

Evaluating the Relationship Between Modernization and Productivity in Udayapur Cement Industry: A Diagnostic and Exploratory Study

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Abstract

This study examines how modernization relates to productivity at Udayapur Cement Industries Ltd. (UCIL), a state-owned producer operating well below installed capacity. The purpose is to diagnose organizational and technical bottlenecks and explain how modernization shortfalls translate into measurable productivity losses. Using a diagnostic, exploratory design, the study applies qualitative document analysis to an internal UCIL report. Texts were thematically coded into modernization dimensions automation and process control, energy efficiency, workforce capability, digital integration, and administrative enablers and mapped against productivity outcomes: output levels, operational efficiency, cost structure, downtime profile, and competitiveness. Findings indicate pervasive modernization gaps: legacy machinery and limited real-time control; manual quality control without online analytics; a predominantly reactive maintenance regime lacking predictive tools; unreliable grid power with diesel dependence and no Variable Frequency Drives or Waste Heat Recovery; workforce skill deficits and aging profiles; fragmented information systems without an Enterprise Resource Planning backbone; and bureaucratic procurement with constrained financial autonomy. These conditions are consistently associated with under-utilized capacity, unstable operations, elevated unit energy and operating costs, frequent unplanned downtime, and weakened market competitiveness. The results point to a phased pathway: establish plant-wide control and online quality analytics, shift to predictive maintenance with sensor-enabled monitoring and a Computerized Maintenance Management System, reduce energy intensity via targeted retrofits, deploy ERP and basic dispatch tracking, and embed targeted upskilling to secure adoption.

Keywords: Energy efficiency, modernization, nepal, productivity, udayapur cement industries Ltd.,

Introduction

The cement industry is a cornerstone of Nepal's economic development, providing essential raw materials for infrastructure, housing, and hydropower projects. With the nation's annual

cement demand exceeding five million metric tons, enhancing efficiency and productivity in this sector has become a strategic priority (Nepal, 2024). Among the country's producers, Udayapur Cement Industries Ltd. (UCIL) occupies a distinctive place as one of the oldest and largest state-owned cement manufacturers. Established in 1987 with technical and financial support from Japan's Overseas Economic Cooperation Fund (OECF), UCIL was envisioned as a symbol of industrial self-reliance and was equipped with then-advanced technologies such as Vertical Roller Mills (VRMs) and Programmable Logic Controllers (PLCs) (Shrestha et al., 2016; Pandey & Banskota, 2008).

Despite its promising beginnings, UCIL's performance has declined sharply over time. The plant currently operates at only 35–36% of its installed capacity, well below the global benchmark of 80–90% (Mishra & Chaudhary, 2018). Persistent issues such as outdated machinery, frequent breakdowns, and excessive energy consumption 148.56 kWh per ton of cement compared to Nepal's national standard of 105 kWh have severely undermined operational efficiency (Shrestha et al., 2016). As a result, production costs have often exceeded selling prices, with cumulative financial losses surpassing NRs. 360 million by FY 2020 (Singh & Shakya, 2016). Although UCIL was originally established with modern equipment and innovative logistics systems, such as a 13.8 km aerial ropeway for limestone transport, it has failed to keep pace with technological advancements in subsequent decades (Chakrabarti et al., 2018). Past efforts have largely focused on maintaining existing systems rather than comprehensive modernization, leaving UCIL unable to adapt to the increasingly competitive cement market (Thakuri et al., 2024). This trajectory reveals a critical gap: while modernization is widely recognized as a driver of industrial efficiency, there is limited empirical research evaluating how modernization efforts or their absence affect productivity in Nepal's state-owned cement industry.

Against this backdrop, the present study aims to address this gap by examining the relationship between modernization and productivity in UCIL through a diagnostic and exploratory approach. Specifically, it seeks to answer three interrelated questions: i) What are the major challenges affecting productivity at UCIL? ii) To what extent has modernization been attempted, and what gaps remain? and iii) How are modernization efforts linked with productivity outcomes? By investigating how technological upgrades, energy efficiency measures, and process improvements influence operational performance, the research seeks to generate evidence-based insights to guide both enterprise-level reforms and broader industrial policy.

Methodology

This study adopts a diagnostic and exploratory research design, relying on qualitative document analysis to investigate the relationship between modernization and productivity in Udayapur Cement Industry Ltd. (UCIL). A diagnostic orientation helps to uncover the root causes of inefficiencies, while an exploratory approach is suitable for examining under-researched areas where relationships are not yet clearly defined (Stebbins, 2001). Document analysis was selected because it provides a systematic means of interpreting organizational records, allowing the researcher to identify themes, patterns, and linkages that might not be evident through numerical or survey-based methods (Bowen, 2009). The internal report

used in this study offers rich insights into UCIL's operational, workforce, financial, and technological challenges, making it an appropriate foundation for qualitative analysis.

The data were thematically coded into two broad categories: modernization dimensions and productivity outcomes. The analysis proceeded in three stages: familiarization with the text, systematic coding of excerpts into the thematic categories, and interpretive mapping of the relationships between modernization and productivity outcomes. This approach enabled the study to move beyond description and toward explanation by showing how gaps in modernization contribute to reduced productivity. Such a method aligns with the objectives of exploratory research, which seeks to generate insights and provide a foundation for future empirical studies (Elo & Kyngäs, 2008).

Findings

Outdated Technology and Equipment

UCIL operates with obsolete machinery, leading to frequent breakdowns, inconsistent quality, and high maintenance costs. The absence of real-time process control and predictive maintenance reduces efficiency. UCIL's production machinery is predominantly outdated, with frequent breakdowns and inefficiencies and a high maintenance burden. Modern automation is limited. Reported effects include increased downtime, lower throughput, and higher unit costs due to repairs and stoppages. Operations rely on older control systems with limited real-time monitoring; basic PLCs are used instead of integrated DCS/SCADA. Reported effects include greater process variability, slower corrective action, inconsistent product quality, and reduced efficiency.

Maintenance practices are largely reactive, characterized by urgent, ad-hoc spare-parts procurement and non-standardized equipment that broadens the parts inventory. Reported effects include more unplanned downtime, higher maintenance spending, longer time to restore, and lower asset availability. In addition, there is no sensor/IoT-based vibration or temperature monitoring to detect early faults, and reported effects include missed early warnings, escalation of failures, lengthened outages, and loss of operational efficiency.

Quality control is predominantly manual, with no online analyzers (e.g., XRF) to provide instant feedback. Reported effects include inconsistent quality, rework, material waste, and slower stabilization of process parameters. Repairs are breakdown-driven, with last-minute purchasing; the wide variety of spares increases inventory levels and lead times. Reported effects include elevated maintenance costs, extended stoppages, and a persistent reliability drag on the plant.

Table 1: Evidence summary

Aspect	Evidence from UCIL document	Productivity / Efficiency Impact
Obsolete machinery & frequent breakdowns	Majority of production machinery is outdated, causing frequent breakdowns, inefficiencies, and high maintenance costs; limited modern automation.	Increased downtime, lower throughput, and higher unit cost due to repairs and stoppages.
Limited real-time process control / automation	Reliance on older control systems with limited real-time monitoring; basic PLCs instead of integrated DCS/SCADA.	Greater process variability and slower corrective action leading to inconsistent quality and reduced efficiency.
Reactive (breakdown-based) maintenance	Maintenance is largely reactive; urgent, ad-hoc spare procurement; non-standardized equipment broadens parts inventory.	More unplanned downtime, higher maintenance spend, longer time to restore, and lower asset availability.
Lack of predictive maintenance (PdM)	No sensor/IoT-based vibration or temperature monitoring to detect early faults.	Missed early warnings cause failures to escalate, lengthening outages and eroding efficiency.
Manual/semi-automated quality control	Quality control is predominantly manual; absence of online analyzers (e.g., XRF) for instant feedback.	Inconsistent quality, rework, and waste; slower stabilization of process parameters.
High maintenance & spare-parts burden	Breakdown-driven repairs and last-minute purchasing increase costs; varied spares raise inventory and lead times.	Elevated maintenance costs, extended stoppages, and persistent reliability drag on the pl

Modernization Dimensions

The analyzed document portrays limited process automation and control at UCIL. Core production assets are identified as legacy machines, with operations relying on older control systems and only basic PLC use in parts of the line rather than integrated DCS/SCADA. Quality control is described as predominantly manual, with no online, real-time analyzers (e.g., XRF), and maintenance practices are characterized as reactive with no plant-wide predictive monitoring to anticipate failures. On energy efficiency, the document notes an unreliable grid supply that drives frequent reliance on diesel generators. Modern energy-saving technologies such as Variable Frequency Drives (VFDs) and Waste Heat Recovery Systems (WHRS) are reported as absent, and energy audits or conservation practices are

underused. Regarding workforce capability, the text highlights skill gaps associated with legacy systems, limited structured technical upskilling and succession planning, and resistance to adopting new technologies set against an aging staff profile.

For digital integration, information flows are depicted as fragmented. The enterprise lacks a unified ERP and real-time dashboards linking production, maintenance, inventory, finance, and dispatch; packing and dispatch systems are described as outdated with minimal digital tracking. Concerning administrative enablers, the document points to bureaucratic procurement procedures and approval delays, seniority-oriented HR systems with constrained performance management, and limited financial autonomy each cited as factors that slow or defer modernization initiatives.

Table 2: Targeted Modernization Themes

Dimension	Evidence from UCIL document	Observed status / effect
Energy efficiency	Frequent grid outages driving reliance on diesel generators; energy audits and modern energy-saving technologies underused; no deployment of VFDs/WHRS; lack of priority power and limited incentives for industrial renewables.	Elevated energy cost; operational interruptions; higher kWh/ton than modernized peers; missed efficiency gains.
Workforce capability	Skill gaps tied to legacy systems; aging workforce with limited succession planning; insufficient technical training and resistance to new practices; absence of a modern HR/performance tracking system.	Constrained ability to operate/absorb new technologies; slower troubleshooting; lower labor productivity.
Digital integration	Operations largely manual or disconnected; no unified ERP or real-time dashboards linking production, maintenance, inventory, finance, and dispatch; packing/dispatch has limited digital tracking.	Fragmented information flows; slower cross-functional decisions; weak supply-chain visibility; dispatch delays.
Administrative enablers	Bureaucratic procurement and approval delays; limited financial autonomy; public procurement rules impede fast sourcing; policy gaps (e.g., energy incentives).	Slow uptake of upgrades; prolonged reliance on legacy configurations; schedule slippage and cost overruns on projects.

As shown in table 2, energy efficiency is hampered by frequent grid outages, heavy reliance on diesel, underused audits, absence of VFD/WHRS, and no priority power raising costs, interrupting operations, and keeping kWh/ton high. Workforce capability shows skill gaps and an aging staff with limited upskilling and no modern HR tracking, slowing troubleshooting and lowering labor productivity. Digital integration is minimal no unified ERP or real-time dashboards and only limited tracking in packing/dispatch fragmenting decisions and delaying deliveries. Administrative enablers are weak due to bureaucratic procurement, limited financial autonomy, and policy gaps, resulting in slow upgrades, prolonged legacy systems, and schedule/cost overruns.

Productivity Outcomes

Frequent equipment stoppages and unstable process conditions lead to persistent under-utilization of installed capacity. Production runs are repeatedly interrupted and require extended recovery to reach steady state, resulting in lower sustained throughput relative to nameplate capacity. Process variability is evident across key sections of the line. In the absence of robust real-time control, quality adjustments are largely manual, which lengthens changeover and correction cycles and increases rework. Overall line stability remains fragile. Energy is a major component of production cost due to unreliable grid supply and reliance on diesel back-up. Underused energy-saving practices, reactive maintenance, emergency spare-parts procurement, and logistics bottlenecks further elevate unit operating costs. Preventive and predictive maintenance practices are limited. Unplanned outages occur frequently, and restoration times are prolonged by ad-hoc troubleshooting and parts delays, reducing equipment availability and effective operating hours. Delivery timelines are affected by dispatch constraints and production interruptions, while product consistency is uneven. Combined with higher costs, these factors weaken the enterprise’s price and service position relative to modernized private plants with tighter process control and integrated logistics.

Table 3: Summary table

Outcome	Evidence from UCIL document	Observed effect
Output levels	Obsolete equipment, frequent breakdowns, and unstable processes disrupt sustained runs.	Under-utilization of capacity; lower sustained throughput.
Operational efficiency	Manual quality adjustments and limited real-time control across the line.	Higher process variability; longer correction/changeover cycles; more rework.
Cost structure	Grid unreliability → diesel back-up; efficiency measures underused; reactive maintenance and urgent spares; logistics bottlenecks.	Elevated unit energy and operating costs; weaker cost position.
Downtime profile	Maintenance is predominantly reactive with limited preventive/predictive planning.	More unplanned outages; longer time to restore; reduced availability.
Competitiveness	Dispatch delays, distribution gaps, and inconsistent quality relative to modernized rivals.	Weakened price/service competitiveness; erosion of market position.

As shown in table 3, UCIL's productivity outcomes reflect persistent under-utilization of capacity due to obsolete equipment, frequent breakdowns, and unstable processes; operational efficiency is constrained by largely manual quality adjustments and limited real-time control, which increase process variability, lengthen correction/changeover cycles, and drive rework. The cost structure is burdened by unreliable grid supply that necessitates diesel back-up, underused efficiency measures, reactive maintenance with urgent spare-parts procurement, and logistics bottlenecks, all of which elevate unit energy and operating costs and weaken the cost position. Downtime remains high because maintenance is predominantly reactive with limited preventive or predictive planning, leading to more unplanned outages and longer restoration times. Consequently, competitiveness is eroded by dispatch delays, distribution gaps, and inconsistent quality relative to modernized rivals, weakening both price and service performance in the market.

Discussion

The evidence indicates a clear pathway from modernization gaps to productivity losses at UCIL. In continuous-process industries, legacy equipment, stand-alone PLC "islands" rather than integrated DCS/SCADA, and manual quality checks are associated with unstable operations, slower corrective action, and higher variability conditions that depress capacity utilization and raise unit costs (Walther, 2018; Zhang & Li, 2020). Studies in cement report that strengthening plant-wide control and online quality monitoring stabilizes processes, tightens product variability, and improves throughput while lowering specific energy consumption (International Energy Agency, 2018; Zhang & Li, 2020). Maintenance strategy is a second mechanism: where preventive/predictive practices are weak, unplanned outages increase, restoration times lengthen, and availability falls. Reliability availability maintainability analyses on cement lines show how reactive maintenance becomes a structural bottleneck, whereas condition-based approaches raise availability and output (Choudhary et al., 2019). Energy performance operates as a plant-wide constraint. Grid unreliability and diesel back-up raise energy intensity and interrupt continuous operations, while the absence of proven levers variable-frequency drives (VFDs) on large fans/pumps and waste-heat recovery (WHR) on kiln/preheater streams leaves avoidable electrical and thermal losses in place. Global best-practice and techno-economic assessments identify WHR and VFDs among the highest-impact retrofits for cement, with documented reductions in purchased power and specific electricity use (Guo et al., 2024; IEA, 2018). Field evidence from South Asia similarly links structured energy management to cost and reliability improvements in cement plants (Hossain et al., 2020; Fayomi et al., 2019).

Digital fragmentation compounds these issues. Without an integrated ERP and real-time dashboards spanning production, maintenance, inventory, finance, and dispatch, information remains siloed, decision cycles are slower, and work-order/spares scheduling is less timely conditions associated with longer restoration times, higher inventories, and dispatch delays. Research across operations and supply chains associates stronger integration (physical, informational, organizational) with improved coordination and performance outcomes (Afshan, 2013; Walther, 2018). The pace and depth of change are also shaped by human capital and governance: skill gaps tied to legacy systems and insufficient upskilling slow the absorption of automation and digital tools (Shrestha, 2021), while procurement frictions and

limited financial autonomy in state-owned enterprises delay upgrades and increase lifecycle costs (Casanova et al., 2021; Edimon & Naqvi, 2020).

Taken together, the results argue for a portfolio of mutually reinforcing interventions rather than isolated fixes. Priorities with strong support in the cement literature include plant-wide control and online quality analytics (DCS/SCADA; on-line analyzers), a shift to predictive maintenance (condition sensors plus CMMS) to lift availability, and energy-intensity reduction via VFDs, WHR, and structured energy management (Guo et al., 2024; IEA, 2018; Walther, 2018; Zhang & Li, 2020). A digital backbone (ERP with operational dashboards) can compress decision cycles and help lock in gains across production, maintenance, and logistics (Afshan, 2013; Walther, 2018). To link technical changes to financial outcomes, plants commonly track a focused KPI set overall equipment effectiveness (OEE), mean time between failures (MTBF), mean time to repair (MTTR), specific energy consumption, and on-time dispatch which aligns with RAM/OEE practice in cement and helps sequence investments by verified payback (Choudhary et al., 2019; Maity et al., 2019; IEA, 2018). Emerging work also points to AI-assisted energy optimization as a complementary lever once foundational data systems are in place (Oguntola et al., 2024).

Implementation sequencing matters. “No-regret” steps spares standardization, preventive routines, and targeted instrumentation on chronic failure points stabilize the base while larger capital projects (e.g., kiln/drive retrofits, WHR) are prepared. Embedding workforce upskilling alongside each deployment is critical for adoption and performance capture (Shrestha, 2021). In SOE contexts, enabling measures such as streamlined procurement pathways for critical upgrades and performance-linked maintenance KPIs can accelerate execution and reduce the risk that modernization stalls midstream (Edimon & Naqvi, 2020). Finally, this document-based diagnosis provides explanatory insight but cannot quantify effect sizes or establish counterfactuals; future work should pair the diagnostic with plant time-series (before/after interventions), apply RAM/OEE tracking to verify availability gains, and conduct techno-economic assessments for VFD/WHR and digital investments under UCIL-specific conditions (Choudhary et al., 2019; IEA, 2018; Maity et al., 2019).

Conclusion

This diagnostic and exploratory analysis reveals a clear, system-level linkage between modernization gaps and productivity losses at Udayapur Cement Industries Ltd. Beyond confirming obsolete equipment, the study surfaces new, integrative findings: a tight coupling between limited automation and real-time control and a reactive maintenance trap that sustains high downtime and rework; energy unreliability and diesel dependence as a continuous constraint that elevates specific energy consumption and interrupts steady-state operations; digital fragmentation the absence of an Enterprise Resource Planning (ERP) backbone and operational dashboards as a silent amplifier of technical issues that slows decisions on work orders, spare parts, and dispatch; and administrative frictions procurement delays and low financial autonomy as binding constraints that prevent otherwise standard efficiency levers from taking hold.

Collectively, these pathways explain under-utilized capacity, fragile line stability, elevated unit costs, prolonged restoration times, and a weakened market position. The analysis moves beyond description by mapping how each modernization dimension automation and process control (transitioning from stand-alone Programmable Logic Controllers to plant-wide Distributed Control System/Supervisory Control and Data Acquisition), energy systems, digital integration, workforce capability, and administrative enablers feed directly into five productivity outcomes: output levels, operational efficiency, cost structure, downtime profile, and competitiveness.

A pragmatic modernization sequence emerges: stabilize the base through spare-parts standardization, preventive routines, and targeted instrumentation; implement plant-wide control and online quality analytics; shift to predictive maintenance via sensor networks and a Computerized Maintenance Management System (CMMS); reduce energy intensity with Variable Frequency Drives (VFDs) and Waste Heat Recovery systems; and connect operations with an ERP backbone and basic dispatch tracking. Embedding focused upskilling alongside each step is essential. To verify benefits and prioritize investments, track a concise set of Key Performance Indicators (KPIs): Overall Equipment Effectiveness (OEE), Mean Time Between Failures (MTBF), Mean Time to Repair (MTTR), specific energy consumption, and on-time dispatch. Together, these actions provide a concrete roadmap for measurable productivity gains through coordinated modernization.

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