IJLRSA
The International Journal of Law Review and State Administration
https://www.ijems.id/index.php/ijlrsa/
E-ISSN 3025-843X
Vol 4, No 1, (January - February 2026) Pages: 29-45
Submitted : 27/12/2025
Published :30/01/2026

Innovation and Investment Strategies to Strengthen The Defence Industry and The Research and Development Capabilities of The Indonesian Army Through Triple Helix Collaboration

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Doi: https://doi.org/10.58818/ijlrsa.v3i5.285

Abstract

This study evaluates the effectiveness of the Indonesian Army's defence research and development (Litbanghan) ecosystem through a qualitative approach based on policy document analysis and quantitative prototype data. Analysis of 427 Litbanghan prototypes from 2006 to 2024 shows that only 3.9% entered mass production, indicating structural barriers in the downstream phase and weak integration between Litbang and Bangtekindhan. A review of regulations found gaps between the policy framework, such as Permenhan 16/2019 and Permenhan 39/2016, and implementation in the field, particularly in the certification process, incentive mechanisms, and clarity of intellectual property rights. An international comparative study (Turkey, Brazil, Portugal, South Korea) confirms that institutional coordination, sustainable research funding, and research-procurement connectivity are prerequisites for an effective defence innovation ecosystem. This study recommends increasing R&D funding, simplifying certification, establishing proportional IPR regulations, and integrating R&D results into the defence equipment procurement pipeline. Theoretically, this study expands the application of the Triple Helix model in the defence sector, which is characterised by strict regulations and a non-market environment. Practically, these findings provide strategic input for the formulation of the 2025–2029 Defence Industry Master Plan and the strengthening of national defence innovation governance.

Keywords: Cross-Sector Collaboration, Defence Modernisation, Defence Research, Indonesian Army, Triple Helix

A. Introduction

The Indonesian Army (TNI AD), as the main component of Indonesia's land defence, faces increasingly complex military technology challenges in line with the dynamics of multidimensional threats and rapid global technological advances. The modernisation of Defence and Security Equipment (Alpalhankam), which according to Indonesian Ministry of Defence Regulation No. 16 of 2019 covers not only major weapon systems (such as tanks, fighter aircraft, and warships), but also supporting components, raw materials, and other related technologies, is an important strategy in the 2025–2029 defence policy, which emphasises the transformation from defence spending to sustainable defence investment (Sri Yanto, 2025; TNI AD, 2022).

Data shows that there is a significant gap between the results of the Indonesian Army's research and development activities and the level of commercialisation of prototypes, which was also highlighted in the evaluation by the Director General of Defence Potential of the Indonesian Ministry of Defence (Sri Yanto, 2025) regarding the weak connection between the Bangtekindhan and Litbanghan programmes across the armed forces. In the period 2006–2024, less than 4% of prototypes successfully reached the mass production stage (Napitupulu, 2024). Meanwhile, more than 50% of the Indonesian Army's defence equipment has been in operation for more than 20 years, requiring urgent renewal (Navirinda K., 2024). The high dependence on imported components further emphasises the need for an import reduction strategy and the strengthening of the domestic supply chain as pillars of the National Defence Industry (Syahputra, 2025).

In this context, the Triple Helix collaboration model, which involves synergy between government, industry, and academia, offers a strategic solution in line with the direction of establishing a Permanent Defence Research Consortium (Sri Yanto, 2025). The application of this model has the potential to improve coordination between stakeholders, accelerate the commercialisation of innovation, and optimise existing resources. Some initial successes have been demonstrated through collaborative projects such as the Lidikzi Robot (Zeni Investigation), the Meteorological Ballistic System, and the Integration of Command, Control, Computer, and Communication (C4) Systems for Arhanud Defence Equipment, although most are still in the prototype or early commercialisation stages. The strengthening of defence innovation clusters in Brazil, Türkiye, and Portugal using similar approaches provides additional references for formulating relevant strategies for Indonesia.

The findings of this study are expected to serve as strategic guideline for the Indonesian Army, the Ministry of Defence, and defence industry partners in realising the modernisation of defence equipment and national defence technology independence, in line with the policy direction of the 2025–2029 Defence Industry Master Plan.

B. Research Method

This study employs a descriptive qualitative method with a multi-source case study approach, including the 2025 policy document from the Director General of Defence Industry of the Indonesian Ministry of Defence (Sri Yanto, 2025) and the 2025 Research and Development Evaluation Report as primary institutional data. The research focuses on three main aspects: (1) policy evaluation, (2) analysis of the performance of the Indonesian Army's Research and Development Agency, and (3) implementation of the Triple Helix collaboration model. Policies were evaluated through a review of Litbanghan regulations and the 2025–2029 defence policy flow, which emphasises the integration of Litbanghan–Bangtekindhan (Sri Yanto, 2025), including Indonesian Ministry of Defence Regulation No. 9 of 2019 concerning the Implementation of Defence Research and Development within the Indonesian Ministry of Defence and the Indonesian National Army; Indonesian Ministry of Defence Regulation No. 8 of 2021 concerning the Implementation of Defence Equipment Research and Development within the Indonesian Ministry of Defence and the Indonesian National Armed Forces; Indonesian National Armed Forces Commander Decree No. Kep/1522/XII/2019 concerning the Indonesian National Armed Forces Defence Research and Development Doctrine (Indonesian National Armed Forces, 2019); and Indonesian Army Chief of Staff Decree No. Kep/1015/XI/2022 concerning Guidelines for the Implementation of Research and Development and System Analysis and Operations Research within the Indonesian Army (Indonesian Army, 2022).

This analysis aims to identify gaps between regulatory norms and implementation practices in the field, particularly regarding the downstreaming process of R&D results towards mass production, including current issues such as coordination fragmentation and import reduction as stated by Syahputra (2025). Furthermore, the analysis of the performance of the Indonesian Army's Litbanghan uses budget data, the age of Alpalhankam, the number of prototypes, and downstream readiness indicators, which are the focus of the evaluation by the Director General of Pothan Kemhan RI (Sri Yanto, 2025). Based on data from Paban III/Litbang Asro Srenaad (Napitupulu, 2024), 427 prototypes have been developed, but only 17 prototypes (around 3.9%) have successfully reached the mass production stage. The analysis focused on factors hindering the low level of downstreaming, including budget constraints, lack of cross-sector coordination, and dependence on imported components.

The Triple Helix approach as a model of collaboration between government, industry, and academia was examined through a number of case studies, including: (1) Lidikzi Robot Prototype: collaboration between Pusziad, PT Respati Solusi Rekatama, and the Bandung Institute of Technology (ITB), (2) Meteorological Ballistic System: cooperation between Pussenarmed, PT Nexin Inovasi Sejahtera, and Telkom University, and (3) Command, Control, Computer, and Communication (C4) Integration System for Arhanud Defence Equipment: the result of synergy between Pussenarhanud, PT Nexin Inovasi Sejahtera, and Brawijaya University. In addition, this study also adopts international references from Türkiye, Brazil, and Portugal to examine the relevance of applying the Triple Helix model in the development of national defence technology.

The main data for this study was obtained from presentations by policy makers during the Verification of Defence Industry Capabilities in Supporting TNI AD Research and Development on 20–21 November 2024 and supplementary material for 2025 (Directorate General of Defence Industry, Ministry of Defence and Dislitbangad) to strengthen the depth of policy analysis. The data sources included: (1) Paban III/Litbang Asro Srenaad (Napitupulu, 2024) (prototype data), (2) Paban I/Jakrenstra Srenaad (Navirinda K., 2024) (budget allocation and Alpalhankam age data), (3) Deputy Director of Defence Industry, Directorate General of Defence Industry, Ministry of Defence (Nainggolan, 2024) (national defence industry profile, which was later updated by source number (4)), (4) Director General of Defence Industry, Ministry of Defence of the Republic of Indonesia (Sri Yanto, 2025) (defence policy flow 2025–2029), and (5) Research and Development Agency (supporting data for Research and Development of the Indonesian Army for the 2006-2025 fiscal year).

The analysis process was conducted in three stages:

a. Document analysis, comparing the Indonesian Army's research and development targets with actual production and assessing the suitability of policy implementation with the direction of Jakumhanneg 2025–2029.
b. Comparative analysis of Triple Helix-based and non-collaborative projects to identify factors contributing to the success or failure of downstreaming, including an assessment of the industrial readiness level.
c. Contextual analysis linking the findings to the policy direction of the 2025–2029 Defence Industry Master Plan.

Although this study has strong internal validity because it is based on official data from the Indonesian Army and the Ministry of Defence, there are several limitations that should be noted. There is limited access to internal documents, such as unpublished project evaluation reports, and there is a lack of complete data on Litbanghan 2025, which is still in the policy internalisation stage. In addition, the scope of the case study is limited by the availability of data, so it does not fully represent all Litbanghan initiatives within the Indonesian Army or the national defence industry.

C. Result

1. The Performance of the Indonesian Army's Research and Development Agency: Between Potential and Challenges

During the period 2006–2024, the Indonesian Army's Research and Development Agency produced 427 prototypes, with an additional 15 still in progress in 2025 (Dislitbangad, 2025). However, by the end of 2024, only 17 prototypes (≈3.9%) had reached mass production (Napitupulu, 2024). This low level of downstreaming indicates a large gap between research output and operational realisation, which, according to an evaluation by the Director General of Defence Industry of the Indonesian Ministry of Defence (Sri Yanto, 2025), is caused by the lack of connection between the Litbanghan programme and the cross-sectoral Bangtekindhan scheme.

One of the main factors contributing to the low level of commercialisation is the limited budget and fragmented research-production financing mechanisms, as identified in the 2025 R&D policy evaluation (Syahputra, 2025). In the 2016–2024 period, the budget for the Defence Technology and Industry Development (Bangtekindhan) programme only reached Rp238.4 billion for 35 first articles across the armed forces (Sri Yanto, 2025), with a downward trend each year (see Diagram-1).

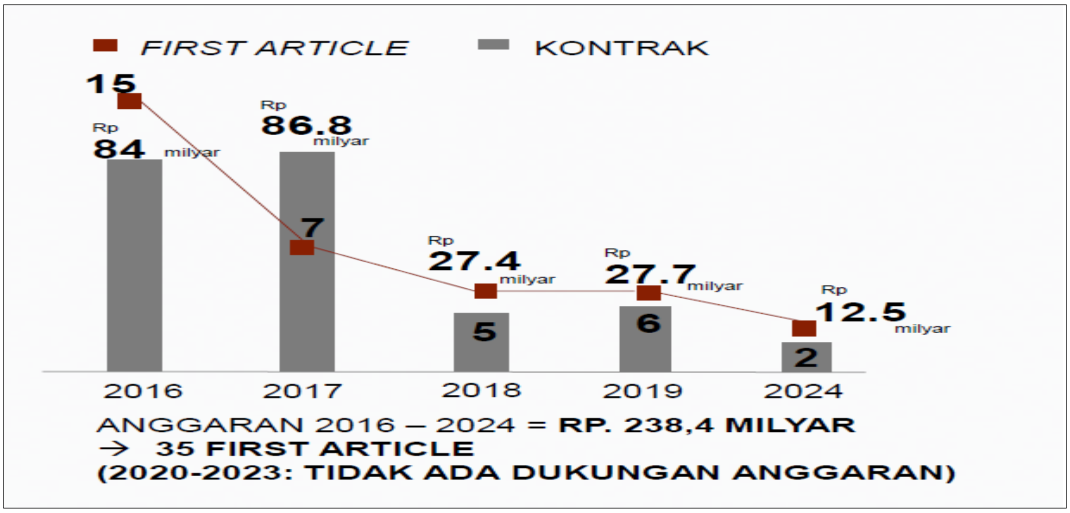

Diagram 1. Budget for the Defence Technology and Industry Development Programme for 2016–2019 Source: Sri Yanto (2025)

For the Indonesian Army's material research and development programme, the budget allocation for 2006–2025 is only around Rp552.5 billion for 442 activities, with a downward trend in the last five years (Dislitbangad, 2025; see Diagram 2). An assessment by the Director General of Defence Equipment of the Indonesian Ministry of Defence (Sri Yanto, 2025) highlights the absence of a sustainable funding mechanism, which has prevented many prototypes from entering the first article stage. Of all these activities, only eight first articles and 17 prototypes have reached mass production, a disparity that shows that limited resources are one of the root causes of stagnation in downstreaming.

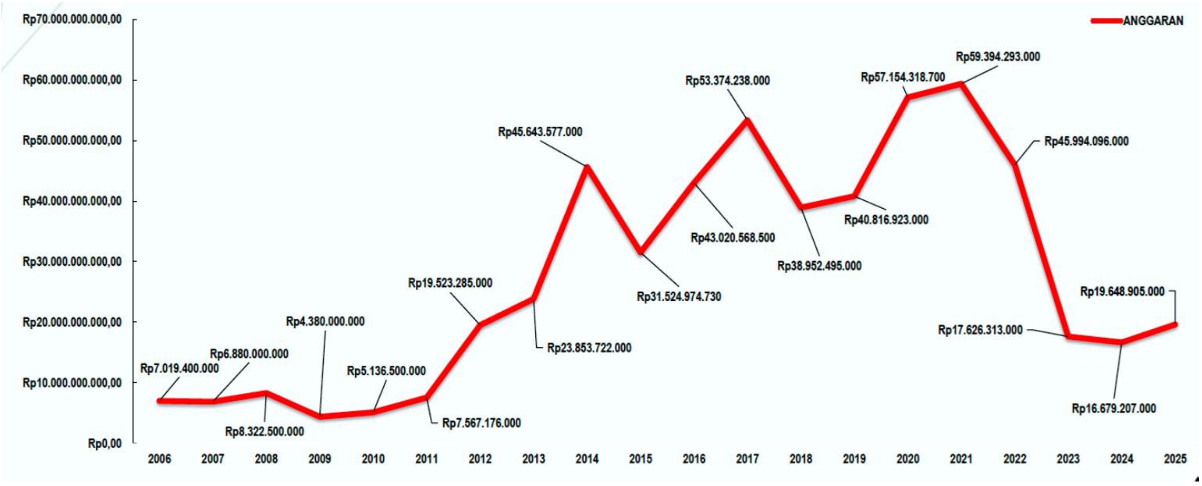

Diagram 2. Budget for the Defence Research and Development Programme in the field of Materials Indonesian Army 2020–2025 Source: Dislitbangad (2025)

In addition to budget constraints, the relatively old age of Alpalhankam is also a challenge. Approximately 54.8% of the Indonesian Army's Alpalhankam has been in operation for more than 20 years (Navirinda K., 2024). This condition increases maintenance costs and makes it difficult to integrate new technology into outdated platforms. The obstacle of interoperability between old platforms and new technology was again emphasised in the evaluation by the Ministry of Defence's Research and Development Agency (Syahputra, 2025).

Another factor limiting commercialisation is the low funding priority for prototypes, as well as the absence of a commercialisation guarantee mechanism, which is a major concern in the 2025 policy. Many technically feasible prototypes are not put into production because they lose priority in budget competitions controlled by user organisations. Under these conditions, only platforms with high operational urgency, such as the Battle Management System (BMS), which reached 523 units in 2020–2024, receive continuous funding (Napitupulu, 2024).

The downstreaming process is also influenced by regulatory mechanisms, whereby mass production is outside the authority of the Indonesian Army's Research and Development Agency and depends on the Bangtekindhan programme or the decisions of user organisational units in accordance with Indonesian Minister of Defence Regulation No. 39 of 2016. The lack of synchronisation between the R&D and Bangtekindhan pipelines, which is the focus of reform by the Director General of Defence Industry at the Ministry of Defence (Sri Yanto, 2025), further increases the risk of downstreaming stagnation.

Thus, although the Indonesian Army has great potential in defence technology innovation, various structural constraints, such as budget limitations, ageing platforms, fragmented funding, and the lack of downstream guarantees, are major factors hindering the achievement of national defence technology independence.

2. Triple Helix Model: Building a Path for Collaboration

The Triple Helix model, which emphasises synergy between the government, industry, and academia, offers a collaborative framework that is relevant to the plan to establish the 2025 Defence Innovation Consortium by the Director General of Defence Industry of the Indonesian Ministry of Defence (Sri Yanto, 2025). However, the effectiveness of this model is highly dependent on the existence of institutionalised coordination and funding mechanisms, an aspect that, in the 2025 evaluation, still shows significant gaps. Theoretically, cross-sector collaboration can accelerate the commercialisation of innovation through institutional capacity building and resource optimisation (Etzkowitz & Leydesdorff, 2000), but in the Indonesian context, the realisation of these benefits is still only potential because the Litbanghan–Bangtekindhan (Defence Research and Development–Defence Technology) ecosystem is not yet systematically connected.

Within the Indonesian Army, a number of collaborative projects are beginning to show the beginnings of the Triple Helix model, although the 2025 evaluation notes that capacity gaps between actors and the absence of joint governance mechanisms remain major obstacles (Syahputra, 2025). The development of the Lidikzi Robot by Pusziad, PT Respati Solusi Rekatama, and the Bandung Institute of Technology reflects a three-party collaboration pattern, but this collaboration is still project-specific and is not yet supported by a technology roadmap and joint funding scheme, which are characteristics of the Triple Helix. This project has reached the functional prototype stage in FY 2024, but to move towards the first article, it is still necessary to expand manufacturing capacity and ensure sustainable funding. With its dual technology characteristics, the Lidikzi Robot shows significant potential, but the effectiveness of the underlying collaboration model cannot yet be optimally assessed because the research-production ecosystem has not been systematically integrated.

Another example is the Meteorological Ballistic System developed through collaboration between Pussenarmed, PT Nexin Inovasi Sejahtera, and Telkom University. This project demonstrates positive synergy in the development of ballistic prediction devices based on real-time weather data, but the 2025 evaluation confirms that the main challenges lie not only in standardising interoperability but also in the industry's readiness to achieve an adequate level of manufacturing readiness (Sri Yanto, 2025). The collaboration between academia, industry and the military in this project has improved the quality of the system design, but has not yet fully met the ideal characteristics of the Triple Helix, such as a joint roadmap, a sustainable funding scheme and a structured downstream mechanism. Thus, although this project shows promising direction, the effectiveness of its collaborative model remains limited by a defence technology ecosystem that is not yet systematically integrated.

The implementation of the Triple Helix is also evident in the development of the Command, Control, Computer, and Communication (C4) Integration System for Arhanud Defence Equipment, which involves Pussenarhanud, PT Nexin Inovasi Sejahtera, and Brawijaya University. This project is an initial effort to build a data-based integrated defence platform, but a 2025 evaluation shows that the main challenge lies in the gap between the prototype design and the readiness of the industrial system to realise it on a manufacturing scale (Sri Yanto, 2025). Reliance on outdated platforms and the absence of national C4 architecture standards limit the effectiveness of the planned integration. At the end of FY 2024, the product was still at the functional prototype stage, so its role was more as a basis for learning than as a full indicator of the success of the Triple Helix. The collaboration between the three actors in this project showed a positive direction, but it was not yet supported by the downstreaming mechanisms and structured technology governance necessary to achieve operational readiness and mass production.

International lessons from Türkiye, Brazil, and Portugal provide important illustrations of how cross-sector collaboration can be institutionalised, even though the context is different from Indonesia. Türkiye, through the Rotary Wing Technology Centre (RWTC), demonstrates the effectiveness of a state-led cluster model, in which the government is the main driver in aligning the technology roadmap between industry and academia in the development of national helicopters (Tiraş, 2020). Brazil, with its Open Innovation Arena, highlights the use of dual-use technology to accelerate innovation that can enter both the commercial and defence sectors (Fernandes et al., 2020). Portugal uses the Triple Helix approach to build the interoperability of ICT-based defence systems and organise a more standardised innovation ecosystem (Simões et al., 2020). Although the contexts are different, these three experiences are relevant to the policy direction of the Director General of Defence Industry of the Indonesian Ministry of Defence (Sri Yanto, 2025). particularly in the formation of the Defence Innovation Consortium, which requires the integration of technology roadmaps, collaborative governance, and continuity of research and manufacturing funding.

Although the Triple Helix model offers great potential for improving the R&D capabilities of the Indonesian Army, its implementation in Indonesia is still hampered by structural issues that are more fundamental than simply capacity gaps between actors. The 2025 evaluation shows that the absence of an integrated pipeline between Litbanghan and Bangtekindhan and the lack of a downstream guarantee mechanism are major obstacles to promoting sustainable collaboration (Sri Yanto, 2025). This situation means that industry has no certainty about increasing its manufacturing capacity, while universities find it difficult to map out long-term research roadmaps. On the other hand, the available incentive schemes have not been designed as part of sustainable defence innovation governance, so that the involvement of industry and academia is still ad hoc and dependent on annual budget priorities. As a result, the potential of the Triple Helix as a downstreaming acceleration mechanism has not been optimally realised.

According to Efendie et al. (2022), the Penta-Helix approach, which adds the roles of the community and the media, can serve as a supporting layer in the innovation ecosystem, particularly in terms of strengthening technological literacy, STEM education, and public acceptance. However, in the context of defence, the 2025 evaluation emphasises that the core of collaboration remains based on government-industry-academia synergy, given the sensitivity of security and the need for controlled technology governance. Thus, the Penta-Helix element can contribute to a limited extent to expanding the innovation base and supporting the sustainability of research human resources, but it does not replace the main role of the Triple Helix model as the foundation for accelerating the downstreaming of defence technology.

3. The Role of the National Defence Industry

The national defence industry, which as of October 2025 consisted of ten state-owned enterprises and 200 private companies (Sri Yanto, 2025), contributed significantly to meeting the Indonesian Army's defence equipment needs, although the evaluation showed that only a small number of industry players had an adequate level of industrial readiness. The industry's contribution to fulfilling Alpalhankam in the 2015–2024 period also shows an upward trend (see Diagram-3), but this readiness is not yet in line with the increasingly complex defence system requirements. In line with Irfan et al. (2023), strengthening the defence industry requires synergy between the government, industry and academia, as well as the development of local capacity aimed at component substitution. The industry's contribution to fulfilling Alpalhankam requirements in the 2015–2024 period also shows an upward trend (see Diagram 3), but this readiness is not yet in line with the increasingly complex defence system requirements. In line with Irfan et al. (2023), strengthening the defence industry requires synergy among the government, industry and academia, as well as local capacity building aimed at substituting imported components and increasing industrial readiness.

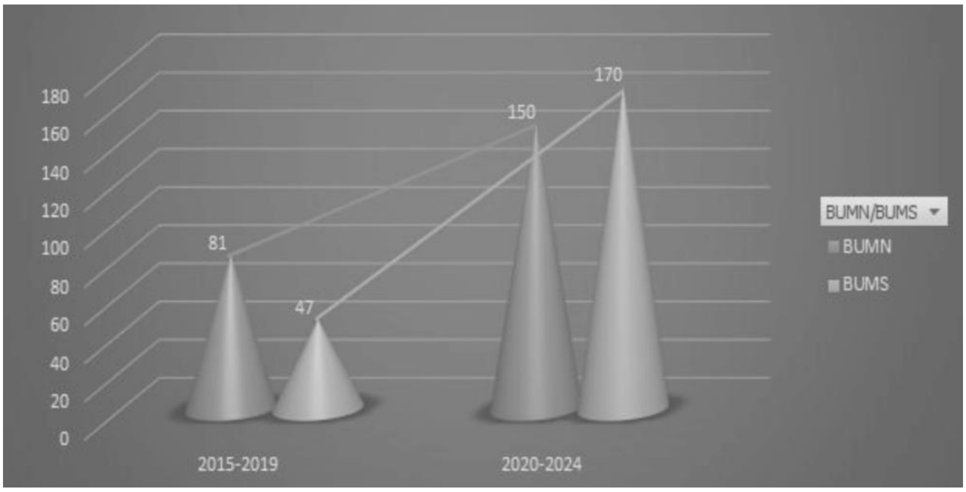

Diagram 3. Contribution of the Defence Industry to the Fulfilment of Defence Equipment Requirements 2015–2024
Source: Sri Yanto (2025)

PT Pindad, as a strategic state-owned enterprise, is an example of the successful integration of the Indonesian Army's research and development with national production capabilities. A number of collaborative products have entered mass production, including 155 units of 7.62 mm weapons along with 700,000 rounds of ammunition, 165 units of 12.7 mm SMB, and 161 units of Maung armoured vehicles (Napitupulu, 2024). This success demonstrates the compatibility between research results, manufacturing capacity, and operational needs, while also reflecting the 2025 policy direction that emphasises the importance of the Litbang–Bangtekindhan pipeline. However, such achievements are still the exception compared to the majority of national industries that do not yet have equivalent manufacturing readiness and process integration.

Apart from state-owned enterprises, the private sector also contributed significantly. PT Hariff Daya Tunggal Engineering successfully developed 523 Battle Management System (BMS) units and 259 sets of computer-based mortar firing systems. These achievements demonstrate the capability of some of the national private industry in developing command and control systems for the Indonesian Army. However, the 2025 evaluation emphasises that such successes are still limited to industries with specialised technological competencies, while most private companies still face limitations in terms of IRL and interoperability standardisation.

International collaboration also plays a role in enhancing the capacity of the national defence industry. The Harimau tank project, a collaboration with Türkiye, is an example of a strategic partnership based on joint production and technology transfer (Elisabeth et al., 2021). This model shows that independence does not mean isolation, but rather the ability to selectively absorb strategic technology. The 2025 policy direction also emphasises the importance of international partnerships that provide added value through offsets, increased local content, and strengthened domestic manufacturing capabilities.

However, the national defence industry still faces significant structural challenges. High dependence on imports of key components, such as electronic chipsets, optical sensors, and special energy materials, as mapped in the 2025 Evaluation (Sri Yanto, 2025), is a major obstacle to achieving independence. Production capacity, especially in the SME sector which is a supplier to the supply chain, is also still limited. In addition, the gap between research capabilities and the operational needs of the Indonesian Army shows that technological readiness and manufacturing readiness are not yet well integrated in the R&D–Bangtekindhan pipeline.

To overcome these obstacles, strengthening the defence industry needs to be directed towards strategic measures that are consistent with the agenda of reducing imports and revitalising manufacturing in the 2025 policy, namely: (1) import substitution through the development of key components and materials, (2) increasing production capacity, especially in the SME sector as the main supplier in the supply chain, (3) optimising international cooperation based on offsets and joint production to accelerate technology mastery, (4) establishing innovation clusters and integrated research consortia to synergise government, industry and academia, and (5) providing fiscal and non-fiscal incentives to encourage investment and ensure the downstreaming of R&D results. By strengthening these measures, the national defence industry has the potential to become the backbone of Indonesia's defence independence. The integration of technical readiness, manufacturing readiness, and the 2025 policy direction will determine the industry's ability to support the sustainable modernisation of defence equipment.

4. Policy and Regulatory Analysis

Policy implementation in the defence sector exhibits complex dynamics, reflecting various challenges within the national defence equipment ecosystem. Indonesian Ministry of Defence Regulation No. 16 of 2019 concerning the Procurement of Defence and Security Equipment within the Ministry of Defence and the Indonesian National Armed Forces and Indonesian Ministry of Defence Regulation No. 39 of 2016 concerning the Defence Industry Technology Development Programme were designed to strengthen the use of domestic products. but the 2025 evaluation shows that their implementation is still hampered by lengthy certification processes, weak integration between research and development and defence technology, and the absence of a mechanism to guarantee the downstreaming of research results to the mass production stage (Sri Yanto, 2025).

One of the main obstacles is the slow and complex certification process for domestic products, especially in the transition from R&D prototypes to first articles, which slows down the adoption of new technologies into the operational environment. Uncertainty in demand from users also hinders industrial planning, as there is no certainty that R&D results will enter the Bangtekindhan pipeline. In addition, limited fiscal incentives integrated with the technology roadmap reduce long-term investment interest in the national defence industry sector.

Although the regulatory framework for research and development has been established through Indonesian Minister of Defence Regulation No. 9 of 2019 concerning the Implementation of Research and Development within the Ministry of Defence and the Indonesian National Armed Forces, Indonesian Minister of Defence Regulation No. 8 of 2021 concerning the Implementation of Research and Development of Defence Equipment within the Ministry of Defence and the Indonesian National Armed Forces, and the Indonesian National Armed Forces Research and Development Doctrine (TNI, 2019), evaluations show that these regulations do not yet provide an integrated mechanism for the commercialisation of research results or the governance of collaboration with industry and universities. The 2005–2025 White Paper on Research, Development and Application of Science and Technology (Ministry of Research and Technology, 2006) provides a strategic vision, but is not binding, resulting in inconsistent implementation at the operational level.

The 2005–2025 Science and Technology Research and Development White Paper emphasises the need to shift towards a knowledge-based society, increase defence technology independence, and strengthen collaboration between industry, universities, research institutions, and the government. This document targets independence in the production of strategic equipment and a reduction in imports through the development of materials, propulsion, information technology, and weapons systems. However, without binding derivative regulations, this vision has not been realised in the form of an integrated research-production pipeline.

At the operational level, TNI Commander Decree Number Kep/1522/XII/2019 (TNI, 2019) and Army Chief of Staff Decree Number Kep/1015/XI/2022 (TNI AD, 2022) provide guidelines for the implementation of R&D within the Indonesian Army. However, none of these regulations govern the Triple Helix collaboration mechanism or the governance of R&D results downstream. While the 2005–2025 White Paper mentions the importance of industry–academia–government synergy, it is not legally binding, so collaboration remains optional and not institutionalised.

The internal initiative through ST Kasad Number ST/149/2024, which requires R&D to be carried out through cooperation between the Indonesian Army, industry, and universities, is a progressive step. However, its implementation is still hampered by the lack of clarity regarding the division of intellectual property rights (IPR), weak inter-agency coordination, and the absence of guarantees for the purchase of research results by users. This situation means that industry involvement is often ad hoc and not attractive enough for long-term investment.

Army Chief of Staff Decree No. Kep/867/XII/2023 on Independent Research and Development (TNI AD, 2023) opens up opportunities for joint funding between user units and industry. Although several initial examples, such as the Light Cavalry Tank and VVIP Combat Vehicle prototypes, show potential, their utilisation is still limited and not yet connected to broader downstream mechanisms. To function optimally, this policy needs to be synergised with the Triple Helix approach and the 2025 agenda related to the integration of the R&D–Bangtekindhan pipeline and the improvement of industrial R&D.

At the national level, the implementation of Indonesian Minister of Defence Regulation No. 16 of 2019 still faces rigid and opaque bureaucracy, resulting in slow procurement processes that are not in line with the modernisation needs of the Armed Forces. This situation reinforces the urgency of reforming procurement governance to make it more efficient, accountable, and adaptive to technological developments and increasingly dynamic operational needs.

5. Lessons from International Cases

The panel discussion in the Verification of Defence Industry Capabilities in Supporting the Indonesian Army's Research and Development (2024) emphasised that the dynamics of the Russia-Ukraine conflict demonstrate the importance of rapid technological adaptation capabilities, not just the number of defence equipment. The relevance of these findings for the Indonesian Army lies in the need to gradually build operational and technological capabilities amid budget constraints, as noted by Paban I/Jakrenstra Srenaad (Navirinda K., 2024). However, its implementation must take into account the capacity of the industry and the national innovation ecosystem, which are not yet on par with those of the countries used as references.

Several other countries with strategic characteristics comparable to Indonesia also provide valuable lessons. Türkiye, through the establishment of the Rotary Wing Technology Centre (RWTC), has demonstrated the successful application of the Triple Helix with synergy between the government, universities and industry in accelerating the development of national helicopters (Tiraş, 2020). However, Türkiye's success is also supported by long-term industrialisation planning and more established manufacturing capacity than Indonesia, so its relevance should be seen as a medium-term development direction rather than a model that can be directly replicated.

In Brazil, the Open Innovation Arena model serves as a platform for collaboration between the military, universities and industry in the development of communications technology and smart energy systems (Fernandes et al., 2020). This approach is effective because it is supported by a relatively mature civil innovation ecosystem and a large commercial market. Thus, lessons from Brazil are more suitable as a reference for strengthening the national innovation ecosystem than as an operational model that can be directly adopted.

Portugal's experience confirms the relevance of the Triple Helix in improving the interoperability of defence systems and the development of information and communication technology (Simões et al., 2020). Collaboration between technical universities, local industry, and the government has resulted in a responsive and adaptive innovation ecosystem. For Indonesia, the main lesson lies in the consistency of strengthening human resources and applied research, given that Portugal's defence technology capacity was also built gradually through long-term investment.

South Korea's experience, as noted by Paik (2024), shows that the success of the modern defence industry relies on aggressive research funding and close collaboration between the government, large industries, and universities. This strategy accelerates the mastery of strategic technology and increases import substitution. However, the effectiveness of this approach is greatly influenced by an integrated industrial structure and stronger fiscal capacity than Indonesia, so its implementation needs to be adapted to domestic conditions.

Many countries also emphasise the importance of applying the Life Cycle Cost (LCC) concept in the procurement of defence equipment to ensure cost efficiency throughout the life cycle of weapon systems. In the national context, Paban I/Jakrenstra Srenaad (Navirinda K., 2024) noted that although the Indonesian Army's budget requirements for the 2020–2024 period amounted to nearly Rp30 trillion, the actual budget of less than Rp5 trillion hampered operational readiness. This condition highlights the urgency of implementing LCC so that procurement decisions are more efficient and long-term oriented.

Based on these global lessons, strengthening the national defence R&D system requires three strategic steps adapted to domestic conditions. First, the application of the Triple Helix must take into account institutional capacity and national manufacturing capabilities so as not to simply imitate foreign models. Second, the application of Life Cycle Cost is important to improve budget efficiency and prevent long-term dependence on imports for maintenance and spare parts. Third, applied research-based human resource development must be carried out consistently, as reference countries have shown that defence innovation is only successful when investment in people and institutions is sustained. Thus, these international lessons must be adapted, not merely adopted, to ensure that Indonesia's defence policies remain realistic and contextual.

6. Barriers to Implementing the Triple Helix

Although the Triple Helix model has great potential to accelerate the commercialisation of defence innovation, its implementation in Indonesia, particularly in the context of the Indonesian Army's Research and Development Agency (Litbanghan TNI AD), still faces a number of structural obstacles. These obstacles include a lack of institutionalised cross-sector coordination, limited national industrial capabilities, and a lack of policy incentives that can bind actors into long-term collaboration. These conditions indicate that the potential of the

Triple Helix has not been fully utilised by the national defence innovation ecosystem.

a. Fragmented Coordination Between Actors. One of the main obstacles is fragmented coordination between actors, due to the lack of a structured collaboration mechanism between the government, industry, and academia. Collaboration, which should be at the core of the Triple Helix, tends to be sporadic due to differences in institutional priorities: industry is commercially oriented, academia emphasises research novelty, while the military demands compliance with operational standards and user urgency.

It is this lack of incentive synchronisation (not merely a lack of communication) that makes it difficult for many collaborative projects to reach a stable implementation stage.

b. Limitations in National Industrial Technology Capabilities. The national defence industry, particularly the private sector, still faces limitations in the high-tech capabilities required by the Indonesian Army. Strategic components such as sensors, electronic control devices, and military software are still dependent on imports, which not only increase costs but also slow down the prototyping process. This dependence is exacerbated by a domestic supply chain that is not yet integrated and manufacturing infrastructure that has not yet reached an adequate scale of economy, so that the industry's ability to meet international technical standards is still limited.
c. Limited Policy Incentives. Although Indonesian Minister of Defence Regulation No. 9 of 2019 and (Indonesian Ministry of Defence, 2021) provide a legal framework for Litbanghan, these regulations are not accompanied by incentive mechanisms that can motivate industry and academia. Without fiscal support, tax breaks, or reward schemes, Triple Helix collaboration risks becoming dependent on actors with the largest funds and capacity. As a result, the participation of non-governmental actors in high-risk projects is low, thereby reducing the effectiveness of the Triple Helix model itself.
d. Intellectual Property Rights (IPR) conflicts. The issue of intellectual property rights (IPR) distribution in defence research collaborations is a crucial issue that is often not discussed openly. The absence of proportional regulations regarding IPR ownership and utilisation between the Indonesian Army, industry, and academia creates uncertainty that hinders the formation of long-term trust. This uncertainty not only reduces investment motivation but also has the potential to stifle local innovation because actors are reluctant to take risks in projects that do not provide certainty of benefits.
e. Lack of a Product Commercialisation Guarantee Mechanism. The biggest obstacle in the implementation of the Triple Helix is the lack of a commercialisation guarantee mechanism that ensures that R&D results can enter mass production. Various prototypes such as the Lidikzi Robot, Meteorological Ballistic System, and C4 Arhanud Integration System demonstrate national innovative capabilities, but the transition to production is hampered by uncertainty in procurement and user budget allocation. This reflects the absence of an integrated R&D–Bangtekindhan–user pipeline, resulting in many innovations stopping at the prototype stage without sustainable operational value.

7. Strategic Recommendations for Overcoming Obstacles

To overcome these obstacles, strategic steps are needed that not only improve the R&D process, but also address the root causes of fragmentation in the innovation ecosystem. The following recommendations are aimed at ensuring that the Triple Helix model can function in a more structured, effective and sustainable manner in strengthening defence capabilities.

a. Strengthening Institutional Coordination. This should be done not only through the establishment of a joint coordination office, but also through mechanisms for aligning priorities and decision pipelines between the government, industry, and academia. Coordination must be based on clear mandates and integrative authority, so that each R&D project has agreed-upon targets, stages, and deadlines from the outset.
b. Enhancement of Local Technological Capabilities. The focus should be on active technology transfer through joint projects with concrete production objectives, rather than merely training or workshops. This programme needs to be reinforced by

increased investment in research and development and the selection of international partners relevant to the operational needs of the Indonesian Army so that local industry can gradually build technological excellence.

c. Provision of Policy Incentives. The government needs to provide selective fiscal and non-fiscal incentives to attract industry and academia to participate in defence research. Tax incentives, priority access to funding, and innovation reward mechanisms can reduce the financial risks of high-tech projects. Without a clear incentive scheme, Triple Helix collaboration is likely to remain sporadic and unsustainable.
d. Proportional Intellectual Property Rights Regulations. The formulation of proportional IPR regulations is key to ensuring the sustainability of collaboration. Clear rules regarding ownership, utilisation, and distribution of the benefits of innovation will provide legal certainty for all parties. This clarity is important to prevent conflicts of interest and increase the interest of industry and academia in investing in long-term projects.
e. Integration of Defence Research and Development Programmes with Procurement Policies. It is necessary to ensure that each prototype has a clear transition path to mass production. This mechanism must connect research and development, defence technology and industry, and users in a structured pipeline. Without certainty of demand from users, many research results will stop at the prototype stage and not generate operational value.

By implementing these steps in an integrated manner, the Triple Helix model has the potential to increase the effectiveness of defence innovation, strengthen local industrial capabilities, and accelerate the commercialisation of R&D results. However, the success of implementation depends heavily on policy consistency, funding commitment, and governance that ensures each actor bears a proportional role and responsibility in the national defence innovation ecosystem.

8. Challenges and Opportunities Ahead

To strengthen the Triple Helix model-based national defence ecosystem, a number of strategic issues need to be addressed in an integrated manner. The challenges faced are not only technical and institutional in nature, but also relate to human resource readiness, industrial capacity, and the ability to adapt to ongoing digital transformation. The strength of the defence innovation ecosystem is largely determined by policy consistency and the readiness of actors to take advantage of technological opportunities.

a. Enhancing the Capacity of the National Defence Industry. Strengthening the capacity of the national defence industry, especially among SMEs, is an urgent need. However, its development needs to be based on strict selection of SMEs that have technological readiness and investment commitment. Technical and managerial assistance programmes must be directed at improving capabilities that are relevant to Alpalhankam standards, because without focused capacity building, the target of import substitution for high-tech components will not be achieved.
b. Strengthening Cross-Sector Research Synergy. Synergy between research institutions, universities, and industry needs to be strengthened to create continuity between basic research, applied research, and production. Universities can produce fundamental innovations, but their adoption requires regulations that provide legal certainty, a stable investment climate, and incentives for industry to absorb research results. Without a clear connecting mechanism, academic innovation risks being irrelevant to the operational needs of the Indonesian Army.

c. Development and Strengthening of Human Resources (HR). Excellent and adaptive human resources are the main foundation of defence modernisation. Education, technical training, and certification programmes must be developed to bridge the skills gap between the specific needs of the Indonesian Army and the capabilities of domestic industry. HR strengthening needs to be directed towards the multidisciplinary competencies required in high technology, because without competent HR, Alpalhankam modernisation will be hampered even if technology and funding are available.

International experience shows that Indonesia's opportunities to strengthen its defence innovation ecosystem are highly dependent on its ability to adapt global collaborative models in a contextual manner. South Korea, for example, demonstrates how progressive research funding and close synergy between the government, large companies and universities can accelerate the mastery of strategic technologies and open up export opportunities (Paik, 2024). While the Fourth Industrial Revolution presents significant opportunities through the integration of information technology, artificial intelligence, big data, autonomous systems, and cybersecurity into defence systems (Utomo & Darma, 2020). This digital transformation further reinforces the relevance of the Triple Helix model, although the readiness of ICT infrastructure, military data protection, and dependence on foreign technology remain major challenges.

D. Conclusion

1. Conclusion

This study identified a number of critical findings that reflect structural challenges in the Indonesian Army's research and development ecosystem. These findings indicate that the main obstacles stem not only from technical factors, but also from policy design, institutional governance, and the capacity of the national defence industry.

a. Production Gap in R&D Results. In the period 2006–2024, only 3.9% of the 427 Indonesian Army R&D prototypes successfully reached mass production (17 prototypes). This low level of commercialisation is not only due to the limited budget for Bangtekindhan, which between 2016 and 2024 amounted to only Rp238.4 billion for 35 first articles, but also to the lack of integration between Litbanghan, the Bangtekindhan programme, and user needs. Without a clear pipeline from research to procurement, many Litbanghan results remain at the prototype stage.

b. Implementation of the Triple Helix Model. The implementation of the Triple Helix model has shown partial success through pilot projects such as the Lidikzi Robot, the Meteorological Ballistic System, and the C4 Arhanud Integration System. All three prove that collaboration between the Indonesian Army, industry, and academia can produce relevant prototypes. However, this success is still sporadic. Challenges in cross-sector coordination, unclear division of intellectual property rights, and technological capability gaps between actors limit the effectiveness of systemic Triple Helix implementation.

c. Dependence on Foreign Technology. High dependence on foreign technology remains a major obstacle to achieving defence independence. Core components such as sensors, chipsets, electronic control systems, and military software are still largely imported, indicating that the national industry's capacity is not yet able to meet strategic technology needs. These limitations hamper the improvement of the Industrial Readiness Level (IRL) and slow down the downstreaming process of R&D results.

d. Constraints in Policy Implementation. Although a number of regulations such as Indonesian Minister of Defence Regulation No. 16 of 2019, Indonesian Minister of Defence Regulation No. 39 of 2016, and Indonesian Army Chief of Staff Telegram ST/149/2024 have provided a formal framework for procurement and R&D, their implementation is still hampered by lengthy and inflexible bureaucratic procedures. The absence adequate policy incentives weakens industry motivation to engage in high-risk R&D projects, resulting in low participation from the non-governmental sector and slow technology commercialisation.

2. Recommendations

A number of policy recommendations have been put forward to strengthen the defence innovation ecosystem and accelerate national technological independence. These recommendations are addressed to the government, the Indonesian Army, and the defence industry as the three main actors in the Triple Helix model, with a focus on increasing the effectiveness of downstreaming, collaborative governance, and strengthening domestic technological capacity.

For the Government (Ministry of Defence):

a. Increased R&D Funding. The government needs to ensure consistent R&D funding through budget allocations that are proportional to strategic technology needs. The establishment of a Defence Innovation Fund could be a specific mechanism to support priority projects and reduce dependence on annual budget cycles, which are often unstable.
b. Simplification of Bureaucratic Procedures. The defence product certification process needs to be simplified through a fast-track mechanism for R&D results that meet technical standards. This simplification aims to accelerate the transition from prototypes to first articles and mass production.
c. Provision of Policy Incentives. The government needs to establish fiscal incentives such as tax breaks and easier access to funding for industries that invest in defence research. In addition, offset policies need to be optimised as instruments of technology transfer, particularly through international cooperation that is directly relevant to the needs of the Indonesian Army (Savitri & Matthews, 2016).

For the Indonesian Army:

a. Establishment of a Technology Scouting Team. The Indonesian Army needs to form a special team to identify future technology needs and map the readiness of national industry as well as opportunities for collaboration with academics and international partners.
b. Preparation of a Defence Technology Roadmap. The Indonesian Army needs to develop a five-year technology roadmap in collaboration with industry and universities, so that the direction of technology development is more coordinated, measurable, and avoids fragmentation of priorities among actors.
c. Strengthening R&D Human Resources. The capacity of R&D personnel needs to be improved through technical training, certification, and international internship programmes in strategic technologies. This programme must be followed by a competency internalisation mechanism so that the knowledge gained can be adopted sustainably within the TNI AD.

For the National Defense Industry:

a. Strategic Partnerships (Joint Ventures). The national defense industry needs to expand collaboration with global companies to gain access to critical technology and expand export markets. Strategic partnerships should also be designed to increase domestic production scale and manufacturing capabilities.

b. Investment in R&D. The national industry needs to increase investment in research and development facilities to accelerate product innovation. Strengthening R&D capacity is crucial for improving technological readiness and industrial readiness for downstream processes.
c. Research Consortiums with Universities. The formation of research consortiums between industry and universities needs to be directed at developing basic and applied technologies relevant to the needs of the Indonesian Army. Structured collaboration can reduce research fragmentation and increase the likelihood of innovations entering production.

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