

Key Success Factors for a Latecomer Electronics Manufacturer: A Case Study of HDD Component Production in Laos

Umawadee Nuchniyom

Department of Industrial Engineering, Faculty of Engineering
Chiangmai University, Chiangmai, Thailand
umawadee_nuch@cmu.ac.th

Apichat Sopadang

Professor
Department of Industrial Engineering, Faculty of Engineering
Chiangmai University, Chiangmai, Thailand
apichat@eng.cmu.ac.th

Komgrit Leksakul

Professor
Department of Industrial Engineering, Faculty of Engineering
Chiangmai University, Chiangmai, Thailand
komgrit@eng.cmu.ac.th

Abstract

This study identifies customer-validated Key Success Factors (KSFs) that enabled a latecomer electronics manufacturer in Lao PDR to successfully integrate into global value chains through the production of high-precision Hard Disk Drive (HDD) components. In response to the demands of Artificial Intelligence (AI)-driven storage and stringent Heat-Assisted Magnetic Recording (HAMR) requirements, the firm meticulously translated challenging customer specifications, such as thermal stability, flatness, and rigidity, into disciplined operational capabilities. The study employed an embedded single-case mixed-methods design, combining elite interviews, anonymized KPI analysis, and customer audit evidence. During qualification, the firm achieved customer accepted yield within a $\pm 1\%$ tolerance band, met documentation compliance on schedule, and consistently maintained On-Time-In-Full (OTIF) delivery at 100%. All customer audits were passed, with corrective actions formally closed. Thematic analysis revealed four interconnected mechanisms that underpinned the firm's capability upgrading: staged cross-border knowledge transfer with embedded mentors, early codification of standard work, audit-ready KPI governance, and logistics alignment within the constraints of the Special Economic Zone (SEZ). These findings provide a mechanism-based pathway that explains how latecomer firms can achieve operational upgrading and successfully integrate into advanced, audit-intensive electronics supply chains.

Keywords

Heat-Assisted Magnetic Recording (HAMR); global value chains; capability upgrading; customer qualification; Lao PDR

1. Introduction

1.1 AI-Driven Data Expansion and Nearline HDD Demand

The rapid expansion of Artificial Intelligence (AI)-generated data has markedly intensified the need for high-capacity storage solutions, positioning nearline Hard Disk Drives (HDDs) as a pivotal element of modern data-center architectures. While Solid-State Drives (SSDs) are optimized for latency-sensitive “hot” data tiers, nearline HDDs remain indispensable for “warm” and “cold” storage due to their superior cost-per-byte efficiency. This economic advantage has made nearline HDDs the preferred medium for hyperscale cloud and AI service providers managing petabyte- to exabyte-scale datasets.

Industry analyses confirm this structural shift. Nearline HDDs now represent approximately 70–75 % of all HDD capacity shipped globally (Mellor, 2024), and total HDD exabytes shipped surged by more than 70 % year-over-year from late 2023 to late 2024. By the third quarter of 2024, global HDD shipments reached an all-time high of over 300 exabytes (TrendForce, 2025), as illustrated in Figure 1.

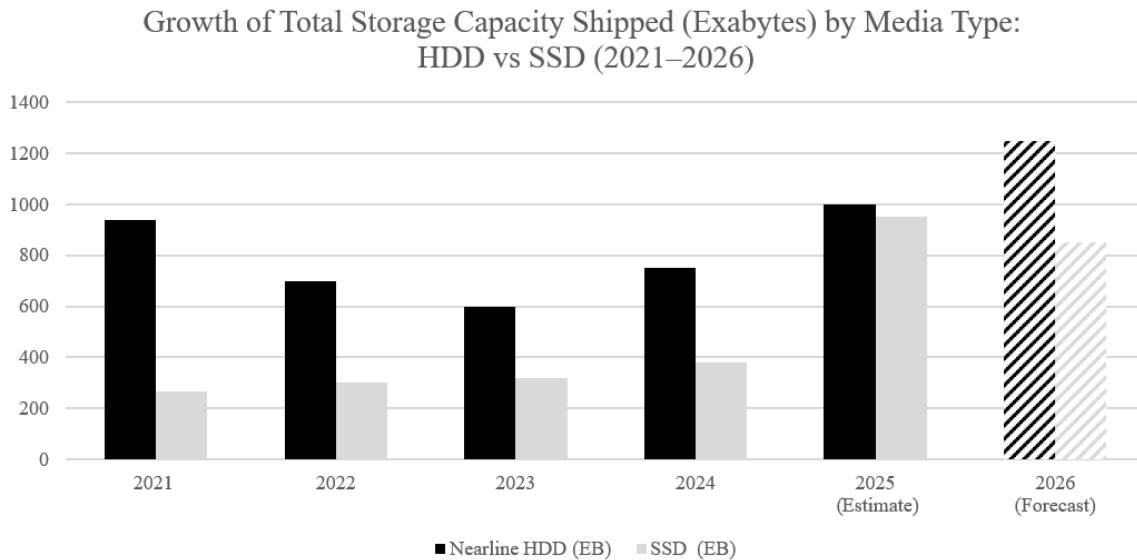


Figure 1. Growth of Total Storage Capacity Shipped (Exabytes) by Media type.

Figure 1. Bar chart showing global storage capacity shipped (in exabytes) for Nearline HDD and SSD (all types) from 2021 to 2026. The chart highlights the dominant role of Nearline HDDs in supporting large-scale data storage needs, particularly in hyperscale and enterprise data centers. While SSDs continue to grow in performance-sensitive applications, Nearline HDDs consistently account for the majority of total exabytes shipped throughout the period. In 2025, Nearline HDD shipments exceeded 1,000 EB, surpassing the total global NAND flash output, which underscores HDDs’ unmatched cost-per-byte advantage. The 2026 bars are forecasted values, indicated with diagonal hatching.

1.2 Supply Chain Volatility and Industrial Responses

The rapid escalation in demand has significantly strained the HDD supply chain. According to TrendForce (2025), lead times for nearline HDDs extended from a few weeks to over 52 weeks during the peak of the recent shortage. Concurrently, industry reports indicated enterprise HDD backorders stretching up to 24 months (Nasir, 2025).

In response, major HDD vendors operated manufacturing facilities at maximum capacity throughout 2025 and implemented price adjustments for high-capacity drives (Killian, 2025). To mitigate shortages, some cloud service providers explored the use of Quad-Level Cell (QLC) SSDs for cold data storage as a temporary measure; however, this shift risks further straining flash memory supply and inflating market prices (Nasir, 2025; TrendForce, 2025).

1.3 Technological Evolution and Heightened Quality Standards

The industry’s transition toward Heat-Assisted Magnetic Recording (HAMR) technology has established more rigorous reliability and consistency benchmarks for components. HAMR-based drives necessitate extreme material uniformity and precise process control to ensure media integrity (Seagate, 2017). Consequently, customers have

intensified their supplier qualification criteria, emphasizing stable operations, rigorous process discipline, and proven quality performance. For new manufacturing sites, this entails passing exhaustive audits and demonstrating performance metrics equivalent to established suppliers, thereby creating a high barrier to entry for latecomer facilities.

1.4 The Latecomer Context: Lao PDR and the Saysettha Special Economic Zone (SSEZ)

To enhance supply chain resilience, HDD manufacturers have diversified production into emerging regions. This study focuses on a new HDD component plant located within the Saysettha Special Economic Zone (SSEZ) in Lao PDR. The SSEZ is a joint-venture industrial hub designed to attract foreign direct investment through a "one-stop" administrative service and fiscal incentives, including tax holidays and customs duty exemptions (PwC, 2026).

Despite these policy advantages, Lao PDR presents several "latecomer" challenges, including a limited skilled labor pool, nascent supplier ecosystems, and infrastructure constraints. While recent developments—such as expanded hydropower capacity and new logistics corridors—have improved connectivity (JICA, 2014; U.S. Department of State, 2025), bridging the skills gap in advanced manufacturing remains a critical hurdle. Achieving world-class performance in such a context requires deliberate firm-level capability building beyond mere policy incentives (Asian Development Bank, 2018; Choi et al., 2024).

1.5 Research Gap and Objectives

While existing literature emphasizes geographic diversification as a risk mitigation strategy (Ahn & Tan, 2025; Asher, 2025), there is a paucity of research on how latecomer manufacturing sites in emerging economies meet the stringent acceptance criteria of high-tech electronics supply chains. Specifically, we lack a granular understanding of the operational factors that allow a new plant to achieve performance parity with established facilities during the critical ramp-up and qualification phase.

This study addresses this gap by investigating a real-world case of an HDD component plant in Lao PDR. The primary research question is: How can a new HDD component manufacturing plant in Lao PDR achieve customer-validated performance during its ramp-up under stringent acceptance criteria? By addressing this question, the study elucidates the mechanisms of capability upgrading within global value chains and offers practical insights for overcoming contextual disadvantages in high-tech manufacturing.

2. Strategic Context and Research Challenge

2.1 Supply Chain Diversification and the Latecomer Dilemma

The surge in AI-driven data and the shift toward Heat-Assisted Magnetic Recording (HAMR) technology present a complex backdrop for HDD component suppliers. On one hand, these trends offer growth opportunities: industry leaders are actively diversifying their supply base to reduce concentration risk, thereby opening the door for new entrants. On the other hand, latecomer plants face exceptionally high performance expectations, as customers now require yields, quality, and reliability on par with incumbent suppliers even during ramp-up. This latecomer dilemma—growth potential versus high entry standards—sets the strategic stage for our study.

2.2 Operational Environment: The SSEZ in Lao PDR

Our focal case is a latecomer HDD component plant located in the Saysettha Special Economic Zone (SSEZ) of Lao PDR. The plant was established by a multinational firm as part of its business continuity plan to expand manufacturing capacity and geographically diversify its supply chain. The SSEZ offers one-stop administrative services and investment incentives—such as tax relief and customs simplifications—intended to attract foreign investment (Government of Lao PDR 2018; VDB LOI 2025; PwC 2026). Despite these supports, the site had to overcome typical latecomer disadvantages: a limited pool of experienced local engineers, an underdeveloped supporting industry, and infrastructure gaps. Compounding this, the plant had to meet strict customer acceptance criteria tied to next-generation HAMR technology while responding to supply-chain pressures from surging AI data volumes. These contextual factors—global demand risk, technological requirements, local capabilities, and customer standards—shape the operational environment.

2.3 The Core Research Challenge

Within this environment, the basic research question becomes: How can a latecomer plant achieve customer-accepted performance during its ramp-up under stringent requirements and contextual constraints? To gain approval as a production source, the Lao plant needed to satisfy a combination of quantitative and qualitative benchmarks, including:

- Achieving yield within $\pm 1\%$ of the customer target during trial production;
- Maintaining 100% on-time, in-full (OTIF) delivery for all pre-production orders;
- Completing all required documentation and quality procedures by scheduled deadlines;
- Passing multiple rounds of customer audits—covering process control, quality systems, and regulatory compliance—with no major findings.

These criteria had to be met swiftly to secure full production approval. Figure 2 summarizes these intersecting pressures and how they coalesce into our core research question.

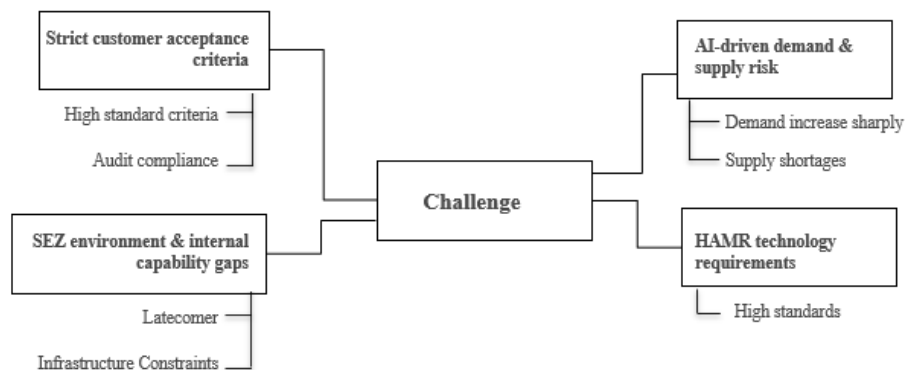


Figure 2. Research Context Framework

This figure maps four contextual factors—AI-driven demand & supply risk, HAMR technology requirements, SSEZ environment & internal capability gaps, and strict customer acceptance criteria—onto the core research question of how a latecomer plant can meet stringent customer-accepted performance during its ramp-up phase.

3. Methods

Research design: We adopted a single-case, embedded case study design (Yin 2018) to deeply investigate the research question within its real context. This approach is suited for a “how” question focusing on a contemporary phenomenon in a real-world setting. A mixed-methods strategy (Creswell et al. 2011) was implemented to capture both qualitative and quantitative perspectives. Specifically:

- Qualitative methods (semi-structured interviews and thematic analysis) were employed to explore and explain how and why certain mechanisms contributed to the plant’s success.
- Quantitative data and documents (KPI records, audit reports, training logs, etc.) were analyzed to verify what outcomes were achieved and to triangulate the qualitative findings.

This combination of methods allowed us to cross-validate evidence from multiple sources, enhancing the reliability of our conclusions through triangulation.

Data collection: We collected evidence from various sources across the ramp-up and qualification period:

- Elite interviews: ~10 semi-structured interviews were conducted with key plant personnel from Quality Assurance, Operations, Engineering, Supply Chain, Finance, and Training. The interviewees were *pioneer members* who played central roles in establishing the Lao PDR plant and leading it through the customer qualification process, providing authoritative insights into the ramp-up activities, challenges, and critical practices.
- Internal documents: project plans, training records, approved SOPs/work instructions, control plans, internal audit reports, and CAPA logs provided factual evidence of the actions taken and their timing.
- Performance and audit records: summarized KPI data (yields, process capability indices, delivery performance) and official customer audit reports were examined to assess whether targets were met and audits passed.

All proprietary numeric data have been sanitized for confidentiality (we describe results in relative terms—e.g., “within $\pm 1\%$ of target”—rather than giving exact figures). These multi-source data sets allowed us to validate interview insights against hard evidence, ensuring that each critical mechanism was corroborated by *multiple* sources.

Data analysis: Qualitative data (interviews and field notes) were analyzed using thematic analysis (Braun & Clarke 2006). We followed a six-phase process (familiarization, coding, theme development, review, definition, and writing) to inductively derive key themes related to the plant’s successful ramp-up. These themes centered on the importance of structured training/mentoring, early process standardization, performance monitoring and audits, and logistics coordination. We then iteratively matched these themes against the quantitative and documentary evidence (following a triangulation approach per Fusch et al. 2018) to ensure each identified mechanism was supported by concrete data (e.g., training hours, audit outcomes, performance metrics). Any inconsistent findings were further investigated and resolved through revisiting data or clarifying with respondents, ensuring that our conclusions were robust and credible.

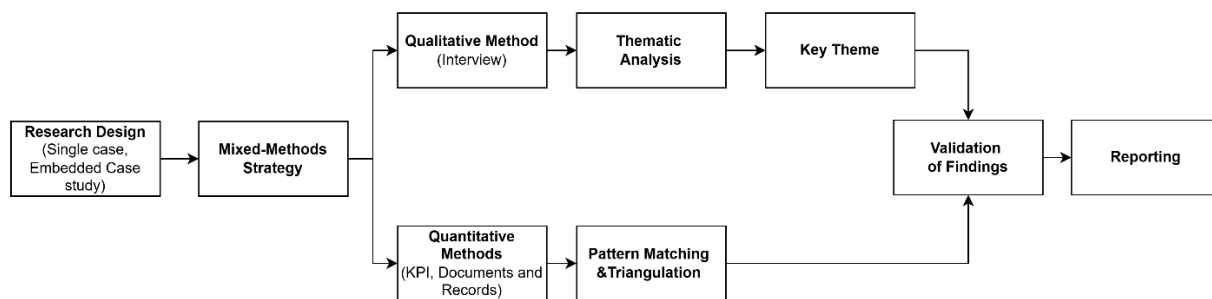


Figure 3. Overview of the research methodology

This Figure 3 illustrates the integration of qualitative and quantitative approaches used to investigate the latecomer plant’s success. The methodology combined semi-structured interviews (to capture perceptions of key mechanisms), comprehensive document reviews (to gather objective evidence), and performance data analysis (to verify outcomes), highlighting how these methods were triangulated to answer the research question.

4. Data Collection

Case background: The focal company established the Lao PDR plant as a complementary site to its main manufacturing facility in Southeast Asia. This new plant’s mission was to produce advanced HDD components (including next-generation HAMR-compatible media) to serve the company’s major customers (leading HDD manufacturers) while acting as a business continuity site. Before the plant could fully operate, it underwent an intensive ramp-up and customer qualification process, which is the focus of this study.

Ramp-up and qualification timeline: Construction of the plant began in 2018, with production line installation and internal pilot runs after that. Customer evaluation activities started in 2020, culminating in the successful qualification of the first production line by the end of that year. During qualification, the plant operated under close monitoring by internal experts and customer representatives while producing multiple trial lots for testing. Key milestones included initial process qualification trial runs, incremental yield and quality improvements guided by customer feedback, several internal audits (or “readiness reviews” to anticipate customer audits), various type of customer audit at different purpose to ensure overall performance and quality system will be good, and final customer audits. Figure 4 presents a timeline of these ramp-up and qualification events. The plant met all targets and received full volume production approval post-qualification in early 2021.

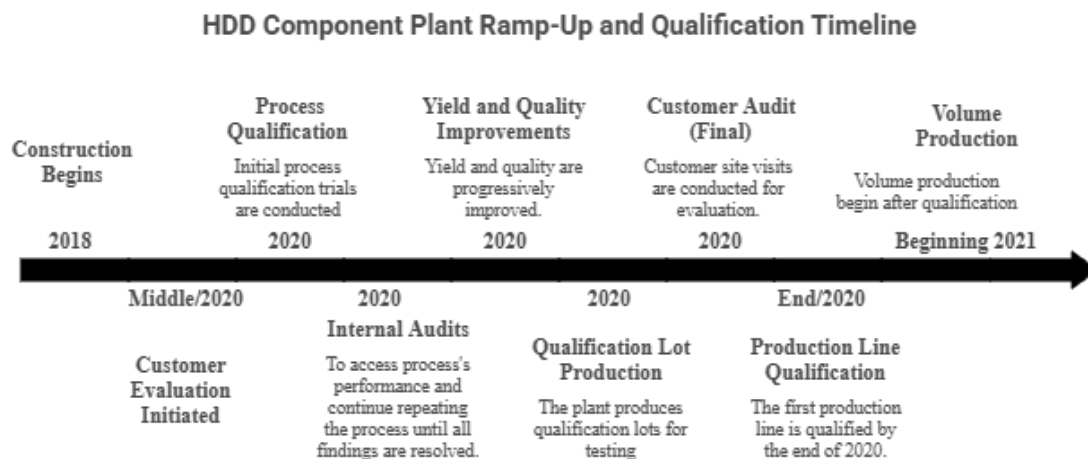


Figure 4. Timeline of the latecomer plant's ramp-up and qualification process (2018–2021).

Key milestones are shown from initial construction and training (2018) to pilot production and early customer evaluations (2020), to achieving full qualification and customer approval by late 2020, enabling volume production in 2021. Each milestone involved critical activities like knowledge transfer, standardization of processes, internal and customer audits, and performance validations, which aligned the plant with the customer's stringent acceptance criteria.

Comprehensive data sources: Throughout the ramp-up, we collected a combination of qualitative and quantitative data:

- *Interviews:* Provided insights into how the plant addressed challenges through specific initiatives (e.g., mentorship, documentation, internal audits, logistics planning).
- *Documents & Records:* Showed what actions were taken (e.g., training hours, SOP approvals, project schedules).
- *Performance Metrics & Audits:* Verified outcomes, like hitting yield targets, meeting delivery schedules, and passing audits.

By corroborating these sources, we ensured that our analysis of the plant's success was grounded in evidence and not just perceptions.

5. Results and Discussion

5.1 Key Findings and KSF Mechanisms

Building on the contextual analysis in Chapter 2, this chapter presents the empirical results of our mixed-method study. In particular, it reveals four interrelated capability-building mechanisms that enabled the Lao plant to meet stringent customer requirements. These mechanisms—focused on people, processes, quality governance, and logistics—are explained in detail below.

Our analysis identified four Key Success Factors (KSFs), each corresponding to a mechanism the plant implemented—that were crucial in meeting the customer's acceptance criteria. Table 1 summarizes these KSF mechanisms, each supported by representative evidence and linked to customer requirements.

Table 1. Key success factor (KSF) mechanisms enabling the Lao PDR plant’s successful customer acceptance

KSF Mechanism (summary)	Description and representative evidence (with linkage to customer acceptance)
KSF1: Cross-border training with embedded mentors (People)	Knowledge transfer through mentorship and OJT: Early deployment of experts from the firm’s established sites to the Lao plant enabled accelerated on-the-job training for local staff. Each new technician was paired with an experienced “buddy” mentor, receiving guided support until able to operate independently with a high degree of accuracy. This approach significantly reduced errors and process variability, contributing to consistently high first-pass yields during qualification. Internal feedback noted that the buddy system made new staff proficient within months—essential for meeting quality and yield expectations from the outset. This mechanism laid the foundation for the other KSFs by ensuring that the workforce could perform to customer standards from day one.
KSF2: Early codification of standard work (Process Discipline)	Rapid establishment of SOPs and quality controls: The plant quickly developed and localized all critical Standard Operating Procedures (SOPs), work instructions, and quality control plans by adapting documentation from the firm’s reference plant. Over 120 controlled documents were approved and implemented before mass production, with training provided to all employees. For example, visual defect criteria sheets were created and used in training to ensure a consistent understanding of quality standards. This early codification of processes led to uniform operations and positively impressed customer auditors, fulfilling documentation and quality management system compliance requirements.
KSF3: Audit-ready performance governance (Quality & Evidence)	Rigorous internal audits and KPI monitoring: The plant instituted regular internal “readiness reviews” using the customer’s audit criteria as a checklist. Multiple internal audits were conducted, and any issues were promptly addressed via formal CAPA. For instance, one pre-audit identified 12 minor non-conformances; all were corrected and verified within two weeks. The plant also maintained real-time KPI dashboards (e.g., yield trends, process capability indices) and shared them with the customer to demonstrate control and transparency. As a result, the plant passed all customer audits with no major findings, and every action item was closed, thereby fulfilling the customer’s audit and quality assurance expectations.
KSF4: Logistics alignment under SEZ constraints (Operations)	Proactive supply chain and infrastructure management: Operating in a land-linked country necessitated careful planning. The team established streamlined import–export procedures using SSEZ’s one-stop services and maintained buffer stocks to prevent border or customs delays. Transport routes were optimized (e.g., coordinating cross-border truck transfers at the Thai–Lao border) and contingency plans were implemented for critical utilities (power, water). Consequently, the plant consistently achieved 100% OTIF delivery for all trial shipments. This reliable delivery performance gave the customer confidence that the new site could meet supply commitments despite Laos’s logistical challenges.

These mechanisms did not work in isolation; rather, they reinforced each other during ramp-up. Early training and mentorship (KSF1) enabled rapid adoption of standard processes (KSF2). In turn, having standardized procedures and well-trained staff facilitated effective internal audits and KPI control (KSF3). Robust logistics planning (KSF4) ensured that these operational gains were not undermined by external disruptions. Together, the KSF bundle enabled the Lao PDR plant to meet all customer-defined acceptance criteria, demonstrating that it could operate at the required performance level from the start.

Performance outcomes: Table 2 presents the key performance and compliance outcomes achieved by the Lao PDR plant during qualification, showing how the KSF mechanisms translated into meeting each of the customer’s acceptance criteria.

Table 2. Key customer acceptance criteria and the Lao PDR plant’s performance outcomes

Acceptance Criterion	Customer Requirement	Lao PDR Plant Performance
Product quality & yield	Meet customer accepted yield within a $\pm 1\%$ tolerance band	Achieved: A $\pm 1\%$ yield tolerance was achieved and accepted by the customer. Furthermore, the product passed all customer quality checkpoints, including incoming inspection, in-process evaluation, and final reliability testing without any reported quality issues.
Process documentation & control	Complete all required process documentation and quality control procedures on schedule; robust quality management system (QMS) implementation	Achieved. 100% of required SOPs, work instructions, and control plans were in place and fully trained to staff before mass production. Internal audits confirmed that the plant’s QMS met all customer documentation and process control standards.
Delivery performance (OTIF)	100% on-time, in-full delivery of all committed orders	Achieved. 100% OTIF delivery was maintained for all pre-production and qualification lots. Every shipment was delivered on or before the due date and in the correct quantity, assuring the customer of the plant’s reliability.
Audit results & CAPA closure	Pass all customer audits; all findings resolved	Achieved. The plant passed every customer audit with no major non-conformities. All minor findings from internal and customer audits were addressed and closed through documented CAPA, satisfying the customer’s audit requirements.

Overall, the Lao PDR plant met or exceeded every key acceptance requirement during ramp-up: it consistently achieved the target yields, maintained flawless delivery performance, completed all documentation on time, and passed all audits. This exceptional performance validated the effectiveness of the identified KSF mechanisms and led to full production approval by the customer.

5.2 Graphical Results

To visually summarize our findings, Figure 5 illustrates how each KSF mechanism contributed to the plant’s success during different ramp-up stages. The diagram shows that the four mechanisms were not isolated; instead, they were progressively activated and reinforced over time, collectively building the plant’s capabilities to meet and sustain customer requirements.

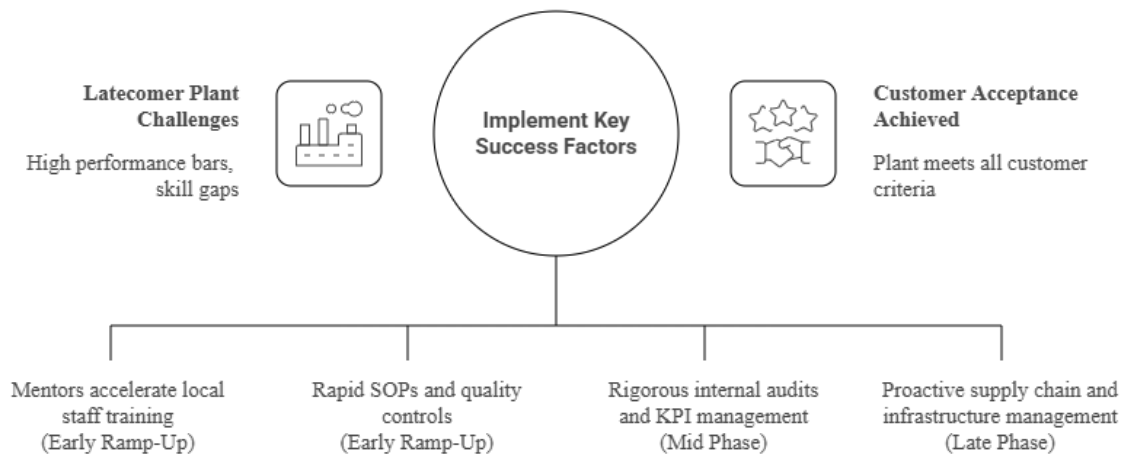


Figure 5. Visual summary of the four Key Success Factors (KSFs) and their roles in enabling the latecomer plant’s success.

The diagram illustrates how KSF1 (cross-border mentorship), KSF2 (early process standardization), KSF3 (audit-ready performance governance), and KSF4 (logistics alignment) collectively contributed to the plant's operational capability upgrading. Each KSF addresses a distinct domain—people, process, quality, and operations—and together they formed an interdependent mechanism bundle that enabled the plant to meet stringent customer qualification standards and sustain high performance in a challenging latecomer context.

5.3 Proposed Improvements

From a practical perspective, our case study suggests that latecomer factories can meet world-class standards by focusing on a bundle of interrelated capability-building mechanisms. Key recommendations for practitioners include: (i) *Invest early in structured cross-site training and mentoring programs* (embedding experienced “buddies” to accelerate skill transfer and reduce trial-and-error); (ii) *Establish process discipline from day one*, with thorough documentation and strict adherence to standard work and quality procedures; (iii) *Implement rigorous internal audits and KPI monitoring* to catch and address issues proactively, thus mirroring and anticipating customer audit requirements; and (iv) *Proactively manage logistics and infrastructure* (e.g., secure supply routes, dependable utilities, and streamlined customs processes) to prevent external bottlenecks. By systematically deploying these interlinked strategies, latecomer plants can shorten their learning curve, ensure operational consistency, and build the operational discipline required to satisfy demanding customers.

5.4 Validation

We strengthened the validity of our conclusions through triangulation of multiple evidentiary sources. Qualitative findings (e.g., insights from interviews about the importance of mentorship and standardization) were cross-verified against quantitative performance data (e.g., yield trends, delivery records) and documentary evidence (e.g., audit reports, training logs). The convergence of evidence increased confidence that our identified KSF mechanisms are indeed the factors that led to the plant's success. For example, interviewees credited the buddy training system with improved early performance, and this claim was verified by training completion records and high initial yields; similarly, internal audit logs confirming CAPA closures aligned with managers' statements about a culture of continuous improvement. By using a reflexive and iterative approach to analysis (following Braun & Clarke 2006; Fusch et al. 2018), we mitigated single-source bias and ensured our conclusions are robust.

6. Conclusion

In this study, the process by which a latecomer HDD component manufacturing plant in Lao PDR was able to meet stringent customer qualification standards has been examined. Operating within a challenging local context, the plant was required to demonstrate full compliance with customer-defined criteria in terms of yield, quality, delivery, and audit readiness. Despite the constraints typically faced by emerging manufacturing locations, full customer acceptance was achieved within a compressed timeline.

Through a mechanism-based analysis, four interdependent capability-building factors were identified. These included structured cross-border mentorship, early process standardization, audit-ready performance governance, and logistics alignment. Each mechanism addressed a distinct operational domain, and together they formed a mutually reinforcing system that enabled the plant to meet and sustain customer-defined expectations.

For practitioners, this case offers a practical roadmap for establishing new manufacturing sites in emerging economies. Emphasis should be placed on early knowledge transfer, rigorous documentation and process control, proactive audit preparation, and resilient logistics planning. When implemented in coordination, these mechanisms can enable latecomer plants to overcome initial disadvantages and contribute to more diversified and resilient global supply chains.

The interrelationship of these mechanisms and their collective contribution to operational upgrading are conceptually summarized in Figure 6. The diagram illustrates how each mechanism supports a specific capability domain, and how their integration enables the plant to achieve and maintain customer-accepted performance in a high-standard, audit-intensive environment. The visual also emphasizes that no single mechanism alone is sufficient. Instead, it is the coordinated implementation of all four mechanisms—spanning people, process, quality, and operations—that allows a latecomer plant to build the operational discipline required for successful integration into advanced electronics supply chains.

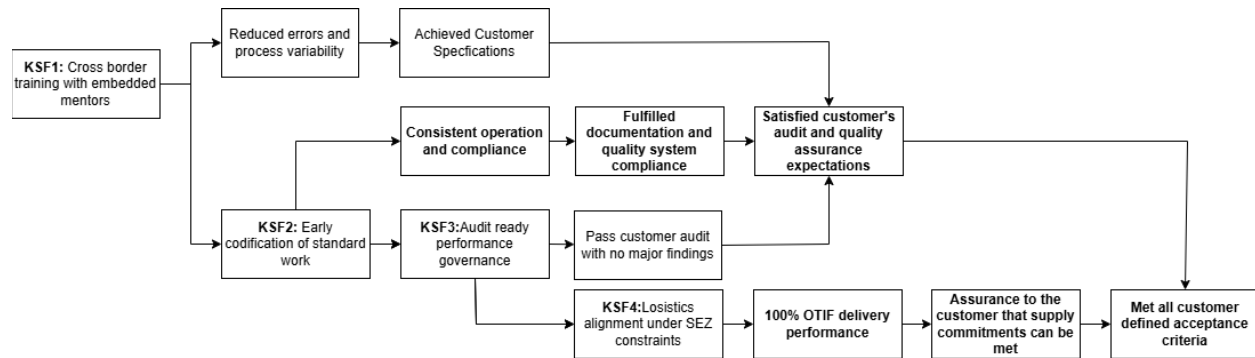


Figure 6. Integrated Capability-Building Mechanisms Enabling Latecomer Plant Performance

This conceptual diagram illustrates how four interdependent Key Success Factors (KSFs)—cross-border mentorship (KSF1), early process standardization (KSF2), audit-ready performance governance (KSF3), and logistics alignment (KSF4)—collectively contribute to the operational capability upgrading of a latecomer electronics manufacturing plant. Each KSF addresses a distinct domain (people, process, quality, and operations), and their integration enables the plant to meet stringent customer qualification standards. The arrows and interlinkages emphasize the synergistic nature of these mechanisms, showing that no single factor alone is sufficient. Instead, it is the coordinated implementation of all four that allows the plant to achieve and sustain customer-accepted performance in a high-standard, audit-intensive supply chain environment.

Future research could further investigate the post-qualification development stage by exploring how the Lao PDR plant improves its performance after customer acceptance, particularly through comparison with the established mentor plant in Vietnam. In addition, the findings from this case may serve as a preliminary guideline for other latecomer manufacturers—especially those in Southeast Asia’s HDD component sector—seeking to enter high-tech global value chains. Longitudinal tracking of capability development over time will also be pursued to better understand how latecomer plants can evolve toward performance parity with established competitors and sustain operational excellence in dynamic global supply environments.

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Biographies

Umawadee Nuchniyom is a Ph.D. student at the Faculty of Industrial Engineering, Chiang Mai University. Her research interests include capability building in emerging manufacturing ecosystems, supplier development, and operations excellence. She also serves as Vice President of Global Quality Assurance at HOYA Memory Disk Division, bringing over 25 years of practical QA experience in glass disk manufacturing across Thailand, Vietnam, and Laos.

Professor Dr. Apichat Sopadang is a faculty member in the Industrial Engineering department at Chiang Mai University. His research areas of expertise include Supply Chain and Logistics Management, Multiple Criteria Decision Making, and Sustainable Management.

Professor Dr. Komgrit Leksakul is a faculty member in the Industrial Engineering department at Chiang Mai University. His research areas of expertise include mathematical modeling and exact and heuristic optimization in large scale linear, nonlinear and NP-hard problems. Besides above mentioned, he also experts in plasma and MEMs technology in both agriculture and medical areas which are the new trend of the world technologies.