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Organization of Information Exchange in Production Processes at “Muborak Gazni Qayta Ishlash Zavodi MCHJ” Based on Digital Technologies

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Abstract: The rapid advancement of digital transformation has fundamentally changed the principles of information management in industrial enterprises, particularly within the oil and gas sector. Efficient information exchange among production units has become a critical prerequisite for ensuring operational reliability, optimizing technological processes, and improving managerial decision-making. This study investigates the organization of information exchange in production processes at “Muborak gazni qayta ishlash zavodi MCHJ” by analyzing the interaction of industrial information systems within the enterprise's digital environment. The research focuses on the integration of Supervisory Control and Data Acquisition (SCADA), Distributed Control Systems (DCS), Manufacturing Execution Systems (MES), Enterprise Resource Planning (ERP), Laboratory Information Management Systems (LIMS), and Business Intelligence (BI) platforms. A qualitative case-study methodology combined with systems analysis and process modeling was employed to evaluate the existing information infrastructure and identify integration challenges. The findings reveal that although the enterprise has achieved a relatively satisfactory level of horizontal integration among operational information systems, vertical integration between technological and corporate management levels remains incomplete. Several critical limitations were identified, including manual transfer of laboratory information, fragmented energy monitoring data, and insufficient interoperability among enterprise applications. Based on the obtained results, an integrated digital architecture utilizing OPC Unified Architecture (OPC UA), API-based communication mechanisms, and a centralized Data Lake is proposed to improve real-time information exchange and support intelligent decision-making. The implementation of these solutions is expected to increase data reliability, reduce operational delays, enhance resource utilization, and accelerate the digital transformation of the enterprise. The study contributes to the development of practical recommendations for improving industrial information exchange systems in accordance with Industry 4.0 principles and international digitalization standards [1]–[12].

Keywords: Digital Transformation, Information Exchange, Industrial Information Systems, SCADA, DCS, MES, ERP, LIMS, Business Intelligence, Data Lake, Industry 4.0, OPC UA, Oil and Gas Industry, Production Management, Digital Integration.

1. Introduction

Digital transformation has become one of the primary drivers of sustainable industrial development, fundamentally changing the mechanisms through which manufacturing enterprises collect, process, exchange, and utilize information. In modern industrial environments, production efficiency is determined not only by technological

capacity or investment volume but also by the ability of enterprises to establish continuous, reliable, and real-time information exchange across all organizational levels. Consequently, information has evolved into a strategic production resource whose quality, availability, and integration directly influence operational performance and managerial effectiveness [2], [3], [4].

The global transition toward Industry 4.0 has accelerated the implementation of intelligent manufacturing technologies that integrate cyber-physical systems, industrial Internet of Things (IIoT), cloud computing, artificial intelligence, digital twins, and advanced data analytics into production processes. These technologies require seamless interoperability among enterprise information systems to ensure uninterrupted data exchange and support automated decision-making throughout the entire production lifecycle [4], [5], [12].

In industrial enterprises, production data are generated simultaneously by numerous independent information systems, including Supervisory Control and Data Acquisition (SCADA), Distributed Control Systems (DCS), Manufacturing Execution Systems (MES), Laboratory Information Management Systems (LIMS), Enterprise Resource Planning (ERP), Computerized Maintenance Management Systems (CMMS), and Business Intelligence (BI) platforms. Although each system performs specialized operational functions, ineffective integration among them frequently results in fragmented databases, duplicated information, delayed reporting, and inconsistent managerial decisions [1], [2], [13].

Previous studies have demonstrated that horizontal integration among operational information systems and vertical integration between technological and managerial levels constitute the foundation of modern digital enterprises. Levina emphasized that integrated information environments significantly improve production transparency, coordination, and organizational efficiency by enabling continuous information flows across all enterprise functions [1]. Similarly, Dmitrievskiy and Yeromin identified technological incompatibility, organizational fragmentation, cybersecurity concerns, and insufficient digital competencies as the principal barriers limiting effective information exchange within oil and gas enterprises [2], [13], [14]. Porter and Heppelmann further argued that smart connected industrial systems generate strategic value only when operational data can be continuously exchanged across organizational boundaries through integrated digital platforms [3].

The oil and gas industry represents one of the most information-intensive industrial sectors because production processes involve continuous monitoring of technological parameters, laboratory quality control, equipment diagnostics, logistics management, environmental protection, and resource optimization. Consequently, production reliability increasingly depends on the efficiency of digital information exchange rather than solely on technological infrastructure [8], [9], [10], [11].

In Uzbekistan, the digital transformation of the fuel and energy sector has become a national strategic priority. Presidential Decree No. PF-77 emphasizes the necessity of establishing integrated digital management systems, strengthening information interoperability among industrial enterprises, and expanding the implementation of intelligent production technologies throughout the energy sector [15]. These governmental initiatives encourage manufacturing enterprises to modernize their digital infrastructure and improve information exchange mechanisms in accordance with international standards.

"Muborak gazni qayta ishlash zavodi MCHJ" represents one of Uzbekistan's largest gas processing enterprises, operating numerous technological facilities supported by various industrial information systems. Despite substantial investments in automation technologies, information generated by production control systems, laboratory platforms, maintenance applications, and enterprise management software remains only partially

integrated. As a consequence, decision-makers frequently rely on fragmented datasets that reduce analytical accuracy and delay operational responses.

The objective of this study is to evaluate the current organization of information exchange within the production processes of "Muborak gazni qayta ishlash zavodi MCHJ", identify the existing technological and organizational limitations affecting system integration, and develop scientifically grounded recommendations for establishing an integrated digital information environment based on Industry 4.0 technologies. The proposed approach aims to enhance interoperability among enterprise information systems, improve data quality, support real-time managerial decision-making, and strengthen the overall digital transformation of industrial production.

Literature Review

The organization of information exchange in industrial enterprises has become one of the central research topics within the broader context of digital transformation and Industry 4.0. The increasing complexity of manufacturing systems, together with the rapid growth of industrial data, has created a demand for integrated information environments capable of supporting real-time monitoring, predictive analytics, and intelligent decision-making. Numerous researchers have emphasized that sustainable industrial development depends not only on the automation of technological processes but also on the establishment of interoperable information systems that ensure continuous data exchange across all organizational levels [1], [2], [3].

One of the most comprehensive theoretical approaches to enterprise information integration was proposed by Levina, who introduced the concept of horizontal and vertical integration of industrial information systems [1]. According to this concept, horizontal integration enables information exchange among systems operating at the same organizational level, whereas vertical integration establishes continuous communication between production equipment, manufacturing execution systems, enterprise resource planning applications, and strategic management platforms. Such an integrated architecture minimizes information fragmentation, improves data consistency, and significantly enhances managerial decision-making. The principles proposed by Levina provide an important theoretical foundation for evaluating the effectiveness of information exchange within industrial enterprises undergoing digital transformation.

The digital transformation of the oil and gas industry has been extensively investigated by Dmitrievskiy and Yeromin, who argue that industrial digitalization extends beyond the implementation of individual automation technologies and requires the creation of integrated digital ecosystems that combine operational technologies with enterprise management systems [2], [13]. Their studies classify the barriers affecting information exchange into four major categories: technological incompatibility among heterogeneous software platforms, organizational fragmentation between functional departments, shortages of qualified digital specialists, and growing cybersecurity requirements. According to these researchers, overcoming these barriers requires standardized communication protocols, unified data architectures, and coordinated digital transformation strategies.

In subsequent studies, Yeromin further demonstrated that the evolution of digital production follows a sequential development trajectory consisting of digitization, optimization, and intelligent autonomous management [14]. During the initial stage, analog production information is converted into digital form through automation technologies. The second stage focuses on optimizing industrial processes using integrated enterprise information systems, while the final stage introduces artificial intelligence, digital twins, machine learning, and predictive analytics capable of supporting autonomous industrial decision-making. This evolutionary model provides an appropriate conceptual framework for assessing the digital maturity of manufacturing enterprises.

The strategic importance of integrated information exchange has also been emphasized by Porter and Heppelmann, who introduced the concept of smart, connected products and demonstrated that digital connectivity fundamentally changes industrial competition [3]. According to their research, manufacturing enterprises can no longer rely solely on physical assets because competitive advantage increasingly depends on continuous information exchange among production equipment, digital platforms, customers, suppliers, and management systems. Integrated digital information environments therefore become strategic assets supporting innovation, operational flexibility, and value creation.

A significant contribution to Industry 4.0 research was made by Lee, Bagheri, and Kao, who proposed a cyber-physical systems architecture specifically designed for intelligent manufacturing [4]. Their framework integrates physical production equipment with computational systems through industrial communication networks capable of collecting, processing, and analyzing operational data in real time. The authors emphasize that cyber-physical systems require uninterrupted information exchange among sensors, controllers, enterprise databases, and advanced analytical platforms to support autonomous industrial operations.

The strategic vision of Industry 4.0 was further developed by Kagermann, Wahlster, and Helbig, whose recommendations established interoperability, decentralization, virtualization, service orientation, modularity, and real-time capability as the fundamental principles of modern industrial production [5]. These principles require manufacturing enterprises to establish unified digital ecosystems where heterogeneous information systems communicate through standardized architectures. Their work has become one of the most influential references supporting industrial digital transformation worldwide.

From a technological perspective, industrial interoperability largely depends on internationally accepted communication standards. The OPC Foundation introduced the OPC Unified Architecture (OPC UA), which enables secure, platform-independent communication among industrial automation systems developed by different vendors [6]. OPC UA has become one of the most widely implemented technologies for integrating SCADA, DCS, MES, ERP, and cloud-based industrial applications because it ensures standardized data exchange while maintaining high cybersecurity requirements.

Industrial information integration is also supported by sector-specific technical standards. The Energy Standards Resource Centre proposed standardized industrial data exchange frameworks that facilitate interoperability among energy management systems, production monitoring platforms, and enterprise information systems [7]. These standards contribute to improving data consistency and reducing the complexity of integrating heterogeneous industrial software solutions.

Enterprise Resource Planning systems continue to play a central role in coordinating industrial information exchange. According to SAP SE, modern ERP platforms serve as unified repositories integrating production planning, procurement, maintenance, logistics, finance, and human resource management into a single digital environment [8]. The adoption of integrated ERP solutions significantly improves operational transparency while supporting real-time managerial decision-making.

Recent analytical reports published by Gartner indicate that industrial organizations implementing fully integrated digital platforms achieve considerably higher operational efficiency, shorter production cycles, and improved predictive maintenance capabilities compared with enterprises relying on fragmented information systems [9]. Gartner further emphasizes that successful implementation of artificial intelligence and predictive analytics requires highly standardized, high-quality enterprise data integrated across all business processes.

Similarly, Ernst & Young (EY) reported that digital transformation in capital-intensive industries increasingly depends on the integration of operational technologies

with enterprise management platforms through unified digital ecosystems [10]. Their findings demonstrate that organizations implementing integrated digital architectures reduce project risks, improve information transparency, and significantly enhance investment efficiency.

The International Energy Agency (IEA) also recognizes digitalization as one of the principal factors influencing the future development of global energy industries [11]. According to the IEA, intelligent industrial information systems improve production reliability, optimize energy consumption, reduce environmental impacts, and strengthen the resilience of energy infrastructure through continuous data exchange and advanced analytics.

Finally, the ISO 23247 Digital Twin Framework for Manufacturing establishes internationally recognized requirements for integrating physical production systems with virtual digital models capable of supporting simulation, predictive maintenance, and intelligent production management [12]. The implementation of digital twins requires highly integrated industrial information systems capable of providing complete, standardized, and real-time production data.

Although previous studies have extensively examined industrial digital transformation, relatively limited research has focused on the practical organization of information exchange within gas-processing enterprises operating under the specific technological and organizational conditions of Uzbekistan. Existing international studies primarily address general Industry 4.0 concepts without considering the integration challenges associated with SCADA, DCS, MES, ERP, LIMS, Business Intelligence platforms, and energy management systems simultaneously. Therefore, the present study addresses this research gap by analyzing the existing information exchange architecture at "Muborak gazni qayta ishlash zavodi MCHJ", evaluating its current integration level, identifying practical limitations affecting data interoperability, and proposing an integrated digital architecture aligned with international best practices and Industry 4.0 principle.

2. Materials and Methods

This study employed a qualitative case study approach to investigate the organization of information exchange in the production processes of "Muborak gazni qayta ishlash zavodi MCHJ." The case study method was selected because it enables an in-depth examination of information flows, digital infrastructure, and system interoperability within a real industrial environment. This approach is widely applied in industrial digital transformation research, where organizational processes and technological systems are analyzed under actual operating conditions [2], [4], [5].

The research was conducted in four consecutive stages. During the first stage, the existing digital infrastructure of the enterprise was examined to identify the information systems supporting production and management activities. Particular attention was devoted to Supervisory Control and Data Acquisition (SCADA), Distributed Control Systems (DCS), Manufacturing Execution Systems (MES), Enterprise Resource Planning (ERP), Laboratory Information Management Systems (LIMS), Business Intelligence (BI), and Energy Monitoring Systems (EMS). Their functional responsibilities, operational interactions, and existing communication mechanisms were analyzed to determine the current architecture of enterprise information exchange [1], [6], [8].

The second stage focused on analyzing the movement of information throughout the production process. Data flows between operational departments, production workshops, laboratories, maintenance services, warehouse management, planning units, and corporate management were mapped using process analysis techniques. Horizontal information exchange between systems operating at the same management level and

vertical information exchange between operational and strategic management levels were evaluated according to the enterprise integration framework proposed by Levina [1].

During the third stage, the level of interoperability among enterprise information systems was assessed. The analysis considered communication protocols, database connectivity, application interfaces, synchronization mechanisms, and the degree of automation associated with data transmission. Particular emphasis was placed on identifying manual operations, duplicated information, isolated databases, delayed reporting, and fragmented data repositories that reduce the overall efficiency of enterprise information exchange. Existing integration technologies, including OPC Unified Architecture (OPC UA), Application Programming Interfaces (API), and centralized database management mechanisms, were evaluated against internationally recognized industrial digitalization practices [6], [7], [12].

The final stage consisted of developing an integrated digital architecture intended to improve information exchange across the enterprise. Comparative analysis was applied to evaluate the current information infrastructure against internationally recognized Industry 4.0 principles and digital manufacturing standards [4], [5]. Recommendations were formulated for integrating production information systems through a centralized Data Lake architecture capable of supporting real-time information exchange, advanced analytics, predictive maintenance, and intelligent decision-making.

The research relied primarily on document analysis, systems analysis, process modeling, architectural analysis, and comparative evaluation. Enterprise documentation describing information systems, production workflows, system architecture, and organizational management structure served as the principal sources of empirical information. In addition, information flow diagrams and digital system architectures developed during the research were used to visualize relationships among enterprise information systems and identify existing integration gaps.

To evaluate the effectiveness of information exchange, several analytical criteria were established, including:

- Degree of system integration;
- Completeness of enterprise data exchange;
- Level of automation;
- Information transmission speed;
- Interoperability among information systems;
- Availability of real-time production information;
- Accessibility of analytical information for managerial decision-making.

The reliability of the research findings was ensured through comparison with internationally recognized digital transformation frameworks and industrial integration standards proposed by Levina [1], Dmitrievskiy and Yeromin [2], [13], [14], Porter and Heppelmann [3], Lee et al. [4], Kagermann et al. [5], the OPC Foundation [6], SAP [8], Gartner [9], EY [10], the International Energy Agency [11], and ISO 23247 [12]. This comparative approach strengthened the scientific validity of the proposed recommendations and ensured consistency with current international best practices in industrial digital transformation.

The methodological framework developed in this study provides a systematic basis for evaluating information exchange processes in industrial enterprises and may be applied to other manufacturing organizations seeking to improve digital interoperability, optimize production management, and accelerate the implementation of Industry 4.0 technologies.

3. Results

The analysis of the existing digital infrastructure at "Muborak gazni qayta ishlash zavodi MCHJ" demonstrated that the enterprise has established a comprehensive technological environment supported by multiple industrial information systems responsible for production control, resource planning, laboratory operations, equipment monitoring, and corporate management. Although these systems perform their designated functions effectively, the investigation revealed that the degree of interoperability among them varies considerably, resulting in fragmented information exchange and limiting the efficiency of enterprise-wide digital management.

The research identified seven principal information systems currently supporting production activities: Supervisory Control and Data Acquisition (SCADA), Distributed Control Systems (DCS), Manufacturing Execution Systems (MES), Enterprise Resource Planning (ERP), Laboratory Information Management Systems (LIMS), Customer Relationship Management (CRM), and Business Intelligence (BI). Each system manages specific operational tasks; however, complete integration among these platforms has not yet been achieved.

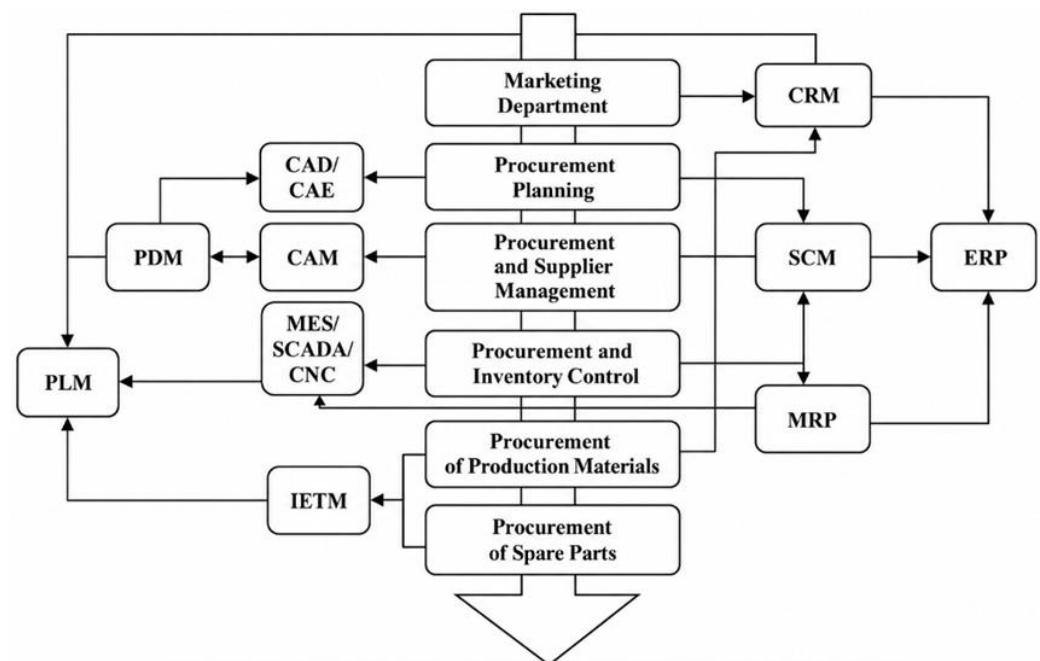


Figure 1. Integrated information systems supporting production processes at "Muborak gazni qayta ishlash zavodi MCHJ".

Source: Adapted from Abdullaev (2019) [16].

As illustrated in **Figure 1**, customer requirements are initially processed through the Customer Relationship Management (CRM) platform. Engineering documentation is subsequently developed using CAD/CAE and Product Data Management (PDM) systems. Manufacturing planning is supported by Material Requirements Planning (MRP), Supply Chain Management (SCM), and Computer-Aided Manufacturing (CAM) applications. During production, technological parameters are continuously monitored through SCADA and DCS systems, while Manufacturing Execution Systems coordinate production scheduling and operational control. Finally, operational information is transferred to the Enterprise Resource Planning platform, where financial, logistical, and managerial information is consolidated into a unified corporate database. These findings indicate that horizontal information exchange has been partially established among operational information systems.

Despite this level of integration, several production stages continue to rely on manual information transfer and isolated databases, reducing information consistency and increasing the possibility of data duplication.

To evaluate organizational information flows, the management structure of the enterprise was examined.

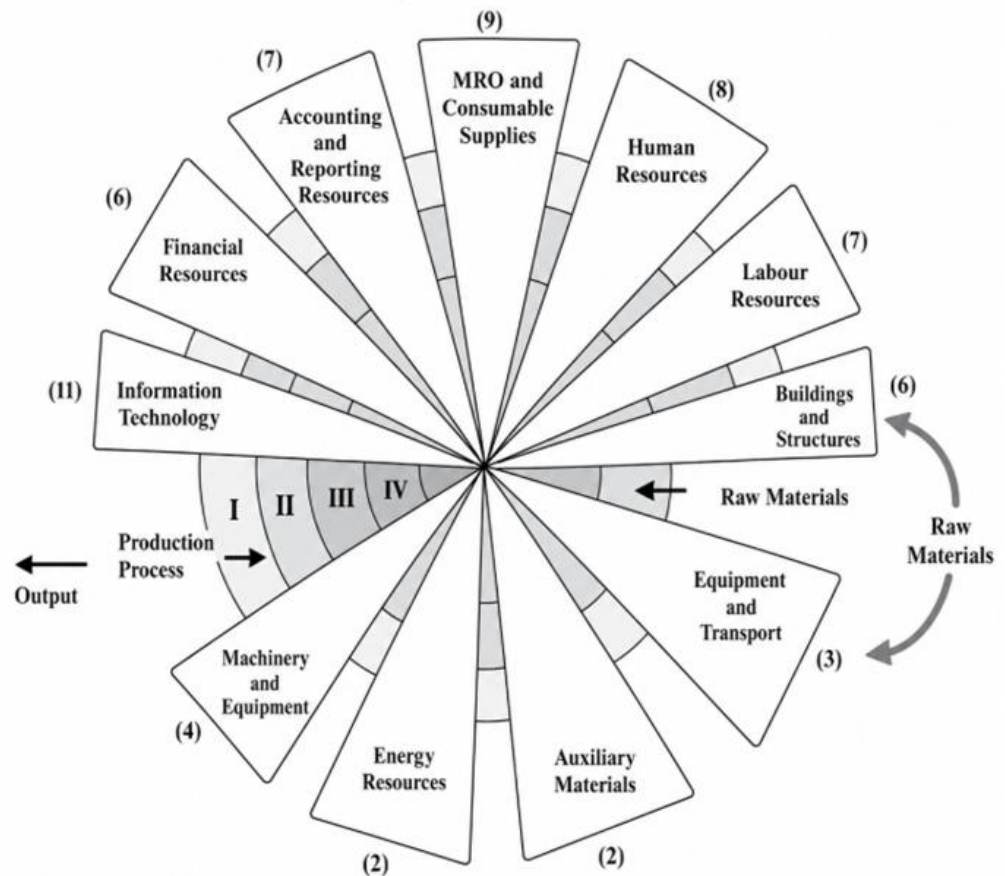


Figure 2. Organizational hierarchy supporting enterprise information exchange.

Source: Adapted from Abdullaev (2019) [16].

As presented in Figure 2, production workshops, laboratory services, maintenance departments, warehouse operations, transportation services, financial management, marketing divisions, and administrative units operate within a hierarchical organizational structure. Operational information generated at the production level is transferred through several management levels before reaching executive decision-makers. Although information exchange between neighboring organizational units has been largely automated, communication between operational technologies and corporate management systems remains only partially integrated. Consequently, managerial decisions are frequently based on information received with a certain delay.

To determine the current maturity of enterprise information integration, the overall architecture of digital information exchange was analyzed.

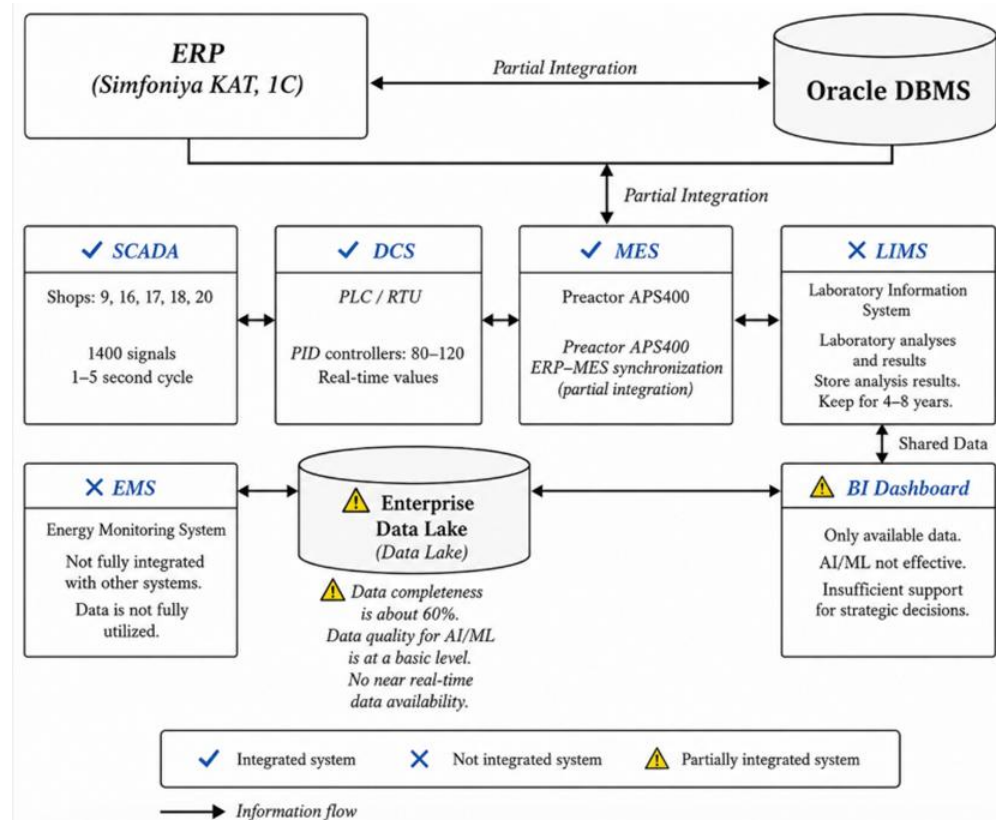


Figure 3. Current architecture of enterprise information exchange and identified integration gaps.

Source: Adapted from Abdullaev (2019) [16].

As shown in Figure 3, the strongest level of integration exists between SCADA, DCS, MES, and ERP platforms. These systems continuously exchange production parameters, operational indicators, and manufacturing performance data, enabling production monitoring and operational control in near real time.

However, the analysis also identified several critical integration gaps. The Laboratory Information Management System (LIMS) remains only partially connected to the ERP environment. Laboratory quality-control results are transferred manually, creating reporting delays and increasing the probability of transcription errors. Similarly, the Energy Monitoring System operates independently from Business Intelligence applications, preventing enterprise managers from accessing real-time energy consumption indicators through centralized analytical dashboards.

The assessment of enterprise-wide information integration further demonstrated that approximately 60% of operational production data are currently incorporated into the unified corporate information environment. This estimate was calculated during the present study by comparing the number of fully integrated information systems with the total number of digital platforms supporting production and management activities. The remaining information continues to reside within isolated databases or is transferred manually between organizational units, thereby limiting opportunities for comprehensive digital analysis.

The obtained findings indicate that the existing level of information completeness is insufficient for implementing advanced digital technologies such as artificial intelligence, machine learning, predictive analytics, and Digital Twin applications. According to international industrial digitalization guidelines published by SAP, Gartner, and ISO 23247, successful deployment of intelligent industrial analytics generally requires standardized enterprise datasets with completeness levels approaching 90–95% [8], [9],

[12]. Consequently, increasing enterprise data integration represents a strategic prerequisite for future digital transformation.

The comparative analysis also demonstrated that introducing OPC Unified Architecture (OPC UA), standardized API-based communication mechanisms, centralized Data Lake architecture, and automated synchronization between LIMS, ERP, MES, and Business Intelligence platforms would substantially improve enterprise interoperability. Such integration would eliminate duplicated information, reduce reporting delays, improve analytical accuracy, and provide decision-makers with continuous access to reliable operational information.

Overall, the results indicate that "Muborak gazni qayta ishlash zavodi MCHJ" has established a solid technological foundation for digital transformation. Nevertheless, achieving full digital maturity requires strengthening vertical integration between operational technologies and corporate management systems while expanding interoperability among all enterprise information resources. These improvements would significantly increase production efficiency, enhance managerial responsiveness, reduce operational costs, and establish the technological basis for implementing intelligent Industry 4.0 solutions.

4. Discussion

The findings of this study demonstrate that digital technologies have significantly improved the organization of information exchange within the production processes of "Muborak gazni qayta ishlash zavodi MCHJ". Nevertheless, the current level of digital integration remains insufficient to support fully automated, data-driven production management. The results indicate that while operational information systems have been successfully implemented across different production stages, the absence of complete interoperability limits the efficiency of information exchange and reduces the enterprise's readiness for advanced Industry 4.0 applications.

The analysis confirms the theoretical framework proposed by **Levina**, who argued that effective enterprise management requires the simultaneous implementation of horizontal and vertical integration of information systems [1]. The present study revealed that horizontal integration among SCADA, DCS, MES, and ERP systems has reached a relatively satisfactory level, enabling continuous monitoring of technological processes and supporting operational decision-making. However, vertical integration between production-level information systems and corporate management platforms remains incomplete. Consequently, strategic decisions are not always supported by comprehensive real-time production information, reducing managerial responsiveness and limiting the effectiveness of enterprise-wide digital governance.

The identified integration challenges are also consistent with the observations reported by Dmitrievskiy and Yeromin, who classified technological incompatibility, organizational fragmentation, and insufficient interoperability as the primary barriers to digital transformation in oil and gas enterprises [2], [13], [14]. Similar limitations were observed during the present investigation, particularly regarding the incomplete integration of the Laboratory Information Management System (LIMS) and Energy Monitoring System with enterprise resource planning and business intelligence platforms. These isolated information environments require manual data processing, increase reporting delays, and reduce the overall quality of managerial information.

The study further supports the concept introduced by Porter and Heppelmann, who emphasized that the competitive advantage of modern industrial enterprises increasingly depends on the continuous exchange of reliable digital information rather than on physical production assets alone [3]. The findings indicate that although production data are continuously generated by operational technologies, incomplete synchronization among

enterprise applications prevents management from fully utilizing these information resources for strategic planning and performance optimization.

The proposed cyber-physical manufacturing architecture developed by Lee, Bagheri, and Kao provides an appropriate conceptual framework for interpreting the obtained results [4]. Their model assumes uninterrupted communication among production equipment, industrial sensors, enterprise databases, and analytical platforms. The present research demonstrates that the enterprise has already established several essential components of such an architecture through SCADA, DCS, and MES technologies. However, incomplete integration with laboratory information systems and business intelligence applications prevents the realization of a fully connected cyber-physical production environment.

The findings are also closely aligned with the Industry 4.0 implementation principles formulated by Kagermann, Wahlster, and Helbig, particularly regarding interoperability, decentralization, real-time capability, and service orientation [5]. Although several of these principles have already been incorporated into the enterprise's production management infrastructure, further development is required to establish standardized communication among all digital platforms. The implementation of internationally recognized interoperability technologies such as OPC Unified Architecture (OPC UA) and standardized Application Programming Interfaces (APIs) would substantially improve communication reliability among heterogeneous industrial systems [6].

One of the most significant findings of this study concerns enterprise data completeness. The investigation estimated that approximately 60% of operational production data are currently integrated into the unified corporate information environment. This level of information integration limits the implementation of advanced analytical technologies, including predictive maintenance, artificial intelligence, machine learning, and Digital Twin applications. According to recommendations published by SAP, Gartner, and ISO 23247, successful deployment of intelligent industrial analytics generally requires highly standardized enterprise datasets with completeness approaching 90–95% [8], [9], [12]. Consequently, improving enterprise-wide data integration should be regarded as one of the organization's highest strategic priorities.

Another important implication of the research concerns the establishment of a centralized Data Lake capable of integrating information generated by operational technologies, enterprise applications, laboratory systems, maintenance services, and energy management platforms. Such an architecture would eliminate duplicated databases, improve data consistency, facilitate advanced analytics, and provide a reliable foundation for artificial intelligence applications. Similar digital integration strategies have been recommended in recent industrial reports published by Ernst & Young and the International Energy Agency, both of which identify unified enterprise information environments as essential components of sustainable industrial digital transformation [10], [11].

Although the proposed recommendations provide practical opportunities for improving information exchange at "Muborak gazni qayta ishlash zavodi MCHJ" several limitations should be acknowledged. The research was conducted as a single-enterprise case study; therefore, the findings primarily reflect the organizational and technological characteristics of one gas-processing facility. Future research should extend the proposed analytical framework to additional industrial enterprises within the oil and gas sector to enable comparative analysis and strengthen the generalizability of the obtained results. Furthermore, future investigations may incorporate quantitative performance indicators, economic efficiency assessments, and simulation-based validation of proposed integration architectures.

Overall, the findings demonstrate that strengthening interoperability among industrial information systems represents a critical prerequisite for achieving intelligent

manufacturing, improving production efficiency, and accelerating digital transformation within Uzbekistan's oil and gas industry. The implementation of integrated information architectures based on international digitalization standards would substantially improve enterprise competitiveness while creating favorable conditions for the adoption of advanced Industry 4.0 technology.

5. Conclusions

This study investigated the organization of information exchange in the production processes of "**Muborak gazni qayta ishlash zavodi MCHJ**" within the context of digital transformation and Industry 4.0. The research focused on evaluating the current architecture of enterprise information systems, assessing the effectiveness of information exchange among operational and managerial platforms, and identifying technological limitations affecting digital integration.

The findings indicate that the enterprise has established a modern digital infrastructure consisting of SCADA, DCS, MES, ERP, CRM, and other industrial information systems supporting production monitoring, operational control, and enterprise resource management. These technologies have significantly improved operational transparency and enabled partial automation of production management. Nevertheless, the current investigation revealed that interoperability among several critical information systems remains incomplete, particularly regarding the integration of Laboratory Information Management Systems (LIMS), Energy Monitoring Systems, Business Intelligence platforms, and centralized enterprise databases.

The research demonstrated that horizontal integration among operational information systems has reached a satisfactory level, whereas vertical integration between production control systems and corporate management platforms remains insufficient. As a consequence, information generated during technological operations is not always transferred automatically to strategic management systems, thereby reducing the efficiency of managerial decision-making and limiting the implementation of advanced digital technologies.

Another important outcome of the study concerns the evaluation of enterprise-wide information completeness. The analysis estimated that approximately **60%** of operational production data are currently integrated within the unified corporate information environment. Although this level of integration supports routine production management, it remains insufficient for implementing artificial intelligence, predictive analytics, Digital Twin technologies, and other intelligent manufacturing applications. International industrial digitalization guidelines indicate that highly standardized and nearly complete enterprise datasets are essential for achieving reliable data-driven decision-making [8], [9], [12].

Based on the obtained findings, the study proposes the implementation of a unified **Data Lake** architecture supported by **OPC Unified Architecture (OPC UA)**, standardized **Application Programming Interfaces (APIs)**, and automated synchronization mechanisms connecting SCADA, DCS, MES, ERP, LIMS, Energy Monitoring Systems, and Business Intelligence platforms. The proposed digital architecture is expected to improve interoperability, eliminate duplicated information, reduce reporting delays, enhance data quality, and provide continuous access to reliable operational information.

The scientific contribution of this research lies in the development of an integrated conceptual framework for organizing information exchange within industrial enterprises undergoing digital transformation. Unlike previous studies that primarily examined theoretical aspects of Industry 4.0, this research presents a practical case study demonstrating how digital integration principles can be applied to a large gas-processing enterprise in Uzbekistan. The proposed recommendations may serve as methodological

guidance for other industrial enterprises seeking to improve digital interoperability and strengthen enterprise-wide information management.

From a practical perspective, the implementation of the proposed integration mechanisms would improve production efficiency, optimize resource utilization, strengthen operational transparency, accelerate managerial decision-making, and enhance the enterprise's competitiveness within the rapidly evolving digital economy.

Future research should extend the proposed methodology to additional industrial enterprises within the oil and gas sector and evaluate the economic effectiveness of digital integration projects using quantitative performance indicators, simulation models, and artificial intelligence-based optimization techniques.

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