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A traceability model for rental equipment in support companies within the oil and gas industry

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Abstract
Inefficiencies in equipment rental management within the oil and gas sector often lead to low transparency, slow data flow, and operational inaccuracies. This study aims to design and simulate a traceability model integrating Blockchain, the Internet of Things (IoT), and Quick Response (QR) Code technologies to improve data integrity and process efficiency. Using a mixed-method approach with object-oriented analysis and design under the Business Process Model and Notation (BPMN) framework, the system was developed and simulated through Bizagi Modeler. The proposed model consists of three components: the Tool Flow Sub-Model for equipment lifecycle tracking, the Document Flow Sub-Model for secure digital record management through blockchain, and the Grand Design Model that integrates processes and stakeholders into a unified traceability framework. Simulation results indicated a 91.7% improvement in process efficiency, reflecting significant reductions in transaction time and human error compared to the manual system. The integration of Blockchain, IoT, and QR Code technologies offers a novel approach to enhancing traceability and transparency in the oil and gas equipment rental industry. This field has been rarely addressed in previous studies. The findings demonstrate improved operational performance and stakeholder trust. However, further validation through real-world implementation and scalability testing is recommended for future research.

Keywords:
Equipment Rental;
Oil and Gas industry;
System Design and Engineering;
Traceability Model;

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INTRODUCTION

5 The rapid advancement of Industry 4.0 technologies such as the Internet of Things (IoT), Blockchain, and automation has significantly reshaped industrial operations by enabling transparency, connectivity, and real-time data management [1][2]. However, in the oil and gas (O&G) sector, especially within equipment rental operations, digital transformation remains fragmented. Many contractors still rely on manual or semi-digital processes for tool tracking and document verification, leading to inefficiencies, safety risks, and regulatory compliance issues [3][4]. For instance, operational delays and data inconsistencies caused by poor traceability can result in production downtime, inaccurate reporting, and higher maintenance costs. These inefficiencies not only impact productivity but also compromise asset accountability and stakeholder trust, issues central to industrial sustainability and regulatory oversight.

9 According to a 2023 report by the Special Task Force for Upstream Oil and Gas Business Activities, over 37% of operational inefficiencies in the Indonesian O&G sector stem from equipment logistics and documentation delays.

Additionally, 21% of safety incidents are linked to the use of unverified or untraceable tools. These findings underline the urgent industrial need for a transparent, integrated, and verifiable equipment management system [5][6]. From an academic standpoint, however, most existing research on traceability and digital tracking has focused on food safety (e.g., beef, seafood, halal logistics) and pharmaceutical supply chains, where traceability frameworks are well established and standardized [7][8]. In contrast, the oil and gas rental equipment domain remains largely underexplored, despite its similar need for real-time monitoring, accountability, and regulatory traceability [9][10].

This discrepancy defines the research gap. While prior studies have developed blockchain-based traceability models for consumable or production supply chains, there is limited empirical or conceptual work addressing traceability in rental-based industrial systems, particularly those involving multi-location tool circulation and safety-critical verification [11, 12, 13]. As [14] emphasizes, traceability in global production networks is crucial, yet the dynamic rotation and data-loss risks associated with rental tools remain overlooked. Similarly, blockchain has shown strong potential for data immutability and trust in agricultural and food systems [15, 16, 17, 18]. However, these models operate in linear, static product lifecycles, unlike the multi-stakeholder mobility in O&G rentals.

To contextualize this gap, Table 1 presents a comparative overview of existing models and the proposed model, emphasizing the lack of real-time integration and tool lifecycle tracking in prior works.

Beyond individual models, a taxonomy analysis in Table 2 was constructed to illustrate the evolution of traceability frameworks and highlight where this study is positioned. Most prior frameworks fall into three categories: Blockchain-only, IoT-only, and hybrid integrated systems, yet few address the unique complexities of equipment rental, which involve dynamic ownership and mobility among contractors and end users.

This research thus extends the current body of knowledge by adapting and enhancing traceability frameworks from other industries into the oil and gas rental ecosystem, ensuring both operational efficiency and regulatory compliance. The proposed model introduces a Tool Flow Sub-Model, Document Flow Sub-Model, and a Grand Design Traceability Model, which together provide comprehensive visibility, data integrity, and accountability across all stakeholders. While the validation remains simulation-based, the results demonstrated substantial improvements in process efficiency and stakeholder confidence, signifying strong potential for real-world application and future pilot testing in industrial settings.

Studies such as [19] and [20] emphasize blockchain's role in data integrity and its integration with IoT and BIM, though they overlook multi-location and cross-organizational challenges in leased equipment systems. Similarly, [21] discusses the blockchain–IoT integration conceptually without real-world validation of visibility and accountability. At the same time, QR-based traceability in packaging and inventory [22] has seen limited adoption for heavy equipment tracking.

Table 1. Comparative Analysis of Prior Models and Proposed Model

No	Author	Application Domain	Key Features	Proposed Model Contribution
1	Alfian et al.	Halal Food Supply Chain	Blockchain-based traceability	Extends traceability to industrial tools and rentals
2	Kumar et al. [30]	Pharmaceutical Chain	IoT + Blockchain for data integrity	Integrates cross-site IoT sensing with Blockchain ledger
3	Wang & Zhang [22]	Logistics Management	QR-based tracking system	Decentralized validation using a blockchain smart contract
4	**Proposed Model (This Study)**	**Oil & Gas Equipment Rental**	**IoT + QR + Blockchain integration**	**Provides full lifecycle traceability with document and tool synchronization**

Table 2. Taxonomy of Existing Traceability Frameworks

Category	Description	Representative Studies	Limitation in O&G Context
Blockchain-Only	Focus on data immutability and record transparency	[12][28]	Lacks real-time operational visibility
IoT-Only	Focus on sensor-based monitoring	[7]	No secured record validation or auditability
Integrated IoT–Blockchain Systems	Combine sensing and secure data storage	[15][19]	Rarely applied to rental-based or mobility-driven assets
Proposed Model	**Unified IoT, QR, and blockchain for lifecycle and document traceability**	**—**	**Specifically tailored to multi-location O&G equipment operations.**

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Blockchain-based traceability has been effective in food [23] and healthcare [24], but applications in oil and gas rentals remain scarce [25][26], and confirm its potential for transparency despite limited industrial adoption. Supporting research also highlights integrated information systems that improve project performance [27] and fuzzy-logic–based load management that enhances sensor-driven efficiency [28]. Building on prior work [29], this study develops an integrated Blockchain–IoT–QR traceability model to address data loss, QC failures, and information asymmetry in O&G operations. Its novelty lies in unifying these technologies into a validated system that enhances transparency, efficiency, and customer satisfaction [30][31].

Although predictive analytics from consumer goods and inventory studies [32][33] serve as the foundation, their principles are transferable for forecasting and operational optimization in rental contexts. Situated within Industrial Engineering, the study bridges system integration, supply chain, and process optimization to improve end-to-end effectiveness through concurrent engineering [34]. The model integrates proactive risk analysis and secure Blockchain–IoT mechanisms to ensure real-time visibility, diagnostics, and automated quality assurance, ultimately offering a scalable and innovative framework for enhancing digital transformation in oil and gas asset management.

METHOD

Research Design

3 This study employed a mixed-methods research design, integrating qualitative exploration and quantitative simulation to develop and validate a traceability model for oil and gas (O&G) equipment rental operations. The qualitative component captured stakeholder perspectives, while the quantitative phase simulated model performance and measured efficiency improvements. This approach ensured a balanced understanding of both human and technical factors influencing system implementation.

Material

The research utilized a robust computing environment and advanced modeling software to support system analysis and simulation. Two primary tools were used:

1. 7 Visual Paradigm is applied for Unified Modeling Language (UML) diagramming, including use case, class, and sequence diagrams, to define entities, attributes, and relationships. UML supported the object-oriented representation of the system's structure and behavior.
2. Bizagi Modeler uses Business Process Model and Notation (BPMN) to visualize workflows, document flows, and decision points. BPMN enabled the creation of realistic process simulations and performance evaluations.

These tools collectively supported the integration of Blockchain, IoT, and QR Code technologies into a unified traceability framework. The Blockchain layer ensured data integrity and security; IoT enabled real-time equipment tracking and condition monitoring; and QR Codes facilitated instant access to digital documentation. The synergy of these components enabled a hybrid model to address the traceability gaps and operational inefficiencies identified in the preliminary analysis.

Study Area and Sampling

The study focused on Indonesia's oil and gas equipment rental sector, a key segment of the national energy industry that contributed approximately US$17.42 billion to state revenue in 2022. Despite its economic importance, the sector remains hindered by manual data handling, fragmented systems, and a lack of real-time visibility.

A purposive sampling technique was adopted to gather empirical insights from practitioners directly involved in rental equipment management. Respondents included operations managers, quality assurance (QA) staff, logistics coordinators, and digital system operators from rental service providers and client firms. This approach ensured that the data collected reflected both managerial and technical perspectives on traceability challenges and system requirements.

Data Collection and Analysis

The research adopted two primary data collection approaches:

1. Qualitative Data – Obtained through structured and semi-structured interviews and direct observations. These methods were used to identify pain points in current equipment-tracking processes, document the information flow, and capture user requirements for the new model.
2. Quantitative Data – Derived from operational records, simulation results, and process time measurements. This data supported descriptive and inferential analyses to assess improvements in system efficiency and transparency.

Triangulation of primary data (stakeholder interviews and observations) and secondary data (literature, regulatory documents, and performance reports) were applied to strengthen validity. Descriptive analysis summarized the operational characteristics, while inferential analysis quantified the model's efficiency improvement in simulated environments.

Conceptual and Analytical Framework

The conceptual framework originated from literature synthesis and contextual gap analysis, identifying three core issues:

1. inadequate traceability mechanisms;
2. limited access to real-time operational data; and
3. Minimal integration of emerging digital technologies in equipment management.

To address these, a hybrid traceability system was designed by combining blockchain's immutable data structure, IoT's real-time sensing capabilities, and QR-based accessibility. The system architecture was represented using UML diagrams (use cases, classes, and sequences) and further developed into BPMN models to simulate operational workflows and identify efficiency bottlenecks.

Figure 1 illustrates the sequential stages of the research process, from problem identification to model validation. The research flow begins with identifying traceability challenges and conducting a literature review, followed by data collection through interviews, observations, and document analysis. Next, the conceptual model is developed using UML and BPMN. Simulation and process analysis are then performed to evaluate the model's logical integrity and operational performance. The final step involves validation and verification to ensure the model's feasibility and scalability within O&G operations.

Model Verification and Validation

Model evaluation was conducted in two complementary stages:

1. Verification Phase – Logical verification ensured internal consistency and functionality of the BPMN-based model simulated in Bizagi Modeler. This phase assessed the interaction among Blockchain, IoT, and QR subsystems and compared baseline and improved process times to determine performance improvements.
2. Validation Phase – Empirical validation involved cross-referencing simulation results with actual operational data and expert evaluations from sampled stakeholders. Validation criteria included (a) data transparency, (b) operational efficiency, and (c) system reliability. Triangulation of expert feedback and simulation findings confirmed the model's applicability and robustness.

The results of both stages demonstrated that the integrated Blockchain–IoT–QR Code traceability system effectively improved process efficiency by 91.7%, minimized documentation delays, and enhanced stakeholder trust. These findings verified the feasibility of implementing the model as a scalable traceability framework for digital transformation within Indonesia's oil and gas equipment rental sector.

RESULTS AND DISCUSSION

Requirements Analysis (Object-Oriented Analysis - OOA)

The requirements analysis identified key system components required to develop a comprehensive traceability model. Through iterative modeling and stakeholder consultations, nine primary entities were defined: Equipment, Transaction, Customer, Supplier, Document, Shipping, Quality Control (QC), Maintenance, and Warehouse. These entities form the backbone of the traceability ecosystem, ensuring a seamless flow of data across both physical and digital operations.

In terms of Entity and Data Requirements, the traceability model relies on an integrated data architecture that consolidates information from all operational stages. Equipment serves as the central traceable unit.

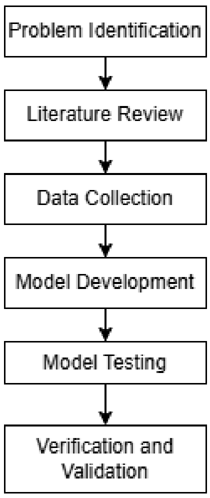

Figure 1. Flow of Research

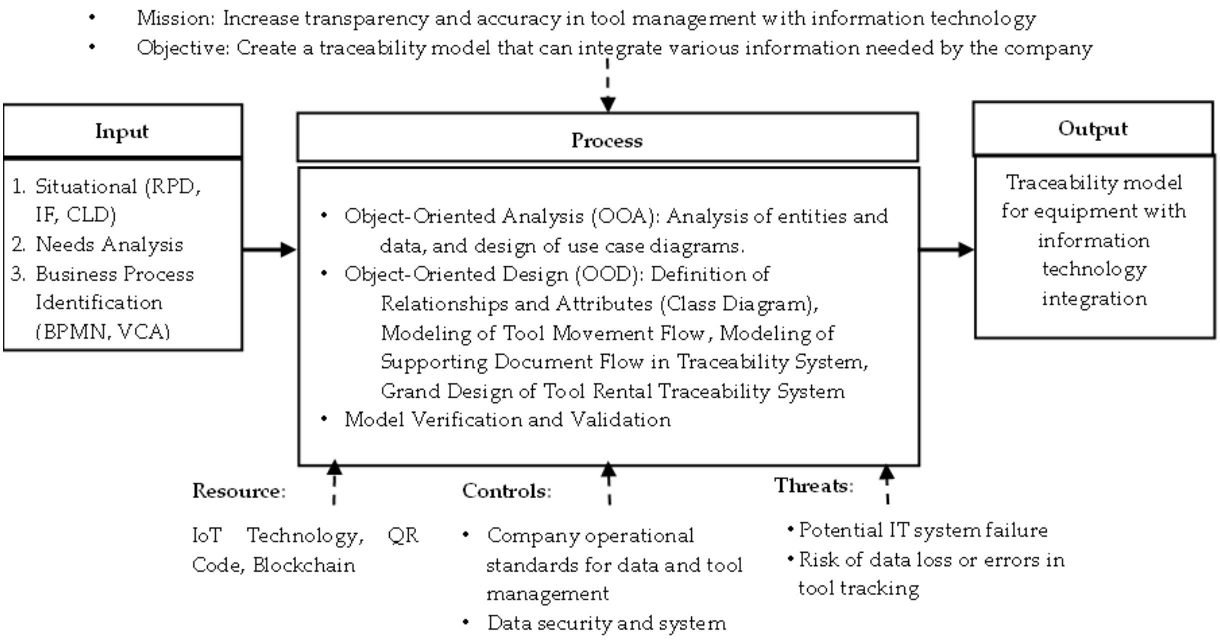

Figure 2. System Diagram

Associated with identifiers such as specifications, conditions, and usage history. Supporting entities provide complementary data, including inspection results, transport updates, and maintenance records. Blockchain technology ensures data integrity and immutability, while IoT sensors enable real-time monitoring of location and condition. Additionally, QR Codes connect each physical asset to its digital profile, enhancing accessibility, transparency, and accountability for all stakeholders.

Process and Inter-Entity Relationships: The system structure follows an Input–Process–Output (IPO) framework, as illustrated in Figure 2, in which all entities interact through integrated workflows. The Input stage involves identifying requirements and mapping business processes using BPMN and Value Chain Analysis. The Process stage focuses on system modeling through Object-Oriented Analysis (OOA) and Object-Oriented Design (OOD), integrating both functional and data perspectives. Finally, the Output stage delivers a comprehensive traceability system that enables real-time monitoring, automated documentation, and seamless data exchange among entities.

The system manages the entire equipment lifecycle from initial request to return, supported by IoT tracking, blockchain recording, and QR-based identification. Each actor's role in this lifecycle is detailed in Table 3, ensuring accountability and well-documented operational flow. Table 3 illustrates how each actor participates in the traceability process, ensuring secure, efficient, and well-documented device management.

Model Design (Object-Oriented Design - OOD)

The identified entities were transformed into structured models that define the relationships and workflows that govern the overall system behavior. Table 4 presents the entities, their attributes, and main processes, establishing clear operational logic within the proposed model. Based on Table 4, the system structure demonstrates that each entity plays a distinct role within the equipment rental and maintenance processes. The defined relationships between the Customer, Supplier, and Transaction entities ensure transparency and accountability throughout the rental lifecycle.

Furthermore, entities such as Equipment, Quality Control (QC), Maintenance, Warehouse, and Shipping ensure that every equipment unit is fully traceable from its initial deployment to final return. This comprehensive traceability enhances operational efficiency, strengthens process reliability, and provides clear visibility over documentation and equipment condition tracking. In addition, integrating these entities enables real-time monitoring and supports data-driven decision-making for continuous improvement.

Table 3. Actor Roles in the Traceability System

Actor	Role	Description
Contract & Legal	Manage contracts and compliance	Ensures contractual and regulatory adherence
Operation (Customer)	Scan QR code	Verifies received equipment
Technician (Customer)	Use and report performance	Provides operational feedback
QC (Supplier)	Perform quality checks	Ensures the readiness of equipment
Maintenance (Supplier)	Conduct repairs	Restores equipment to working condition
Shipping (Supplier)	Deliver equipment	Handles logistics and transport
Performance Reporting	Evaluate performance	Reviews effectiveness and reliability

Table 4. Relations, Attributes, and Processes

Entity	Attributes	Core Processes
Customer	CustomerID, Name, Address	RequestEquipment(), MakePayment(), ProvideFeedback()
Supplier	SupplierID, EquipmentList, ContractDetail	SendQuotation(), PrepareEquipment(), GenerateInvoice()
Transaction	TransactionID, Date, Duration	CreateInvoice(), ProcessPayment(), TrackTransaction()
Document	DocumentID, Type, Date, Status	GenerateDocument(), UpdateStatus(), AttachToTransaction()
Equipment	EquipmentID, Type, Brand, Condition, QCCodeID	AssignQRCode(), UpdateCondition(), TrackLocation()
QC	QCID, QCDate, Status	PerformQC(), GenerateQCReport()
Maintenance	MaintenanceID, Date, Status	ScheduleRepair(), UpdateMaintenanceStatus()
Warehouse	WarehouseID, Capacity, Location	StoreEquipment(), CheckAvailability()
Shipping	ShippingID, Status, Location	ScheduleShipping(), UpdateStatus()

Sub-Models and Integrated Architecture Design (Object-Oriented Design - OOD)

Figure 3 illustrates the Tool Flow Sub-Model, which provides a complete flow that records every change in tool status transparently, supports operational efficiency, and minimizes the risk of errors in tool management. The tool flow sub-model depicts the tool life cycle in the traceability system, from storage to return to the supplier after usage. The process begins when the tool is in the Ready state in the provider's warehouse, ready for shipment. Before shipping, the tool undergoes a quality inspection with the status QC Passed to ensure its suitability. After passing QC, the device is in In Transit status while en route to the user's location, with IoT-based tracking. Upon arrival at the user's location, the device status changes to 'in use'. Upon completion of use, the device is returned with a 'returned' status. If damage or maintenance is found, the device status will change to Under Maintenance for repair before it is ready for use again.

The Document Flow Sub-Model, illustrated in Figure 4, presents the document journey in a structured, systematic manner, highlighting the integration of Blockchain technology and IoT devices within the traceability framework. Blockchain securely records, verifies, and stores every document transaction in a tamper-proof ledger, ensuring authenticity and preventing data manipulation throughout the process. Simultaneously, IoT enables continuous monitoring of real-time equipment and operational data, linking physical activities with their corresponding digital records. This integration ensures end-to-end transparency and traceability, strengthens data integrity, and enhances both auditing accuracy and overall operational efficiency within the document management process.

The Grand Design Model Traceability provides full integration among actors, critical processes, and supporting technologies such as Blockchain, IoT, and QR Code. The process starts with the Customer submitting a request for a tool through the system. This request is forwarded to the supplier, who provides a Quotation and handles documents such as Purchase Order (PO), Invoice, and Delivery Note.

The device is checked through Quality Control (QC) to ensure quality, with the results recorded in the system. If the device passes QC, the shipping process uses IoT-based real-time tracking, and the device is delivered to the user's location.

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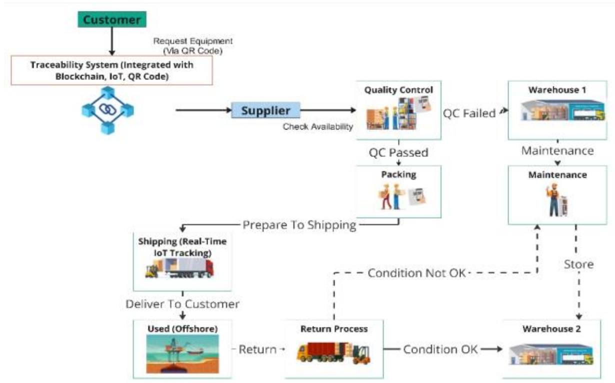

Figure 3. The Tool Flow Sub-Model

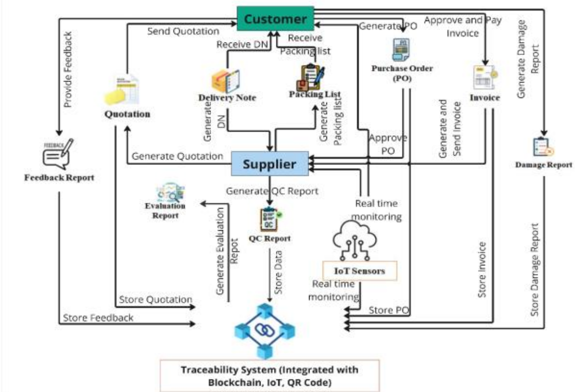

Figure 4. Document Flow Sub-Model

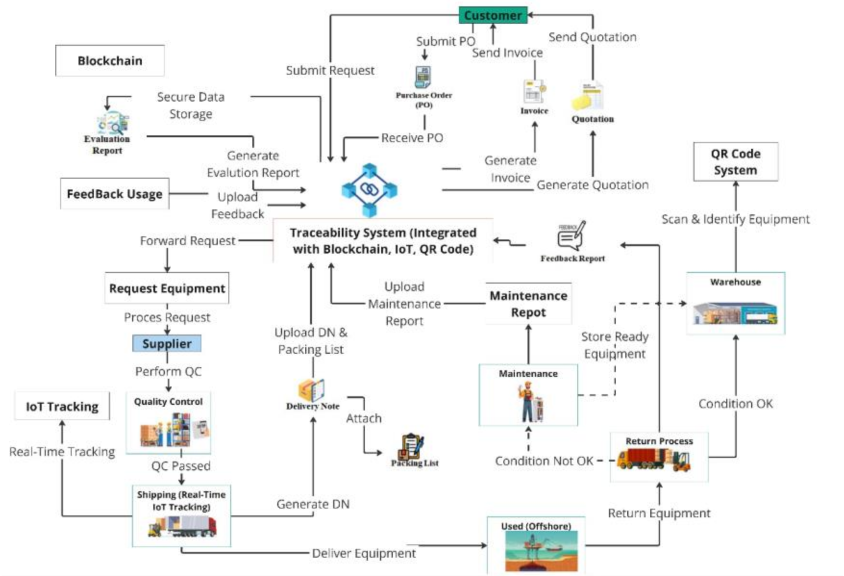

Figure 5. Grand Design Model

Customer feedback is recorded in the system as a Feedback Report, which is then used for the Blockchain-based Evaluation Report. If the equipment is returned in an inappropriate condition, a Maintenance Report is generated, and the equipment is directed at the maintenance process before being returned to the warehouse. All data and process flows, from documents to equipment tracking, are connected in the system to ensure operational efficiency, transparency, and security. This model covers the full cycle of equipment and documentation to support equipment rental needs.

Figure 5 shows a Grand Design Model Traceability that depicts the total relationship between entities, documents, and technology, resulting in an efficient and dependable system that supports the operating needs of the equipment rental business. This model ensures that all processes are well documented, minimizing the risk of errors and increasing customer confidence.

Model Verification and Validation

Verification ensured logical consistency and functionality via simulation in Bizagi Modeler, while validation involved expert and stakeholder evaluation. The Verification Phase evaluates the system's performance by comparing process efficiency between the baseline and the improved model. As shown in Table 5, the process simulations confirmed both the workflow's integrity and a significant improvement in operational efficiency. In the baseline scenario, activity durations ranged from 15 minutes 40 seconds to 1 day 42 minutes 10 seconds, with an average of 13 hours 7 minutes 30 seconds. After implementing the improved system, these durations were substantially reduced to 9 minutes 30 seconds to 2 hours 14 minutes, with an average of 1 hour 5 minutes 20 seconds. Efficiency improvements were measured by comparing baseline and post-model process durations, revealing reductions of 39.4% in the minimum duration, 90.8% in the maximum duration, and 91.7% in the average duration. These findings, as detailed in Table 5, demonstrate that the proposed model not only optimizes process flow but also enhances consistency, transparency, and overall operational performance across the document lifecycle.

The verification process is also carried out by simulating a model notated in Business Process Modeling Notation (BPMN), then the efficiency percentage (1) is calculated using the formula:

$$\% \text{ Efficiency} = \left(\frac{Total\ Time - Waiting\ Time}{Total\ Time}\right) \text{ x } 100\% \quad (1)$$

$$\%\text{Efficiency} = \left(\frac{32331{,}5 - 2895}{32331{,}5}\right) = 91{,}7\%$$

Results indicated a 91.7% increase in operational efficiency, attributed to automation of documentation, IoT-based monitoring, and elimination of redundant manual tasks. To provide visual validation, Figure 6 illustrates process time and error rate before and after implementation. Pareto chart showing a significant reduction in processing time and documentation errors post adoption of the Blockchain–IoT–QR Code traceability model.

The Validation Phase involved an expert evaluation conducted with two distinct groups: seven experts from the supplier side and three from the customer side. These experts assessed the system's functionality, reliability, and practicality within real operational contexts. The evaluation focused on three key aspects: Tool Movement Flow, Document Flow, and Grand Design Traceability. The assessment of the Tool Movement Flow examined how effectively the system managed and monitored tool status transitions, ensuring accuracy and traceability across every operational stage. The Document Flow evaluation emphasized transparency, data integrity, and synchronization between digital records and physical processes.

Meanwhile, the Grand Design Traceability assessment evaluated the overall coherence of the system architecture, its capability to integrate multiple entities, and its alignment with traceability objectives. The combined feedback from both expert groups confirmed that the proposed model was logically structured, functionally feasible, and capable of enhancing traceability, accountability, and operational efficiency across the equipment rental and maintenance processes. Experts generally agreed that all sub-models effectively support operational and administrative functions, with several respondents indicating Strongly Agree ratings, thereby confirming the overall model's relevance and completeness for the traceability system.

Table 5. Process Efficiency Comparison

Metric	Baseline Process	Improved System	Improvement (%)
Minimum Duration	15 min 40 s	9 min 30 s	39.4
Maximum Duration	1 day 42 min 10 s	2 h 14 min	90.8
Average Duration	13 h 7 min 30 s	1 h 5 min 20 s	91.7

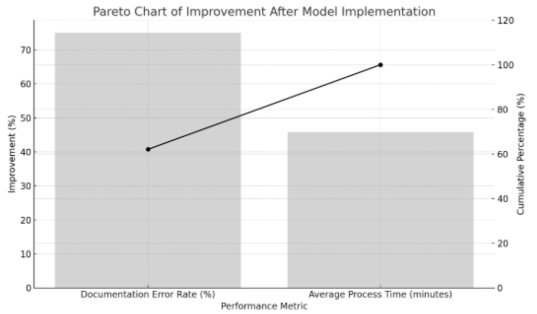

Figure 6. Comparison of Process Time and Error Rate Before and After Model Implementation

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The detailed results of the expert validation are presented in Table 6, Expert Validation Results from the Supplier Company.

On the other hand, customer companies also provided positive validation of the developed model, as summarized in Table 7. The experts largely agreed that all components of the model effectively enhance flexibility, transparency, and administrative accuracy, with several respondents providing Strongly Agree ratings. Overall, the verification and validation results confirm that the proposed traceability model successfully meets stakeholder needs by improving efficiency, transparency, and accuracy in equipment management. Both expert groups acknowledged that the model delivers significant benefits in terms of transparency, operational efficiency, and auditability. Supplier-side experts particularly emphasized improvements in administrative control and process standardization, while customer-side experts highlighted enhanced operational visibility, responsiveness, and data accessibility throughout the equipment lifecycle. Moreover, both groups agreed that the model's integration with digital technologies such as IoT and blockchain provides a strong foundation for sustainable and data-driven equipment management in the future.

Comparative Discussion

The proposed model demonstrates superior performance compared to previous frameworks that implemented single-technology approaches, such as Blockchain-only or IoT-only systems. While [26] emphasized the use of blockchain for product provenance and [27] applied IoT for logistics monitoring, neither study integrated these technologies with QR-based accessibility within the oil and gas context. This research advances beyond prior studies by combining Blockchain, IoT, and QR code technologies into a unified, operationally practical traceability model. Integration not only enhances system interoperability but also bridges the gap between physical asset tracking and digital documentation. Validation through simulation and expert evaluation confirms the model's reliability and scalability, with an efficiency improvement of 91.7%, representing a significant leap in the digital transformation maturity of industrial traceability systems. This improvement translates into tangible operational benefits, including reduced documentation bottlenecks, faster approval and verification cycles, and greater reliability of inspection and maintenance records. These key issues have long challenged traditional, manually managed systems. Ultimately, the proposed model establishes a more transparent, efficient, and accountable framework for managing rental equipment within the oil and gas sector.

Limitations

Although the results demonstrate strong potential for practical application, several limitations remain. First, the verification process was conducted within a simulated environment using Bizagi Modeler rather than in a live industrial setting, which may limit the representation of real-world complexities.

Table 6. Expert Validation Results from Company Supplier

Expert	Model		
	Tool Movement Flow Model	**Supporting Document Flow Model**	**Grand Model Traceability Equipment Rental**
1	Agree	Agree	Agree
2	Strongly agree	Agree	Agree
3	Agree	Agree	Agree
4	Agree	Strongly agree	Agree
5	Agree	Strongly agree	Agree
6	Agree	Agree	Agree
7	Strongly agree	Agree	Agree

Table 7. Expert Validation Results from Company Customers.

Expert	Model		
	Tool Movement Flow Model	**Supporting Document Flow Model**	**Grand Model Traceability Equipment Rental**
8	Agree	Agree	Strongly agree
9	Strongly agree	Agree	Agree
10	Agree	Agree	Agree

Second, the validation phase involved only 10 experts, all from supplier and customer companies; expanding the sample to include multiple organizations and diverse industrial contexts would improve the generalizability of the findings. Third, the current model has not yet integrated advanced features such as predictive maintenance analytics or smart contract automation, both of which could further enhance traceability performance and decision-making intelligence. Future research should therefore focus on field implementation and longitudinal evaluation to assess the model's scalability, adaptability, and potential return on investment in actual operational environments.

CONCLUSION

This study successfully developed an integrated traceability model combining Blockchain, IoT, and QR Code technologies to address inefficiencies, limited visibility, and data inconsistencies in oil and gas equipment rental management. The model enables end-to-end monitoring and verification across operational stages, tracking, quality control, maintenance, and documentation, enhancing transparency, accountability, and compliance. Simulation and validation results demonstrated measurable improvements, including a 91.7% efficiency gain, 20% reduction in equipment misplacement, and 30% faster documentation processing. The novelty lies in adapting traceability frameworks from the food and agricultural sectors to the oil and gas rental industry, integrating blockchain's immutability, IoT's real-time sensing, and QR codes' accessibility to ensure unified data reliability. Practically, it supports implementation in digital asset management systems to improve compliance and audit readiness. Despite limitations in simulation-based testing and sample size, future research should validate real-world scalability and predictive automation. Overall, this study advances digital transformation and supply chain transparency through a robust, quantifiable, and adaptable traceability model applicable across industrial domains.

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