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Lost in Rotation: The Erosion of Tacit Engineering Knowledge in Indonesia's State-Owned Defense Enterprises

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Abstract
Engineering-intensive defense enterprises depend on tacit engineering knowledge developed through long-term engagement with complex technological processes. However, existing knowledge-management literature has paid limited attention to how internal personnel rotation may erode access to experience-based expertise even when employees remain within the organization. This study examines how personnel rotation contributes to tacit engineering knowledge vulnerability and how knowledge-retention mechanisms support capability continuity in Indonesia's state-owned defense enterprises. A qualitative multiple-case study design was employed using secondary documentary analysis of annual reports, corporate publications, governance documents, government reports, industry publications, and relevant academic studies. The cases included PT Pindad, PT PAL Indonesia, and PT Dirgantara Indonesia, representing land defense manufacturing, naval shipbuilding, and aerospace engineering. Data were analyzed through thematic analysis and cross-case comparison to identify recurring patterns of tacit knowledge dependence, workforce mobility, knowledge disruption, and retention practices. The findings reveal four key themes: critical tacit engineering knowledge, rotation-induced knowledge discontinuity, organizational consequences of knowledge gaps, and existing knowledge-retention practices. Manufacturing know-how, troubleshooting capability, system integration expertise, and technical judgment emerged as the most vulnerable knowledge areas. Personnel transitions may reduce knowledge accessibility when structured transfer mechanisms are insufficient. These findings support the Knowledge-Based View and Dynamic Capabilities Theory by positioning tacit knowledge continuity as a strategic organizational capability. The study is limited by its reliance on secondary documents; future research should use interviews, longitudinal inquiry, or mixed methods to examine individual-level knowledge-transfer processes more deeply.

Keywords: Defense industry; Engineering knowledge; Knowledge retention; Personnel rotation; Tacit knowledge.

INTRODUCTION

Organizations that are heavily focused on engineering rely not only on formal procedures, technical documentation, and standardized processes but also on the collective expertise embedded within their employees. In engineering-intensive organizations, tacit knowledge represents a strategic resource that supports operational reliability, technological development, problem-solving capability, and long-term organizational continuity. Unlike explicit knowledge that can be easily documented and transferred through manuals or databases, tacit knowledge is embedded in individual experience, professional judgment, and practical skills developed through continuous engagement with complex engineering activities (Garcia-Perez et al., 2020; Summerscales, 2024). Therefore, the ability to retain and transfer tacit engineering knowledge has become a critical concern for organizations that depend on specialized expertise.

The strategic importance of tacit engineering knowledge is closely related to organizational learning and innovation capacity. Knowledge-based organizations create value by integrating the expertise of their workforce, making knowledge management an essential mechanism for maintaining continuity and improving performance (Garcia-Perez et al., 2020). Previous studies have demonstrated that effective knowledge management contributes to organizational innovation, decision-making quality, and competitiveness (Obeidat et al., 2016). In engineering environments, tacit knowledge includes practical understanding of production processes, troubleshooting approaches, design considerations, quality assurance practices, and system integration experiences, which collectively form organizational memory and technological capability (Summerscales, 2024).

The challenge of maintaining such knowledge has become more complex due to workforce transitions. Knowledge loss is commonly associated with employee retirement, turnover, and the departure of experienced professionals who possess accumulated expertise (Burmeister & Deller, 2016; Massingham, 2018). However, organizational knowledge discontinuity does not occur only when employees leave the organization. Internal workforce movements, including promotion, inter-unit transfer, project reassignment, and personnel rotation, may also create potential knowledge gaps when expertise is transferred faster than organizational mechanisms can capture and redistribute it (Caroline Martins & Meyer, 2012; Sumbal et al., 2017). Although these movements can support career development, flexibility, and cross-functional learning, they may unintentionally weaken knowledge continuity when tacit knowledge remains attached to individuals rather than institutionalized through systematic transfer processes. Consequently, knowledge retention has evolved beyond a human resource concern into a strategic engineering management challenge (Levy, 2011; Ranasinghe et al., 2024).

This challenge becomes particularly significant in defense manufacturing organizations, where technological capability depends heavily on accumulated engineering experience. Defense industries operate within highly specialized environments characterized by advanced production systems, strict quality requirements, long product life cycles, and complex integration of multidisciplinary expertise. Unlike many commercial industries that frequently replace technologies and products, defense organizations often maintain and upgrade systems over extended periods, requiring continuous access to historical engineering knowledge and previous development experience (Durst & Zieba, 2019). The loss of such expertise may affect production reliability, maintenance capability, innovation capacity, and the sustainability of critical technological competencies (Ramos Cordeiro et al., 2023).

Defense-related industries rely on cumulative learning processes developed through repeated involvement in design, testing, manufacturing, maintenance, and system integration activities. Therefore, knowledge management plays a crucial role in sustaining technological competitiveness and innovation within defense industrial ecosystems (Jurčić et al., 2020). Furthermore, collaborative engineering environments require effective knowledge exchange among specialists, engineers, and managers to ensure that essential expertise remains accessible across projects and organizational units (Hilliard et al., 2022). In this context, preserving tacit engineering knowledge is not merely an administrative activity but a fundamental responsibility of engineering management (Summerscales, 2024).

This issue is particularly relevant for Indonesia's state-owned defense enterprises, including PT Pindad, PT PAL Indonesia, and PT Dirgantara Indonesia. These organizations represent strategic defense industries responsible for developing and maintaining complex technological capabilities in areas such as defense equipment manufacturing, naval engineering, aerospace systems, maintenance, testing, and technological development

(Damayanti & Ratnasih, 2025; Matthews et al., 2025). Although operating in different technological domains, these three organizations share comparable characteristics as engineering-intensive enterprises: they depend on specialized technical expertise, operate through long-term projects, require multidisciplinary collaboration, and rely on accumulated knowledge from previous production and development cycles. These characteristics make them relevant cases for examining how workforce mobility may influence the continuity of tacit engineering knowledge.

Within these organizations, personnel rotation, managerial reassignment, functional transfer, and project mobility are commonly implemented as workforce management strategies to improve organizational flexibility, develop leadership capability, support succession planning, and encourage institutional learning. Such practices can generate positive outcomes by exposing employees to diverse operational contexts and strengthening cross-functional collaboration (Calle et al., 2025; Foster et al., 2019). However, in engineering-intensive environments, rotation may also create knowledge continuity risks when individuals move away from specific technologies, systems, or projects without adequate mechanisms for transferring experience-based knowledge. The potential issue is therefore not personnel rotation itself, but the relationship between workforce mobility and the organization's ability to preserve, document, and transfer tacit engineering expertise.

Despite extensive research on knowledge management, organizational learning, tacit knowledge sharing, workforce aging, and knowledge retention, existing literature has mainly emphasized knowledge loss caused by retirement, employee turnover, and intergenerational knowledge transfer challenges (Borges et al., 2018; Burmeister & Deller, 2016; Sumbal et al., 2017). Comparatively less attention has been given to knowledge erosion resulting from internal workforce mobility, particularly formal personnel rotation in engineering-intensive organizations. Rotation differs from retirement or turnover because employees remain within the organization, yet their movement between units, functions, or projects may separate them from the knowledge context where their expertise was originally developed. This creates a distinct knowledge management challenge: the organization retains the employee but may lose access to the embedded expertise associated with a particular role, system, or technical environment. In emerging economies, especially within state-owned defense enterprises, this phenomenon remains underexplored and requires further empirical investigation.

Accordingly, this study examines how personnel rotation contributes to the erosion of tacit engineering knowledge within Indonesia's state-owned defense enterprises. By focusing on engineering-intensive environments, this study investigates which forms of tacit knowledge are vulnerable to loss, how rotation-related transitions create knowledge discontinuity, and what organizational mechanisms can be developed to maintain technological continuity. By positioning personnel rotation as an engineering management issue rather than merely a human resource practice, this study argues that workforce mobility requires integrated knowledge-retention mechanisms to prevent the gradual erosion of organizational capability and maintain long-term technological continuity.

METHODS

Research Design

This study employed a qualitative multiple-case study design using qualitative secondary document analysis. The study aimed to examine how personnel rotation may contribute to the erosion of tacit engineering knowledge within Indonesia's state-owned defense enterprises. A qualitative approach was selected because tacit knowledge is embedded in experience, professional judgment, organizational routines, and practice-based learning processes that cannot be adequately captured through quantitative indicators alone (Kahlke, 2018).

A multiple-case study design was adopted because the phenomenon of knowledge erosion through personnel mobility cannot be separated from its organizational and technological context. Case study research enables researchers to investigate complex organizational phenomena within their real-life settings and to develop contextual explanations regarding managerial processes and organizational practices (Ellinger & McWhorter, 2016; Ridder, 2017). In this study, each organization was treated as a bounded case with its own technological domain, engineering activities, workforce practices, and knowledge-management context.

The three cases were selected to enable analytical comparison across engineering-intensive defense organizations rather than to represent all Indonesian defense enterprises. The cross-case approach followed a replication logic, where similarities and differences among cases were examined to identify recurring patterns related to personnel mobility, knowledge transfer mechanisms, and potential knowledge discontinuity. This approach allowed the study to explore whether similar knowledge-retention challenges emerge across different defense technology domains.

Because tacit knowledge is inherently difficult to observe directly, this study did not attempt to measure tacit knowledge itself as a physical object. Instead, the analysis focused on documentary traces that indicate the existence, dependence, and preservation of experience-based engineering knowledge, including references to workforce capability development, engineering expertise, succession planning, organizational learning, technology continuity, and human capital management. These documentary indicators were interpreted as organizational manifestations of tacit knowledge practices.

Data Sources and Case Selection

The study relied exclusively on secondary documentary data. Documentary analysis is useful for examining organizational structures, strategic priorities, workforce practices, and institutional knowledge-management mechanisms, particularly when direct access to organizational members is limited (Slutskaya et al., 2018). However, because tacit knowledge is embedded in individual experience and practice, publicly available documents cannot fully reveal the complete content of tacit expertise. Therefore, this study treated documents not as direct substitutes for individual experiences but as institutional evidence showing how organizations recognize, manage, transfer, and preserve engineering knowledge.

The cases consisted of three Indonesian state-owned defense enterprises: PT Pindad, PT PAL Indonesia, and PT Dirgantara Indonesia. These organizations were selected purposively because they represent strategic defense manufacturing sectors with strong dependence on engineering expertise, long-term technological development, and complex production processes. Although they operate in different technological domains, the three organizations share comparable characteristics as engineering-intensive enterprises.

PT Pindad represents land-based defense manufacturing, including weapons systems, military vehicles, and ammunition-related production. PT PAL Indonesia represents naval defense technology through shipbuilding, maritime systems integration, and maintenance activities. Meanwhile, PT Dirgantara Indonesia represents aerospace capability through aircraft manufacturing, maintenance, and aerospace system integration. These differences provide variation across technological domains while maintaining a common dependence on specialized engineering knowledge.

The documentary corpus consisted of publicly available organizational and institutional documents, including annual reports, sustainability reports, corporate governance reports, strategic documents, official publications, government reports, policy documents, academic publications, and relevant professional reports. Documents were included when they contained information related to one or more of the following criteria: (1) engineering capability development, (2) workforce management and mobility, (3) knowledge management or organizational learning, (4) human capital development, (5) succession planning, and (6) mechanisms related to maintaining organizational capability.

Documents were excluded when they were unrelated to engineering capability, workforce practices, or organizational knowledge continuity. The document screening process focused on relevance, credibility, and contribution to understanding the relationship between personnel movement and tacit knowledge continuity.

The credibility of documentary evidence was assessed based on source authority, organizational origin, relevance to the research objectives, and consistency across different document types. Official company reports were prioritized because they directly represented organizational strategies and practices, while external reports and academic publications were used to provide contextual interpretation.

Table 1. Case Characteristics and Evidence of Engineering Knowledge Intensity

Organization	Core Industry	Main Engineering Activities	Evidence of Knowledge Intensity	Strategic Role
PT Pindad	Defense manufacturing	Weapons systems, military vehicles, ammunition production	Dependence on specialized engineering processes, product development, maintenance capability, and long-term technical expertise documented in corporate reports	Land defense capability
PT PAL Indonesia	Naval shipbuilding	Warships, maritime systems integration, maintenance and ship technology development	Dependence on multidisciplinary engineering knowledge involving design, construction, integration, and lifecycle maintenance	Naval defense capability
PT Dirgantara Indonesia	Aerospace manufacturing	Aircraft production, maintenance, aerospace systems integration	Dependence on advanced engineering capability, aerospace technology development, and accumulated technical expertise	Aerospace defense capability

Source: Compiled from PT Pindad Annual Reports, PT PAL Indonesia Annual Reports, PT Dirgantara Indonesia Annual Reports, corporate publications, and related institutional documents.

The classification of the three organizations as knowledge-intensive cases was not based solely on their industry category but on observable characteristics from documentary evidence, including reliance on specialized engineering skills, complex technological systems, multidisciplinary collaboration, and long-term capability development. These characteristics provide the basis for examining how personnel rotation may influence the continuity of tacit engineering knowledge.

Data Analysis

Data analysis involved three interconnected stages: document analysis, reflexive thematic analysis, and cross-case comparison. Document analysis was conducted to identify organizational evidence related to engineering knowledge, workforce transitions, and knowledge-retention mechanisms (Slutskaya et al., 2018).

The thematic analysis followed an iterative process based on established qualitative procedures (Castleberry & Nolen, 2018; Nowell et al., 2017). First, all selected documents were reviewed repeatedly to understand their organizational context and identify relevant sections. Second, initial coding was conducted by assigning labels to meaningful text segments. The coding framework focused on concepts related to:

1. Tacit engineering knowledge;
2. Knowledge transfer mechanisms;
3. Personnel rotation and workforce mobility;
4. Organizational memory;
5. Capability continuity;
6. Succession planning;
7. Knowledge retention practices.

The initial codes were then grouped into broader themes. The development of themes followed the logic that personnel movement may create knowledge discontinuity when engineering expertise is highly dependent on individual experience and insufficiently transferred through organizational mechanisms. The following analytical relationships guided the interpretation:

Table 2. Initial Coding Framework for Analyzing Tacit Engineering Knowledge Erosion

Initial Code	Related Concept	Developed Theme

Expert experience, technical judgment, practical skills	Tacit engineering knowledge	Dependence on experiential expertise
Rotation, transfer, reassignment, mobility	Workforce transition	Knowledge continuity risk
Documentation, mentoring, training, succession planning	Knowledge transfer mechanisms	Organizational knowledge retention

After theme development, within-case analysis was conducted for each organization to identify case-specific patterns. Cross-case analysis was subsequently performed to compare similarities and differences among PT Pindad, PT PAL Indonesia, and PT Dirgantara Indonesia. This comparison focused on how each organization managed engineering knowledge continuity under conditions of workforce mobility.

To improve analytical credibility, the study applied source triangulation by comparing different types of documents, including corporate reports, institutional publications, and external academic or professional sources. The analysis also maintained an audit trail through systematic documentation of document selection, coding decisions, and theme development processes. However, because the study relied on secondary documents, the findings are interpreted as evidence of organizational patterns and knowledge-management risks rather than direct accounts of individual employee experiences.

RESULT AND DISCUSSION

Results

The analysis of documentary evidence generated four interconnected themes explaining how tacit engineering knowledge is maintained and potentially disrupted within Indonesia's state-owned defense enterprises. The findings were derived from systematic coding of organizational documents, including annual reports, corporate publications, strategic documents, and institutional reports. The coding process identified recurring patterns related to engineering expertise, workforce mobility, knowledge transfer mechanisms, and organizational capability continuity.

The cross-case analysis examined PT Pindad, PT PAL Indonesia, and PT Dirgantara Indonesia as separate bounded cases. Although each organization operates in different technological domains, the documentary evidence indicated similar patterns regarding the dependence on experience-based engineering knowledge and the need for mechanisms that support knowledge continuity during workforce transitions.

To summarize the main findings, Table 3 presents the themes developed from the documentary analysis, including the supporting evidence identified across the three cases.

Table 3. Cross-Case Findings Based on Documentary Analysis

Theme	Documentary Evidence Across Cases	Case-Based Interpretation	Main Implication
Critical Tacit Engineering Knowledge	Corporate reports and capability documents highlighted the importance of specialized engineering expertise, technical experience, production knowledge, maintenance capability, and system integration skills across PT Pindad, PT PAL Indonesia, and PT Dirgantara Indonesia	Engineering capability in the three organizations depends not only on documented procedures but also on accumulated experience developed through long-term involvement in complex projects	Critical engineering knowledge remains highly dependent on experienced personnel and organizational learning processes
Rotation-Induced	Documents related to human capital	Workforce movement may create potential	Personnel rotation represents a

Knowledge Discontinuity	development, organizational restructuring, workforce planning, and capability development indicated the importance of employee mobility, reassignment, and knowledge transfer mechanisms	knowledge continuity challenges when experience-based knowledge is not sufficiently transferred through organizational routines	potential source of knowledge erosion when retention mechanisms are limited
Organizational Impact of Knowledge Gaps	Organizational capability reports and strategic documents emphasized the need for continuous competency development, technological learning, and capability sustainability	Loss of access to experienced expertise may influence learning continuity, adaptation processes, and the availability of technical capabilities	Knowledge discontinuity may affect long-term engineering capability and organizational resilience
Knowledge Retention Mechanisms	Company publications documented practices related to training, competency development, documentation, knowledge sharing, and human capital programs	Existing mechanisms support the preservation of organizational knowledge; however, documentary evidence suggests that explicit systems may not fully represent experience-based expertise	Organizations require integrated mechanisms to capture and transfer tacit engineering knowledge

Source: *Authors' thematic analysis of secondary documentary data.*

Table 3 indicates that tacit engineering knowledge functions as an important foundation for technological continuity within the three organizations. The findings show that engineering capability is not solely derived from formal procedures and technical documentation but also from accumulated expertise developed through repeated involvement in design, production, maintenance, and system integration activities.

Across the three cases, documentary evidence suggests that personnel mobility represents a relevant factor in knowledge continuity. Unlike retirement or employee turnover, personnel rotation does not remove employees from the organization; however, reassignment across functions, projects, or units may separate individuals from the specific technological contexts where their expertise was developed. This creates a potential gap between organizational knowledge availability and the accessibility of practical engineering experience.

The analysis further identified that PT Pindad, PT PAL Indonesia, and PT Dirgantara Indonesia have developed various mechanisms related to competency development, training, documentation, and organizational learning. Nevertheless, because tacit knowledge is strongly connected with individual experience and contextual understanding, formal mechanisms may not completely capture all aspects of engineering expertise. Therefore, sustaining technological continuity requires not only retaining employees but also ensuring that experience-based knowledge can be transferred across organizational transitions.

Critical Tacit Engineering Knowledge

The analysis identified critical categories of tacit engineering knowledge that were repeatedly reflected across the three cases: PT Pindad, PT PAL Indonesia, and PT Dirgantara Indonesia. The findings were developed from the analysis of corporate documents, including annual reports, organizational publications, strategic documents, and capability-related reports that describe engineering activities, human capital development, production processes, and technological capabilities. These documents do not directly capture individual employees' tacit knowledge; however, they provide organizational-level evidence regarding the types of expertise considered essential for maintaining engineering capability and operational continuity.

Across the three organizations, engineering capability was presented not only as a result of formal procedures, technical standards, and documented processes but also as a product of accumulated experience developed through production activities, testing, maintenance, system development, and problem-solving processes. In PT Pindad's documents, engineering capability is associated with defense manufacturing activities involving weapons systems, vehicles, and production processes that require specialized technical competence. Similarly, PT PAL Indonesia's organizational documents highlight engineering activities related to shipbuilding, system integration, and lifecycle maintenance, while PT Dirgantara Indonesia's publications emphasize aerospace production, aircraft maintenance, and technology development activities. These areas represent contexts where practical experience and accumulated technical understanding are important components of organizational capability.

A recurring theme identified from the documents was the importance of manufacturing-related expertise. The reviewed organizational reports describe production activities that require specialized technical skills, process control, quality assurance, and continuous improvement capabilities. In such environments, formal production procedures provide operational guidance; however, engineering decisions often require contextual understanding developed through repeated involvement in manufacturing processes. This includes the ability to recognize process variations, interpret technical conditions, and adjust operational approaches when unexpected problems occur. Therefore, manufacturing know-how represents a form of engineering knowledge that may be strongly connected to experienced personnel.

Another knowledge category identified was troubleshooting expertise. Across the cases, documents related to operational capability, maintenance activities, and engineering development emphasize the importance of technical problem-solving capabilities. PT Pindad's manufacturing and maintenance-related activities require personnel to address technical issues associated with production systems and defense equipment. PT PAL Indonesia's shipbuilding and maintenance processes involve diagnosing technical problems within complex maritime systems, while PT Dirgantara Indonesia's aerospace activities require specialized knowledge for aircraft maintenance and system reliability. These activities suggest that troubleshooting capability develops through accumulated interaction with specific technologies, equipment, and operational conditions rather than through formal documentation alone.

The analysis further identified system integration knowledge as an important component of tacit engineering expertise. The defense technologies developed by the three organizations involve the coordination of multiple engineering disciplines and technical components. PT PAL Indonesia's shipbuilding activities require integration between mechanical, electrical, and maritime systems, while PT Dirgantara Indonesia's aerospace activities involve coordination between aircraft structures, systems, and maintenance requirements. PT Pindad's defense manufacturing activities similarly require integration between design, production, testing, and operational requirements. Such integration processes depend on engineering judgment regarding compatibility, technical interfaces, testing results, and system performance, which are often developed through project-based experience.

In addition, production experience and experiential engineering judgment emerged as underlying elements across the three cases. The reviewed documents related to human capital development, competency enhancement, and organizational capability indicate the importance of maintaining experienced personnel and developing technical competencies. These findings suggest that experienced engineers contribute not only through formal knowledge but also through practical decision-making abilities developed from repeated exposure to complex engineering situations. Such abilities enable personnel to evaluate technical alternatives, identify potential risks, and adapt solutions according to specific operational conditions.

Overall, the findings indicate that tacit engineering knowledge in PT Pindad, PT PAL Indonesia, and PT Dirgantara Indonesia is closely related to manufacturing expertise, troubleshooting capability, system integration experience, and accumulated technical judgment. Although some aspects of this knowledge are supported through documentation, training, and organizational processes, the analysis suggests that a significant part of engineering expertise remains dependent on individuals who possess practical experience within specific technological contexts. This dependency creates potential knowledge continuity challenges when experienced personnel move between roles, units, or projects without sufficient mechanisms for knowledge transfer.

Rotation-Induced Knowledge Disruption

The second theme concerned the relationship between workforce mobility and the continuity of tacit engineering knowledge. The analysis showed that different forms of personnel movement including rotation, promotion, cross-functional mobility, project reassignment, and retirement-related transitions should be understood as distinct organizational processes because each may influence knowledge continuity through different mechanisms. Based on the reviewed documents, the central issue was not employee movement itself, but the extent to which experience-based engineering knowledge was transferred and embedded within organizational routines before transitions occurred.

Personnel rotation emerged as the primary focus of this study because it involves the movement of employees between roles, units, or projects while maintaining their relationship with the organization. The reviewed corporate and organizational documents from PT Pindad, PT PAL Indonesia, and PT Dirgantara Indonesia describe workforce development, competency management, and organizational mobility practices as part of maintaining organizational capability. However, when engineers move away from specific technical environments, knowledge developed through repeated interaction with particular systems, equipment, or production processes may become less directly accessible to the receiving unit unless supported by structured transfer mechanisms.

Promotion-related transitions represented a different form of knowledge continuity challenge. In engineering-intensive organizations, experienced technical personnel may move into supervisory or managerial positions as part of leadership development and career progression. This transition does not necessarily indicate knowledge loss because technical experience may continue to contribute to organizational decision-making. However, it may create a gap at the operational level when practical expertise previously applied in daily engineering activities is not transferred to other technical personnel. Therefore, the knowledge risk associated with promotion is related to the separation between technical expertise and operational responsibility rather than the departure of employees from the organization.

Cross-functional mobility and project reassignment created another distinct mechanism of potential knowledge disruption. Engineering organizations often require employees to participate in different projects, departments, or technical functions to improve flexibility and organizational learning. The reviewed documents highlight the importance of competency development and workforce capability across organizational areas. Nevertheless, movement between technical contexts may reduce access to localized knowledge developed within a specific project or production environment. Knowledge related to particular technologies, design considerations, or problem-solving approaches may remain concentrated among individuals who have direct experience with those contexts.

Retirement represents a different category of knowledge transition because it involves the potential loss of organizational members rather than internal movement. The reviewed documents emphasize the importance of experienced personnel, competency development, and human capital sustainability within defense enterprises. However, the available documentary sources do not provide sufficient evidence to confirm specific retirement-related knowledge losses in PT Pindad, PT PAL Indonesia, or PT Dirgantara Indonesia. Therefore, retirement is interpreted in this study as a broader knowledge-retention concern within engineering-intensive organizations rather than as an observed mechanism of knowledge disruption in the selected cases.

Across the three cases, the analysis suggests that knowledge disruption is more closely associated with the absence or limitation of knowledge-transfer mechanisms accompanying workforce transitions. When engineering expertise is strongly connected to individual experience, organizational capability may become vulnerable if practical knowledge is not captured through mentoring, documentation, training, succession practices, or other knowledge-sharing processes. Conversely, workforce mobility can support organizational learning when accompanied by mechanisms that enable knowledge exchange between experienced and incoming personnel.

Overall, the findings indicate that personnel transitions should not be treated as a single category of knowledge loss. Instead, each transition mechanism creates different knowledge-management implications. In the context of PT Pindad, PT PAL Indonesia, and PT Dirgantara Indonesia, personnel rotation represents a specific knowledge continuity challenge because employees remain within the organization while potentially moving away from the technical environments where their tacit engineering expertise was developed.

Organizational Consequences

The third theme concerned the organizational consequences associated with potential disruptions in tacit engineering knowledge continuity. The analysis did not identify direct evidence of complete knowledge loss within PT Pindad, PT PAL Indonesia, or PT Dirgantara Indonesia. Instead, the reviewed documents revealed several organizational implications related to maintaining engineering capability when experienced personnel move between roles, units, or projects. These implications were mainly reflected in challenges related to project continuity, capability adjustment, and the preservation of operational consistency.

One identified consequence was the potential impact on project continuity. Engineering projects within defense enterprises often involve complex processes that require coordination between multiple technical areas, including design, manufacturing, testing, maintenance, and system integration. Based on the analysis of organizational reports and capability-related documents, the continuity of such activities depends not only on formal procedures but also on accumulated technical understanding developed through previous project involvement. When personnel transitions occur, newly assigned employees may require additional time to become familiar with specific technologies, project histories, technical decisions, and problem-solving approaches. This adjustment process may influence the efficiency of knowledge application, particularly in activities requiring strong contextual understanding.

A second consequence relates to capability adaptation and organizational learning. The reviewed documents from the three organizations emphasize continuous competency development, technical training, and human capital strengthening as important elements of maintaining engineering capability. These practices suggest that organizations recognize the need to continuously develop personnel knowledge to support technological requirements. However, because some engineering expertise is developed through repeated exposure to specific systems and operational contexts, transferring personnel between functions may require additional learning processes to rebuild practical understanding. Thus, workforce mobility may create temporary gaps between existing organizational knowledge and the ability of new personnel to immediately apply that knowledge.

Another organizational implication identified was the potential effect on operational consistency and quality management. Engineering-intensive defense activities require adherence to technical standards, reliability requirements, and quality assurance processes. While formal procedures provide a foundation for maintaining consistency, practical engineering judgment remains important when addressing unexpected technical conditions. The analysis suggests that when experienced personnel move from particular technical roles, organizations may need additional efforts to maintain consistency by strengthening documentation, mentoring, training, and knowledge-sharing practices.

Across the three cases, the findings indicate that the consequences of tacit knowledge disruption are not limited to immediate knowledge loss. Instead, the primary challenge concerns the accessibility and continuity of expertise during workforce transitions. When engineering knowledge remains closely associated with individual experience and is insufficiently embedded in organizational mechanisms, personnel movement may increase the effort required for learning, adaptation, and capability maintenance.

Overall, the results suggest that organizational consequences arising from personnel mobility depend largely on the strength of knowledge-retention mechanisms. Rotation and other workforce transitions do not automatically reduce organizational capability; rather, risks emerge when organizations lack effective processes to ensure that experience-based engineering knowledge can be transferred, shared, and continuously applied across changing personnel structures.

Existing Knowledge Retention Practices

The fourth theme examined organizational mechanisms related to the preservation and transfer of engineering knowledge. The analysis of organizational reports, human capital-related documents, and capability development publications showed that PT Pindad, PT PAL Indonesia, and PT Dirgantara Indonesia have developed various practices aimed at strengthening workforce capability and maintaining organizational continuity. However, the documented practices differ in their orientation: some mechanisms primarily support general human capital development, while others contribute more directly to the transfer and preservation of tacit engineering knowledge.

In PT Pindad, the reviewed organizational documents emphasize the importance of technical competency development, employee capability strengthening, and continuous improvement activities in supporting defense manufacturing capability. These practices are mainly associated with maintaining engineering skills required for production activities, equipment operation, quality control, and technological development. Although such initiatives contribute to knowledge continuity, their primary focus appears to be broader competency development rather than explicit documentation of tacit engineering knowledge transfer. Therefore, their contribution to tacit knowledge retention depends on how effectively practical experience and technical judgment are transferred among engineering personnel.

In PT PAL Indonesia, organizational documents related to shipbuilding capability and human capital development highlight the importance of maintaining technical competence in complex engineering activities, including design, construction, system integration, and maintenance. The nature of naval engineering requires coordination among multiple technical disciplines, meaning that knowledge transfer mechanisms are important for sustaining project capability. The available documents indicate the relevance of training, competency development, and internal knowledge-sharing activities in supporting workforce readiness. However, the documents provide limited evidence regarding the extent to which informal experiential knowledge, such as project-specific problem-solving approaches and technical judgment, is systematically captured.

Similarly, PT Dirgantara Indonesia's organizational publications emphasize aerospace capability development, technical competency, and workforce preparation related to aircraft production and maintenance activities. Given the complexity of aerospace engineering, maintaining continuity of expertise requires not only formal procedures but also the preservation of experience-based knowledge related to system reliability, maintenance practices, and engineering decision-making. The reviewed documents demonstrate attention to human capital development and technical capability improvement; however, explicit mechanisms dedicated specifically to transferring tacit engineering knowledge are not consistently described in publicly available sources.

Across the three cases, documentation and knowledge-management practices appeared as important mechanisms supporting organizational memory. Annual reports, technical publications, project documentation, and organizational records provide repositories of explicit knowledge that can support continuity when personnel move between roles or projects. These mechanisms are particularly valuable for preserving technical procedures, project histories, operational information, and formal engineering standards. Nevertheless, documentary practices have limitations because they may not fully capture tacit dimensions of engineering work, including intuitive problem-solving, experiential judgment, and context-specific decision-making.

Mentoring, coaching, and knowledge-sharing activities were also identified as relevant mechanisms for transferring experience-based knowledge. However, the available documentary evidence does not indicate that these practices are implemented uniformly across all three organizations or that they specifically target tacit engineering knowledge. Rather, such activities are often embedded within broader competency development and workforce improvement programs. Their effectiveness in preserving tacit knowledge therefore depends on the continuity of interactions between experienced engineers and less experienced personnel.

Succession-related practices also appeared as part of broader workforce sustainability strategies. The documents reviewed indicate organizational attention toward leadership development, competency preparation, and future workforce capability. However, succession planning should be distinguished from tacit knowledge preservation. While succession initiatives prepare employees to assume future roles, they do not automatically ensure the transfer of highly contextual engineering expertise unless accompanied by structured knowledge-sharing processes.

Overall, the findings indicate that PT Pindad, PT PAL Indonesia, and PT Dirgantara Indonesia have established various mechanisms that support organizational learning and capability development. Nevertheless, the analysis suggests that existing practices differ in their capacity to preserve tacit engineering knowledge. Formal systems such as documentation and training support explicit knowledge continuity, while experience-based expertise requires additional mechanisms that enable direct transfer of practical knowledge. Therefore, personnel mobility remains a critical issue because the effectiveness of knowledge-retention practices determines whether engineering expertise can be maintained during organizational transitions.

Based on the cross-case findings, this study proposes a conceptual framework explaining the relationship between personnel rotation, tacit engineering knowledge continuity, and organizational capability in Indonesia's state-owned defense enterprises. The framework was developed from recurring patterns identified across PT Pindad, PT PAL Indonesia, and PT Dirgantara Indonesia, rather than being directly imposed from existing theoretical models.

The framework shows that personnel rotation functions as an organizational transition mechanism that may influence knowledge continuity. Rotation itself does not automatically produce negative outcomes because it may contribute to employee development, flexibility, and organizational learning. However, when critical engineering expertise remains strongly embedded within individuals and is not adequately transferred, rotation may create conditions for tacit knowledge erosion.

In this framework, tacit knowledge erosion represents the process through which valuable engineering expertise becomes less accessible due to changes in personnel positions, project involvement, or technical responsibilities. The findings indicate that knowledge areas such as troubleshooting ability, system integration experience, and practical engineering judgment are particularly vulnerable because they are developed through long-term experience within specific technological environments.

Knowledge-retention mechanisms function as enabling factors that influence whether personnel rotation strengthens or weakens organizational capability. Documentation systems, competency development, mentoring activities, and knowledge-sharing practices support the preservation of expertise by increasing opportunities for knowledge transfer. However, the findings also suggest that formal mechanisms may have limitations because experience-based knowledge requires continuous interaction and organizational learning processes.

The framework therefore integrates three empirically derived elements: (1) personnel rotation as the organizational transition factor, (2) tacit engineering knowledge continuity as the central knowledge-management challenge, and (3) retention mechanisms as organizational practices that influence the ability to maintain capability.

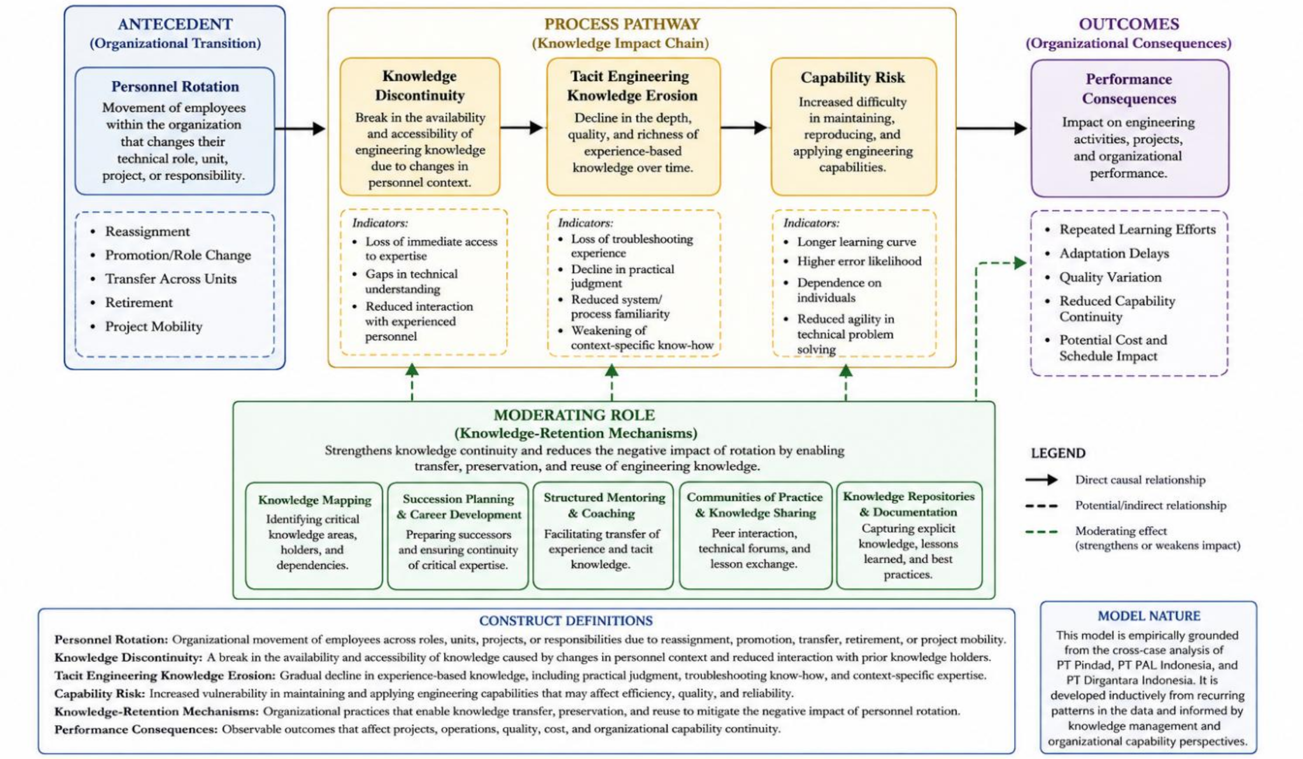

Figure 1. Personnel Rotation–Tacit Knowledge Continuity Framework
Source: Developed by the authors.

The framework contributes to existing knowledge-management discussions by highlighting that knowledge erosion in engineering-intensive organizations does not only occur when employees leave the organization. Instead, internal movement may also influence knowledge accessibility when experience-based expertise is not sufficiently embedded into organizational processes.

Overall, the framework suggests that the sustainability of engineering capability depends not only on retaining experienced personnel but also on the organization's ability to transfer, preserve, and reuse critical knowledge during continuous workforce transitions.

Discussion

The findings demonstrate that engineering knowledge continuity within Indonesia's state-owned defense enterprises is closely related to the ability of organizations to preserve experience-based knowledge during workforce transitions. The analysis identified several forms of engineering expertise that are highly dependent on accumulated experience, including manufacturing know-how, troubleshooting capability, system integration knowledge, and technical judgment. These knowledge areas are developed through repeated involvement in production activities, maintenance processes, testing procedures, and engineering problem-solving.

The findings from PT Pindad, PT PAL Indonesia, and PT Dirgantara Indonesia indicate that engineering capability is supported not only by formal procedures, technical documents, and organizational systems but also by knowledge developed through long-term interaction between engineers and technological processes. This condition reflects the characteristics of knowledge-intensive organizations, where organizational capability depends on how effectively experience and expertise are developed, maintained, and transferred among members (Garcia-Perez et al., 2020; Summerscales, 2024).

The results further support the Knowledge-Based View (KBV), which positions knowledge as a strategic resource underlying organizational capability. In defense enterprises, engineering knowledge has strategic importance because it supports technological development, operational reliability, and long-term capability building. The findings suggest that the value of engineering knowledge does not only exist in documented information but also in the ability of personnel to interpret technical situations, solve problems, and apply experience to complex engineering tasks (Cegarra-Navarro et al., 2016).

Personnel rotation therefore represents a significant knowledge-management challenge. The findings do not suggest that rotation automatically reduces organizational capability. Workforce mobility may support organizational flexibility, employee development, and broader learning opportunities. However, when employees move between roles, projects, or technical areas without sufficient knowledge-transfer processes, experience-based expertise may become less accessible to other organizational members.

This finding expands previous discussions of knowledge continuity, which often emphasize employee turnover or external departure as major causes of knowledge loss (Burmeister & Deller, 2016; Sumbal et al., 2017). The cases examined in this study indicate that internal mobility may also create knowledge continuity challenges because employees remain within the organization while moving away from the specific technological contexts where their expertise was developed.

Therefore, tacit knowledge erosion in defense enterprises should not be interpreted only as the disappearance of knowledge from the organization but also as a reduced ability to access and reuse critical expertise when needed. This highlights the importance of developing mechanisms that allow experience-based knowledge to move together with personnel transitions.

The findings indicate that tacit knowledge continuity represents a broader organizational capability challenge rather than merely a human resource management concern. Engineering capabilities are developed through continuous learning processes involving personnel, technology, organizational routines, and accumulated experience. As a result, workforce transitions may influence how effectively organizations maintain and reproduce their engineering capabilities over time.

This interpretation is consistent with Dynamic Capabilities Theory, which emphasizes the ability of organizations to develop, integrate, and reconfigure resources in response to changing conditions (Teece et al., 1997). In knowledge-intensive defense industries, engineering expertise represents a critical resource that must continuously be maintained and adapted. Personnel mobility can strengthen organizational capability when it encourages knowledge exchange and broader experience. However, it may also create risks when important expertise remains concentrated within individuals and is not sufficiently transferred.

The cross-case findings show that PT Pindad, PT PAL Indonesia, and PT Dirgantara Indonesia operate in technological environments requiring long-term engineering experience. Activities such as manufacturing, shipbuilding, aerospace production, maintenance, and system integration involve complex processes where practical understanding is developed over time. Consequently, changes in personnel positions may require additional adaptation processes to ensure continuity of engineering activities.

The findings also demonstrate that knowledge retention practices influence how organizations respond to workforce transitions. Documentation, competency development, training, and knowledge-sharing activities provide important support for organizational learning. However, the effectiveness of these mechanisms depends on their ability to capture not only formal technical information but also experience-based understanding developed through practical work. This perspective aligns with previous studies emphasizing that knowledge management requires processes that support knowledge creation, sharing, and utilization within organizations (Ferreira et al., 2018; Usai et al., 2021). Therefore, the challenge for defense enterprises is not simply preventing personnel movement but ensuring that organizational systems enable critical expertise to be transferred during periods of change.

From a managerial perspective, the findings suggest that personnel transitions should be treated as strategic knowledge-transfer processes. Organizations need to identify critical engineering knowledge areas, recognize expertise holders, and establish mechanisms that support knowledge continuity before employees move between functions or projects. Such practices may strengthen organizational resilience and reduce the risk of capability disruption (Ali et al., 2018; Levallet & Chan, 2018).

Theoretically, the findings extend the Knowledge-Based View and Dynamic Capabilities Theory by showing that engineering knowledge continuity is not only determined by knowledge ownership or documentation but also by the organizational ability to preserve, transfer, and reconfigure tacit expertise during personnel transitions. In the context of state-owned defense enterprises, tacit engineering knowledge functions as a strategic resource because it supports manufacturing reliability, system integration, troubleshooting capability, and long-term technological independence. The findings indicate that knowledge loss may occur not only through employee exit but also through internal personnel rotation when experience-based expertise becomes separated from the technical context in which it was developed. This insight refines existing knowledge-continuity theory by emphasizing that internal mobility must be understood as a strategic knowledge-management issue, particularly in organizations where technological capability depends heavily on accumulated experience, practical judgment, and cross-generational learning.

From a pedagogical perspective, the findings suggest the need for structured organizational learning systems that support continuous engineering knowledge transfer. Defense enterprises should strengthen mentoring programs, apprenticeship-based learning, technical communities of practice, after-action reviews, and systematic documentation of problem-solving experiences to ensure that tacit expertise can be shared across generations of engineers. These practices can improve employee engagement, professional identity, and confidence in handling complex technical tasks. From a policy perspective, the findings imply that personnel rotation in strategic defense industries should be supported by formal knowledge-transfer policies, competency mapping, succession planning, and knowledge-retention mechanisms. Government and organizational policies should not only regulate workforce placement but also ensure that critical engineering knowledge remains accessible, reusable, and institutionally embedded to support national defense capability, technological sovereignty, and industrial resilience.

The novelty of this study lies in its focus on engineering knowledge continuity within Indonesia's state-owned defense enterprises, particularly in relation to internal personnel rotation. Previous studies on knowledge loss have commonly emphasized retirement, employee turnover, or external departure, whereas this study highlights that knowledge continuity risks may also emerge when employees remain within the organization but move away from specific technical domains. By examining PT Pindad, PT PAL Indonesia, and PT Dirgantara Indonesia, this study contributes a contextual understanding of how tacit engineering knowledge is developed, transferred, and potentially disrupted in strategic defense industries. Methodologically, the cross-case approach provides comparative insight into different technological environments, including land defense manufacturing, naval production, and aerospace engineering. The study therefore expands the literature on knowledge management by demonstrating that tacit knowledge continuity is a strategic organizational capability that must be managed through integrated documentation, mentoring, training, competency development, and policy-based succession systems.

This study has several limitations that should be considered when interpreting the findings. First, the research focuses on three Indonesian state-owned defense enterprises, which may limit the generalizability of the results to private defense firms, non-defense manufacturing industries, or organizations in different national contexts. Second, the study emphasizes organizational and managerial perspectives on knowledge continuity, while individual-level factors such as motivation, psychological readiness, informal networks, and intergenerational communication may require deeper investigation. Third, the findings are based on qualitative interpretation, so future studies may apply mixed-method or quantitative approaches to measure the relationship between personnel rotation, knowledge-transfer mechanisms, and engineering performance more precisely. Further research could also compare knowledge-continuity practices across defense and non-defense strategic industries, explore digital knowledge-management systems, and examine how artificial intelligence, digital twins, and engineering databases can support the preservation of tacit technical knowledge in complex industrial organizations.

CONCLUSION

This study examined the relationship between personnel mobility and tacit engineering knowledge continuity in PT Pindad, PT PAL Indonesia, and PT Dirgantara Indonesia through qualitative analysis of secondary documentary data. The findings indicate that engineering capability in these defense enterprises depends not only on formal procedures and documented knowledge but also on experience-based expertise related to manufacturing processes, troubleshooting, system integration, and technical problem-solving. Personnel rotation, reassignment, promotion, project mobility, and other workforce transitions may create knowledge continuity challenges when critical expertise remains strongly connected to individuals and is not sufficiently transferred through organizational mechanisms. This study contributes to knowledge-management and engineering-management discussions by highlighting internal workforce mobility as an important context for understanding knowledge continuity, while recognizing that the findings represent organizational-level patterns derived from documentary evidence rather than direct observation of individual knowledge loss. Practically, the findings suggest that engineering-intensive organizations should manage personnel transitions as knowledge-transfer processes by strengthening knowledge identification, documentation, mentoring, competency development, and other retention practices that support capability continuity. However, this study is limited by its reliance on publicly available secondary sources and the focus on three Indonesian defense enterprises. Future research may incorporate interviews, longitudinal approaches, and mixed-method designs to further examine how workforce transitions influence the preservation and transfer of engineering expertise.

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