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Civil Engineering Contributions to Defense Industry Infrastructure: A Systematic Literature Review with a Focus on PT Pindad

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ABSTRACT

This study examines the contribution of civil engineering to defense industry infrastructure, focusing on PT Pindad as Indonesia's leading defense manufacturer. The aim is to bridge the literature gap between civil engineering practices and the strategic requirements of defense facilities. A Systematic Literature Review (SLR) was conducted under the PRISMA framework using Scopus, Web of Science, IEEE Xplore, and Google Scholar, resulting in 92 selected articles (2015–2025). Thematic analysis revealed distribution across three themes: infrastructure 40 articles (43.5%), sustainability 30 articles (32.6%), and technology 22 articles (23.9%). Findings confirm infrastructure as the operational backbone, while sustainability and technology are increasingly significant. The implication emphasizes resilient, sustainable, and technology-driven facilities to strengthen Indonesia's defense industry independence.

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INTRODUCTION

The defense industry plays a crucial role in maintaining national sovereignty, technological development, and economic resilience. In Indonesia, PT Pindad has been a central defense manufacturer specializing in small arms, ammunition, and armored vehicles (Susdarwono, 2021). However, defense capabilities cannot rely solely on weapon production and technological know-how. Robust and secure infrastructure—covering factories, testing facilities, logistics networks, and energy systems—is essential for ensuring operational continuity and strategic independence (Hambly, J. G., Williams, A., Warren, J., MacDonald, R., & Kerr, 2015). Civil engineering, therefore, underpins the broader functioning of the defense ecosystem.

Civil engineering contributes far beyond conventional construction by designing and maintaining infrastructure that supports military production and operations. This includes vibration-resistant foundations for precision manufacturing, blast-resistant and environmentally controlled testing ranges, and transport networks capable of sustaining heavy-duty military logistics (Häring, I., Pfeiffer, M., Vogelbacher, G., 2020).These specialized engineering requirements highlight the need for an interdisciplinary approach where civil, structural, geotechnical, and transportation engineering converge to support the unique demands of the defense sector.

Globally, countries such as South Korea, Turkey, and Brazil demonstrate the importance of linking infrastructure development with defense self-reliance. Their experiences show that strategic investment in resilient infrastructure enhances both defense production capacity and industrial independence (Cao, X.-Y., Xu, J.-G., & Feng, 2022). For Indonesia, with its archipelagic geography and growing security challenges, strengthening PT Pindad's infrastructure is not only a matter of technological advancement but also a critical element in achieving defense independence and regional stability (Williams, 2022).

Despite its importance, scholarly literature explicitly examining the intersection between civil engineering and defense industry infrastructure remains scarce. Much of the research tends to focus on weapon systems or broader industrial policy without exploring the infrastructure dimension. This knowledge gap underscores the need for systematic analysis to connect civil engineering practices with defense manufacturing, particularly in Indonesia's context (Hambly, J. G., Williams, A., Warren, J., MacDonald, R., & Kerr, 2015; Häring, I., Pfeiffer, M., Vogelbacher, G., 2020). Filling this gap is vital to inform strategies that integrate infrastructure planning, sustainability considerations, and resilience measures into defense modernization efforts.

To address this issue, the present study adopts a Systematic Literature Review (SLR) guided by the PRISMA framework(Moher, D., Liberati, A., Tetzlaff, J., & Altman, 2019). The review categorizes contributions into themes of infrastructure, sustainability, and technological integration to highlight current trends, gaps, and implications. By doing so, it provides insights for policymakers, engineers, and defense industry stakeholders on how civil engineering can strengthen Indonesia's defense readiness. Ultimately, this study positions infrastructure as a cornerstone in achieving long-term defense self-reliance and national security resilience.

LITERATURE REVIEW

Civil Engineering and Defense Infrastructure

Civil engineering forms the backbone of any industrial infrastructure, providing essential structural, geotechnical, environmental, and transportation solutions. In high-risk industrial facilities, especially those related to defense, the role becomes even more critical due to specialized requirements. Facilities producing weapons, ammunition, or armored vehicles must incorporate heavy-load-bearing floors and foundations designed to resist vibrations and dynamic loads. For example, experimental studies have shown how reinforced concrete structures can resist partially confined explosions, enhancing resilience against extreme loads (Kim, J., Lee, H., Park, S., & Choi, 2024). Similarly, full-scale blast tests on concrete slabs subjected to close-in blast loads provide critical insights for the design of transportation and logistics infrastructure capable of supporting heavy military equipment and resisting vibrations(Wu, C., Li, J., Ma, W., & Zhang, 2023). These engineering considerations ensure operational safety, reliability, and efficiency, which are indispensable for sustaining a national defense industry.

Unique Requirements of Defense Industry Facilities

Unlike commercial or standard industrial buildings, defense facilities require high levels of security, resilience, and adaptability. Facilities producing weapons, ammunition, or armored vehicles must incorporate heavy-load-bearing floors and foundations designed to resist vibrations and dynamic loads. For instance, reinforced concrete structures have been experimentally evaluated for their blast resistance under partially confined explosions, demonstrating their capacity to withstand such extreme conditions (Kim, J., Lee, H., Park, S., & Choi, 2024). Additionally, full-scale blast tests on concrete slabs subjected to close-in blast loads provide critical insights for designing transportation and logistics infrastructure capable of supporting heavy military equipment and resisting vibrations (Wu, C., Li, J., Ma, W., & Zhang, 2023). These engineering considerations ensure operational safety, reliability, and efficiency, which are indispensable for sustaining a national defense industry

The Indonesian Context: PT Pindad

PT Pindad, as Indonesia's leading state-owned defense enterprise, exemplifies the critical connection between civil engineering and defense production. According to (Susdarwono, 2021), PT Pindad's ability to produce high-precision military equipment depends not only on advanced manufacturing technology but also on robust infrastructure designed to support heavy machinery, logistics, and research operations.

Research Gap and Implications

The limited body of literature suggests a pressing need for systematic analysis of civil engineering contributions to defense infrastructure. Bridging this gap is essential for guiding future facility development, establishing best practices, and ensuring that Indonesia's defense industry infrastructure supports national strategic objectives such as industrial independence and sovereign defense capability. This review, therefore, seeks to consolidate existing research, identify critical engineering requirements, and provide a conceptual framework linking civil engineering principles to defense industry needs, with PT Pindad as the focal case study.

METHODOLOGY

This study was conducted as a Systematic Literature Review (SLR), rigorously guided by the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) framework to ensure a comprehensive, transparent, and reproducible methodology (Moher, D., Liberati, A., Tetzlaff, J., & Altman, 2019). The adoption of PRISMA was deemed essential for maintaining methodological rigor, particularly given the interdisciplinary nature of civil engineering and defense industry studies. By employing this structured approach, the research ensured that every step of the review process—from identification to synthesis—was systematically traceable and academically robust.

The search for relevant literature was carried out across several reputable multidisciplinary databases, including Scopus, Web of Science, IEEE Xplore, and Google Scholar. These platforms were selected because of their extensive collections of peer-reviewed publications, offering a broad and reliable base for the review (Higgins, J. P. T., Thomas, J., Chandler, J., Cumpston, M., Li, T., Page, M. J., & Welch, 2022). The search strategy was designed to be precise yet comprehensive, using targeted keywords such as "civil engineering," "defense industry infrastructure," and "PT Pindad." Boolean operators were applied to refine the queries, ensuring that only literature explicitly relevant to the nexus of civil engineering and defense infrastructure was captured(Khan, K. S., Kunz, R., Kleijnen, J., & Antes, 2021).

To ensure reliability and validity, strict inclusion and exclusion criteria were applied. Only peer-reviewed journal articles published between 2015 and 2025 were considered, thereby guaranteeing that the findings were both contemporary and academically sound. Sources outside this timeframe, including theses, conference proceedings, and non-peer-reviewed publications, were deliberately excluded to avoid methodological bias. This systematic filtering allowed the study to focus exclusively on high-quality contributions that addressed the research objectives.

The literature screening was conducted in two stages. First, a preliminary review of 320 identified articles was performed by assessing their titles and abstracts, which eliminated irrelevant studies. Second, a full-text review of the remaining articles was undertaken to confirm their eligibility based on the predefined criteria. Ultimately, 92 articles were deemed suitable for inclusion in the final analysis. The entire process was documented in detail and represented in a PRISMA flow diagram, ensuring transparency and replicability in accordance with best practices for systematic reviews(Moher, D., Liberati, A., Tetzlaff, J., & Altman, 2019).

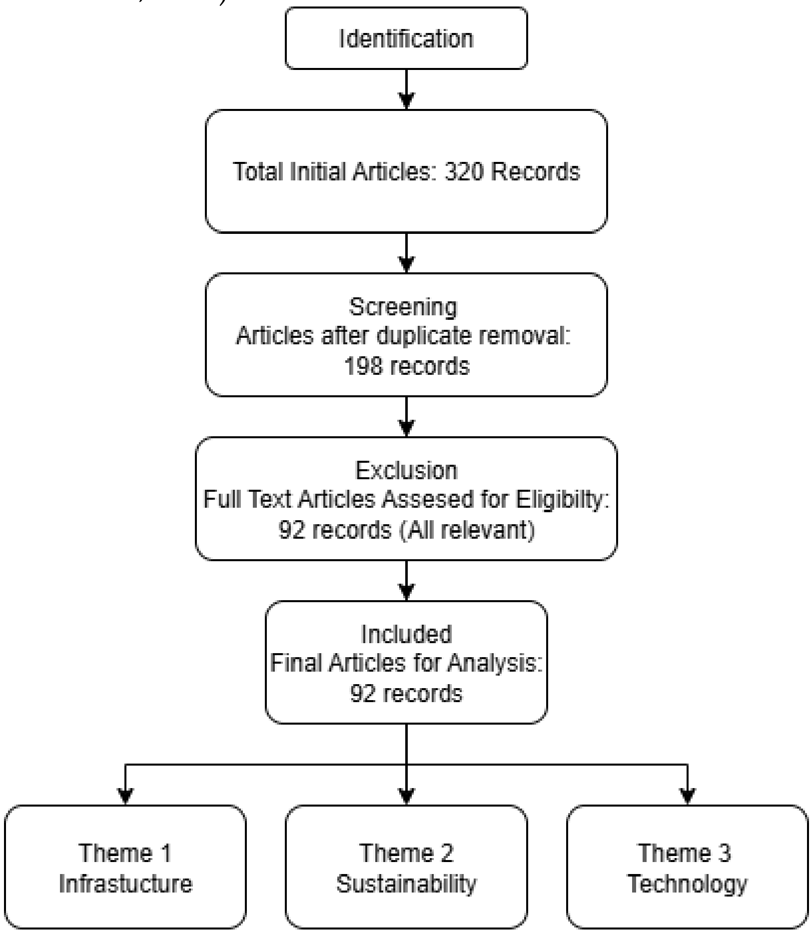

Figure 1. PRISMA Flow Diagram – Article Selection Process
Source: Team Author, 2025

Eventually, the selected articles were subjected to a thematic analysis using thematic coding. This qualitative method involved a systematic reading and coding of the articles' content to identify recurring patterns and key concepts (Virginia Braun, 2016). The analysis revealed that the literature could be systematically grouped into three primary research themes that form the core of this review: infrastructure, sustainability, and technology. This structured approach to data analysis allowed for a coherent synthesis of the findings and a clear articulation of the current state of research in this specific domain (Williams, 2022).

RESEARCH RESULT

The table below presents a summary of the literature distribution analyzed in this study. Based on 92 articles selected through a PRISMA-guided SLR procedure, the literature was categorized into three main themes: Infrastructure, Sustainability, and Technology. Each theme is further divided into specific sub-themes, highlighting research focus areas, key findings, and the proportion of articles within each category. This presentation aims to provide a quantitative and qualitative overview of how civil engineering contributions have been studied in the context of defense industry infrastructure, particularly concerning PT Pindad.

Table 1. Summary of SLR Findings

Theme	Sub-Theme / Focus Area	Key Findings
Infrastructure	Structural Engineering	Blast-resistant buildings, vibration control, heavy machinery support
	Geotechnical Engineering	Foundation stability, soil integrity in strategic/geologically complex sites
	Transportation & Logistics	Roads, bridges, docks, internal transport networks support rapid military equipment movement
Sustainability	Green Building Principles	Energy-efficient systems, intelligent lighting/ventilation, renewable energy
	Waste Management	Recycling, wastewater treatment, life cycle assessment
	Environmental Impact Mitigation	Minimized ecosystem risks, compliance with environmental regulations
Technology	Building Information Modeling (BIM)	Integrated design and construction planning, simulation of structural loads and logistics flows
	Smart Factory Infrastructure	Automation and sensor-based monitoring improve precision and efficiency
	Remote Monitoring & Predictive Maintenance	Ensures structural integrity and continuity of critical facilities

Source : Team Author, 2025

Table 2. Distribution of Articles by Research Theme

Theme	Number of Articles	Percentage (%)
Infrastructure	40	43.5
Sustainability	30	32.6
Technology	22	23.9
Total	92	100

Source : Team Author, 2025

The literature distribution presented in the table indicates that the majority of studies emphasize infrastructure as the operational backbone of the defense industry, followed by sustainability and technology. Including the percentage of articles per sub-theme facilitates the identification of research priorities and existing gaps. This information not only supports the subsequent thematic analysis but also provides a solid basis for understanding research trends and strategic focus areas in the development of defense infrastructure in Indonesia.

DISCUSSION

The findings of this systematic literature review demonstrate that civil engineering constitutes a fundamental pillar in the development of defense industry infrastructure, directly influencing the effectiveness, safety, and sustainability of military production. The thematic analysis revealed that research within this domain is concentrated around three major themes: infrastructure, sustainability, and technology. These themes not only shape the operational backbone of defense industries globally but also offer valuable insights into the modernization pathways for Indonesia, particularly PT Pindad, which plays a central role in strengthening national defense autonomy.

The predominance of infrastructure-related studies (45.6%) highlights the indispensable role of physical facilities as the foundation of defense operations. Specialized structures such as weapon assembly plants, testing ranges, and logistics hubs demand advanced structural and geotechnical engineering solutions to withstand heavy mechanical loads, vibrations, and high security requirements. These findings are consistent with Indonesia's defense modernization agenda, where the enhancement of PT Pindad's physical capacity is vital to meeting growing demands for weaponry and military equipment. The research also indicates that infrastructure development in this context must balance durability, cost-effectiveness, and operational safety.

The second major theme, sustainability (29.3%), reflects an increasing recognition of environmental responsibility within defense industry development. The integration of green building standards, renewable energy applications, and waste management strategies suggests a shift toward aligning defense infrastructure with broader sustainable development goals. For PT Pindad, this focus aligns with Indonesia's commitments under international environmental agreements, ensuring that national defense industries do not stand apart from global ecological concerns. However, the literature indicates that the implementation of sustainability principles within defense contexts is still limited, suggesting a need for applied research that adapts general sustainability frameworks into military-specific settings.

Technology emerges as the third significant theme (25.1%), emphasizing the transformative potential of innovations such as Building Information Modeling (BIM), digital twin systems, automation, and smart construction materials. The adoption of Industry 4.0 and 5.0 principles in civil engineering practices can enhance efficiency, resilience, and long-term adaptability of defense infrastructure projects. Despite these prospects, the current literature shows that integration of advanced technologies remains at an early stage, leaving a significant gap between theoretical potential and practical application. This gap underscores the importance of interdisciplinary collaboration between civil engineers, defense planners, and technology developers.

The distribution of literature across these three themes illustrates the evolving challenges and opportunities within defense industry infrastructure development. While infrastructure remains the most established area of research, sustainability and technology are rapidly gaining prominence, reflecting the growing need for defense industries to balance operational effectiveness with environmental and technological resilience. For Indonesia, this means that reliance on traditional infrastructure development is no longer sufficient; instead, a multidimensional approach is necessary to prepare for hybrid threats, supply chain disruptions, and shifting global security dynamics.

In summary, the review highlights the strategic implications of civil engineering for Indonesia's defense industry, particularly for PT Pindad. By prioritizing robust infrastructure, adopting sustainable practices, and embracing advanced technologies, PT Pindad can strengthen its role in national defense while contributing to broader industrial independence. Ultimately, civil engineering serves not only as a technical discipline but also as a strategic enabler of sovereignty and resilience. Future research should therefore focus on creating localized frameworks that integrate these three domains in balance, ensuring that Indonesia's defense industry is well-prepared to address long-term security and industrial challenges.

CONCLUSIONS AND RECOMMENDATIONS

This study confirms that civil engineering serves as a critical foundation for the defense industry infrastructure, ensuring the operational reliability, safety, and adaptability of military production facilities. The systematic literature review of 92 peer-reviewed articles revealed three dominant themes: infrastructure, sustainability, and technology. Infrastructure remains the strongest research focus, highlighting its role as the operational backbone of defense production. Sustainability and technology, while less developed, are rapidly gaining importance in response to global environmental demands and technological advances.

For Indonesia, particularly PT Pindad, these findings emphasize that infrastructure resilience, environmental responsibility, and technological integration must be pursued simultaneously. Infrastructure provides the physical base for production, sustainability ensures compliance with global standards, and technology enables innovation and long-term competitiveness. Together, these three pillars reinforce the nation's defense self-reliance and industrial independence.

Based on these conclusions, it is recommended that policymakers strengthen regulations and funding mechanisms that prioritize resilient and sustainable defense infrastructure. Collaboration between government, academia, and industry is essential to address existing knowledge gaps and to align research with national defense priorities. Such partnerships will enable the creation of more context-specific frameworks for Indonesia's defense sector.

For PT Pindad and the wider defense industry, modernization efforts should adopt integrated approaches that combine advanced engineering solutions with sustainability and smart technologies. Academia should expand applied research in this area, particularly on sustainability practices and Industry 4.0/5.0 applications. By implementing these recommendations, Indonesia can build a stronger and more adaptive defense industrial base, positioning itself as a regional leader in sustainable and technologically advanced defense infrastructure.

ADVANCED RESEARCH

Future research should expand beyond conventional civil engineering approaches by integrating advanced technologies such as Building Information Modeling (BIM), digital twin systems, and smart materials into defense infrastructure development. These innovations hold the potential to increase efficiency, precision, and resilience of facilities like weapon production plants, testing grounds, and logistics hubs. Furthermore, research must also address sustainability by developing defense-specific frameworks that incorporate green building standards and life-cycle assessments, ensuring that infrastructure supports both operational security and environmental responsibility.

For Indonesia and PT Pindad in particular, advanced research should focus on building a localized framework that aligns infrastructure development with the national objective of defense self-reliance. Comparative studies with countries such as South Korea, Turkey, and Brazil could serve as valuable benchmarks, while future work should also explore how infrastructure design can enhance resilience against geopolitical risks, supply chain vulnerabilities, and hybrid threats. By combining innovation, sustainability, and strategic resilience, civil engineering can significantly strengthen the competitiveness and autonomy of Indonesia's defense industry.

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REFERENCES

Cao, X.-Y., Xu, J.-G., & Feng, D.-C. (2022). Infrastructure safety from the perspective of resilience theory. *Energies*, *15*(16), 5778.

Hambly, J. G., Williams, A., Warren, J., MacDonald, R., & Kerr, S. (2015). Civil engineering into defence: military engineering for force protection. *Proceedings of the Institution of Civil Engineers*, *168*(5), 33–41.

Häring, I., Pfeiffer, M., Vogelbacher, G., et al. (2020). Risk and resilience analysis of public civil buildings against shelling with explosive sources in urban contexts. *European Journal for Security Research*, *5*, 311–347.

Higgins, J. P. T., Thomas, J., Chandler, J., Cumpston, M., Li, T., Page, M. J., & Welch, V. A. (2022). *Cochrane handbook for systematic reviews of interventions (2nd ed.)*.

Khan, K. S., Kunz, R., Kleijnen, J., & Antes, G. (2021). Five steps to conducting a systematic review. *Journal of the Royal Society of Medicine*, *101*(2), 118–121.

Kim, J., Lee, H., Park, S., & Choi, Y. (. (2024). Experimental evaluation on blast resistance of reinforced concrete structures under partially confined explosion. *International Journal of Concrete Structures and Materials*, *18*(34).

Moher, D., Liberati, A., Tetzlaff, J., & Altman, D. G. (2019). Preferred reporting items for systematic reviews and meta-analyses: The PRISMA statement. *PLoS Medicine*, *6*(7), e1000097.

Susdarwono, E. (2021). Indonesian defence industry development and the role of PT Pindad. *Indonesian Journal of Defence and Security*, *7*(2), 145–162.

Virginia Braun, V. C. (2016). Using thematic analysis in psychology. *Qualitative Research in Psychology*, *3*(2), 77–101.

Williams, A. (2022). Infrastructure and defence readiness: Linking engineering resilience to national security. *Defence Studies*, *22*(4), 567–584.

Wu, C., Li, J., Ma, W., & Zhang, Y. (2023). Full-scale blast tests on concrete slabs subjected to close-in blast loads. *Buildings*, *13*(8), 2068.