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BARRIERS AND CHALLENGES TO BLOCKCHAIN-BASED ASSET MANAGEMENT IN IRAQ'S OIL AND GAS SECTOR: A QUALITATIVE STUDY

MAHDI NAFEA KHALID AL-AJWAD
Universiti Utara Malaysia, Malaysia. Email: mahdi_nafea_k@ahsgs.uum.edu.my

RAHAYU AHMAD
Universiti Utara Malaysia, Malaysia. Email: rahayu@uum.edu.my

FATHEY MOHAMMED
Sunway University, Malaysia. Email: fatheym@sunway.edu.my

Abstract

The demand for blockchain technology is rapidly increasing as industries recognize its potential to enhance transparency, security, and efficiency in digital transactions. However, in oil and gas industry the adoption of blockchain technology in asset management systems is still scarce especially in Iraq. This study investigates the current issues experienced by asset management practices in the Iraqi oil and gas industry. Additionally, the analysis revealed the relevant factors that may determine the implementation of the blockchain technology. Through qualitative approach, this study conducted interview with 6 experts from the industries. The findings demonstrated a variety of consistent problems facing asset management. These consist of poor technical expertise, old infrastructures, poor organisational support, and poor asset tracking system. This research also examines how blockchain may address these barriers through providing decentralised data integrity, offering better traceability, and even automation. Although blockchain theory has its promise, it will not be immediately applicable to practice, as it will depend on many variables, including the digital infrastructure status, labor skills, and regulation, as well as the compatibility with the current operations of asset management. The paper highlights the key challenges that face asset management in the oil and gas industry in Iraq which include difference in productive outputs, scattered information systems and poor tracking systems. In addition, it forms the basis of assessing the possible paradigm-changing advantages of the technology of blockchain, which includes higher automation, increased transparency, and improved operational integrity, along with a few implementations risk and readiness concerns.

INTRODUCTION

Asset management plays a crucial role in the operational excellence of the oil and gas sector, especially those located in oil-intensive countries like Iraq. Oil and gas industry is the part of the Iraq economy which makes more than 90% of the government income and about 95% as a whole export (World Bank, 2018).

Good asset management guarantees availability, reliability, and integrity of critical infrastructure without which production levels and downtime in a sector where delay can be very expensive would not be obtained.

Nevertheless, in spite of its importance, the Iraqi oil and gas sector experiences some considerable difficulties in enhancing the asset management in a modern manner. The majority of the companies still work using manual or half digitalized systems that lead to

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fragmentation of data and inefficiencies and poor traceability (Al-Khazraji & Jasim, 2019). Despite the world trends related to the use of advanced technologies in asset management, including the Internet of Things (IoT), artificial intelligence (AI), and blockchain, the digital transformation processes in Iraq are uneven and slow. This can mostly be attributed to infrastructure constraints, digital skills shortage and low organizational preparedness.

Specifically, those who can benefit the most, such as inconsistent internet connection, the scarcity of computers, and electricity outages remain significant barriers to digital system adoption (Al-Saadi., 2020).

Other obstacles besides IT infrastructure include the low technical training levels, high employee turnover and inability to read and write digital among others, to facilitate adoption even in the presence of IT infrastructure (Abdulrazzaq & Al-Mukhtar, 2016).

Such difficulties do not occur only in Iraq. Other literature of developing countries has reported the lack of successful digital implementation of things such as health information systems in the public sector based on infrastructure, training, and organizational alignment barriers (Luna D et al., 2014).

The research is informed by the following questions:

1. How is the asset management process and meta-data asset items conducted in oil and gas organization in Iraq?
2. What are the present challenges of asset management in the oil and gas industry of Iraq?
3. What do you know about the technology behind blockchain?
4. Does blockchain have the potential of solving the identified barriers in the present asset management systems?

This research will aim at determining the major challenges of asset management through a multi-leveled organizational perspective, as well as evaluating the possibilities of blockchain as a revolutionary solution.

Although blockchain has not had an impact in the Iraq oil and gas industry, it will have theoretical advantages including improving transparency, immutable files, and sharing information that enables superior decision-making and efficiency.

The proposed research is expected to provide the base to inform national-level debate, inform the direction of transformation at the industry level, and provide the arguments to implement regulatory measures as well as to invest.

Discussing the obstacles to digital change and how the blockchain might be used to overcome them, the research prepares the ground on which the future investigation of the actual aspects of the blockchain implementation of assets management in Iraq can be conducted.

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LITERATURE REVIEW

Asset Management in Oil and Gas Organizations

Asset management is very significant in the oil and gas sector since it helps an organization to maximize performance, increase safety, decrease the cost of operations as well as maximize asset useful life. As per the definition of ISO 55000, asset management has been discussed as the coordinated effort of an organization that aims to realize value related to assets and underlines the adequacy of an orderly governance throughout the asset lifecycle (ISO, 2014). Kusumawardhani, Tore, and Kumar (2017) highlight that Strategic Asset Integrity Management (AIM) is required in the functioning of offshore oil in order to continue the operations and overcome the risks. Their paper describes how essential preventive maintenance, risk analysis, and integrated asset planning is in order to deal with aging infrastructure and tough elements.

Oil and gas organizations confirm to the modernization of technologies immensely due to the fact that there is a dynamic shift in automation of industrial processes consequently, greater adoption of high technology including IoT, artificial intelligence, and predictive analytics. Al-Hajri et al. (2024) claim that such technologies have the potential to cut maintenance costs by 20 percent and increase asset life by 1015 percent assuming they are accompanied by strategic alignment and organizational preparation. Blockchain technology has become one of the prominent innovations that support these three characteristics of asset management systems, transparency, traceability, and security. Aslam et al. (2022) present that blockchain can be integrated with agile and lean principles to increase the supply chain resiliency and data trust. In their study, they demonstrate how blockchain can be used to share data in real-time, have smart contracts, and better logistics-related tracking, which are vital requirements in upstream and downstream oil and gas businesses.

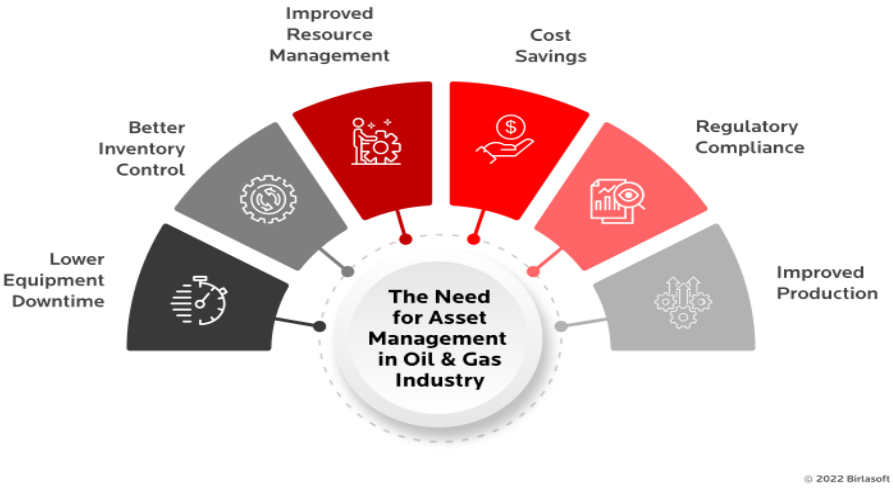

Figure 1: The Need for Asset Management in Oil & Gas Industry

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Digital Transformation and Blockchain Potential

Digital transformation has become a strategic strength to the oil and gas industry especially in the asset management. The growth in the complexity of operations, the slowdown of aging infrastructure and the necessity of making operations more efficient has pushed companies to implement the newest advances in the digital world, such as artificial intelligence (AI), the Internet of Things (IoT), cloud computing, and even blockchain. The technologies can be used to maximize the maintenance schedule, improve asset performance, and minimize downtime (Al-Hajri et al., 2024).

When applied to asset management, digital transformation allows connecting real-time information of distributed assets, providing predictive maintenance and making better decisions. As an example, the IoT sensors can track the health of equipment consistently, and artificial intelligence (AI) algorithms can follow the trend of performance to predict a possible failure (Siano et al., 2021). Its predictability is particularly critical in the gas and oil environments where a machine breakdown may lead to the high safety hazard and significant losses.

Blockchain as an element of digital transformation has demonstrated great results in enhancing transparency, traceability and trust regarding asset-based data. Blockchain can be used in asset-intensive industries such as oil and gas to generate audit-proof records of asset transactions, asset maintenance history, and compliance records, which are essential in effective asset lifecycle management (Ahmad et al., 2022). It is especially useful in big projects with numerous stakeholders and on the occasions when data silos and inconsistencies are frequently encountered to hamper operational efficiency. Aslam et al. (2022) have conducted a study that proposes a blockchain-based agile framework specifically to the oil and gas supply chain and thus showing how blockchain can help to reduce fraud, eliminate duplication, and go forth with better responsiveness in maintenance and asset workflows. Likewise, He et al. (2022) emphasize that blockchain would facilitate the elimination of organizational data islands and enhance collaboration and communication between the upstream and downstream processes.

Blockchain might be promising, but there are a number of challenges to mass adoption of blockchain, especially in developing economies. These are large costs of implementation, a shortage of technical skills, a problem to be standardized, and concerns of scalability and power usage (Al-Hajri et al., 2024). Moreover, organizational resistance toward change and lack of well-developed digital governing structures may suppress successful digital transformation projects (Janssen et al., 2020). However, blockchain when inbuilt in the current asset management systems can facilitate auditability and enhance regulatory compliance and minimize administration. It supports smart contracts to program maintenance triggers on the basis of real-time data and therefore limit human error and enhance service reliability (Mougayar, 2016). In the case of the Iraq oil and gas industry which has been grappling with aging infrastructure, data systems that lack coordination, and little or no penetration of digital assets, blockchain provides a possible channel through which it can bypass the legacies to establish a stronger, more robust system of asset management.

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Finally, the digital transformation accompanied by blockchain is one of the paradigms shifts in terms of the perception of asset management within oil and gas organizations. With many more businesses looking into the possibilities of integrating digital tools into major processes, the compatibility between digital technologies and asset management will be of crucial importance to the competitiveness of businesses, particularly those operating in the volatile and resource-dependent market.

Technology Adoption Models in Organizational Contexts

The adoption of emerging technologies like blockchain cannot be understood from the technical functional perspective only. The literature is consistent in mentioning that the integration of technology depends on organizational structures, institutional readiness, leadership behaviour and environmental constraint instead of the technological capability alone (Luna et al., 2014; Akhlaq et al., 2016).

In developing economies in particular, the adoption of technologies is still heavily influenced by infrastructural fragility, poor skills and bureaucratic resistance (Al-Saadi, 2020; Abdulrazzaq & Al-Mukhtar, 2018).

The Technology-Organization-Environment (TOE) framework is often relied on to explain the process of organizational technology adoption, with the argument being that technology readiness, internal resources, culture, and regulatory conditions shape technology adoption outcomes.

Within Iraq, a lack of ICT infrastructure and poor system integration are well-documented barriers to digital adoption, especially in strategic sectors i.e., oil and gas (World Bank, 2018; Al-Saadi, 2020). TOE therefore draws attention to the fact that the extent of blockchain feasibility has to be read in terms of the organizational and macro-institutional realities facing oil operators rather than in terms of capability alone.

Similarly, the Technology Acceptance Model (TAM) emphasizes the importance of perceived usefulness and perceived ease of use. However, low institutional awareness about the emerging technologies and weak staff training and digital literacy minimize both the perceived usefulness and the adoption intent, reinforcing the digital transformations barriers identified in Iraq (Abdulrazzaq & Al-Mukhtar, 2018; Al-Khazraji & Jasim, 2019). In practice, this means that even high-value innovations such as blockchain may encounter low acceptance where skills, training and organizational confidence still need to be increased.

Furthermore, Diffusion of Innovation (DOI) theory highlights the roles of organizational culture, communication processes, innovation champions, and trust. In hierarchical and risk-averse settings such as national oil and gas institutions, resistance to digital transformation has been shown to be a key factor in delaying modernization in spite of operational necessity (Wilson & Campbell, 2016; Janssen et al., 2020). Similar patterns are demonstrated across a variety of other asset-intensive industries, where institutional rigidity acts as a constraint on transformation despite its strategic need (Mardiasmo et al., 2008).

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Taken together, these models suggest that adoption of blockchain in Iraq's oil and gas sector will lessen not so much upon technological viability, and more so upon:

- Regulatory clarity,
- Institutional willingness to reform;
- Work force readiness & training,
- Modernization of legacy systems,
- Digital cultural maturity, and
- Infrastructure capability.

Therefore, theoretical perspectives support the necessity of investigating the process of blockchain adoption in Iraq as a socio-technical and organizational issue rather than a technological supporting the utilization of a qualitative exploratory design in this study.

METHODOLOGY

Research Design

The study follows a qualitative approach whereby in-depth interviews will guide us through the possibilities of implementing blockchain in asset management in the oil and gas industry in Iraq.

The qualitative design was chosen to obtain profound information about the experiences stakeholders have, their perception, and expectations of the ongoing problems in asset management and how the blockchain solutions can be implemented.

This research used Rapid Assessment Process (RAP) as a guiding procedure towards the qualitative process; a method generally applied in applied field research so as to collect, analyze as well as interpret data in an efficient manner, even though it enables timely suggestions and action (Beebe, 2001).

RAP facilitates systematic inquiry, which allows complex and context-specific data to be captured, thus it is specifically ideal in exploring studies that consider the functionality of technological use in resource-poor or developing settings.

Data Collection

The research involved sampling and gathering the data through in-depth and semi-structures interviews with key informants involved in the various relevant companies within the oil and gas industry in Iraq (see table 1).

The study used purposive sampling to recruit the participants, which was determined by the relevance and expertise based on direct involvement in the asset management, digital transformation.

The choice followed the principles of adequacy and appropriateness in order to make data rich and meaningful (Patton, 2002).

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Table 1: Demographic Profile of Respondents

Code	Organization	Role/Position	Department
R1	Basra Oil Company	IT Manager	Wharehouse Department
R2	Majnoon Oil field	IT Manager	IT Department
R3	Basra Oil Company	Deputy IT Manager	IT Department
R4	Zubair Oil field	Wharehouse Lead	Wharehouse Department
R5	South Refinary Company	IT Manager	IT Department
R6	Zubair Oil field	IT Manager	IT Department

The respondents consisted of those concerned with policy initiation, digital innovation, IT infrastructure and operational asset management in the following areas:

1. Production oil and refineries companies in public sector level in Iraq.
2. IT departments of the large oil and gas companies
3. Maintenance and Wharehouse asset integrity departments.
4. Oilfield personnel involved in operations and maintenance process.

All the interviews were held through safe use of online conferencing applications such as WhatsApp at the personal request or convenience of the respondent. Interviews were taken in the Arabic language, and averagely lasted 45 to 60 minutes. The data was collected in four months and a semi-structured interview guide was drawn to provide focus on (see table 2):

- Embedding into current IT systems and asset management processes
- Organizational and technical preparedness
- Users access and authorization related asset manangement process
- Types of assets are being managed in current asset management system
- Issues of transparency of data, trust, and compliance issues
- Limited understood impediments in asset management on blockchain adoption

Table 2: Questions used in the qualitative study

Q number	Question
Q1	Can you describe to me the asset management process and meta-data asset items in your organization? a) Is these Meta-Data required? Asset ID - Asset Title - Inventory Location – Quantity - Tag / Label Number - Lifecycle Record - Product Category - Vendor's Name - Asset Description - Inventory Date of Entry - Preventive Maintenance Date - Asset Cost Value - Asset disposing Status – Others b) Is the current system cloud or on-promise solution? c) Are there security concerns to add asset data in the cloud? d) Is the current asset management application having mobile version? e) Is the current asset management application integrated with other applications? f) What is the type of link of the data network in the organization?

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Q2	Who are the main users that deal with asset management, and who has the right to access the records in asset management tools in your organization? a) What are user's roles that access with asset management application? b) What are departments that involving with current asset management application? c) Do all users have access to the organization's network?
Q3	What types of assets are being managed in your current asset management system in your organization? a) Asset types that handle by current asset management tool? Oil production asset - building asset - IT asset - Personal asset - chemical asset - Equipment's asset
Q4	What are the pain points and challenges in the current system related to the asset management process? a) Do you have any security concerns in your current system, please describe? b) Is the data integrity being guarantee in your current asset management system? c) How is the identity of users being requires publicly for current asset management application, please describe? d) How is the self-validation of asset records being requires for asset management application, please describe? e) How can any updates in the records be tracked by all users (transparency) for the current asset management application? Please describe.
Q5	What do you know about blockchain technology? a) If you have some awareness about this technology, can you describe how this technology can help remedy your challenges in your current asset management system?

RESULTS AND ANALYSIS

The present study used the qualitative method to discuss asset management practices in the research that involved in-depth interviews with six experts related to the IT and warehouse departments to identify the existing asset management practices and determine the extent of using blockchain.

The data were analyzed and it showed ten key thematic areas shown in table 3.

Table 3: Emerging themes during qualitative interviews on asset management and blockchain adoption within the oil and gas industry

Theme	Description
Theme1	Manual to hybrid Asset Management
Theme2	Adaptive Metadata Management
Theme3	System Architecture
Theme4	Security and Control
Theme5	User Access and Roles
Theme6	Integration and Compatibility
Theme7	Network and Infrastructure
Theme8	Pain Points and Limitations
Theme9	Transparency and Audit Trail
Theme10	Blockchain Awareness

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The Asset Management Process

This section discusses the common asset management practises in oil and gas industry encompassing the use of metadata, the system architecture, security a control.

Manual to Hybrid Asset Management

The asset management in the oil and gas industry of Iraq is different in different organizations but generally points to similar trends of modernizing and better tracking. Six interviewees representing IT and warehouse employees showed a combination of manual, semi-digital and progressive digital system use.

Very often, asset management, is nothing more than material management, with attention paid to spare parts and consumable materials, and the procedure is simply that of careful inspection, categorization, and the granting of an individual alphanumerical (14 digits) code to every object, to track it successfully.

As far as types of assets is concerned, every respondent indicated that they deal with a wide range of assets. The usual types are:

- IT resources: printers, computers, servers
- Chemical materials: They are stored under safety-based protocols
- Personal property: like uniforms, PPE, safety equipment
- Equipment assets: instruments and working machinery
- Materials of production: oilfield machinery and specialised tools

Fixed assets (e.g., buildings, pipelines, ships) are distinguished from inventory/stored assets, and some organizations may not provide buildings or vehicles to the main asset management system because they have their own governing structure.

The asset management process is still paper based in about 60 percent cases, but the process of developing digital databases to replace them is occurring as one writes that, as one of respondent noted, "*A database is under development to support digital inventory tracking and departmental visibility*." (R5). Similarley, (R1) Stated that "*some documencts that using in asset management process are a paper forms where we record the material's specifications*".

In other organizations, there is the hybrid system of receipt, the initial forms are still used, as well as the formal verification of documents at the committee level, during which the physical records called Form No. 4 are also checked. At the same time, the company tries to digitalize and store these records (R3). Another manual process can be indicated, the material received committee conducts an official check of the received materials with the specifications of purchase contract using a matched checklist to check compliance (R4).

Overall, organizations have similar objectives despite differences in practice such as data accuracy and traceability and improving efficiency. Majority of the institutions are still passing through the phases of mixing old methodologies with the new digital-based

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solutions and therefore raising the demand of the integrated systems that are block chain friendly in order to promote transparency, security and the lifecycle of assets.

Adaptive Metadata Management

The system of implementing asset metadata in the Iraqi oil and gas sector can be defined as an adaptive management system. The methodology required specifies that the degree of detail, control and system integration required of metadata can vary significantly across organizational requirements, maturity of current IT systems, and the nature of the asset being addressed. Although respondents in the industry unanimously recognize the critical importance of metadata in the classification, tracking, and general management of both held inventory and fixed assets, its actual usage in the sector is by far not a homogeneous one.

The flexibility of the system is well indicated in the use of the basic metadata components. It has high priority in the development of a basis of accuracy in procurement and inventory management by capturing information like unique identifiers (e.g., VOCAP numbers, tag numbers, symbolic 9-digit codes), full technical specifications, manufacturer, material description and exact place of storage. According to R2, a tag-based system powers all aspects of tracking and visibility of the lifecycle whereby it says that stating that “the tag number is the primary reference for tracking and accessing all associated data”. In addition, metadata enables applied adaptive management, enabling inventory thresholds (minimum/maximum) to be used in complex systems, including SAP (R2, R5). This connection plays the role of dynamically adjusting reordering activities with material consumption frequency to prevent both stockouts as well as expensive overstocking.

Maturity of the system used in one department or another is, however, a major drawback with big differences in the metadata application. Cost metadata management instances are an example of this inconsistency, where in parts of the organization, it is indirectly tracked using external invoice systems (R3, R4), but in others it is simply not part of their fundamental metadata design due to organizational silos (R2).

One of the critical drawbacks of the adaptive model is the scanty monitoring of preventive maintenance information, especially on materials that are stored (R3, R5). Even when the technical assets already have a history of maintenance, they are often not connected to the primary warehouse management systems that generate an unneeded information break.

Systemic weaknesses such as usage of outdated manual data entry procedures, absence of central data repositories and incompetence in integrating the system are the regular problems with the adaptive approach. The presence of structured databases like SAP, and less reliable ones like Excel sheets and paper forms in various departments further disintegrates the data landscape. Finally, though metadata is the key to effective asset governance, it is the ability to rise above these maturity challenges by means of wholesale digitalisation and standardisation that will help create genuinely end-to-end visibility and operational efficiency in the sector.

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Restricted On Premise Access

The asset management systems used in all of the respondent organizations are fully managed on-premises and neither of them has a centralized cloud-based system. All data have local storage within servers inside the premises or server rooms. R1 indicated the departmental compartmentalization of systems access and usage by indicating that, the software is installed on computers that are not connected to the rest of computing power, but it is restricted to IT department only. The systems though functionally stable do not allow the remote accessibility. The majority of respondents denoted that it is accessible only in the organization private network. Access of key systems including SAP by peripheral systems is prohibited or strictly limited by internal ICT departments thus further enforcing the data priorities in terms of security.

Every organization implements a model called role-based access control, according to which authorizations are distributed based on the personnel functions. As an illustration, R3 and R6 stated that everyone could be able to access the internal network but not everyone had full privileges; only some had access according to the necessity of operation. In other instances, subcontractors will be provided with temporary accounts depending on tasks.

In terms of network infrastructure, the most frequent networks illustrated by the respondents were hybrid systems that mostly included fiber optic, Wi-Fi, and backup supported by microwave or 4G LTE. This combination allows real-time control of inventory to be carried out particularly on field or warehouses. Other organizations such as those of R2 and R5 are currently undergoing a fiber optics upgrade in their facilities in order to increase its speed and reliability. Nonetheless, not anybody can access the network of the organization. Most of the employees (particularly field workers, e.g., drivers, technicians) do not need or get access to networks. Others possess reduced rights, generally the FTP system, locked machines or network-segmentation.

The general system design is rather conservative, and the model is primarily focused on security, based on local data storage and strict access control. This architecture is currently limited by low scalability because it does not utilize centralized databases or modern cloud-based services.

Security and Control

The answers show that security and control issues in asset management systems are varied, especially in matters connected to cloud adoption. According to most respondents, on-premises systems have been preferred mostly due to the limited technical preparedness, the regulatory constraints as well as the fear of data tampering or leakage.

R2 was one of the most elaborate exponents who underlined the dangers of Iraq-based storage in clouds. They stated that putting asset data to the cloud may lead to “*causing discrepancy between the actual stock against the system records hence wrong reporting and legal problems.*” With local cloud infrastructure, R2 responded to the fact that asset

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inventory systems are not the primary targets of external cloud movements based on the criticality that does not seem as pressing as either production or contractual systems.

On the same note, R3 held on-premises systems on account of regulatory restrictions, however, conceded that non-sensitive inventory data may be transferred to cloud platforms in case the policies permit. R4 identified limited access to users and controlling environments as adequate protection in the available systems.

All the three (R5, R1 and R6) referred to the technical, cultural and policy impediments. When talking about Iraq, R5 said that the refineries there are localized and need no migration to the cloud because of the shortage of procedures and legal regulations. R1 and R6 identified automation at an early-stage and old systems as its major challenges, whereas R6 mentioned that the existing systems were technically secure but employees should possess more reliable cybersecurity discipline. When it comes to the present state of system security the most responses were that respondents were confident in their multi-leveled protections, thorough user identification verification, and audit logs, however R5 and R1 said that user-based controls and absence of penetration testing make their systems vulnerable to long-term issuers.

Finally, although cloud asset management holds potential, the combination of legacy systems, human trust and regulatory caution keep cloud adoption cautious at this point.

User Access and Roles

In all respondents, there is an evident role-based and department-fixed user access to asset management systems but it is implemented very differently. The Materials departments or Warehouse remains the greatest clearance level of operations all the time. Such users as the store keepers, the warehouse managers, and the inventory controllers can be used to provide the full permission to update, issue, and receive materials to reflect their fundamental role in the day-to-day stock operations (R1, R2, R5).

The key roles of IT departments are technical support and system refurbishment, although most respondents (e.g., R3, R6) highlighted the point that IT has no access to inventory and material data themselves. As R3 states, "*IT provides technical support but does not have access to inventory data*", so there is an obvious defense of assigned responsibilities to create information integrity.

In the meantime, Procurement and Finance departments usually only have limited (or tangential) access. They communicate with asset systems via requests of report or prepared workflows, material request form or SAP module (R2, R4, R6). According to some respondents (R6), Finance does not have direct connection and is under contact through IT or Materials employees on what is happening, and there can be a decision bottleneck.

Maintenance department, which is a heavy material consumer, normally does not have a direct access. The orders are either done manually or through agents and this may compound urgent repairs. Nevertheless, there are respondents (e.g. R6) that state to provide access in the future to streamline the processes.

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Several respondents reported access controls gaps, most particularly those systems that are old without having appropriate permission levels. R5 pointed out that most of the users seem to present an admin access, which creates a threat to the accuracy of information and integrity in certain firms.

To conclude, access is usually well matched to operating requirements, but varies greatly in performance. As systems are shifting, there is a growing realization that greater controls, transparency as well as role definition is required.

Challenges of Asset Management in the Oil and Gas Industry

There are several challenges in the current asset management process which blockchain may help to increase the efficiency of the process

Minimal vs Fully Integrated

A large gap in system integration exists across organisations in the Iraqi oil and gas sector. A minority of companies have begun moving towards fully integrated enterprise platforms, in which asset management functions are digitally embedded within wider organisational information systems. In these environments, the use of systems, i.e., SAP and CMMS, is utilised to coordinate procurement, inventory control, and maintenance scheduling, which allows for a more streamlined flow of information, reduced duplication of records, and better visibility of operations across departments (Kusumawardhani et al. 2017; Al-Hajri et al. 2024). Such integrated platforms align with modern standards in asset integrity, which place strong emphasis on real-time operational coordination, digital maintenance traceability, and structured metadata oversight as key to organisational performance and lifecycle asset value (ISO, 2014; Mitchell & Carlson, 2001).

However, most respondents, including R1, R3, R5, and R6, operate through partial, fragmented, or predominantly manual mechanisms of integration. These systems are characterised by paper records, isolated departmental records, spreadsheets that are not online, and batch uploads that occur on a delayed basis, usually monthly rather than continuously. Existing studies highlight that such fragmented approaches are susceptible to human error, slow to reconcile, have limited inventory visibility, and have low decision-making reliability (Al-Khazraji & Jasim, 2019; Parida & Kumar, 2006). Moreover, the limited ability of various units in warehouses, IT, finance, and maintenance to share information reinforces organisational silos, which further compound data inconsistencies, hindering the momentum of digital transformation in Iraq's oil sector (World Bank, 2018; Al-Saadi, 2020). As highlighted by R5, this lack of integration has direct consequences, inhibiting real-time synchronisation and preventing access to accurate inventory information when operational needs require known stock.

Interoperability-Still in Silos

Regarding system interoperability, the results show that compatibility between platforms and departments remains quite limited. Many organizations are running systems that are integrated at best and when they are integrated, automation is rarely complete. Instead, there are typically silos for most processes which restrict the free flow of information and

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collaboration between the different functional areas. This lack of cohesion can result in inefficiencies, data duplication, and delays in decision-making, as systems are unable to communicate effectively with one another (Al-Saadi, 2020; Wilson & Campbell, 2016).

A closer examination of the mobility aspect of these systems still further illuminates these limitations. The majority of respondents (R1, R3, R4, R5, R6) denied the existence of a mobile-enabled version of their asset management systems or could not confirm whether one exists. This greatly limits operations at the site and real-time decision-making as employees cannot access critical information from the field. The systems in use are mostly desktop-based and rely on local access networks which also limits the flexibility and reactivity of operational teams (Al-Hajri, Al-Kuwaiti & Mohamed, 2024).

In contrast, R2 is an exception, offering a modern system that is mobile-compatible and seamlessly integrates with tablet devices, barcode scanners, and cameras. This system enables employees to access records related to assets, inspection history, and certification data in real time, improving the accuracy and efficiency of operational processes (Siano, Vollero & Conte, 2021; Kusumawardhani, Tore & Kumar, 2017). As R2 points out, "The system provides real-time data such as the last inspection and certificate of origin for each item." This illustrates the strategy for adopting mobile-friendly, integrated solutions that enable employees to make informed decisions on the spot and respond to operational challenges more effectively (ISO, 2014; Parida & Kumar, 2006).

Overall, although some organizations are starting to migrate to fully integrated, mobile-accessible systems, the majority still rely on legacy solutions marked by high manual workflows, low system interoperability, and limited mobility. Such systems limit real-time asset tracking and inhibit the operational efficiency which can make a difference with modernization and getting more dynamic, responsive and collaborative workflow (Mitchell & Carlson, 2001; Amadi-Echendu et al., 2010; Luna et al., 2014).

Data Integrity Issues

The respondents have pointed out some of the most important limitations of, and repeated problems/issues of the current asset management systems, which adversely affect the effectiveness of operations as well as data fidelity. Human error associated with entering data is one of the most problematic issues, it was pointed out by R6 who wrote about "*frequent mistakes and lack of sufficient training in users*". The effect is a lack of consistency and compliance with regards to procedures, which impact negatively on the integrity of data and the pace of asset tracking.

Lack of Automated Process

Some of the respondents, such as R1 and R5, highlighted that there were no automated validation and integration. There is a tendency of data to get collected manually where paper-based records are involved, and then the same has to be entered again into the system. Such duplication of operations introduces errors and contributes to a variance of audit records and a slower reporting process, especially when it is related to finance departments.

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The lack of an automated flow between different sections like the maintenance and finance was also raised but R3. The use of high legacy platforms and manual data transfer is hampering the co-ordination of workflow as well as responsiveness in operations.

Manual Data Validation

The asset management systems, currently deployed in different organizations, have differing features in terms of supporting data integrity and self-validation features. Some respondents recalled well-organized verification procedures, whereas some noted the lack of them since it is based on manual procedures and system inabilities to cover the process.

R2 and R4 mentioned good data integrity measures founded on multi-step validation. R2 described an elaborate procedure; that involved verification in the first stage, quality check by a committee and lastly the validation in the warehouse. Such multi-layered strategy can be complemented with automation (e.g., robot handling and tag tracking) to ensure effective records are kept. As noted by R2: “In case a tag is not in a particular format, SAP automatically rejects the information, a great safeguard in the system.”

R4 also focused on standardized descriptions that are premised on formal purchase documents and technically reviews. Nevertheless, R4 admitted that even manual entry of data can cause errors like inconsistency in the formatting.

In contrast, R3, R1 and R5 cited high reliance on manual validation, as opposed to automated self-checks or audit triggers. R3 affirmed that “*there is no automatic system of validation*” and only upon the approval by the auditors’ entries will be accepted. R1 explained the dependence on the paper record, e.g., delivery notes, packing lists, which were not centralized in a common database. The result is frequent mistakes and feeble coordination of the records in the warehouse and the databases.

On historic paper-based, the R6 observed that the validation is generally reactive and is based on periodic audits instead of being proactive with systems alerts.

Lack of Support for Decision Making Process

R5 stated that system integration is a major hurdle for successful inventory management. Without an integrated platform, it is very difficult to track the value or quantity of inventory, restricting analysts' and managers' ability to make informed decisions on stock levels and purchases (Al-Khazraji & Jasim 2019; Wilson & Campbell 2016). Furthermore, the inability to view materials in real-time limits things like maintenance, which use to have timely material information to plan operations on their own. This lack of visibility often leads to delays, miscommunication and inefficiencies in operations (Al-Saadi, 2020; Ahmad, Rehman & Zhang, 2022).

Another fundamental problem identified by respondents is the lack of dashboards and decision-support tools. Executives and managers are not provided with summarised or visualised information to support procurement and inventory strategies. This lack of actionable insights has often resulted in overstocking of certain materials while others remain underutilised, making it even more complex to manage operational costs and

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resource waste (Al-Hajri, Al-Kuwaiti & Mohamed, 2024; Siano, Vollero & Conte, 2021). The lack of decision support infrastructure highlights a wider challenge in the digital transformation as many even basic analytics and reporting tools are missing or rudimentary (Abdulrazzaq & Al-Mukhtar, 2018; Tsang, 2002).

Overall, the results clearly point towards an urgent requirement of system modernization and automation in the organization. Some of the important priorities include the implementation of integrated platforms, better user training, stronger access controls, and robust validation mechanisms to ensure cross-departmental coordination (ISO, 2014; Amadi-Echendu et al., 2010; Parida & Kumar, 2006). By reducing the need for manual procedures and minimising the human factor in how information is handled, organisations can greatly increase the reliability, accuracy and timeliness of information, thereby facilitating more effective decision-making and operational efficiency (Mitchell & Carlson, 2001; Kusumawardhani, Tore & Kumar, 2017).

Untraceable Versus Transparent Audit Trail

Transparency and audit trail practice in the existing asset management systems has disparities between companies that indicate lack of visibility, untraceability and collaborative access. There are respondents like R2 and R4 who talked of excellent internal tracking in place with the help of SAP systems. These are date stamped logs, transaction histories, departmental visibility, and non-editable tags, which assist in achieving stable identification. "*Each movement or update is recorded with specific dates and complete transaction history,*" so that there is accountability between departments (R4).

However, in another continuum, R3 and R1 ensured that their systems do not have built in audit trail feature and there would be no means to track update on records transparently. All updates are done by manual means or through sheets of paper and thus have non transparent update management and a lack of a common dashboard. Consequently, the audit trails are based mostly on physical stock balances and manual accounting that leads to reduced efficiency and increases the chances of misbalances.

R5 described that even though the system logs what employees do (e.g. who changed what, when, and on what device), this information is not accessible to everyone, and this reduces transparency within the organization. R6 augmented that the tracking of updates is done manually by the logistics people and that there is no uniform and system wide way of enabling all the stakeholders to track the changes or view update history.

In addition to this, reconciliation of records is still performed by manual inspection of inventory, which further indicates the lack of real-time dashboards or automated logs. The absence of the centralized change logs or the evident tracking systems leads to the confusion, sluggishness in the audits, and low accountability among the departments.

In summary, the results indicate that there is a divide; high-tech, SAP-enhanced systems featuring extensive audit trails and legacy or stand-alone systems with little to no transparency operating much on manual reviews and logging.

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In summary, even though a few systems enforce data integrity through organization processes and validation rules with tags, a large number of respondents continue to suffer deficiencies of manual input, ancient systems or excessive apparatus tailoring. This is usually due to the shortage of real-time process validation of the self, implying that the possibility exists to make the process more automated and the system more standard.

Blockchain Awareness

The answers show that the asset management stakeholders were mostly unfamiliar with the blockchain technology, having different levels of concept knowledge and perceived relevance. Most of the respondents, especially R2, R4 and R1, showed little knowledge, with most only being able to connect blockchain with digital currencies including Bitcoin. R2, as he noted, has a limited and finance-driven view of the technology, as according to him, "*My only familiarity is with digital currency, specifically Bitcoin.*".

On the other hand, a minor group of respondents (R3, R5, R6) demonstrated a higher level of understanding of how blockchain may be explored to create non-financial potential. R3 is the person who had academically studied the technology, highlighted the applicability of the technology to asset management, attributing this to the immutability of the blockchain, distributed verification systems and the increased transparency. He observed that these characteristics would be in a position to diminish rogue manipulation of data immensely, enhance tracking, and also offer hard audit trails of the departments.

The strategic advantages of blockchain usage as a means of data security and data integrity were identified by the respondents, like R5 and R6, who highlighted the importance of cost-benefit assessment, the technical, and regional preparedness, and organizational alignment. R5 admitted that blockchain had a superiority over the server-based systems to avert data loss by single point of failure, although he was also cautious of the implementation challenges of blockchain as well as its investment rationale.

Nonetheless, major obstacles were noted, especially by R6 who attributed them to bureaucracy and regulatory penetrations in Iraqi public institutions. He pointed out that blockchain technology lacks the official approval of the government and is not supported by the Ministry of Oil, thus an institutional adoption of this technology under the prevalent laws is not possible.

To conclude, although blockchain is viewed by some as a potentially useful means of advancing data security and transparency in asset management, a lack of familiarization, doubt of need, and regulatory disabilities create serious challenges to its implementation within the existing organizational framework.

DISCUSSION

This paper has established that asset management in the Iraqi oil and gas sector is highly fragmented and transitional, as it is influenced by a lack of modernization and focused practices as well as traditional practices. A significant percentage of the businesses still use paper-based processes that are associated with manual inspections, alphanumerical

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codification of the spare parts, and documentations at the committee level. About two-thirds of all operations still rely on hard-copy documents, although some groups of organizations have developed as a result of investing in SAP systems, digital archives, and databases developed by an organization. Such a hybrid environment indicates the collision of two opposite processes, vested legacy practice on one side, and an increasing acknowledgement of the necessity of digital transformation to pursue efficiency and transparency goals on the other. Similar patterns of slow digital adoption have been noted in other oil and gas contexts, where legacy paper-based processes coexist with ERP solutions, creating inefficiencies (Wilson & Campbell, 2016; Khater et al., 2020).

Asset management spans an immense variety of areas, such as IT hardware, personal protective equipment (PPE) and uniforms, chemical stores, specialized oilfield equipment and cyclical infrastructure e.g., pipelines, buildings. Nevertheless, these segments are rarely applied in an all-purpose structure. Although warehouses often control consumables and manufacturing tooling, departments that manage long term activities tend to manage infrastructure in silos, so there is fragmented control and poor visibility. This fragmented approach is also consistent with findings from other industries where silos in asset management reduce lifecycle visibility and weaken integration (Amadi-Echendu et al., 2010). These barriers and challenges are summarized in Figure 1.

Metadata is essential to streamlining monitoring activities and guaranteeing the accuracy of procurement, and some researchers and practitioners see it as important that unique tag numbers, VOCAP references, and supplier details are provided in metadata. The quality and consistency in utilization of the metadata, however, is wide. Systematic reordering in a highly advanced organization is supported with metadata, results into trace that supplements the lifecycle visibility. On the other hand, in less mature environments metadata is disjointed and mostly restricted to Excel spreadsheets or inaccurately associated with maintenance data. In particular, preventive maintenance metadata is poorly monitored and therefore limits the ability to gain wide asset lifecycle insight. Previous research has also highlighted how weak metadata structures undermine preventive maintenance, leading to inefficiencies in reliability and safety performance (Mitchell & Carlson, 2001; Tsang, 2002).

The system architecture that supports asset management is conservative in nature, largely influenced by the organizational priorities of focusing on control and security. All the respondents were in agreement that the systems are maintained on-premises; servers use local facilities and are monitored by information and communication technology (ICT) departments. The role-based access control forms a major aspect that limits the capabilities of users to particular job functions. Although such strategy increases protective performance, it also decreases the scalability and the capability to integrate mobile and cloud-based features. These findings mirror global literature showing that conservative IT practices in asset management often privilege control over flexibility, slowing cloud adoption (ISO 55000, 2014; Nguyen & Medjaher, 2019). As much as fiber optic upgrades within network infrastructures are being gradually injected into the systems, the access to these systems is limited to the majority of employees, specifically:

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field workers and subcontractors. Such limited access impedes the exchange of real-time data greatly, and thus, compromises the possibility of interdiction decision-making and real-time responsiveness. Similar barriers to real-time responsiveness have been observed in other oil and gas organizations due to restricted system accessibility (Parida & Kumar, 2006).

These decisions are explained by some security and control concerns. Respondents also noted a general lack of confidence in cloud adoption as it brought about risk of data misalignments, hacking and manipulation of systems in addition to the lack of a well-established legal system in Iraq. Traditional on-premise was considered safer even though not flexible. Although multi-step user authentication and audit logs help, some of the weaknesses exist: limited penetration testing, too many user-based controls are used, and cybersecurity discipline in the staff is typically weak. Security is more focused than innovation, a tendency that has made the shift to more contemporary architecture slow. This echoes the caution reported in other oil and gas studies, where cybersecurity concerns are seen as a barrier to digital transformation (Khater et al., 2020).

Integration and compatibility are among the most essential problems of asset management. Very few companies have been able to effectively integrate SAP or CMMS systems and a sizeable percentage of companies remain reliant to manual processes with updates being conducted at the end of every month. The practices slow down operations and enhance the potential of errors. Additionally, only one of the respondents reported inspections in real time, which was enabled by tablets and barcode readers, therefore highlighting the infrequency of the mobile compatibility in the industry. Without interoperability, the asset management systems are working in isolation hence hindering coordination within the organization and hampering development of a comprehensive and holistic management framework. Other research similarly identifies lack of interoperability as one of the biggest challenges in asset-intensive industries (Mardiasmo et al., 2008).

The greatest asset management weaknesses recognised are human error, overwriting manual/digital entries, inadequate training, compromised platforms, and the absence of dashboards or decision-support tools. Managers cannot access or view synthesized and visualized data and this forces them to use static reports that compromise speed and quality of decisions. This kind of restriction often causes overstocking and underutilization, which aggravate inefficiency. Prior studies have also emphasized that lack of decision-support tools and training is a major bottleneck for efficient asset utilization (Parida & Kumar, 2006; Tsang, 2002).

One of the most important conclusions that we can reach through the analysis of the survey deals with how well known and adopted blockchain technology is in the Iraqi institutions. To the majority of the respondents, blockchain meant cryptocurrency and their knowledge about how they could be used in asset management was limited. Some minimal number of the respondents, especially the respondent (R3) who was exposed to the subject at the academically formal levels, showed a more developed level of knowledge. This is a minority that is interested in the fact that blockchain possesses the ability to produce irreversible audit trails, distributed authorship and increased

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transparency. These features have tremendous capabilities of minimizing record manipulation, bolstering life cycle monitoring and increasing department accountability. Respondents also supported the strength of blockchain as being more resilient as compared to traditional server-based systems, which are still undermined by single points of failure. These insights are consistent with broader research which argues blockchain can significantly enhance transparency and traceability in asset-heavy industries (Crosby et al., 2016; Yermack, 2017). In addition to theoretical benefits, future opportunities in blockchain application in Iraqi environments seem to be limited. The challenges such as the absence of the regulatory approval, the lack of the Ministry of Oil approval, the inertia of bureaucracy or institutional resistance to change are also there. In addition, there is a further limitation on adoption by organizational culture and primitive legal frameworks even when there is something technical in readiness. In turn, without the formal endorsement or a coherent theory of investment rationale and policy support, blockchain will at best remain a theoretical framework, as one respondent noted, and implementation will be virtually unrealisable. Similar barriers related to regulatory ambiguity and institutional resistance have been widely reported in the blockchain adoption literature (Nguyen & Medjaher, 2019; Yermack, 2017).

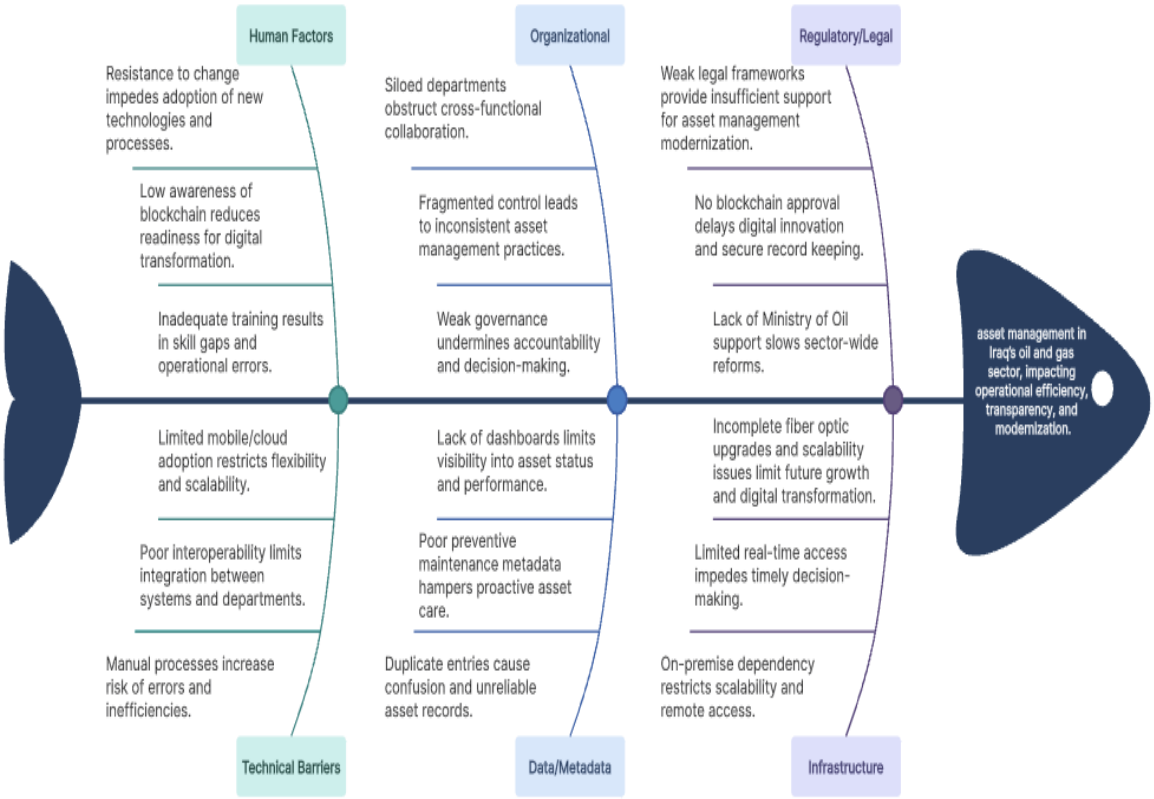

Figure 2: Barriers and challenges in asset management and blockchain adoption in Iraq's oil and gas sector

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CONCLUSION

This current research study illustrates that asset management in the oil and gas of Iraq remains in a disjointed and intermediate position, with its main characteristics represented by the dominance of manual operations, partially computerised systems, and a poor institutional substrate. Although the importance of transparency, lifecycle visibility and systemic integration is becoming clearer, there are still major obstacles such as departmental silos, limited interoperability, partial training and lack of regulation. Such restrictions hinder operational efficiency, compromise accountability and cannot be used to formulate a holistic management structure.

Some companies have launched programmes like the introduction of SAP platforms, creation of digital archives, the use of metadata-based processes, even though there has been inconsistent progress of modernisation. Physical infrastructure and electronic security restrictions; institutional hesitation continue to limit the presence of cloud-based solutions and mobile-enabled solutions. In this context, blockchain technology becomes one of the possible ways to solve some of the outlined problems. It could give immutable audit trails, distributed validation and increase transparency of any information which could significantly help data integrity, decrease the level of record manipulation, and enable accountability within organisational units. However, the phenomenon of blockchain adoption in Iraq is limited because of administrative neglect, bureaucratic stalling, and poor technical literacy.

The combination of a digital capacity-building process, workforce development, and favourable regulation constitutes the backbone of co-ordinated changes that form part of a viable future path. Blockchain and other additional innovative technologies, with efficient usage, can be of transformative use in enhancing asset management and aligning the sector to the international practice.

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