



Aligning Artificial Insemination and Vaccination for Sustainable Beef Cattle Populations

Asep Budi Santoso¹

¹Livestock Development Planning, Department of Fisheries and Livestock, Purwakarta Regency, West Java, Indonesia



*Corresponding Author: Asep Budi Santoso

Article Info

Article history:

Received 12 August 2026

Received in revised from 2

September 2026

Accepted 26 September 2026

Keywords:

Artificial Insemination

Vaccination

Beef Cattle

Policy Alignment

Purwakarta

Abstract

This study evaluates the alignment of artificial insemination and livestock vaccination services as complementary interventions for sustaining the beef cattle population in Purwakarta Regency, Indonesia. A descriptive policy-analysis design was applied to secondary administrative data from 2023–2025, including livestock service performance, vaccination records, population statistics, planning documents, budgets, and the institutional risk register. Trend, gap, strengths–weaknesses–opportunities–threats, policy-option, and risk analyses were used. Artificial insemination performance improved in 2025: the number of acceptors rose by 4.39 percent, pregnancies increased by 4.01 percent, and services per conception declined from 1.51 to 1.47. However, births declined slightly, while foot-and-mouth disease vaccination dropped from 95,539 animals in 2024 to 11,283 in 2025. Service targets, locations, timing, and databases were not systematically connected, limiting the ability to verify whether cattle generated through reproductive services received adequate health protection. The preferred policy is a data- and risk-based alignment model that uses acceptor location, animal population, disease risk, and service history to prioritize vaccination without creating a new program or reallocating formal authority. Integrating service data into annual planning can improve targeting, budget efficiency, accountability, and the durability of population gains. The findings show that reproductive output should be assessed together with animal-health protection rather than as an isolated performance measure.

Introduction

Beef cattle production is central to food security, rural livelihoods, and household asset formation in many Indonesian smallholder systems. In Purwakarta Regency, livestock are not only productive units but also stores of value that help rural households manage income shocks. Sustaining the cattle population therefore requires more than generating additional births; it requires a service system that protects reproductive animals and their offspring from preventable disease. This distinction is especially important where public interventions are delivered by different technical units and are evaluated through separate annual targets (Wienert et al., 2022; Papadakis & Katsaprakakis, 2023; Cenci et al., 2023).

Artificial insemination is widely used to accelerate genetic improvement and increase the reproductive output of cattle. Its effectiveness is commonly monitored through the number of acceptors, pregnancies, births, conception rate, and services per conception (Firman et al., 2023; Sumual et al., 2024). Evidence from Indonesian smallholder cattle indicates that reproductive performance depends on accurate estrus detection, timing, nutrition, parity, and husbandry, so an improved services-per-conception value is informative but not sufficient to establish sustainable herd growth (Isnaini et al., 2019). International evidence similarly shows that artificial insemination can improve pregnancy outcomes when reproductive management

is timely and well organized (Baruselli et al., 2018; Sitko et al., 2023; Rial et al., 2022; Kakkar et al., 2025).

Animal health is the complementary condition for retaining these reproductive gains. Foot-and-mouth disease can produce major production losses and disrupt animal movement, markets, and household income (Humphreys et al., 2025; Kargbo & Bangura, 2024; Khumalo et al., 2026). Indonesia experienced the re-emergence of the disease in 2022 after decades of freedom, and outbreaks in Java displayed significant spatial clustering associated with cattle populations, livestock markets, slaughterhouses, and environmental conditions (Kedang et al., 2025; Aranguiz et al., 2024). Lumpy skin disease also spread in West Java during 2023; a study in Cirebon recorded cases across 82 villages and emphasized the economic and animal-welfare consequences for cattle production (Murti et al., 2024). These events demonstrate that population policy and animal-health policy cannot be treated as unrelated operational domains.

Vaccination is a major disease-control instrument, but its impact depends on coverage, vaccine quality and matching, timing, surveillance, and implementation strategy. Field evaluations show that inadequate coverage can sharply constrain the epidemiological protection produced by vaccination (Knight-Jones et al., 2014). Modelling studies further indicate that early vaccination, combined with other sanitary measures, can reduce outbreak magnitude and duration (Rawdon et al., 2022). The World Organisation for Animal Health (2024) consequently places vaccination within a broader control system that includes surveillance, biosecurity, movement management, and evidence-based targeting. Thus, this article does not assume that vaccination alone guarantees freedom from disease; rather, it treats vaccination as the preventive intervention most directly comparable with the existing reproductive service data.

Purwakarta provides a useful local policy case. Artificial insemination was delivered across 17 subdistricts and its pregnancy indicators improved in 2025. During the same period, reported foot-and-mouth disease vaccination decreased substantially. The available records did not directly link artificial insemination acceptors, pregnancy outcomes, births, and vaccination status at animal or service-location level. Consequently, managers could not readily determine whether the animals contributing to reproductive targets were included in preventive-health priorities. This data separation creates a policy gap even when each technical unit performs its formal mandate.

The study asks how the performance of artificial insemination and vaccination evolved during 2023–2025, where the principal alignment gaps occurred, and which feasible policy option could improve sustainable population outcomes. It aims to formulate an implementable model that aligns targets, locations, service timing, information, annual planning, and budgets while preserving the existing division of authority. The central proposition is that data- and risk-based alignment will produce a more credible pathway to sustainable population growth than continuing to manage reproductive and preventive-health services as separate performance streams.

Methods

Research Design and Study Setting

This study employed a descriptive policy-analysis design to examine the alignment between artificial insemination and preventive animal-health services for beef cattle population sustainability. The study was conducted in Purwakarta Regency, West Java, Indonesia, with the local government service system for cattle reproduction and preventive animal health serving as the unit of analysis. The observation period covered 2023–2025, allowing the study

to identify recent performance trends and assess the relationship between reproductive-service delivery and preventive-health implementation during the transition to the 2025–2029 strategic-planning period.

The study was designed as a non-experimental analysis of administrative and policy records. No experimental treatment, intervention, or direct animal-level observation was conducted. Accordingly, the analysis was not intended to estimate individual-level vaccine effectiveness, establish biological causality, or determine the causal contribution of artificial insemination to changes in the cattle population. Instead, the study focused on identifying administrative patterns, implementation gaps, and feasible mechanisms for improving policy coordination between reproductive and animal-health services.

Data Sources and Variables

The analysis relied primarily on secondary administrative and policy data obtained from the Purwakarta Regency Department of Fisheries and Livestock. The principal documents included the 2025 institutional performance accountability report, the 2025–2029 strategic plan, annual financial records covering 2023–2025, and the 2025 institutional risk register. These sources were selected because they collectively provide information on program performance, policy targets, resource allocation, operational risks, and institutional responsibilities.

The variables extracted from the administrative records included artificial-insemination acceptors, artificial-insemination services, recorded pregnancies, births attributed to artificial insemination, births from natural mating, services per conception, calving rate, cattle population, foot-and-mouth disease vaccination outputs, anthrax vaccination outputs, program expenditures, strategic performance targets, and documented operational risks. Information concerning service locations, planning arrangements, data identifiers, and coordination mechanisms was also examined to assess the extent to which reproductive and preventive-health services were operationally connected.

Published scientific literature and international animal-health guidance were used as contextual and interpretive sources. These materials were not treated as primary evidence of Purwakarta's local performance. Instead, they were used to interpret the administrative findings, particularly with respect to reproductive performance, vaccination, disease risk, spatial targeting, and animal-health management.

Data Collection and Data Management

Data collection was conducted through systematic documentary review. Relevant numerical and qualitative information was extracted from the identified government records and organized according to the study variables and analytical dimensions. Numerical data were arranged chronologically for 2023, 2024, and 2025 to facilitate year-to-year comparison. Qualitative information concerning strategic objectives, institutional arrangements, operational risks, and service coordination was coded according to recurring policy and implementation themes.

The study retained the measurement units reported in the original administrative records. In particular, vaccination figures were treated as recorded vaccination outputs rather than cattle-specific vaccination coverage rates. This distinction is important because the reported vaccination totals include susceptible livestock species other than cattle, and the same animal may receive more than one vaccination according to disease-control schedules. Therefore, vaccination outputs were used to identify changes in service delivery and potential discontinuity rather than to estimate the proportion of cattle protected against disease.

Similarly, annual population figures were treated as aggregate administrative estimates. Changes in population were not attributed directly to artificial insemination or vaccination because the available records did not permit simultaneous assessment of births, deaths, purchases, sales, livestock movements, slaughter, and possible recording adjustments at the individual or herd level.

Data Analysis

The analysis was conducted in five sequential stages. First, descriptive trend analysis was used to examine changes in reproductive performance, preventive-health services, cattle population, and relevant expenditure between 2023 and 2025. Particular attention was given to changes between 2024 and 2025 to identify recent patterns in program implementation. Year-to-year changes were calculated from the administrative records, while percentage-point changes were used for indicators reported as percentages.

Second, a policy gap analysis was undertaken to determine whether reproductive and preventive-health services were connected through common targets, geographical locations, service timing, information systems, and identifiers. The analysis focused on five dimensions: target alignment, spatial alignment, data alignment, timing alignment, and planning and budget alignment. Evidence from the administrative records was compared across these dimensions to identify areas in which the two service streams remained operationally separated.

Third, a strengths–weaknesses–opportunities–threats (SWOT) analysis was applied to the institutional and implementation conditions identified in the administrative records. Internal strengths and weaknesses were derived from existing service arrangements, institutional responsibilities, data availability, and implementation capacity. External opportunities and threats were identified from disease-risk conditions, budget constraints, livestock movements, market connections, and the broader animal-health environment.

Fourth, policy-option analysis was conducted to compare two implementation approaches: continuation of the existing separated service model and a data- and risk-based alignment model. The options were examined according to problem fit, institutional change, cost implications, cross-unit coordination, data utilization, targeting accuracy, and expected contribution to population sustainability. The comparison was descriptive and did not involve numerical scoring or inferential statistical testing.

Fifth, the proposed alignment model was assessed against the institutional risk register to identify implementation safeguards. Documented risks concerning infectious animal disease, livestock movement, veterinary-service limitations, data quality, and operational oversight were mapped against the proposed controls. The findings were subsequently used to formulate a phased implementation framework covering governance and data standardization, spatial and risk-based service prioritization, annual planning integration, monitoring, and gradual scale-up.

Policy Alignment Framework

The analytical framework conceptualized sustainable cattle population management as an interconnected results chain linking reproductive services, preventive animal health, population retention, and institutional planning. Artificial-insemination performance was therefore not interpreted as an isolated measure of population growth. Instead, reproductive outputs were examined together with preventive-health protection and the institutional mechanisms required to connect the two.

The proposed alignment model uses artificial-insemination acceptor locations and service histories as one source of targeting information, while maintaining disease risk, cattle concentration, outbreak history, livestock movement, vaccine eligibility, and other animal-health considerations as additional determinants of vaccination priorities. This approach was deliberately designed to operate within the existing institutional structure rather than create a new program or transfer formal authority between technical units.

Analytical Credibility and Limitations

Several procedures were applied to strengthen the credibility of the analysis. First, numerical findings were cross-checked across the available performance, planning, financial, and risk documents. Second, administrative trends were interpreted alongside relevant scientific literature and international animal-health guidance. Third, potentially misleading indicators were explicitly qualified, particularly vaccination outputs that could not be converted into cattle-specific coverage rates. Fourth, causal claims were avoided where the administrative data could not support them.

The principal limitation is the aggregate and retrospective nature of the available data. The records did not provide a consistently linked individual-animal or herd-level identifier connecting artificial insemination, pregnancy diagnosis, calving, vaccination, disease status, movement, and subsequent population outcomes. Consequently, the study can identify administrative discontinuities and formulate a feasible policy-alignment mechanism, but it cannot establish that artificial insemination or vaccination caused the observed annual population changes. Future studies should therefore employ longitudinal individual- or herd-level data to examine reproductive outcomes, vaccination status, calf survival, disease incidence, livestock movement, and economic returns.

Results and Discussion

This section presents the empirical findings from the analysis of administrative, planning, financial, and institutional risk records for 2023–2025. The results are organized according to the analytical procedures specified in the methodology, beginning with trends in reproductive and preventive-health service performance, followed by the identification of administrative alignment gaps. The findings then present the institutional SWOT assessment, comparison of the two policy options, risk safeguards for the proposed alignment model, and the resulting phased implementation framework. The analysis focuses on documented administrative patterns and does not interpret the observed changes as evidence of direct causal effects between artificial insemination, vaccination, and cattle population dynamics.

Trends in Reproductive and Preventive-Health Service Performance

The administrative records show different patterns between artificial-insemination performance and preventive animal-health services during 2023–2025. Several intermediate reproductive indicators improved in 2025, while vaccination outputs declined substantially. Table 1 summarizes the main reproductive and preventive-health indicators recorded during the three-year observation period.

Table 1. Reproductive and Preventive-Health Performance, 2023–2025

Indicator	2023	2024	2025	Change 2024–2025
Artificial-insemination acceptors (head)	2,305	2,232	2,330	+4.39%
Artificial-insemination services (head)	2,340	2,315	2,300	–0.65%
Pregnancies (head)	1,529	1,523	1,584	+4.01%

Births from artificial insemination (head)	2,189	1,859	1,847	−0.65%
Services per conception	1.53	1.51	1.47	−2.65%
Calving rate	71.46%	68.63%	67.98%	−0.65 points
Foot-and-mouth disease vaccinations (head)	23,583	95,539	11,283	−88.19%
Anthrax vaccinations (head)	17,567	7,103	6,112	−13.95%

Source: Processed from the Purwakarta Regency Department of Fisheries and Livestock performance records, 2023–2025

The number of artificial-insemination acceptors increased from 2,232 in 2024 to 2,330 in 2025, representing a 4.39% increase. Recorded pregnancies also increased from 1,523 to 1,584, or 4.01%. At the same time, services per conception declined from 1.51 to 1.47. Thus, the records indicate improvement in several intermediate reproductive-service indicators in 2025.

The increase in these intermediate indicators was not accompanied by an equivalent increase in recorded births. Births attributed to artificial insemination decreased from 1,859 in 2024 to 1,847 in 2025, while births from natural mating remained at 316. The recorded calving rate also declined from 68.63% to 67.98%. The difference between pregnancy and birth indicators indicates that annual administrative series do not necessarily represent the same biological cohort because pregnancies recorded during one period may result in births during a subsequent period. The preventive-health indicators show a substantially different pattern. Foot-and-mouth disease vaccination increased from 23,583 recorded vaccinations in 2023 to 95,539 in 2024, before falling sharply to 11,283 in 2025. The 2025 figure represents an 88.19% decline from the 2024 output. Anthrax vaccination also decreased from 7,103 in 2024 to 6,112 in 2025, equivalent to a 13.95% decline.

These vaccination figures represent recorded service outputs rather than cattle-specific vaccination coverage. The administrative records include susceptible livestock species beyond cattle, and repeated vaccination of the same animal may occur under disease-control schedules. Therefore, the observed decline is treated as evidence of a substantial change in preventive-health service delivery rather than as a direct measure of the proportion of cattle without immunity. The cattle population also displayed a non-linear pattern during the study period. The recorded population decreased from 13,901 head in 2023 to 10,066 in 2024 and then increased modestly to 10,206 in 2025. The 2024–2025 increase was approximately 1.39%. However, the available aggregate records do not identify the contribution of births, deaths, purchases, sales, livestock movements, slaughter, or administrative adjustments to this change.

Administrative Alignment Gaps

The gap analysis identified five dimensions in which artificial-insemination and preventive-health services were not systematically connected: targets, locations, data, timing, and planning. Table 2 presents the observed gaps and the minimum controls identified from the administrative analysis.

Table 2. Alignment Gaps and Minimum Control Requirements

Dimension	Observed gap	Minimum control
Target	Artificial-insemination acceptors are not routinely considered in vaccination targeting.	Use acceptor, herd, population, and risk data to define priority lists.

Location	Service locations are planned separately.	Overlay service maps and agree priority villages and subdistricts.
Data	No common identifier links insemination, pregnancy, birth, and vaccination.	Adopt a minimum shared dataset with validation and access controls.
Timing	Reproductive follow-up and preventive-health schedules are not connected.	Coordinate pregnancy, calving, calf-health, and vaccination windows.
Planning	Targets and budgets are evaluated by activity rather than joint outcome.	Include alignment indicators and cross-unit review in annual planning.

Source: Analysis of Purwakarta Regency Department of Fisheries and Livestock administrative, planning, and risk records, 2023–2025

The first gap concerns target alignment. Artificial-insemination acceptors were recorded as part of reproductive-service performance but were not systematically incorporated into preventive-health priority setting. Consequently, reproductive-service performance could be monitored independently from the animal-health status of the animals or herds contributing to reproductive outputs.

The second gap concerns spatial alignment. Both reproductive and animal-health services operate geographically, but the available records did not demonstrate a routine process for overlaying reproductive-service locations with cattle concentration, disease risk, outbreak history, or other spatial risk information. This limits the ability to identify priority areas through a common geographical framework. The third gap is related to information management. The records did not provide a stable common identifier connecting artificial insemination, pregnancy, birth, and vaccination histories. As a result, the administrative system could not consistently determine whether animals or herds receiving reproductive services also had a documented preventive-health status. The fourth gap concerns timing. Reproductive follow-up, pregnancy diagnosis, calving, calf-health management, and vaccination activities were not systematically connected within a shared service calendar. The fifth gap concerns annual planning and budgeting, where reproductive and animal-health activities were maintained as separate activity lines. Consequently, changes in one service stream were not automatically incorporated into assessment of the operational implications for the other.

Institutional SWOT Findings

The SWOT analysis identified institutional strengths and weaknesses within the existing service arrangement and external opportunities and threats affecting implementation. The findings were derived from the administrative performance records, strategic plan, financial records, risk register, and identified alignment gaps rather than from a separate scoring exercise.

The principal institutional strength was the existence of established reproductive and animal-health functions within the local government structure. The two technical service streams already generate routine administrative records, maintain defined responsibilities, and operate through geographically distributed field services. The existing strategic framework also contains population-growth and animal-disease objectives, providing an institutional basis for connecting reproductive and preventive-health outcomes. The main institutional weaknesses were fragmented information systems, separate service targets, limited linkage between reproductive and vaccination records, and the absence of shared identifiers. Separate planning

and budgeting processes further reduced the visibility of joint outcomes. These weaknesses make it difficult to determine whether reproductive gains are being adequately protected through preventive-health measures.

The main opportunities were the availability of existing administrative data, the possibility of spatially prioritizing services, and the integration of minimum common data fields into annual planning without establishing a new program. The disease-risk information available from broader surveillance and livestock movement patterns also provides a basis for improving geographic targeting. The principal threats included infectious animal-disease risks, livestock movement, resource constraints, limited veterinary-service capacity, and weaknesses that may arise from poorly managed digital information. These threats indicate that alignment requires not only data linkage but also safeguards for data quality, access, and operational decision-making.

Comparison of Policy Options

Two policy options were identified from the analysis: continuation of the separated service model and data- and risk-based alignment. Table 3 summarizes their documented characteristics across the seven assessment criteria.

Table 3. Comparison of Policy Options

Criterion	Separated status quo	Data- and risk-based alignment
Problem fit	Moderate	High
Institutional change	Low	Moderate process adjustment
Additional cost	Relatively low	Low to moderate
Cross-unit coordination	Low	High
Data use	Separate datasets	Linked minimum dataset
Targeting accuracy	Moderate	Higher
Population sustainability	Not demonstrable	More directly supported

Source: Policy-option analysis based on Purwakarta Regency administrative, planning, financial, and risk records

The separated status quo requires limited institutional adjustment and retains existing administrative boundaries. However, the analysis shows that it cannot adequately establish whether reproductive gains are being protected by preventive-health services. Under this arrangement, each technical unit may report its respective activities without a shared mechanism for evaluating their contribution to a combined population outcome.

The data- and risk-based alignment option requires greater coordination but does not require the creation of a new formal program or transfer of technical authority. Under this option, artificial-insemination acceptor information becomes one input into vaccination prioritization alongside disease risk, cattle concentration, outbreak history, livestock movement, and vaccine eligibility. The analysis therefore identifies this option as providing a more direct operational pathway for connecting the two existing service streams without treating artificial-insemination participation as the sole basis for vaccination decisions.

Risk Safeguards and Implementation Requirements

The risk analysis identified both existing institutional risks and additional risks associated with data integration. Existing risks included delayed control of infectious animal disease, inadequate oversight of livestock movement, and limited veterinary-service capacity. The

proposed alignment mechanism addresses these risks through earlier geographic prioritization, traceable service status, and coordinated field deployment.

Data integration also creates specific operational risks. These include incorrect matching of records, duplicate entries, unauthorized access, outdated information, and decisions based on incomplete records. The analysis therefore identified several minimum safeguards, including role-based access, mandatory data fields, duplicate detection, timestamped record changes, supervisory review, routine reconciliation, and a documented manual procedure for periods of connectivity failure.

The implementation analysis produced a phased framework. During the first three months, the required actions are to define data governance, establish common data fields, standardize definitions, reconcile existing records, and select pilot locations. The expected output is a cleaned baseline and an approved minimum dataset. During months four to six, joint risk reviews, field targeting, record reconciliation, and exception follow-up are proposed, producing a prioritized service list and monitoring dashboard. During the subsequent annual planning cycle, evaluated evidence from the pilot is intended to inform targets, service schedules, and budget priorities. District-wide expansion is conditional on meeting agreed data-quality and workflow-usability thresholds.

Table 4. Phased Implementation Framework

Phase	Key actions	Primary output
0–3 months	Define governance, common fields, validation rules, and pilot locations.	Clean baseline and approved minimum dataset.
4–6 months	Conduct joint risk review, field targeting, reconciliation, and exception follow-up.	Priority service list and monitoring dashboard.
Next planning cycle	Use evaluated results to set targets, schedules, and budget priorities.	Aligned annual work plan and indicators.
Scale-up	Expand after data-quality and workflow-usability thresholds are met.	Sustainable district-wide operating model.

Source: Author's synthesis based on the administrative gap analysis and institutional risk assessment, 2025

The resulting framework establishes a progression from administrative standardization to joint targeting, planning integration, and controlled expansion. The findings indicate that the principal implementation requirement is not the creation of a new institutional structure but the establishment of shared information, spatial prioritization, coordinated timing, and joint planning mechanisms within the existing service system.

The findings demonstrate that improving reproductive-service performance does not automatically translate into a coherent strategy for sustainable cattle-population management. The increase in artificial-insemination acceptors and pregnancies, together with the reduction in services per conception, is consistent with recent evidence that reproductive efficiency depends on the organization, timing, recording quality, and technical management of artificial-insemination programs (Mekonnen & Gebremariam, 2024; Allan et al., 2024). Recent reviews of timed artificial insemination similarly emphasize that reproductive outcomes are shaped by the synchronization of biological and management processes rather than by insemination activity alone (Monteiro et al., 2023; Sartori et al., 2023). The decline in recorded births despite improved intermediate reproductive indicators therefore reinforces the importance of

longitudinal monitoring from insemination and pregnancy through calving and subsequent calf outcomes.

The simultaneous instability of preventive-health services provides an important additional dimension. The sharp decline in recorded FMD vaccinations in 2025 indicates that reproductive and disease-control services were not operating as a sufficiently integrated results chain. This finding is particularly relevant in Indonesia, where FMD re-emerged in 2022 and disease risk has subsequently demonstrated important spatial dimensions. Recent research in West Java identified environmental and socioeconomic activity associated with cattle production as relevant factors in the spatial distribution of FMD, supporting the need for geographically differentiated disease-control strategies (Dede et al., 2025; Kedang et al., 2025; Zewdie et al., 2023; Prasetya et al., 2025; Gunasekera et al., 2026). Evidence on vaccination and reproduction also indicates that timing matters. Experimental research has shown that the reproductive consequences of vaccination can vary according to the stage of pregnancy, while other studies have reported acceptable pregnancy outcomes when vaccination was appropriately positioned within reproductive protocols (Garcia-Pintos et al., 2021; Stewart et al., 2023). The implication for Purwakarta is not that vaccination should be avoided around reproductive services, but that reproductive calendars and animal-health schedules should be coordinated according to veterinary evidence.

The most significant contribution of this study is therefore organizational rather than technological. The identified target, spatial, timing, and identifier gaps illustrate a broader problem of sectoral information silos. Research on One Health surveillance has similarly shown that independently maintained information systems restrict data exchange and coordinated response, whereas common datasets and interoperable reporting structures can improve surveillance and decision-making (Shanbehzadeh et al., 2022; Kahariri et al., 2024). Recent One Health frameworks further emphasize that data integration becomes more valuable when it enables joint analysis and coordinated action rather than simply connecting databases (Oltean et al., 2025; FAO, 2024). In livestock systems, developments in digital traceability likewise demonstrate the growing importance of linking animal-health information with identifiable production and movement events (Papa et al., 2024; Alvarado et al., 2026).

The theoretical contribution is the extension of livestock population sustainability from a predominantly reproductive-performance perspective toward an integrated reproductive–health–information governance model. The study shows that AI acceptors can function as one targeting input for preventive-health planning, while disease risk, cattle concentration, movement, outbreak history, and vaccine eligibility remain independent decision criteria. Practically, this means that alignment can be achieved within existing institutional authority through a minimum shared dataset, spatial prioritization, coordinated service timing, and joint annual planning rather than through creation of a new program.

Several limitations should be acknowledged. The study uses aggregate administrative records and cannot establish individual-level causal relationships between AI, vaccination, disease protection, and population change. Vaccination outputs also cannot be interpreted as cattle-specific coverage. Future research should therefore develop longitudinal animal- or herd-level datasets linking reproductive services, vaccination, disease status, movement, calf survival, and economic outcomes. Such evidence would allow the proposed alignment model to be evaluated through measurable effectiveness and cost-effectiveness indicators.

Conclusion

Purwakarta's artificial-insemination program improved acceptor, pregnancy, and services-per-conception indicators in 2025, but births declined slightly and preventive-health delivery was unstable, most visibly in the sharp reduction in recorded foot-and-mouth disease vaccinations. Because reproductive and vaccination records were not connected by shared targets, locations, timing, or identifiers, the existing system could not demonstrate whether reproductive gains were adequately protected. The most feasible response is a data- and risk-based alignment model within existing authority: use reproductive-service data as one input to geographically prioritized vaccination, connect service histories through a minimum common dataset, and incorporate joint indicators into annual planning. The department should pilot the model, establish data-governance and quality controls, retain surveillance and movement management as complementary measures, and expand only after verifying usability and record completeness. Future research should evaluate individual- or herd-level longitudinal outcomes, including vaccination status, pregnancy, calving, calf survival, movements, and economic effects, so that the causal contribution and cost-effectiveness of aligned services can be tested more rigorously.

Acknowledgment

The author acknowledges the Purwakarta Regency Department of Fisheries and Livestock for the administrative planning and performance records used in this policy analysis. No external research grant was reported for this study.

References

- Allan, F. K., MacVicar, I. S., Peters, A. R., & Schnier, C. (2024). Systematic map of recent evidence on reproductive performance of cattle in Africa. *Tropical Animal Health and Production*, 56(7), 218. <https://doi.org/10.1007/s11250-024-04074-z>
- Aranguiz, A. A., Setiabudi, F. H., & Spoelstra, M. (2024). Trends and outlook of dairy production in Java, Indonesia. *Wageningen Livestock Research, Public Report*, 1522, 24-25. <https://doi.org/10.18174/676664>
- Baruselli, P. S., Ferreira, R. M., Sá Filho, M. F., & Bó, G. A. (2018). Review: Using artificial insemination v. natural service in beef herds. *Animal*, 12(S1), s45–s52. <https://doi.org/10.1017/S175173111800054X>
- Belsham, G. J. (2020). Towards improvements in foot-and-mouth disease vaccine performance. *Acta Veterinaria Scandinavica*, 62, 20. <https://doi.org/10.1186/s13028-020-00519-1>
- Cenci, S., Burato, M., Rei, M., & Zollo, M. (2023). The alignment of companies' sustainability behavior and emissions with global climate targets. *Nature Communications*, 14(1), 7831. <https://doi.org/10.1038/s41467-023-43116-2>
- Dede, M., Sunardi, S., Widiawaty, M. A., Ismail, A., Lam, K. C., Afriana, N. N., ... & Susiati, H. (2025). Spatial distribution and environmental factors analysis of foot-and-mouth disease (FMD) in West Java, Indonesia. *Cogent Food & Agriculture*, 11(1), 2440549. <https://doi.org/10.1080/23311932.2024.2440549>
- Firman, A., Kuswaryan, S., Nurlina, L., Hadiana, M. H., Sulistyati, M., Yunasaf, U., ... & Trisman, I. (2023). Valuation of massive artificial insemination programs and the economic impact for Indonesia. *Adv. Anim. Vet.-Sci*, 11, 1037-1046. <https://doi.org/10.17582/journal.aavs/2023/11.7.1037.1046>

- Food and Agriculture Organization. (2024). Data integration for improved epidemic response and animal disease intelligence.
- Garcia-Pintos, C. G., Riet-Correa, F., & Menchaca, A. M. (2021). Effect of foot-and-mouth disease vaccine on pregnancy failure in beef cows. *Frontiers in Veterinary Science*, 8, 761304. <https://doi.org/10.3389/fvets.2021.761304>
- Gunasekera, U., Diep, N. T., Long, P. T., Chuong, V. D., Arzt, J., & Perez, A. (2026). An Overview of Epidemiological Tools That Support the Progress of Foot-and-Mouth Disease Control in Southeast Asia. *Pathogens*, 15(9), 893. <https://doi.org/10.3390/pathogens15090893>
- Hambisa, A. B. (2025). Enhancing bovine reproduction: The progress of artificial insemination in Ethiopia. *Reproduction in Domestic Animals*, 60, e70003. <https://doi.org/10.1111/rda.70003>
- Humphreys, J. M., Stenfeldt, C., King, D. P., Knight-Jones, T., Perez, A. M., VanderWaal, K., ... & Arzt, J. (2025). Epidemiology and economics of foot-and-mouth disease: current understanding and knowledge gaps. *Veterinary research*, 56(1), 141. <https://doi.org/10.1186/s13567-025-01561-5>
- Integrating veterinary public health data into EPCIS-based digital traceability for dairy supply chains. (2026). *Foods*, 15, 1566.
- Isnaini, N., Wahjuningsih, S., Ma'ruf, A., & Witayanto, D. A. (2019). Evaluation of the reproductive performance of Madura cattle raised by small-scale farmers in Madura, Indonesia. *Livestock Research for Rural Development*, 31(5), Article 70.
- Kahariri, S., Thumbi, S. M., Bett, B., Mureithi, M. W., Nyaga, N., Ogendero, A., ... & Thomas, L. F. (2024). The evolution of Kenya's animal health surveillance system and its potential for efficient detection of zoonoses. *Frontiers in Veterinary Science*, 11, 1379907. <https://doi.org/10.3389/fvets.2024.1379907>
- Kakkar, P., Gupta, S., Paschopoulou, K. I., Paschopoulos, I., Paschopoulos, I., Siafaka, V., & Tsonis, O. (2025). The integration of artificial intelligence in assisted reproduction: a comprehensive review. *Frontiers in Reproductive Health*, 7, 1520919. <https://doi.org/10.3389/frph.2025.1520919>
- Kargbo, M. B., & Bangura, S. R. (2024). The socio-economic impact of foot and mouth disease (FMD) on livestock farming in sierra leone, an empirical evidence from six districts. *Int. J. Agric. Econ*, 9, 59-75. <https://doi.org/10.11648/j.ijae.20240902.13>
- Kedang, V. M. K., Permatasari, I., Chanchaidechachai, T., & Inchainisri, C. (2025). Spatial-temporal distribution and risk factors of foot and mouth disease outbreaks in Java Island, Indonesia from 2022 to 2023. *BMC Veterinary Research*, 21, 180. <https://doi.org/10.1186/s12917-025-04621-2>
- Kedang, V. M. K., Permatasari, I., Chanchaidechachai, T., & Inchainisri, C. (2025). Spatial-temporal distribution and risk factors of foot and mouth disease outbreaks in Java Island, Indonesia from 2022 to 2023. *BMC Veterinary Research*, 21, 180. <https://doi.org/10.1186/s12917-025-04621-2>
- Khumalo, L., Nyaki, S. A., Bahta, Y. T., Jammer, B., & Mokhahla, P. (2026). The impact of foot-and-mouth disease on household food security among smallholder farmers in KwaZulu-Natal Province, South Africa. *Agrekon*, 1-17. <https://doi.org/10.1080/03031853.2026.2701043>

- Knight-Jones, T. J. D., Bulut, A. N., Gubbins, S., Stärk, K. D. C., Pfeiffer, D. U., Sumption, K. J., & Paton, D. J. (2014). Retrospective evaluation of foot-and-mouth disease vaccine effectiveness in Turkey. *Vaccine*, 32(16), 1848–1855. <https://doi.org/10.1016/j.vaccine.2014.01.071>
- Mekonnen, T., & Gebremariam, T. (2024). Cattle artificial insemination service in developing countries: Efficiency, major challenges and economic loss: A review. *Biotechnology Journal International*, 28(4), 18–40. <https://doi.org/10.9734/bji/2024/v28i4725>
- Monteiro, P. L., Consentini, C. E. C., Andrade, J. P. N., Beard, A. D., Garcia-Guerra, A., Sartori, R., & Wiltbank, M. C. (2023). Research on timed AI in beef cattle: Past, present and future, a 27-year perspective. *Theriogenology*, 211, 161–171. <https://doi.org/10.1016/j.theriogenology.2023.07.037>
- Murti, N. T., Safitri, E., Srianoto, P., Madyawati, S. P., & Rofikoh, A. R. (2024). Prevalence and progression of lumpy skin disease cases in cattle over the six months leading up to Eid al-Adha in 2023 in Cirebon District, West Java, Indonesia. *IOP Conference Series: Earth and Environmental Science*, 1292(1), 012037. <https://doi.org/10.1088/1755-1315/1292/1/012037>
- Oltean, H. N., Lipton, B., Black, A., Snekvik, K., Haman, K., Buswell, M., ... & Baseman, J. G. (2025). Developing a one health data integration framework focused on real-time pathogen surveillance and applied genomic epidemiology. *One Health Outlook*, 7(1), 9. <https://doi.org/10.1186/s42522-024-00133-5>
- Papa, M., Oliveira, S. R. M., & Bergier, I. (2024). Technologies in cattle traceability: A bibliometric analysis. *Computers and Electronics in Agriculture*, 227, 109459. <https://doi.org/10.1016/j.compag.2024.109459>
- Papadakis, N., & Katsaprakakis, D. A. (2023). A review of energy efficiency interventions in public buildings. *Energies*, 16(17), 6329. <https://doi.org/10.3390/en16176329>
- Paton, D. J., Valarcher, J.-F., Bergmann, I., Matlho, O. G., Zakharov, V. M., Palma, E. L., & Thomson, G. R. (2005). Selection of foot and mouth disease vaccine strains—A review. *Revue Scientifique et Technique*, 24(3), 981–993.
- Prasetia, B. E., Primatika, R. A., & Nugroho, W. S. (2025). Spatial risk assessment of foot and mouth disease in Sukabumi regency, Indonesia: A GIS and multicriteria decision analysis approach. *Research in Veterinary Science*, 192, 105694. <https://doi.org/10.1016/j.rvsc.2025.105694>
- Purwakarta Regency Department of Fisheries and Livestock. (2025a). Institutional performance accountability report 2025 [Unpublished government report].
- Purwakarta Regency Department of Fisheries and Livestock. (2025b). Strategic plan 2025–2029 [Unpublished government planning document].
- Purwakarta Regency Department of Fisheries and Livestock. (2025c). Institutional risk register 2025 [Unpublished government record].
- Rawdon, T. G., Garner, M. G., Sanson, R. L., et al. (2022). Evaluating vaccination strategies to control foot-and-mouth disease: A model comparison study. *Frontiers in Veterinary Science*, 9, 837485. <https://doi.org/10.3389/fvets.2022.837485>
- Republic of Indonesia. (2009). Law Number 18 of 2009 concerning animal husbandry and animal health.

- Republic of Indonesia. (2014). Law Number 41 of 2014 amending Law Number 18 of 2009 concerning animal husbandry and animal health.
- Rial, C., Laplacette, A., & Giordano, J. O. (2022). Effect of a targeted reproductive management program designed to prioritize insemination at detected estrus and optimize time to insemination on the reproductive performance of lactating dairy cows. *Journal of Dairy Science*, 105(10), 8411-8425. <https://doi.org/10.3168/jds.2022-22082>
- Sartori, R., Consentini, C. E. C., Alves, R. L. O. R., Silva, L. O., & Wiltbank, M. C. (2023). Manipulation of follicle development to improve fertility of cattle in timed-artificial insemination programs. *animal*, 17, 100769. <https://doi.org/10.1016/j.animal.2023.100769>
- Shanbehzadeh, M., Nopour, R., & Kazemi-Arpanahi, H. (2022). Designing a standardized framework for data integration between zoonotic diseases systems: Towards one health surveillance. *Informatics in Medicine Unlocked*, 30, 100893. <https://doi.org/10.1016/j.imu.2022.100893>
- Singh, R. K., Sharma, G. K., Mahajan, S., Dhama, K., Basagoudanavar, S. H., Hosamani, M., Sreenivasa, B. P., Chaicumpa, W., Gupta, V. K., & Sanyal, A. (2019). Foot-and-mouth disease virus: Immunobiology, advances in vaccines and vaccination strategies addressing vaccine failures—An Indian perspective. *Vaccines*, 7(3), 90. <https://doi.org/10.3390/vaccines7030090>
- Sitko, E. M., Di Croce, F. A., McNeel, A. K., Weigel, D. J., & Giordano, J. O. (2023). Effect of reproductive management programs that prioritized artificial insemination at detected estrus or timed artificial insemination on the economic performance of primiparous Holstein cows of different genetic merit for fertility. *Journal of dairy science*, 106(9), 6495-6514. <https://doi.org/10.3168/jds.2022-22673>
- Stewart, J. L., Currin, J., Clark, S. G., Redifer, T., Givens, M. D., & Mercadante, V. R. (2023). Assessing pregnancy outcomes in cow-calf operations after administration of modified-live or killed virus vaccinations at the initiation of synchronization for fixed-time AI. *Theriogenology*, 200, 43-48. <https://doi.org/10.1016/j.theriogenology.2023.01.027>
- Sumual, R., Poli, A., Basir, H., & Pabisa, D. (2024). The Effectiveness of The Family Planning Program In Controlling The Population Growth Rate In North Minahasa Regency, North Sulawesi Province. *Jurnal Registratie*, 6(2), 140-154. <https://doi.org/10.33701/jurnalregistratie.v6i2.4943>
- Wienert, J., Jahnel, T., & Maaß, L. (2022). What are digital public health interventions? First steps toward a definition and an intervention classification framework. *Journal of medical Internet research*, 24(6), e31921. <https://doi.org/10.2196/31921>
- World Organisation for Animal Health. (2024). Infection with foot and mouth disease virus. In *Terrestrial Animal Health Code* (Chapter 8.8). https://www.woah.org/fileadmin/Home/eng/Health_standards/tahc/current/chapitre_fmd.pdf
- Zewdie, G., Akalu, M., Tolossa, W., Belay, H., Deresse, G., Zekarias, M., & Tesfaye, Y. (2023). A review of foot-and-mouth disease in Ethiopia: epidemiological aspects, economic implications, and control strategies. *Virology Journal*, 20(1), 299. <https://doi.org/10.1186/s12985-023-02263-0>