directions

In our own analysis, we find Blockchain systems have higher infrastructure costs compared to traditional databases due to their hybrid architecture requiring both a private Blockchain network and web interface.

However, traditional systems also bear difficult to quantify costs related to potential cyber-attacks, data breaches, and conflicts over data responsibility. When considering the enhanced security and transparency benefits of Blockchain alongside raw infrastructure expenses, we find the cost-benefit tradeoff depends on the application and associated security needs.

Blockchain provides data provenance through encrypted ledgers and consensus protocols, reducing risks of unauthorized alterations and disputes over accountability. While we cannot precisely estimate cost savings from prevented attacks, Blockchain offers clear security advantages. Additionally, the immutable and transparent nature of Blockchain transactions facilitates use cases like supply chain tracking requiring detailed histories. Determining the most suitable system still depends on the specific use case and security priorities. For applications where data accuracy and responsibility tracing are critical, the extra infrastructure costs of Blockchain may be warranted over traditional databases.

4 Conclusion

This paper has laid the foundation for integrating blockchain technology with AWP to enhance construction project management significantly. Through the proposed framework, the introduction of blockchain capabilities into managing and executing AWP workflows for construction firms and project managers is facilitated and optimized. Key features such as security, transparency, and coordination are systematically integrated into AWP's lifecycle, leading to notable improvements in traceability, accountability, and efficiency. The collaboration of blockchain and AWP has been shown to elevate project outcomes and set new standards for managing construction workflows.

Moving forward, the validation of this framework's effectiveness through comprehensive case studies and the development of specialized software systems tailored for the construction industry are identified as pivotal next steps. Furthermore, a concerted effort to quantify the anticipated economic and productivity benefits will substantiate the framework's value proposition, encouraging broader adoption across the sector.

The need for a deeper exploration and empirical validation of the proposed solutions has been recognized, reflecting the feedback received from industry practitioners. Our commitment to expanding research to include a broader array of case studies and deeper engagement with field experts is unwavering. This future research aims to validate the theoretical model and refine it based on practical insights and the complexities encountered in real-world applications of construction project management.

By striving to bridge the gap between theoretical innovation and practical application, we aim to contribute a robust, empirically grounded framework to academic and professional communities. This endeavor seeks to catalyze a shift towards more efficient, transparent, and accountable practices within the construction industry. In doing so, we chart a course towards an innovative, data-driven future that fully leverages the potential of blockchain technology in harmony with AWP methodologies, thus making a substantial contribution to the field.

References

[1] M. J. Ribeirinho *et al.*, "The next normal in construction," 2020. [Online]. Available: https://www.mckinsey.com/~/media/McKinsey/Industries/Capital Projects and Infrastructure/Our Insights/The next normal in construction/The-next-normal-in-construction.pdf (accessed 10 February 2024).

[2] X. Q. Zhang, "The trends, promises and challenges of urbanisation in the world," *Habitat Int.*, vol. 54, no. November 2015, pp. 241–252, 2016, doi: 10.1016/j.habitatint.2015.11.018.

[3] B. Flyvbjerg, "What You Should Know About Megaprojects and Why: An Overview," *Proj. Manag. J.*, vol. 39, pp. 28–42, 2008, doi: 10.1002/pmj.

[4] M. Sohail and S. Cavill, "Accountability to Prevent Corruption in Construction Projects," *J. Constr. Eng. Manag.*, vol. 134, no. 9, pp. 729–738, 2008, doi: 10.1061/(asce)0733-9364(2008)134:9(729).

[5] B. Copeland, "Digital advanced work packaging – a case study in construction-led delivery," *APPEA J.*, vol. 63, no. 2, pp. S169–S172, May 2023, doi: 10.1071/AJ22046.

[6] Y. A. Al Balushi, I. M. B. Ishaq, A. A. Al Naamani, and B. N. Seth, "Advance Work Packaging and Workface Planning ADAA," *Day 2 Tue, Novemb. 01, 2022*, 2022, doi: 10.2118/210850-MS.

[7] R. Jabbar, M. Krichen, M. Shinoy, M. Kharbeche, N. Fetais, and K. Barkaoui, "A Model-Based and Resource-Aware Testing Framework for Parking System Payment using Blockchain," *2020 Int. Wirel. Commun. Mob. Comput. IWCMC 2020*, pp. 1252–1259, Jun. 2020, doi: 10.1109/IWCMC48107.2020.9148212.

[8] V. Ciotta, G. Mariniello, D. Asprone, A. Botta,

and G. Manfredi, "Integration of Blockchains and smart contracts into construction information flows: Proof-of-concept," *Autom. Constr.*, vol. 132, Dec. 2021, doi: 10.1016/J.AUTCON.2021.103925.

[9] N. Adeeb, A. Abdu, and Z. Wang, "Blockchain based Security Solutions with IoT Application in Construction Industry," *IOP Conf. Ser. Earth Environ. Sci.*, vol. 614, no. 1, p. 012052, Dec. 2020, doi: 10.1088/1755-1315/614/1/012052.

[10] Ž. Turk and R. Klinc, "Potentials of Blockchain Technology for Construction Management," *Procedia Eng.*, vol. 196, pp. 638–645, Jan. 2017, doi: 10.1016/J.PROENG.2017.08.052.

[11] Hamdi Olfa, F. Leite, and W. J. O'brien, "Advanced Work Packaging from Project Definition through Site Execution: Driving Successful Implementation of WorkFace Planning," 2013.

[12] Y. S. Halala and A. R. Fayek, "A Framework to Assess the Costs and Benefits of Advanced Work Packaging in Industrial Construction," 2018.

[13] CII - RR272-11, "Construction Industry Institute ® Enhanced Work Packaging: Design through Workface Execution," 2013.

[14] S. Ponticelli, W. J. O'Brien, and F. Leite, "Advanced work packaging as emerging planning approach to improve project performance : case studies from the industrial construction sector," 2015, doi: 10.14288/1.0076409.

[15] C. Wu *et al.*, "Hybrid deep learning model for automating constraint modelling in advanced working packaging," *Autom. Constr.*, vol. 127, p. 103733, Jul. 2021, doi: 10.1016/J.AUTCON.2021.103733.

[16] K. M. San, C. F. Choy, and W. P. Fung, "The Potentials and Impacts of Blockchain Technology in Construction Industry: A Literature Review," *IOP Conf. Ser. Mater. Sci. Eng.*, vol. 495, no. 1, p. 012005, Apr. 2019, doi: 10.1088/1757-899X/495/1/012005.

[17] O. Akinradewo, C. Aigbavboa, A. Oke, and I. Mthimunye, "Applications of Blockchain Technology in the Construction Industry," *Lect. Notes Networks Syst.*, vol. 276, pp. 275–282, 2021, doi: 10.1007/978-3-030-80094-9_33.

[18] S. Nanayakkara, S. Perera, D. Bandara, T. C. Scientific, and T. Weerasuriya, "Blockchain technology and its potential for the construction industry," *AUBEA Conf. 2019*, no. November, 2019, doi: 10.6084/M9.FIGSHARE.10315331.V3.

[19] Z. Dakhli, Z. Lafhaj, and A. Mossman, "The Potential of Blockchain in Building Construction," *Build. 2019, Vol. 9, Page 77*, vol. 9, no. 4, p. 77, Apr. 2019, doi: 10.3390/BUILDINGS9040077.

[20] K. Kim, G. Lee, and S. Kim, "A Study on the Application of Blockchain Technology in the Construction Industry," *KSCE J. Civ. Eng.*, vol. 24, no. 9, pp. 2561–2571, Sep. 2020, doi: 10.1007/S12205-020-0188-X/METRICS.

[21] Z. Chen, "Enhancing the engineering supervision process in China: A solution enabled by integrating hybrid Blockchain system," *Innov. Green Dev.*, vol. 2, no. 4, p. 100091, Dec. 2023, doi: 10.1016/J.IGD.2023.100091.

[22] R. Zhao, Z. Chen, and F. Xue, "A Blockchain 3.0 paradigm for digital twins in construction project management," *Autom. Constr.*, vol. 145, p. 104645, Jan. 2023, doi: 10.1016/J.AUTCON.2022.104645.

[23] W. Lu, L. Wu, and R. Zhao, "Rebuilding trust in the construction industry: a Blockchain-based deployment framework," *Int. J. Constr. Manag.*, vol. 23, no. 8, pp. 1405–1416, 2023, doi: 10.1080/15623599.2021.1974683.

[24] M. S. Kiu, F. C. Chia, and P. F. Wong, "Exploring the potentials of Blockchain application in construction industry: a systematic review," *Int. J. Constr. Manag.*, vol. 22, no. 15, pp. 2931–2940, Nov. 2022, doi: 10.1080/15623599.2020.1833436.

[25] Thomas Allweyer, "BPMN 2.0 Modeling," 2016, [Online]. Available: https://books.google.nl/books?hl=nl&lr=&id=sowaDAAAQBAJ&oi=fnd&pg=PA11&dq=bpmn+an+introduction+to+the+standard&ots=5w51Hp7hyL&sig=h7wxFXs-gS07ZI8RuTsr49HXrrw%0Ahttps://www.itp-commerce.com/bpmn-modeling/bpmn-2-0-modeling/