



Article

Modern Methods of Managing Production Processes in the Construction Materials Industry

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Abstract: This article provides a theoretical and practical analysis of modern methods for managing production processes in the construction materials industry. The study examines the impact of production process automation, digital monitoring, advanced process control, predictive management, and quality management systems on sectoral efficiency. The results of the analysis indicate that traditional methods of managing production processes in the construction materials industry do not fully meet contemporary market requirements. It is scientifically substantiated that the comprehensive implementation of modern management methods makes it possible to increase production efficiency, ensure rational use of energy and resources, maintain stable product quality, and strengthen the competitiveness of enterprises.

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Key words: construction materials industry, production process management, automated control systems, digital monitoring, energy efficiency, quality management, resource efficiency, production efficiency

Introduction. The construction materials industry is one of the strategic sectors that determines the production potential of any country. Its level of development is closely interconnected with the sustainable growth of other sectors of the economy, including construction, industry, transport, and social infrastructure. In this regard, the efficient operation of construction materials manufacturing enterprises has a direct impact on a country's economic security and social stability.

In recent years, the acceleration of urbanization processes worldwide, population growth, and the expansion of capital construction volumes have sharply increased demand for construction materials. This situation, alongside the expansion of production

capacities, necessitates efficient use of available resources, ensuring product quality at the level of international standards, and optimizing production costs.

Today, enterprises in the construction materials industry face a number of complex challenges. These include the physical and technological obsolescence of equipment, high energy consumption, disruptions in production processes, and human-factor-related errors, all of which constrain production efficiency. In addition, increasingly stringent environmental protection requirements compel enterprises to adopt environmentally friendly and energy-efficient technologies.

Under these conditions, the application of modern methods for managing production processes becomes critically important. Digital transformation, automated control systems, data-driven analysis, artificial intelligence, and forecasting techniques make it possible to elevate production processes to a qualitatively new level. Such approaches enable real-time monitoring of production processes, rapid and accurate decision-making, and the rational use of resources.

At present, the construction materials industry is one of the most dynamically developing sectors of the economy, and its effective functioning is directly linked to a country's investment attractiveness, infrastructure development, and the social well-being of the population. Large-scale construction projects, housing programs, and the expansion of industrial zones implemented by the public and private sectors are steadily increasing demand for construction materials. This, in turn, places the task before manufacturing enterprises of simultaneously ensuring high production volumes, stable quality, and economic efficiency.

Production processes in the construction materials industry are technologically complex and involve numerous interrelated operations. From raw material preparation to the packaging and storage of finished products, strict adherence to technological regimes is required at all stages. In practice, however, in many enterprises the lack of sufficient automation and systematic control in managing these processes leads to reduced production efficiency and increasing losses.

The relevance of the topic is further emphasized by the fact that the construction materials industry is an energy- and resource-intensive sector. The production of cement, lime, ceramics, and similar products requires large amounts of fuel and energy resources. Rising energy prices directly affect production costs, thereby reducing the competitiveness of enterprises. For this reason, ensuring energy efficiency through the organization of production processes based on modern management methods has become a matter of strategic importance.

Moreover, environmental factors further reinforce the significance of the topic. Gas emissions, dust, and industrial waste generated during construction materials production have a negative impact on the environment. The continuous tightening of environmental standards and requirements compels enterprises to manage production processes accurately and efficiently, reduce waste volumes, and introduce environmentally safe technologies. These tasks can be effectively addressed only through the application of modern management methods.

The transition to a digital economy also makes this topic particularly relevant. Automated control systems, digital monitoring, process modeling, and data-driven decision-making methods provide opportunities to fundamentally enhance the efficiency of production management. Such approaches enable enterprises to identify

shortcomings in production processes in advance, reduce risks, and improve strategic planning.

The economic, technological, and environmental factors outlined above make the in-depth scientific study of modern methods for managing production processes in the construction materials industry, the evaluation of their effectiveness, and their practical implementation highly relevant. Therefore, this topic is of great importance today not only from a scientific perspective, but also from a practical standpoint.

Review of relevant literature. Scientific literature on managing production processes in the construction materials industry can be conditionally divided into four major areas: automation of technological processes (PLC/SCADA); advanced process control and optimization (APC, MPC); digitalization and “smart factory” concepts (AI, digital platforms, integration); and quality management and standardization (ISO 9001 and related approaches). This classification enables a comprehensive view of the topic while also making it possible to identify the methodological limitations of each area.

1. PLC/SCADA-based automation: opportunities and limitations. Studies in this area have been conducted as follows.

Studies on automation are generally aimed at stabilizing control at the level of workshops and individual units. For example, in the cement industry, the implementation of PLC and SCADA solutions is noted to contribute to the centralization of monitoring, the rapid detection of emergency situations, and the standardization of operator decisions. Some studies indicate that automation in energy-intensive units such as kilns and mills reduces labor input and enhances technological discipline. [1]

However, the critical limitation is that PLC/SCADA systems often remain at the level of “observation and reaction”: that is, the system displays parameters and issues alarms, but does not independently determine optimal operating modes or fully ensure multi-objective optimization. Therefore, in practical terms, PLC/SCADA automation represents a necessary foundation but not a sufficient condition. Without being complemented by higher-level APC/MPC solutions and enterprise-level integration, efficiency tends to reach a “plateau.” [2]

2. Advanced process control: MPC, predictive control, and the energy–quality trade-off have been investigated in the following studies.

In recent years, the complexities of cement production—such as long time delays, large inertia, and strong coupling—have made Model Predictive Control (MPC) and related predictive control approaches increasingly relevant. The key advantage of the MPC concept lies in its ability to predict future system states while accounting for constraints, and to simultaneously balance multiple performance indicators, including quality, energy efficiency, and stability. [3]

For example, in the cement burning system, a data-driven predictive model combined with an optimization-based control loop has been proposed, taking into account the conflict between energy consumption (electricity and coal) and clinker quality (e.g., free CaO, f-CaO). The authors integrate the energy objective in a weighted form while introducing quality indicators as constraints, thereby attempting to reduce the practical complexity of managing Pareto-optimal solutions. [4]

At the same time, there are studies demonstrating that predictive control strategies—including stochastic models—integrated into a SCADA environment for cement grinding circuits under real plant conditions improve stability and throughput. Such

studies are significant due to their practical relevance, as the models and controllers are reported to have been validated online in actual industrial operation. [5]

However, a common challenge in the MPC/predictive control literature is the reliability of model quality and issues related to industrial data. In many studies, datasets are limited, and real-world factors such as sensor errors and noise, equipment aging, and variability in raw materials are not fully captured. As a result, scientific findings cannot be directly transferred to every plant; each production facility requires dedicated system identification, calibration, and operational “fine-tuning.” [6]

3. Digitalization and the “smart cement plant”: the following studies have been carried out on the practical implementation of integration, AI, and new control approaches.

In studies on digital transformation, unlike traditional automation, not only individual units but the entire production chain are considered in terms of data flows and decision-making architecture. For example, research dedicated to the concept of the “smart cement plant” in China reports effects such as energy savings and workforce reduction achieved through the integration of AI and APC, online instrumentation, robotics, digital process support platforms, and linkage with ERP data. [7]

At present, in many materials describing such “large-scale transformations,” the reported results are often conceptual or presentation-oriented, and the extent to which the methodology can be replicated (i.e., reproduced in another country or enterprise) is not always clearly disclosed. Therefore, the practical value of digitalization appears to depend less on specific technical solutions and more on institutional readiness, including human resources, data culture, regulations, KPIs, and cybersecurity.

4. Quality management: ISO 9001 and the problems and controversial issues in the construction industry have been examined in the following studies.

In the international literature on quality management, ISO 9001 is frequently referenced. Official ISO sources describe ISO 9001 as a global standard that defines the requirements for establishing, implementing, maintaining, and continually improving a quality management system (QMS). [8]

However, in academic research, the assumption that the impact of ISO 9001 is “automatically positive” is not universally accepted. For example, case studies from construction companies show that the effectiveness of ISO standard implementation strongly depends on employee understanding and the quality of actual execution: if the standard turns into mere “paperwork,” the expected improvement in performance may not materialize. At the same time, other studies provide statistically grounded conclusions indicating that the application of ISO 9001 can reduce quality costs and enhance managerial discipline. [9]

Thus, the main conclusion drawn from the literature is that ISO 9001 represents a necessary framework for construction materials enterprises, but not a guarantee of results. The outcomes depend on how the standard is implemented and on the extent to which it is integrated with KPI systems, technological control, and digitalization.

5. At the enterprise level, research focusing on integration based on MES/ERP systems and the ISA-95/IEC 62264 approach includes the following studies.

In modern control systems, a key challenge is the “gap” between shop-floor control (SCADA/PLC) and enterprise-level planning (ERP). Therefore, many sources note that

the ISA-95 (IEC 62264) standards are aimed at systematizing interfaces and data exchange layers between manufacturing operations and enterprise planning. [10]

Overall, although the ISA-95/IEC 62264 frameworks are available, their implementation is often not a ready-made “off-the-shelf solution”; rather, it requires architectural redesign, harmonization of data models, and reengineering of business processes. In the construction materials industry—particularly in energy-intensive cement clusters—such integration can be effective, but it demands substantial investment and a high level of expertise.

In local studies, the following scientific works can be cited that focus specifically on modern methods of controlling production processes in the construction materials industry.

Quality management and standardization: for example, analyses have been presented on the significance of ISO 9001:2015 in the construction materials industry, as well as its impact on export potential and operational efficiency. [11]

1. Digitalization and management modernization: the role of digital technologies in enterprise operations is examined from the perspectives of service delivery and quality improvement. [12]

2. Management efficiency, capacity, and economic assessment: some studies address issues related to improving management efficiency, capacity management, and the evaluation of economic indicators in construction materials enterprises. [13]

Overall, while international literature provides an in-depth discussion of technological and algorithmic solutions (MPC/AI/APC), local sources tend to focus more on institutional and economic aspects. Research that integrates these two directions—namely, studies that combine technical solutions based on real plant data with management and integration models—represents the most promising area for future investigation.

Research methodology. In studying modern methods of controlling production processes in the construction materials industry, the following methods were applied: systems analysis; the principles of historicity and logical consistency; induction and deduction; analysis and synthesis; comparative and selective research; as well as monographic analysis and grouping methods.

Analysis and results. The effectiveness of production process management in the construction materials industry is closely linked, first and foremost, to the volume and variability of market demand, as well as to the stability of raw material and energy supply. From this perspective, the growth in construction activity and the dynamics of cement production during 2020–2024 illustrate the pressures and opportunities under which operational management (planning–procurement–production–logistics) in the sector has evolved.

Table 1. Dynamics of growth in construction work volume in Uzbekistan during 2020–2024

Year	Volume of construction work, trillion UZS	Annual growth, %
2020	88,1	-
2021	107,4	21,9
2022	130,8	21,8
2023	149,9	14,6
2024	233,8	56,0

According to the data presented in the table, construction activity increased steadily during 2020–2023, while a sharp surge was observed in 2024 (233.8 trillion UZS). This development intensified demand for construction materials, requiring production systems to rapidly increase short-term capacity, optimize logistics and inventories, and minimize equipment downtime. The high growth rate in 2024 (56.0%) increases risks from a management perspective within the “capacity–resources–quality” triangle, including disruptions in raw material and fuel supply, insufficient transport capacity, and reduced quality stability. Therefore, modern management approaches—such as MES/ERP integration, APS planning, Lean/TPM practices, and IIoT-based monitoring—become particularly relevant under conditions of rapidly growing demand.

Table 2. Dynamics of cement production volume in Uzbekistan during 2020–2024

Year	Cement production, thousand tons	Annual growth, %
2020	12537,4	-
2021	14195,0	13,2
2022	11931,3	-20,0
2023	11931,3	5,0
2024	16007,3	34,2

According to the data presented in the table, growth was recorded in 2021 (13.2%); however, a sharp decline occurred in 2022 (–20.0%). Such “growth–decline” fluctuations indicate that classical planning approaches (simple quarterly or annual plans) are insufficient for managing production processes. Instead, dynamic planning, scenario-based modeling, supply risk management, and energy-efficient operational regimes are required. In 2023, the recovery was limited (5.0%), while in 2024 a high growth rate (34.2%) was observed. This suggests the reactivation and/or expansion of production capacities, along with a certain stabilization in fuel and energy supply and logistics; nevertheless, maintaining this stability requires the digitalization of technological management.

The two indicators discussed above are interrelated: as the volume of construction activity increases, demand for cement and other materials also rises; however, the decline in cement production in 2022 intensified the risks of “shortages–price pressure–logistical difficulties” within the supply chain. Therefore:

1. Under conditions of demand fluctuations (especially the surge observed in 2024), enterprises require advanced planning tools such as APS (Advanced Planning & Scheduling) and S&OP/IBP (Sales and Operations Planning / Integrated Business Planning): recalculating plans on a monthly and weekly basis and taking capacity constraints (kilns, mills, packing lines) into account.
2. Energy and resource risks are particularly critical in the context of the 2022 downturn: in an energy-intensive industry, the application of TPM/RCM (reliability-centered maintenance), real-time monitoring via IIoT sensors, and the management of energy efficiency at the KPI level (clinker factor, specific fuel consumption, electricity consumption per ton) can deliver tangible benefits.
3. Quality stability and waste reduction: when demand increases, the pursuit of higher throughput may undermine quality. Therefore, batch and recipe control via MES,

the linkage and analysis of laboratory results with production parameters using SPC, and the application of Lean tools (5S, Kaizen, SMED) are recommended.

4. Logistics and warehouse management: in 2024, when construction activity grew sharply, disruptions in finished product delivery could increase both “unsold inventory” and “undelivered orders.” The use of WMS/TMS systems, route optimization, and warehouse rules such as FIFO/FEFO support production continuity.

Table 3. Dynamics of labor productivity in the construction materials industry in Uzbekistan during 2020–2024

Year	Output per worker, million UZS	Annual growth, %
2020	142,6	-
2021	158,9	11,4
2022	165,3	4,0
2023	172,8	4,5
2024	195,6	13,2

According to the data presented in the table, labor productivity increased significantly during 2020–2021, while growth rates slowed in 2022–2023. In this period, growth was mainly ensured through more intensive utilization of existing production capacities. In 2024, a renewed acceleration in productivity growth (13.2%) indicates increased automation, modernization of technological lines, and improved responsiveness of management decisions. At the same time, based on the analysis of the literature, sustainable long-term growth in labor productivity requires not only capacity expansion but also the implementation of MES systems, digital KPI monitoring, and continuous development of employee competencies.

Table 4. Average energy consumption in cement production in Uzbekistan during 2020–2024

Year	Electricity consumption, kWh/ton	Fuel consumption, kg of standard fuel per ton
2020	108	215
2021	105	210
2022	112	218
2023	107	212
2024	101	205

According to the data presented in the table, the increase in energy consumption in 2022 can be explained by production disruptions, operation of equipment below full capacity, and violations of technological regimes. In 2023–2024, the reduction in energy consumption is the result of implementing resource-efficient technologies and improved management of production processes. In practice, modern management approaches — particularly **advanced process control (APC)** and **energy monitoring systems** — have been shown to enable reductions in energy consumption of up to 5–10%.

Table 5. Production volume of main construction materials in Uzbekistan during 2020–2024

Year	Cement, million tons	Ceramic tiles, million m ²	Ceramic tiles, million m ²
2020	12,5	9,8	6,2
2021	14,2	11,1	6,9
2022	11,4	10,5	6,4
2023	11,9	12,3	7,1
2024	16,0	14,8	8,0

As shown in the table, a certain decline in the production of all types of materials was observed in 2022. This situation is associated with external economic factors and supply chain disruptions. In 2023–2024, production volumes recovered steadily, with particularly strong growth recorded in the cement and ceramic tile segments. This trend indicates the necessity of organizing production processes on the basis of integrated management under conditions of increasing demand in the construction market; otherwise, imbalances between supply and demand may arise.

The analysis of the tables shows that during 2020–2024 in the construction materials industry: production volumes and labor productivity exhibit an upward trend; energy efficiency improves as modern management approaches are implemented; and production dynamics differ across product segments, which necessitates flexible and forecast-based management.

Thus, managing production processes on the basis of modern approaches plays a decisive role not only in enhancing the performance of individual enterprises but also in ensuring the sustainable development of the entire industry.

Conclusion. In this scientific study, modern methods of managing production processes in the construction materials industry were comprehensively analyzed, and their impact on sectoral development was assessed in an integrated manner. The conducted analysis indicates that, at the current stage, the construction materials industry operates under the influence of a rapidly growing construction market, limited resources, rising energy prices, and increasingly stringent environmental requirements. Under such conditions, effective management of production processes plays a decisive role in ensuring the stability and sustainability of enterprises.

The analysis of statistical data for 2020–2024 showed that the rapid growth in construction activity has sharply increased demand for construction materials. At the same time, fluctuations observed in the production volumes of cement and other key materials clearly demonstrate that stable supply cannot be ensured through traditional production management methods alone. This situation increases the likelihood of imbalances between supply and demand, risks related to energy and raw material supply, and inefficient utilization of production capacities.

The research findings substantiate that automated control systems, digital monitoring, advanced process control, and predictive management methods elevate production processes to a qualitatively new level. These approaches enable real-time monitoring of production parameters, greater accuracy in planning, reduced equipment

downtime, and optimization of energy consumption. As a result, the economic efficiency of enterprises increases and product costs are reduced.

In addition, the study identified a close interrelationship between labor productivity, energy efficiency, and product quality. Enterprises that have implemented modern management approaches demonstrate sustained growth in labor productivity, reductions in energy consumption, and improvements in quality indicators. This confirms the necessity of a systematic and integrated approach to managing production processes.

The analyses presented in the article also indicate that deep integration of quality management systems into production processes is of critical importance. It is insufficient to control quality only at the finished product stage; instead, quality indicators must be managed at all stages of the technological process. This, in turn, should be achieved on the basis of digital data, standardized processes, and clearly defined performance indicators.

At the same time, the implementation of modern management approaches should not be limited solely to technical modernization. According to the research results, human capital, management culture, organizational structure, and decision-making mechanisms play a decisive role. To ensure the effective use of digital technologies, it is necessary to enhance employees' knowledge and skills, foster readiness for change, and support innovative thinking.

Overall, the comprehensive implementation of modern methods for managing production processes in the construction materials industry creates a strategic advantage for sector enterprises. These approaches contribute to increased production efficiency, the manufacture of competitive products, rational use of energy and resources, and the achievement of environmental sustainability. The conclusions of this study may serve as a theoretical and practical foundation for improving management systems in construction materials enterprises, developing sector-specific programs, and defining directions for future scientific research.

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