Reframing Physical Barrier Systems in Preventing Illegal Cross-Border Movement in the Kalimantan Border Region from Technical and Design Perspectives

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KEYWORDS	ABSTRACT
Physical Barrier System, illegal border crossings, Kalimantan border, border security, physical system design	The Indonesia–Malaysia land border in Kalimantan is a strategic area with a high vulnerability to illegal cross-border activities, particularly through unofficial routes known as *jalan tikus* (rat paths), which continue to increase in number. Border security efforts remain largely dependent on conventional patrols, which are constrained by limited personnel, difficult terrain, and insufficient infrastructure, resulting in suboptimal surveillance effectiveness. In this context, the Physical Barrier System (PBS) serves as a critical technical solution, functioning as a physical obstacle, an early detection mechanism, and a deterrent to prevent illegal border crossings. This study aims to analyse the technical and design aspects of PBS implementation in supporting the border security operations of the Indonesian National Armed Forces (*Tentara Nasional Indonesia*, TNI) using a qualitative-descriptive approach. Data were collected through literature review, analysis of operational and regulatory documents, and empirical reports from Border Security Battalions, and analysed using thematic categorization and source triangulation. The findings reveal that PBS deployment remains uneven and weakly integrated with sensor-based technologies, while its design has not yet fulfilled the principles of defense-in-depth, Crime Prevention Through Environmental Design (CPTED), and integrated access control. This study proposes an optimized PBS framework incorporating modular, terrain-adaptive design, intrusion detection sensors, early warning systems, structural reinforcement, and data integration with sector command posts.

INTRODUCTION

Land borders represent a critical element of state sovereignty, necessitating robust security frameworks to manage transnational threats and maintain territorial integrity. For archipelagic nations like Indonesia, with its complex and diverse geography, securing land borders presents multidimensional challenges that extend beyond traditional military concerns to encompass socio-economic, environmental, and governance dimensions (Indonesia, 2015, 2022). The Indonesia-Malaysia land border on the island of Kalimantan, stretching over 2,040 kilometers through dense tropical rainforests, intricate river systems, and remote highlands, exemplifies this complexity. These geographical characteristics inherently create vulnerabilities, making the region susceptible to various forms of illicit cross-border activities.

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Various reports of border security operations show a significant increase in unoffical crossing routes, commonly known as rat routes. In several sectors of West Kalimantan, more than ninety unofficial routes were identified, with a tendency for new routes to emerge in a relatively short period of operation. This phenomenon reflects the adaptability of illegal actors while indicating the limitations of the border security system that still relies on conventional patrols. Although the TNI continuously deploys personnel in Border Security Operations (Opspamtas), the effectiveness of surveillance is still limited by personnel ratios that are not proportional to the length of the border area, hard-to-reach terrain, limited fixed infrastructure, and reliance on manual security methods.

In the global context, countries are facing similar challenges and responding to them by developing a Physical Barrier System (PBS) as part of a border security architecture. The implementation of PBS on the United States-Mexico, Israel-Gaza, and India-Pakistan borders shows that physical barriers that are systemically designed and integrated with detection technology, patrol mobility, and command and control systems can increase the deterrence effect, slow down illegal movements, and strengthen the response capacity of the authorities. However, most of these international studies and practices focus on desert or semi-desert regions, thus providing limited references to the context of tropical forest borders such as Kalimantan.

The urgency of addressing this gap is underscored by the persistent and evolving nature of cross-border threats. Illicit activities, ranging from people smuggling and undocumented labor to drug and wildlife trafficking, continue to exploit security weaknesses (UNODC, 2022). The economic and social costs are substantial, impacting state revenue, public health, and community stability. Therefore, a comprehensive analysis of PBS from technical and design perspectives is not merely an academic exercise but a practical necessity for strengthening national sovereignty and protecting border communities.

This research posits that the effectiveness of PBS cannot be achieved through conventional fence installation alone; it must be reconceptualized as a holistic border security architecture. The novelty of this study lies in its integrated analytical framework, which synthesizes principles of defense engineering, environmental criminology (specifically Crime Prevention Through Environmental Design—CPTED), and military operations research. By applying this framework to the Kalimantan context, the study moves beyond descriptive accounts to provide a diagnostic evaluation of current systems and a prescriptive model for future development, offering a significant departure from prior, more fragmented analyses.

In Indonesia, the implementation of PBS at the Kalimantan border is still partial, has not been nationally standardized, and tends to be treated as stand-alone physical infrastructure rather than an integrated security system. This creates a gap between the needs of modern border security and implementable practices on the ground. Therefore, this study departs from the argument that the effectiveness of PBS cannot be achieved only through the installation of conventional fences or barriers but must be reconceptualized as a border security architecture that integrates technical, design, environmental, and operational aspects in a holistic manner. This study aims to analyze the implementation of the Physical Barrier System in the border area of Kalimantan by examining its technical and design characteristics, as well as identifying the main gaps that limit its effectiveness in supporting border security operations.

The research question in this study is: How can the Physical Barrier System be implemented to prevent illegal border crossings at the Kalimantan border from technical and design perspectives?

METHOD

This research was carried out by conducting interview techniques with experts, policy makers, and practitioners from related agencies, including those conducted in the Jakarta area. The following are the agencies where the research is intended for data collection.

Table 1 Research Place

No.	Institution	Location
1	Dit Wilhan Ditjen Kemhan RI	Gedung A. Yani Jl. Medan Strahan Kemhan Merdeka Barat No.13-14
2	Badan Informasi Geospasial (BIG)	Jl. Raya Jakarta Bogor KM 46, Cibinong, Bogor, Jawa Barat 16911
3	Badan Nasional Pengelolaan Perbatasan (BNPP)	Jl. Kebon Sih No.37A, Rt 4/Rw 5, Kebon Sirih, Menteng, Jakarta
4	Sops TNI Mabes TNI	Jl. Parade Cilangkap, Jakarta Timur
5	Fakultas Strategi Pertahanan Unhan RI	Jl. Salemba Raya No.3, Rt.1/Rw.3, Paseban Jakarta Pusat
6	Deputi Bidang Wilayah Perbatasan Kemenko Polkam	Merdeka Barat No.15, Jakarta Pusat 10110

In this study, the independent variables were physical barrier systems studied from technical and design perspectives, including material and construction quality, resistance to the geographical conditions of the Kalimantan border, integration of supporting technologies, and design configurations that had deterrence and adaptive effects on threat dynamics. This variable represented how the physical barrier system was designed, constructed, and operated as an instrument for controlling border areas.

Meanwhile, the dependent variable was the effectiveness of preventing illegal border crossings, which was reflected in the ability of physical barrier systems to reduce the frequency of cross-border violations, improve early detection and response of authorities, and strengthen the control and security of border areas. The relationship between the two variables showed that the improvement of technical quality and design of physical barrier systems contributed directly to the optimization of the prevention of illegal border crossings at the Kalimantan border.

The researcher determined informants using the purposive sampling technique. The informants selected through this approach were expected to provide data and information in accordance with the research objectives. In the context of this study, the informants used as data sources came from agencies or institutions that were directly related to the research topic.

Table 2. Subjects and Objects of Research

No.	Name	Position	Institution
1	First Admiral Anis Rusdiyono, S.T., MM.	Director of Defense Areas, Directorate General of Defense Strategy	Ministry of Defense of the Republic of Indonesia

2	Marine Colonel Jimmy Pelupessy	Head of Border Region Division	Ministry of Political Affairs and Politics
3	Yudith Octora Sari	Head of the Negotiation Team	Geospatial Information Agency
4	Henry Erafat, S.T., MM.	Assistant Deputy for Land Border Management	National Border Management Agency
5	Lt. Col. Inf Khusnun Purwanto, S.I.P., M.Si., CHRP	Pabandya-1 Rensiap Ops Spaban IV	Sops TNI
6	Colonel Inf Dr. Sigit Purwanto, S.I.P., M.Si., CHRP	Head of Study Program SPD Unhan RI	Unhan RI

The research focused on the physical barrier system in preventing illegal border crossings to support border security operations in Kalimantan. This study also examined strategies implemented to maintain the security and defense of border areas against non-military threats in the Kalimantan region.

The researcher employed two forms of data collection: interviews with relevant informants and literature studies to obtain theoretical foundations and strengthen field findings.

1) Interviews: The researcher conducted structured conversations with key informants to gather primary data related to border security operations and the implementation of physical barrier systems.

2) Documentation: Documents served as complementary sources of data, including materials from informants and official records. Access to certain documents was obtained after ensuring confidentiality and confirming their use solely for research purposes.

To verify the validity of the data, this study used a triangulation approach to test the accuracy of research results by comparing various sources, methods, and perspectives (Basrowi & Suwandi, 2008; Creswell & Creswell, 2017; Hardani, 2020; Moleong, 2017; Nazir, 2014; Sudaryanto, 2015; Sugiyono, 2019).

The researcher applied source triangulation by comparing information from several informants with secondary data such as scientific articles, official documents, journals, field notes, reports, and related publications. Through this method, the researcher ensured the validity and consistency of the data obtained.

Data analysis was conducted to examine and interpret the findings. The researcher employed an interactive analysis model to systematically process the collected data.
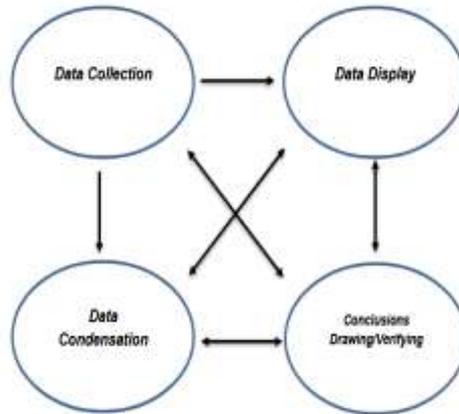
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The data analysis in this study referred to the interactive model of Miles, Huberman, and Saldaña (2014), which included three main stages: data condensation, data presentation, and conclusion drawing and verification. Data condensation was carried out continuously from the early stages of data collection through the process of selection, focusing, summarizing, and transforming data to remain aligned with the research problem formulation. At this stage, the researcher selected the most relevant information, summarized core meanings, and organized the data into more systematic analytical patterns to support the depth of interpretation.

The condensed data was then presented systematically in the form of analytical narratives, tables, and thematic matrices to facilitate the identification of patterns, relationships, and trends between data categories. This data presentation served as a basis to strengthen the analytical reasoning process and support comprehensive retrieval of meaning (Rijali, 2018).

The final stage, conclusion drawing and verification, was carried out iteratively throughout the research process. Initial tentative conclusions were continuously tested and refined through analytical reflection, review of field records, discussions with peers, and comparisons between data sources. This verification process aimed to ensure the consistency, credibility, and validity of the findings so that the conclusions produced had strong analytical accuracy and explanatory power.

RESULTS AND DISCUSSIONS
Empirical Conditions of Kalimantan Border Security

The results of the study show that the border area of Kalimantan is an area with a high level of security vulnerability due to a combination of geographical factors, limited infrastructure, and complexity of cross-border activities (Nations, 2022; OECD, 2019; Smith & Brown, 2021). The characteristics of the terrain in the form of dense forests, river channels, and the existence of unofficial routes (rat roads) create a wide maneuver space for illegal border crossers to smuggle goods, human crossings without documents, and transnational crimes (301/PKS, 2020; Crime, 2020). This condition places the security of the Kalimantan border as a strategic challenge for the country, not only in the context of regional defense, but also national security stability and the protection of state sovereignty (Andreas, 2003).

In this context, the Physical Barrier System (PBS) is the main instrument relied on to limit non-official mobility and strengthen state control over the border. However, field findings show

that the implementation of PBS in Kalimantan is still partial, uneven, and not fully systemically integrated.

Implementation of the Physical Barrier System at the Kalimantan Border

Empirically, the Physical Barrier System in the border area of Kalimantan is realized through a combination of physical fences, state border markers, State Cross Border Posts (PLBN), border parallel roads, and technology-based surveillance systems that are still limited. In West Kalimantan, the implementation of PBS is relatively more developed in major PLBNs such as Entikong and Aruk, which have been equipped with barbed wire fences, concrete stakes, and CCTV support at certain points (Hudallah, 2022). However, outside the main PLBN area, the security system still relies on simple fences and manual patrols, so that unofficial lanes remain open and vulnerable to exploitation.

In North Kalimantan, security conditions show a similar pattern. PLBN Nunukan (Sei Nyamuk and Sebatik) already has a limited combination of physical fences, guard posts, and electronic surveillance, while inland areas such as Krayan and the Krayan–Ba'kelalan border still rely on traditional physical barriers without the support of monitoring technology. A more vulnerable situation is found in East Kalimantan, particularly Mahakam Ulu, where physical security relies almost entirely on unfenced concrete boundary stakes and additional detection systems, making it a weak point in the border defense posture.

Table 3

Province	Location/PLBN	Installed Specifications	Information
West Kalimantan	PLBN Entikong	Barbed wire fence, concrete stakes, large CCTV with limited surveillance	Focus on PLBN
West Kalimantan	PLBN Aruk	Simple physical fence, reinforced near settlements, CCTV	Border near settlements, prone to illegal passers-by
West Kalimantan	PLBN Jagoi Babang	Fence & concrete stakes in rat path	Installation at the prone path point
West Kalimantan	PLBN Badau	Partial fence and manual sensor manual detection	Limited fence
West Kalimantan	PLBN Nanga Badau	Concrete stakes and barbed wire	There are no electronic surveillance standards yet
North Kalimantan	PLBN Nunukan	Barbed wire fence, guard post, multiple CCTV	Tighter supervision on the main PLBN
North Kalimantan	PLBN Krayan	Simple wire fence & boundary stakes	Limited to traditional physical fencing
North Kalimantan	PLBN Krayan Balkelalan	Wire fence & simple concrete stakes	Only wire fence
East Kalimantan	PLBN Mahakam Ulu	Concrete boundary stakes, minimal boundary fence	Without additional systems

These findings indicate that the PBS system in Kalimantan is still oriented towards securing point-based security, while area-based security has not been built optimally. As a result, illegal activities tend to shift from official channels to unofficial channels with minimal supervision.

3.3 Integration Level and Operational Readiness of the Physical Barrier System

The results of the analysis of the implementation of PBS show that although there have been modernization efforts through the use of motion sensors, CCTV, monitoring drones, and chip-based pegs, the operational readiness level of this system is still relatively low. Most devices are still in the development, trial, or technical repair stages, so they are not yet able to function as a layered and sustainable security system.

In addition, the integration between subsystems such as sensors, CCTV, alarms, and security posts has not been carried out in real-time and integrated. Detection information is often not directly connected to the nearest command center or patrol unit, so the response provided is reactive, not preventive. These findings confirm that PBS in Kalimantan currently functions more as a symbol of state presence (symbolic deterrence) than as an intelligent barrier system that is able to effectively prevent and predict illegal activities.

Tabel 4

No	Location	Barrier Type	Installation Purpose	Description	Installation Status
1	West Kalimantan	Fence	Preventing smuggling	10 km long	In the installation stage
2	North Kalimantan	Security Post	Strengthening surveillance	Equipped with CCTV	Already installed
3	Central Kalimantan	Patok	Marking the boundaries of the territory	Equipped chip	In the installation stage
4	West Kalimantan	Electronic Fence	Motion Sensor	Need improvement	Repair
5	East Kalimantan	Warning Signs	Raising awareness	Attached information	Already installed
6	North Kalimantan	Cross Border Post	Facilitate traffic	Complete facilities	In the process
7	Central Kalimantan	Communication Network	Coordination between posts	Built-in Radio	Already installed
8	West Kalimantan	Monitoring System	Activity monitoring	Test drones	In the test phase
9	East Kalimantan	Patrol Team	Routine patrol	Active	Need improvement
10	North Kalimantan	Alarm System	Early warning	Sound Alarm	Need improvement

## Patterns and Characteristics of Illegal Border Crossers

This study identifies that illegal border crossers in Kalimantan have an adaptive pattern to the existence of physical security. When supervision at PLBN was tightened, illegal activities shifted to rat paths spread across forest and inland areas. Illegal crossers generally do not have valid immigration documents, use unofficial routes, and have a variety of motives, ranging from traditional economics, labor without official procedures, to cross-border crimes such as drug and weapons smuggling (Migration, 2020).

Violation data for 2023–2024 shows that smuggling of goods is the most dominant form of offense, followed by illegal labor crossings and narcotics smuggling. The case handling rate reached around 79%, which shows that the performance of the apparatus is quite significant, but still leaves a security gap of 21% that is not addressed. This gap is directly correlated with

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the limitations of PBS, the difficult geographical terrain, and the limited number of personnel and support facilities (Perbatasan, 2023).

Tabel 5

No	Date	Violation	Location	Number of Violations	Information
1	2023-01-15	Smuggling groceries	West Kalimantan	10	8
2	2023-02-20	Illegal crossings	North Kalimantan	5	4
3	2023-03-10	Drug smuggling	Central Kalimantan	2	2
4	2023-04-05	Arms smuggling	West Kalimantan	1	1
5	2023-05-25	Illegal crossings	East Kalimantan	7	6
6	2023-06-12	Smuggling of goods	North Kalimantan	8	8
7	2023-07-15	Drug smuggling	Central Kalimantan	3	2
8	2024-08-20	Illegal crossings	West Kalimantan	4	3
9	2024-09-05	Smuggling of goods	East Kalimantan	6	5
10	2024-09-10	Arms smuggling	North Kalimantan	2	2
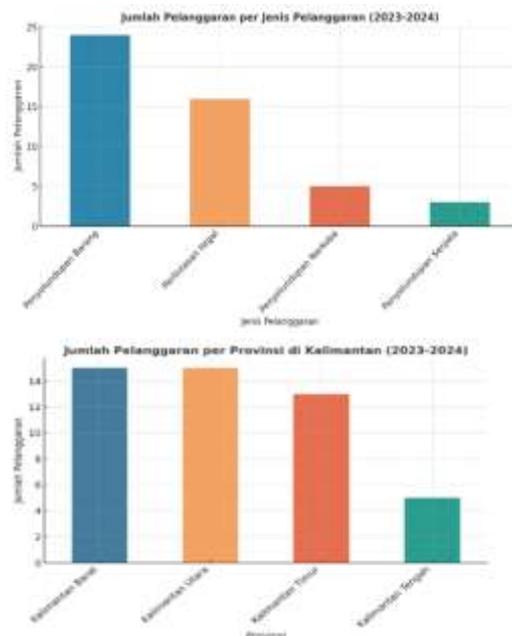
Gambar 2

Implications for Border Security Operations

The results of the study confirm that border security operations in Kalimantan are still highly dependent on conventional patrols and the presence of personnel in the field. With the length of the border line reaching more than 2,000 km and extreme geographical conditions, this approach is no longer adequate if it is not supported by an integrated and technology-based physical barrier system.

The absence of a nationally connected early detection system has led to a slow and fragmentary security response. Therefore, PBS should not be understood only as a purely physical infrastructure, but as part of a multi-layered defense system that combines physical barriers, detection technology, integrated command systems, as well as cross-sector operational support.

Tabel 6

Threat Type	Description	Location/Area	Impact & Conditions
Smuggling of illegal goods	Cigarettes without excise duty, onions, frozen meat, alcoholic beverages enter through the mouse line	West Kalimantan	State losses of trillions of rupiah, weak laws
Weaknesses of law enforcement	Apparatus tends to compromise, many cases are not followed up	Borneo Border	Loss of public confidence in law enforcement
Illegal passers risk of crime	Illegal passers-by are at risk of entering and engaging in illegal activities such as drugs	Indonesian Borders	Security and drug threats at the border
Effects of PLBN development	Strict supervision at Plbn Entikong, Aruk, Badau	Entikong, Aruk, Badau	Supervision is more effective in PLBN but the transfer to another line that has a permanent guard post

Synthesis of Research Findings

Overall, the results of the study show that the Physical Barrier System at the Kalimantan border has made an initial contribution in strengthening regional security, especially on official cross-border routes. However, this system has not been able to significantly suppress illegal border crossing activities because of its uneven, unintegrated, and predominantly reactive nature. This condition emphasizes the urgency of reframing the PBS concept, from just a physical barrier to an Integrated Smart Border System that is adaptive to the geographical characteristics, threat patterns, and security dynamics of Kalimantan's border.

The results of the study show that the implementation of *the Physical Barrier System* (PBS) on the Kalimantan border has conceptually been designed as an integral part of a layered and adaptive regional defense system. From the policy aspect, PBS is a direct derivative of the doctrine of territorial defense as stated in the White Paper on State Defense and the Strategic Plan of the Ministry of Defense, which places border areas at the forefront of maintaining state sovereignty. This approach emphasizes that PBS is not positioned solely as a physical barrier, but rather as a strategic instrument that supports deterrence, situational awareness, and control of border areas (Clarke, 2018).

From a technical and design perspective, the implementation of PBS in Kalimantan shows an adaptive character to the complexity of the geographical terrain. The barrier structure is designed using corrosion-resistant materials and a flexible configuration to deal with unstable soil conditions, swamps, and dense tropical forests. The technical design is combined with technology-based monitoring systems, such as motion sensors, CCTV with night vision capabilities, and drone surveillance support, which are integrated into the security communication network. This integration makes PBS no longer passive, but serves as part of an early detection and rapid response system for illegal cross-border activity.

The effectiveness of PBS is empirically seen in its ability to slow and limit the mobility of illegal border crossers, especially in vulnerable sectors that were previously unofficial routes. Although PBS has not completely closed all crossing gaps, its existence has been proven to increase the efficiency of security operations by shortening the response time of the authorities, strengthening control of the area, and facilitating early detection. These findings confirm that

the effectiveness of PBS relies heavily on its synergy with ground patrols, security posts, and ongoing system maintenance.

In terms of governance, this study shows that the implementation of PBS involves a complex cross-sector coordination structure. The Ministry of Defense plays the role of determining strategic policies and defense standards, while the TNI, especially the TNI AD and the Pamtas Task Force, acts as the operational implementer in the field. The role of BNPP, the Ministry of Public Works and Housing, the Geospatial Information Agency (BIG), and the Coordinating Ministry for Political Affairs and Legal Affairs is crucial in ensuring the synchronization of technical aspects, construction design, spatial planning, and spatial data integration. This pattern of coordination reflects that the success of PBS is determined not only by technical quality, but also by the effectiveness of interagency coordination mechanisms.

The determination of the focus area of PBS implementation is based on an analysis of the level of vulnerability and tactical needs in the field. The border areas of West Kalimantan and North Kalimantan, such as Entikong, Badau, Sebatik, Nunukan, and Krayan, are prioritized due to the high intensity of illegal cross-border activities and the relatively open nature of the terrain to violations. The use of high-resolution geospatial data is a key factor in accurately determining the location of PBS placements, while minimizing the risk of design failure due to incompatibility with environmental conditions.

From the aspect of planning and evaluation, the implementation of PBS is carried out gradually and continuously, in line with the defense force development cycle. Periodic technical evaluations are an important mechanism for assessing the durability of materials, the reliability of detection systems, and the suitability of design to threat dynamics and environmental changes. The results of the evaluation are used as a basis for design adjustments, material quality improvements, and the integration of more advanced surveillance technology, so that PBS remains relevant and effective in the long term.

The integration of PBS with other security systems such as border posts, joint patrols, and aerial surveillance is a decisive factor in building a comprehensive border defense system. Adaptive engineering approaches based on geospatial analysis and threat maps allow PBS to function as part of a dynamic defense system rather than just a static infrastructure (Hudson et al., 2018). Thus, the implementation of PBS at the Kalimantan border reflects a paradigm shift in border security from a conventional approach to an integrated, coordinated, and early prevention-oriented smart border system.

CONCLUSION

This study concluded that the Physical Barrier System (PBS) at the Kalimantan border was an effective strategic instrument in preventing illegal border crossings when designed and applied adaptively to geographical conditions, supported by modern surveillance technology, and integrated within a multi-layered territorial defense framework. From technical and design perspectives, PBS functioned not merely as a passive physical barrier but as an active defense system element that strengthened situational awareness, accelerated operational responses, and increased territorial control by security forces. Field findings revealed that PBS effectiveness was largely determined by structural design quality, selection of materials suited to Kalimantan terrain characteristics, and integration of sensor-based detection systems, CCTV, and aerial

monitoring. The implementation of PBS was proven to reduce the intensity of illegal border crossings in vulnerable sectors, particularly on unofficial routes previously difficult to supervise; however, the system had not completely closed all illegal crossing loopholes and still required active patrol support, ongoing maintenance, and periodic technical evaluations. From an institutional perspective, PBS success was supported by clear role divisions between the Ministry of Defense as strategic policy maker, the TNI as operational implementer, BNPP as border management coordinator, and other technical agencies such as the Ministry of PUPR and the Geospatial Information Agency (BIG), with effective cross-sectoral coordination serving as a key factor in ensuring alignment between PBS technical design, territorial defense doctrine, and national spatial policy. Thus, PBS made a real contribution to strengthening state sovereignty and security stability in the Kalimantan border area. Future research should examine the long-term cost-effectiveness of PBS implementation, explore the integration of emerging technologies such as artificial intelligence and autonomous surveillance systems, and conduct comparative analyses with PBS implementations in other tropical border contexts to develop region-specific best practices.

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