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Challenges And Opportunities In Achieving Defense Industry Independence: An In-Depth Analysis Of Policy Implementation At PT Pindad

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Abstract
This study examines the challenges and opportunities in achieving defense industry independence at PT Pindad, a key state-owned enterprise in Indonesia. Despite policies like Law Number 16 of 2012 and the Minimum Essential Force (MEF) program aimed at reducing reliance on imports and enhancing self-sufficiency, PT Pindad faces significant hurdles, including dependency on foreign raw materials, limited technology transfer, and regulatory inefficiencies. The study suggests that strategic measures, such as increased investment in R&D, effective technology transfer, and stronger collaboration between government, private sectors, and academia, are essential for overcoming these challenges and strengthening Indonesia's defense industry. By analyzing successful examples from countries like China and Turkey, the study emphasizes the importance of integrated and adaptive policies to foster technological innovation, enhance local supply chains, and improve competitiveness. Adopting a collaborative approach under the Penta-Helix model, which brings together government, businesses, academia, communities, and media, is recommended to accelerate the development of a self-sufficient and resilient defense sector in Indonesia.
Keywords: *Defense Industry; Independence; Collaboration; Innovation*

1. INTRODUCTION

The need to strengthen Indonesia's defense sector is increasingly urgent (Yusgiantoro, 2014) . This is because along with the increasing security challenges, both in the form of conventional military threats and non-military threats such as cyber warfare and terrorism, and since the last five years global geopolitical tensions have increased, such as the Russia-Ukraine war (Aviv & Ferri, 2023) and the most recent is Israel-Iran (Shvartsur & Savitsky, 2024) . To strengthen the defense sector in Indonesia, the challenge lies in strengthening and the independence of the defense industry, which includes state-owned companies such as PT Pindad, PT PAL, and PT Dirgantara Indonesia. The ability of this defense industry to maintain autonomy and efficiency is very important in maintaining national sovereignty and stability. Although the Indonesian defense industry has developed gradually since the post-independence era, and focused on increasing capacity to meet the needs of defense and security equipment (alpalhankam) independently, there are still many obstacles they face, for example, financing challenges (Surahman et al., 2024) , dependence on imports and collaboration challenges (Julexi Tambayong & Achmad Farid Wadjdi, 2023; Wadjdi et al., 2023) , R&D and Technological Innovation (Irfan et al., 2023) , regulatory and structural issues (Baiquni et al., 2022) . In essence, Indonesia is still constrained by classic problems such as inefficiency and the need for production competition, budget stability, and system standardization (Leebaert & Gansler, 1981).

The independence of the defense industry is a strategic priority for the Indonesian government to reduce dependence on imports, especially in the provision of defense equipment. Dependence on foreign suppliers for decades has created vulnerabilities, especially when there is an arms embargo as experienced by Indonesia in the late 1990s. This has prompted the government to strengthen the domestic defense industry to ensure the continuity of defense equipment supplies in the future (Priamarizki, 2024) .

In an effort to realize this independence, the government issued Law Number 16 of 2012 concerning the Defense Industry, which regulates the development, management, and utilization of the domestic defense industry. This law emphasizes the importance of independent production of defense equipment by State-Owned Enterprises (BUMN) and private companies located in Indonesia, as well as supporting technology transfer to increase national capacity. In addition, this regulation encourages the national

defense industry to become more competitive at the global level through synergy between the government, academics, and the private sector.

The government has also established a Minimum Essential Force (MEF) policy, which is designed to ensure that Indonesia has the minimum defense force needed to maintain its sovereignty and territorial integrity (Armadani & Kosandi, 2024) . Within this framework, the domestic defense industry is expected to be able to meet most of the defense equipment needs, both in terms of quantity and quality (Hasim, 2022) . The main challenge in achieving MEF is increasing the ability of the defense industry to produce high-quality products that are competitive in the global market, while ensuring effective technology transfer from partner countries (Ariputro et al., 2024) . The MEF policy reflects Indonesia's commitment to building a strong, innovative, and independent defense industry, in line with the development of military technology and the ever-changing dynamics of global geopolitics.

PT Pindad faces several major problems in achieving defense industry independence, especially related to dependence on imported raw materials (Octovianus Oskar Engelberth et al., 2023) , technology transfer (Kasim & Deksino, 2022) , and challenges in policy implementation (Habsari, 2022) . Dependence on raw materials from abroad makes PT Pindad vulnerable to global supply disruptions, such as embargoes, which can hamper the production of defense equipment. In addition, the less than optimal technology transfer process is a significant obstacle, where PT Pindad has difficulty increasing defense technology innovation due to limited strategic partnerships with developed countries and slow adoption of advanced technology. Another challenge is the ineffective implementation of policies, even though the government has enacted Law Number 16 of 2012 concerning the Defense Industry. Lack of coordination between stakeholders, limited funding, and a shortage of competent human resources exacerbate this problem, so that PT Pindad has not been fully able to achieve the expected independence in the defense sector.

The purpose of this article is to analyze the challenges faced by PT Pindad in achieving independence in the defense industry sector, while identifying opportunities that can be utilized to overcome these obstacles. One of the main challenges is the dependence on imported raw materials and limited technology transfer, which hinder innovation and independent production of defense equipment. In addition, although policies such as Law Number 16 of 2012 have been implemented to support the independence of the defense industry, their implementation is still not optimal, especially in terms of coordination between the government and industry and human resource development. This article also seeks to highlight the gap in the literature, where existing research has not thoroughly explored how defense policies can be optimized to support PT Pindad in facing the challenges of technological globalization and increasing competitiveness. Thus, this article will explore opportunities such as strengthening international collaboration, increasing technological innovation, and optimizing policies that can help PT Pindad overcome these obstacles, while filling the gap in research related to the effectiveness of defense industry policies in Indonesia.

2. LITERATURE REVIEW

Developing countries face significant challenges in strengthening their defense industries due to limited technological and financial capacity, often relying on developed countries for military needs. This dependence contrasts with the strategies used by developed countries, which focus on technology transfer, human resource development, and increased R&D investment. The United States has built an innovation ecosystem that integrates civilian technologies into defense, emphasizing technological advancement as a priority through initiatives such as the Third Offset Strategy (Je, 2024) . In contrast, developing countries often struggle with technology transfer due to limited access to advanced technologies and inadequate domestic innovation policies (Fernández-Sastre & Montalvo-Quizhpi, 2019) . This disparity highlights the need for developing countries to adopt strategic measures to enhance their defense capabilities.

In Indonesia, the policy of Law Number 16 of 2012 concerning the Defense Industry is the main foundation in efforts to achieve defense independence. This law encourages the development of the national defense industry through technology enhancement and technology transfer from partner countries. One important supporting policy is the Minimum Essential Force (MEF), which aims to build a minimum essential force to maintain national sovereignty. Effective implementation of the MEF requires strong coordination among various stakeholders, including government agencies, the defense industry, and policy actors. However, differences in understanding and political will among these actors have been identified as significant obstacles. The lack of an integrated approach and commitment to

transparency and accountability hampers the modernization of defense equipment (Armadani & Kosandi, 2024) . The success of domestic production under the MEF framework depends heavily on optimal investment in R&D and technology transfer. The current state of investment is inadequate, which limits the development of advanced technologies needed for modern defense systems. Strategic planning and state support are essential to foster an environment conducive to innovation and technological advancement (Evlampiev, 2024) .

In essence, achieving defense industry independence is a complex challenge faced by many countries, involving issues such as dependence on imported raw materials, technology transfer, and limitations in research and development (R&D). Many countries, including Indonesia, face significant challenges in reducing their dependence on imported raw materials for defense manufacturing (Ramadhoni et al., 2024) . The European defense industry also grapples with similar issues, where strategic autonomy is often compromised by the need to import critical materials. This dependence can hinder the development of an independent defense industry and affect national security. This raw material issue underscores the importance of local supply chains (Farkas, 2023) . These challenges are compounded by geopolitical dynamics and economic constraints, which require strategic collaboration and innovation (Ariputro et al., 2024).

The defense industry presents several growth opportunities, driven by factors such as international collaboration, increasing defense budgets, and technological innovation. These opportunities are shaped by the complex interplay of economic, strategic, and technological dynamics within the industry. For example, international collaboration in the defense sector can lead to significant growth opportunities by pooling resources and expertise (Caliari et al., 2024) . Even local collaboration, for example with the 'Defense Science and Technology Park (DSTP)' policy, the defense industry will benefit from broad domestic-level partnerships that can enhance technological capabilities and improve supply chains (Wadjdi et al., 2023).

2.1 Conceptualization of Defense Industry Independence Policy

In this study, various theories are used to underlie the exploration of factors related to the effectiveness and efficiency of policies at PT Pindad. Policy Evaluation Theory (Patton, 2008; Wang et al., 2020) provides a framework for assessing the effectiveness of implemented defense industry policies, especially in relation to achieving desired goals. Meanwhile, Efficiency Management Theory (Drucker, 2006; Maslennikov et al., 2023) explains the importance of optimizing resources in the development of defense equipment, ensuring that the steps taken by PT Pindad run efficiently. These two theories help measure how existing policies can achieve the expected results by minimizing resource waste, which is very important in the context of the defense industry.

In relation to performance evaluation and policy support for technical objectives, Performance Evaluation Theory (Kaplan & Norton, 1996; Pestana Barros, 2004) and Public Policy Theory (Dye, 2013; James, 2022) provide a strong theoretical foundation. Performance Evaluation Theory allows for the assessment of policy success through measurable performance analysis, while Public Policy Theory helps explain how defense policies can be designed and implemented to support PT Pindad's technical objectives. Both theories emphasize the importance of continuous evaluation in ensuring that implemented policies are aligned with the organization's strategic and operational objectives.

In the context of technology and innovation, the Technology Theory in Organizations (Jakobs, 2019; Rogers, 2003) and the Technology Transfer Theory (Bozeman, 2000) provide insights into the spread of technology within organizations and the transfer of advanced technologies that are critical to the defense industry. The Technology Theory in Organizations helps explain how technological advances can be distributed evenly across all divisions of PT Pindad, while the Technology Transfer Theory focuses on how PT Pindad can acquire and adopt technology from abroad, which is essential in efforts to increase domestic technological independence. Both theories are very relevant to understanding how innovation can be acquired and optimally utilized by PT Pindad.

In addition, Decision-Making Theory (Hukkinen et al., 2022; Simon, 1997) and Adaptive Policy Theory (Li et al., 2023) discuss how policies are made and adapted according to operational changes. Decision-Making Theory explains the factors that influence defense industry policies, especially in the context of strategic decision-making at PT Pindad. On the other hand, Adaptive Policy Theory provides guidance on how policies can be designed to remain relevant and responsive to technological changes and

operational dynamics, which is important to maintain PT Pindad's flexibility in responding to rapid changes in the defense sector.

Finally, Institutional Support Theory (Mowery, 2012; North, 1990) , Industrial Independence Theory (Ahumada, 2023; Lall, 1992), and Policy Collaboration Theory (Siddiki et al., 2022) emphasize the importance of collaboration and support from related institutions in addressing the obstacles faced by PT Pindad. Institutional Support Theory helps understand how institutions such as the Indonesian Army Research and Development Agency can support PT Pindad in overcoming challenges. Industrial Independence Theory examines strategies to achieve industrial independence, while Policy Collaboration Theory highlights the importance of cooperation between stakeholders in addressing policy and operational obstacles. In addition, the Theory of Technological Innovation (Wei et al., 2023) and the Theory of Product Development (Gurbuz, 2018) guide PT Pindad in facing the challenges of developing new products and increasing technological capacity through innovation, which is also enriched with the Theory of Inter-Institutional Collaboration (Sochneva et al., 2021) which supports the importance of partnerships in the development of defense equipment.

By combining these theories, the study can provide comprehensive insights into the challenges and opportunities faced by PT Pindad in achieving defense industry independence. This theoretical structure not only provides an analytical framework for assessing existing policies, but also offers practical guidance for overcoming obstacles and exploiting emerging opportunities in the defense sector.

3. METHOD

This study uses qualitative methods to explore the challenges and opportunities faced by PT Pindad in achieving defense industry independence. Data were collected through in-depth interviews with key stakeholders, including PT Pindad management, engineers, and government officials related to defense policies. These interviews aimed to explore their views on technology transfer, dependence on imported raw materials, and the implementation of defense policies. In addition, an analysis of policy documents such as Law Number 16 of 2012 and the Minimum Essential Force (MEF) policy, as well as PT Pindad's annual reports was conducted to understand the policy context that supports industrial independence.

Data Analysis Techniques were conducted using NVivo software (QSR International, 2016) to manage, code, and analyze the collected data. Data were analyzed thematically to identify key patterns related to policies, technology transfer challenges, and opportunities for increasing industrial independence. This method allows researchers to explore the relationships between identified variables, providing in-depth insights into strategies that PT Pindad can optimize in achieving defense industry independence.

Here is a table for a list of interview questions, which includes the factors to be explored, theories, and references:

Table 1Interview Question Design

Question	Factors to be Explored	Theoretical Basis	Reference
1) How does the Indonesian Army Research and Development Agency assess the effectiveness of policies implemented at PT Pindad?	Policy effectiveness	Policy Evaluation Theory	(Patton, 2008) , (Wang et al., 2020)
2) What steps has the Indonesian Army Research and Development Agency taken to ensure efficiency in the development of defense equipment at PT Pindad?	Efficiency of defense equipment development	Efficiency Management Theory	(Drucker, 2006) , (Maslennikov et al., 2023)
3) How does the Indonesian Army Research and Development Agency play a role in evaluating PT Pindad's performance during the 2018-2023 period?	Policy performance evaluation	Performance Evaluation Theory	(Kaplan & Norton, 1996) , (Pestana Barros, 2004)
4) Is the defense industry policy sufficient to support PT Pindad's technical objectives?	Policy support for technical objectives	Public Policy Theory	(Dye, 2013) , (James, 2022)

Question	Factors to be Explored	Theoretical Basis	Reference
5) How does the policy ensure equal distribution of technological progress across all divisions of PT Pindad?	Equal distribution of technological progress	Technology Theory in Organizations	(Rogers, 2003) , (Jakobs, 2019)
6) How responsive is this policy in addressing the need to supply advanced technology to PT Pindad?	The need for advanced technology	Technology Transfer Theory	(Bozeman, 2000)
7) Is the defense industry policy appropriate and up-to-date in responding to operational changes at PT Pindad?	Policy relevance	Adaptive Policy Theory	(Li et al., 2023)
8) What factors do you think are most influential on policy decisions in the defense industry, especially at PT Pindad?	Policy decision making factors	Decision Making Theory	(Simon, 1997) , (Hukkinen et al., 2022)
9) How does the Indonesian Army Research and Development Agency support PT Pindad in overcoming the challenges faced?	Dislitbang's support for PT Pindad's challenges	Institutional Support Theory	(North, 1990) , (Mowery, 2012)
10)What are the obstacles faced by PT Pindad in increasing the independence of defense equipment?	Obstacles to defense equipment independence	Industrial Independence Theory	(Wilkinson, 1998) , (Ahumada, 2023)
11)What efforts have been made by the Indonesian Army Research and Development Agency to assist PT Pindad in facing these obstacles?	Efforts to overcome obstacles	Policy Collaboration Theory	(Siddiki et al., 2022)
12)How does the Indonesian Army Research and Development Agency contribute to improving technological capabilities at PT Pindad?	Enhancement of technological capabilities	Theory of Technological Innovation	(Wei et al., 2023)
13)What are the main challenges in new product development faced by PT Pindad?	New product development challenges	Product Development Theory	(Gurbuz, 2018)
14)To what extent is the cooperation between the Indonesian Army Research and Development Agency and PT Pindad in developing defense equipment?	Cooperation between Dislitbang and PT Pindad	Inter-Institutional Collaboration Theory	(Sochneva et al., 2021)

4. RESULT AND DISCUSSION

4.1 Interview findings

This study found a number of major obstacles faced by PT Pindad in achieving defense industry independence. One of the biggest challenges is dependence on imported raw materials, which is a crucial factor because the Indonesian defense industry, including PT Pindad, is still very dependent on raw materials and components from abroad. This finding strengthens the findings of Ramadhoni et al. (2024) who emphasized that dependence on imported raw materials is high risk, vulnerable to changes in international trade policies or embargoes, disrupting supply chains and hampering production. This finding also underlines the suggestion of Zemlyanskii & Chuzhenkova (2023) that import substitution policies, such as those implemented in Russia, are to localize production and reduce dependence on imports. However, without technological innovation efforts, this policy can lead to technological stagnation and can be an obstacle in the long term.

The next finding is limited technology transfer. Although there are technology transfer policies from weapons supplier countries or international cooperation partners, the technology transfer process is often slow and not optimal. PT Pindad faces difficulties in adopting advanced technology comprehensively due to limitations in technology transfer agreements, thus hampering innovation and the company's ability to produce high-tech military products independently. In line with this finding, Simms & Frishammar (2024) revealed that the complexity of integrating new technology into existing systems complicates partnerships, delaying or distorting the implementation of innovative solutions. Asymmetric alliances between PT Pindad and its partners often face challenges due to differences in learning approaches, knowledge bases, and collaboration routines. These differences create cognitive distance, leading to asymmetry in technological distance and mismatch in innovation capabilities, which in turn hinder technology transfer.

Another important finding is the lack of competent human resources (HR), especially in cutting-edge technology. PT Pindad still lacks experts who have specific technical expertise to develop, assemble, and maintain high-tech defense products. This limitation is exacerbated by the lack of investment in training and continuing education that can increase HR capacity. These three obstacles—dependence on imported raw materials, limited technology transfer, and HR shortages—make it difficult for PT Pindad to achieve full independence in the defense industry. In line with these findings, several strategies have been offered, such as: massive collaboration (Wadjdi et al., 2023) , utilization of circular economy principles (Reis et al., 2022) , encouraging innovation such as the use of machine learning (Ghamisi et al., 2021) , AI convergence and experimental automation (Xie et al., 2023) including Blockchain and IoT Integration (Alqahtani et al., 2024) , research joint ventures and R&D cartels (Lambertini, 2023) , and forming strategic partnerships in proactive resource procurement (Mohamed Anwar et al., 2023) .

Global and local policies have a significant impact on PT Pindad's ability to develop defense industry independence. At the global level, arms embargoes or restrictions on the export of military technology from developed countries are one of the main obstacles. Such embargoes, which Indonesia experienced in the late 1990s, can disrupt PT Pindad's access to critical components and advanced military technology. When an embargo occurs, PT Pindad is forced to find alternative suppliers or develop its own technology, which often takes a long time and is expensive, and does not always produce products of equivalent quality. This dependence on developed countries for vital technology and raw materials makes PT Pindad vulnerable to international geopolitical dynamics.

On the other hand, local policies related to limited government support also pose their own challenges. Although the Indonesian government has issued policies to encourage the independence of the defense industry, such as Law Number 16 of 2012 concerning the Defense Industry and the Minimum Essential Force (MEF) program, the support provided is still not optimal. One of the limitations is the lack of adequate budget allocation for research and development (R&D) and investment in increasing production capacity. This limited funding prevents PT Pindad from aggressively developing new technologies and producing defense equipment on a large scale. In addition, regulations related to technology transfer are still not strong enough to ensure effective knowledge transfer from international partners, thus slowing down the innovation process.

The combination of global policy influences and limited local support has made it difficult for PT Pindad to achieve full independence in the defense sector. Therefore, to increase competitiveness and independence, PT Pindad needs more supportive local policies, such as increased R&D investment and better technology transfer regulations, as well as strategies that reduce dependence on international suppliers.

PT Pindad has several opportunities to improve its performance and achieve greater independence in the defense industry. One of the main opportunities is through strengthening collaboration between the government, private sector, and academics using the Penta Helix model. This model involves synergy between five important elements: government, business sector, academics, community, and media. With the Penta Helix model, PT Pindad can utilize various expertise and resources from each element to accelerate innovation and technology development. Collaboration with universities and research centers, for example, can help improve research capabilities, while partnerships with the private sector can open access to investment and advanced technology.

In addition, another significant opportunity lies in increasing investment in research and development (R&D). R&D is the backbone of innovation in the defense industry, allowing PT Pindad to develop new military technologies that can compete globally. Greater investment in R&D will not only improve the

quality and production capacity of PT Pindad, but also reduce dependence on technology imports from other countries. Through strong R&D, PT Pindad can increase production efficiency, accelerate technology transfer, and introduce innovative defense equipment products that are in line with national defense needs.

Furthermore, optimizing technology transfer is also a great opportunity for PT Pindad. By strengthening regulations and policies that support technology transfer, PT Pindad can obtain and utilize advanced technology from international partners to improve its production capabilities. The offset program in the procurement of defense equipment from abroad, for example, can be maximized to ensure more significant and in-depth technology transfer. This effort will enable PT Pindad to develop the internal capacity needed to produce products with advanced technology independently.

4.2 Exploration of Defense Industry Independence Factors

Based on findings from the PT Pindad case, there are several main factors that influence the independence of the defense industry, namely:

- Dependence on Imported Raw Materials: One of the biggest obstacles faced by PT Pindad is its high dependence on imported raw materials and high-tech components from abroad. This makes the Indonesian defense industry vulnerable to global market fluctuations and embargoes that can disrupt the supply chain, thus hampering the independence of defense equipment production.
- Limitations of Technology Transfer: Despite initiatives to transfer technology from arms supplier countries, effective technology transfer remains a major challenge. PT Pindad has not been able to fully utilize its technology transfer program due to limited agreements and a lack of focus on the full application of acquired technology domestically.
- Lack of Investment in R&D: Investment in research and development (R&D) in the defense sector is still very limited. PT Pindad faces difficulties in innovating new technologies needed to independently produce high-tech defense equipment. The lack of R&D budget from the government and minimal collaboration with research institutions and academics hamper the pace of innovation in the company.
- Human Resources (HR) Limitations: The independence of the defense industry is also affected by the shortage of experts who have the skills to develop, produce, and maintain high-tech defense equipment. PT Pindad still faces limitations in training and developing HR that focuses on military technology.
- Less than Optimal Policy Support: Although the government has issued policies such as Law Number 16 of 2012 concerning the Defense Industry, the implementation of this policy is still not fully optimal. Government support in the form of budget allocation, stricter technology transfer regulations, and incentives for domestic industry development is still limited.
- Lack of Strategic Collaboration: Collaboration between PT Pindad and the private sector, academics, and research institutions is still not strong. In fact, this synergy is needed to accelerate innovation and improve local technological capabilities. Collaboration within the Penta Helix framework (government, industry, academics, community, and media) can strengthen the defense industry innovation ecosystem.
- Global Market Pressure: Global competition in the defense industry sector also affects PT Pindad's ability to compete in the international market. These challenges include rapid technological innovation from developed countries, which requires PT Pindad to continue to improve their defense equipment products and technology to remain competitive.

In general, these factors pose significant challenges for PT Pindad in achieving defense industry independence. Efforts to overcome dependence on imports, increase technology transfer, strengthen R&D, and develop human resources and strategic collaboration are top priorities for increasing the independence of Indonesia's defense industry,

4.3 Defense Industry Independence Opportunities

In an effort to achieve defense industry independence, PT Pindad can learn from the experiences of countries such as China and Turkey, which have succeeded in developing their defense industries to be independent and competitive at the global level (Bouri et al., 2024; Vernigora, 2023).

China, through its technology indigenization strategy and heavy investment in research and development (R&D), has successfully reduced its dependence on foreign military technology imports. China has prioritized aggressive technology transfer from international partners and utilized protectionist policies to encourage the development of its domestic defense industry (Herlevi & Rodgers, 2023). In addition, the Chinese government has provided strong financial and policy support to ensure that its defense industry has access to the capital and technology needed for innovation. A key lesson learned from China

is the importance of consistent government support through investment in R&D and regulations that prioritize technology transfer and the development of quality human resources (Ma et al., 2023).

Turkey, on the other hand, offers another relevant example through its approach that is more based on international collaboration and strengthening the private sector in the defense industry. Turkey utilizes offset programs in military procurement to obtain technology transfer from arms supplier countries. In addition, Turkey encourages the growth of private defense industries, such as Turkish Aerospace Industries and ASELSAN, supported by government policies that strengthen cooperation between the government, the private sector, and academia (Vernigora, 2023). Turkey also focuses on diversifying defense products, which allows it to export defense equipment products to many countries (Kurç, 2024). From Turkey's experience, PT Pindad can learn about the importance of cross-sector cooperation (government, private sector, academia) and the use of offset programs to gain maximum benefits from foreign military procurement.

Both countries demonstrate that sustained investment in R&D, strategic technology transfer, and close collaboration between sectors are key to achieving defense industry independence. PT Pindad can implement similar strategies by strengthening synergies between the government, academia, and the private sector, and optimizing technology transfer programs to accelerate innovation and increase domestic production capacity.

For PT Pindad, utilizing the latest technologies such as artificial intelligence (AI), automation, and additive manufacturing (3D printing) can increase efficiency in the production process, accelerate the development of new products, and expand innovation capacity. This technology not only increases the production capacity of defense equipment in terms of quantity, but also quality, especially in terms of precision, speed, and the ability to produce products tailored to Indonesia's defense needs.

In addition, innovations in digital technology and network-based defense systems can also help PT Pindad create a more integrated and responsive weapon system to the operational needs of modern military. Such innovations allow interconnection between various defense systems, which increases operational effectiveness in the field.

PT Pindad can take advantage of technological innovation opportunities through increased investment in research and development (R&D) and strategic collaboration with universities, research institutions, and global technology companies. International cooperation in offset programs and technology transfer is also an important strategy for PT Pindad to accelerate the acquisition of advanced technology and develop domestic technical capabilities. Thus, innovation and mastery of the right technology can help PT Pindad achieve stronger and more sustainable defense industry independence, as well as increase competitiveness in the international market.

4.4 Recommendation

Based on the research findings, there are several policy recommendations that can be proposed to increase the independence of the Indonesian defense industry, especially for the government and PT Pindad.

Increased Investment in Technology and R&D: The government needs to increase budget allocation for research and development (R&D) in the defense sector. Investment in advanced technologies such as artificial intelligence (AI), additive manufacturing (3D printing), and automation systems can accelerate innovation and improve the efficiency of defense equipment production. The government can encourage PT Pindad to expand its R&D initiatives through fiscal incentives or direct support, for example through joint research funds or technology grant programs.

Human Resource Development (HRD): One of the biggest obstacles for PT Pindad in achieving independence is the lack of skilled workers with expertise in cutting-edge military technology. To overcome this, there needs to be a policy that focuses on HRD development, including training and certification programs in the field of defense technology. Collaboration between PT Pindad, universities, and training institutions can improve the skills of the workforce in technological innovation and production management. In addition, the government can support sending workers to learn from international defense companies as part of technology transfer.

Strengthening Technology Transfer Policy: The government must strengthen regulations related to technology transfer in every military procurement agreement with partner countries. A more assertive and targeted policy must ensure that every procurement of weapons or military equipment from abroad must be accompanied by a clear technology transfer commitment. The government can introduce a more effective offset program, where every purchase of foreign defense equipment includes a technology transfer element that can be directly applied at PT Pindad.

Development of Innovation Ecosystem Through Penta Helix Model: To accelerate innovation, it is important to build a collaborative ecosystem between the government, private sector, academics, communities, and media through the Penta Helix model. The government can facilitate collaboration between PT Pindad and universities and research centers to develop new technologies that are in line with national defense needs. In addition, the involvement of the private sector can open up opportunities for PT Pindad to obtain funding and the latest technology.
Reducing Dependence on Imported Raw Materials: To strengthen the independence of the defense industry, PT Pindad and the government need to invest in the development of local raw materials that can replace imported components. The government can provide incentives to domestic industries to develop and produce raw materials and components needed by PT Pindad. This will reduce vulnerability to global market fluctuations and dependence on international suppliers.

5. CONCLUSION

This study reveals several key challenges faced by PT Pindad in achieving independence in the defense industry. These challenges include dependence on imported raw materials, which makes the company vulnerable to global fluctuations, as well as limitations in technology transfer that have not been running optimally. In addition, the lack of investment in R&D and the limited competent human resources also hamper the pace of innovation and development of advanced military products. On the other hand, this study also identifies a number of opportunities that can be utilized by PT Pindad, including increasing collaboration between the government, private sector, and academics through the Penta Helix model, as well as strengthening technology transfer regulations and increasing investment in R&D.

5.1 Implications for Policy and Practice

This research provides important implications for policymakers and defense industry players in Indonesia. The government needs to strengthen technology transfer policies and ensure stricter implementation in foreign defense equipment procurement agreements. Policy support in the form of increased investment in research and development is urgently needed to encourage innovation and improve PT Pindad's competitiveness in the international market. In addition, policies must focus on human resource development by providing access to special training to improve the technical competence of workers in the defense sector. For industry players, including PT Pindad, increasing cross-sector cooperation and utilizing digital technology will be important steps to accelerate innovation and independence.

5.2 Future Research Directions

Further research is needed in several strategic areas to support the independence of the defense industry in Indonesia. One important area is defense technology innovation, especially research on the adoption of digital technologies such as artificial intelligence (AI) and automation in defense equipment production. In addition, more in-depth research is needed on strategies to increase PT Pindad's international competitiveness, including analysis of the global market for defense equipment exports and the development of military products that are in accordance with international needs. Research on more effective technology transfer mechanisms is also a priority to ensure that Indonesia can better utilize international partnerships.

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