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ORIGINAL RESEARCH

Perceptions of challenges and strategic interventions for managing transboundary lumpy skin disease: The path forward in Malaysia

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ABSTRACT. Lumpy Skin Disease (LSD) has emerged in Malaysia in recent years, causing significant economic losses and raising industry concerns. With limited data on the local outbreak's impact, this qualitative study investigates the challenges faced by the Malaysian ruminant industry during the 2021–2022 outbreak. Using purposive focus group interviews, the study targeted key government officials to identify challenges and propose strategic interventions for disease management. The findings provide valuable insights for future improvements. A total of 20 responses were successfully analyzed using thematic analysis, yielding three main themes with eight subthemes related to LSD challenges, and four themes with nine subthemes representing multifactorial strategic intervention approaches. Thematic analysis revealed multifactorial challenges and control strategies for LSD: (i) knowledge gaps in disease emergence, (ii) systemic and socio-economic barriers to effective LSD control, and (iii) governance and policy limitations, including issues related to culling policies and inadequate border control. The multifaceted approaches to controlling LSD include improving decision-making and response times, establishing emergency preparedness guidelines such as training and simulation exercises, and enhancing surveillance and investigation strategies. The findings are based on expert opinions from government officials, which may limit the discussion to regulatory improvements. Future research at the farm level could provide more comprehensive insights for LSD management. Overall, the study's findings can inform the development of standard operating procedures for LSD management, supporting better decision-making and budget allocation in the ruminant industry.

KEYWORDS: lumpy skin disease, ruminant industry, qualitative approach, transboundary disease, strategic interventions

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INTRODUCTION

Lumpy skin disease (LSD), recognized as a transboundary animal disease [1], is a vector-borne disease caused by a virus that predominantly affects cattle and buffalo. The primary mode of transmission of the LSD virus is believed to be through vectors such as mosquitoes, biting flies, and ticks [2]. Animals affected by LSD often develop nodules on their skin, which can extend to the mucous membranes and internal organs. The size of these nodules ranges from 1 to 10 cm in diameter, depending on disease severity. The LSD virus exhibits remarkable environmental stability, capable of surviving up to 33 days in necrotic tissue of nodules and dried crusts [3]. This, combined with hot and humid conditions conducive to vector breeding, facilitates the worldwide transmission of LSD, with increases in cases reported during the summer season in several countries [1]. The disease has been recognized for nearly a century and has progressively spread globally, affecting South Africa [4], the Middle East [5], Europe [1], Asia [6,7], and, more recently, Southeast Asia in 2020 [8–10].

The spread of LSD in Malaysia was first reported in 2021, involving a dairy cattle farm in Perak, where PCR testing by the Veterinary Research Institute of Malaysia (VRI) confirmed the presence of LSDV [11,12]. A steady increase in cases occurred throughout 2021, with approximately 700 cases reported across eleven states (Perak, Penang, Kedah, Perlis, Melaka, Selangor, Negeri Sembilan, Johor, Pahang, Kelantan, and Terengganu). Implementation of LSD vaccination at the end of 2021 led to a substantial reduction in cases, with only three reported in 2022 [13].

LSD reduces livestock productivity through multiple mechanisms. First, it causes significant weight loss in infected animals, reducing meat and milk yield [14]. Second, treatment and prevention involve high costs for industry stakeholders and the government [15]. Third, the infection impacts reproductive performance, causing abortion, stillbirth, and infertility [1]. Additionally, mortality may increase in animals with low immunity or in calves, further exacerbating economic losses [16–19]. Potential public health concerns have also been raised, including possible zoonotic effects with LSDV detection in humans and risks from contaminated animal products affecting consumers or farmers [20].

Effective control, eradication, and prevention of LSD require measures such as mass vaccination, control of animal movement, vector management, and improved farm biosecurity [7]. Some countries also employ trade restrictions and culling of affected animals to contain outbreaks [2]. Despite extensive global studies on LSD, there is limited qualitative evidence on how Malaysia specifically adapts these mitigation strategies within its local context. Previous research has primarily focused on epidemiology, economic impact, and clinical aspects [1,14,15], leaving a gap in understanding the systemic, socio-economic, and governance challenges faced by local stakeholders during outbreaks. Moreover, there is a lack of studies connecting these practical challenges to stakeholder-informed, multifaceted strategic interventions suitable for the Malaysian ruminant industry. Therefore, this study aimed to: (1) explore the challenges associated with the LSD outbreak during 2021–2022 for the ruminant industry in Peninsular Malaysia, and (2) propose potential strategic interventions for LSD management.

MATERIALS AND METHODS

Ethical approval

The study was approved by the Ethics Committee for Research Involving Human Subjects (JKEUPM), Universiti Putra Malaysia (UPM), under project number UPM/TNCPI/RMC/JKEUPM/1.4.18.2 (JKEUPM).

Study period and location

This study employed a qualitative approach using focus group interviews (FGIs), which allowed in-depth exploration of the events associated with the LSD outbreak in Malaysia from 2021 to 2022. Eleven states in Peninsular Malaysia—Perlis, Kedah, Penang, Perak, Selangor, Negeri Sembilan, Melaka, Johor, Pahang, Terengganu, and Kelantan—were affected by LSD during this period. The FGI approach provided direct and

valuable data through expert opinions regarding: (1) participants' experiences during LSD outbreaks and their management, (2) how they cognitively and emotionally processed these events, and (3) what they considered essential for mitigating future outbreaks [21].

Data collection

A total of 24 officers participated in the FGIs. Participants included 11 state Veterinary Officers from the Department of Veterinary Services (DVS), four officers from the Regional Veterinary Laboratories, seven representatives from the federal level, one from the Veterinary Research Institute (VRI), and one from the Department of Malaysian Animal Quarantine and Inspection Services (MAQIS). A purposive sampling strategy was employed to select participants who were most knowledgeable and directly involved in managing LSD outbreaks.

Participant recruitment

Candidates were selected based on the following criteria:

i. Government officers who directly managed LSD outbreaks during 2021–2022.
ii. Officers with diverse responsibilities, including human resource management, budget allocation, legal regulations within the veterinary system, industry perspectives, government involvement, and the cost-reporting system for LSD outbreaks.

Selected candidates were contacted via an official letter to the Director of the Disease Control and Veterinary Biosecurity Division (DVS). A consent form was provided to inform participants about the study's purpose, how their data would be handled, and the assurance that no personally identifiable information would be collected during the FGI sessions. After obtaining permission, the DVS issued invitation letters to all State Directors and regional laboratories, allowing their officers to participate in the FGIs.

Development of interview protocol

Managing LSD requires more than epidemiological surveillance; it demands an integrated perspective that combines institutional, strategic, and resource-based dimensions. Outbreak responses are shaped not only by disease transmission patterns but also by institutional structures, where formal regulations and informal norms influence compliance, reporting, and trust between farmers and authority officers [22]. Epidemiological data provide the evidence base, yet their effectiveness depends on strategic translation into targeted policies and adaptive planning that prioritize high-risk areas, allocate resources efficiently, and build resilience through farmer education and supply chain stability [23].

The Resource-Based View highlights the critical role of unique assets—such as trained personnel, diagnostic laboratories, and logistics systems—in determining the capacity to respond effectively, explaining why some states manage outbreaks better than others [24]. In the present study, a theoretical framework adapted from the epidemiological triad [25,26] was applied, considering three domains required for an integrated vision of LSD strategic interventions from the authorities' operational perspective (Figure 1): (i) the disease itself (LSD), (ii) the ruminant industry in Malaysia, and (iii) the policy environment. This framework guided the development of nine open-ended interview questions (Table 1). Interviews were conducted in Bahasa Malaysia, and participants' responses were subsequently transcribed and translated into English.

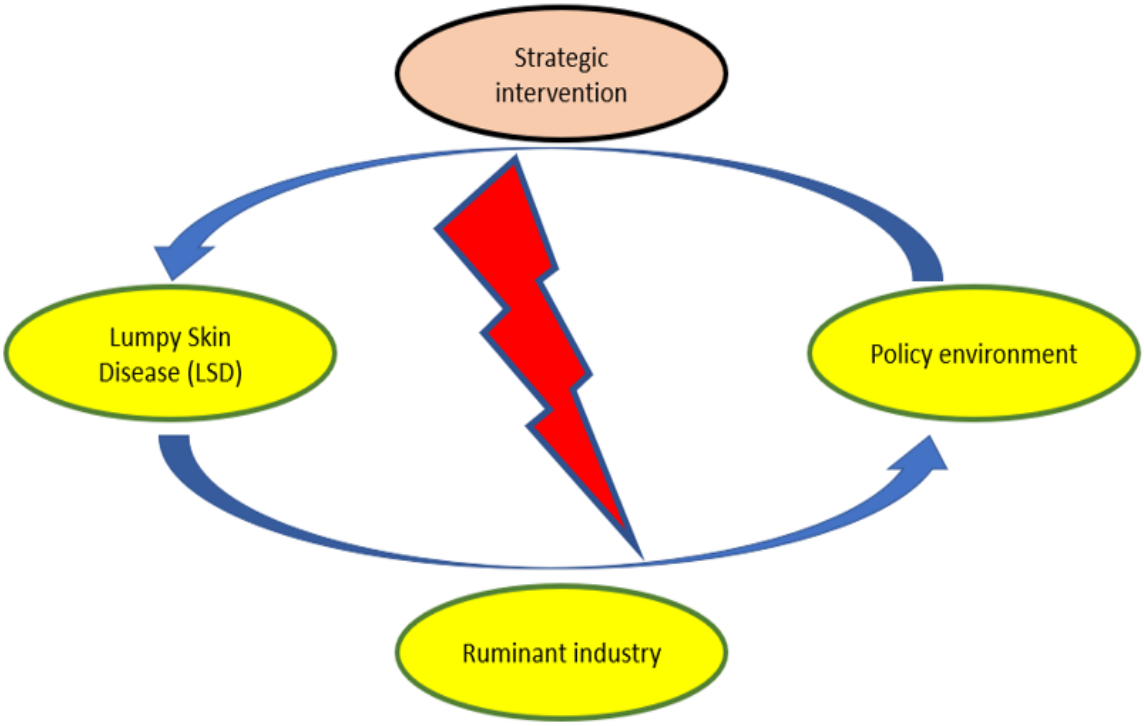

Figure 1. A theoretical framework adapted from Robertson (2020) illustrating the relationships of LSD strategic interventions in Malaysia.

Table 1. Semi-structured interview questions for participants in focus group sessions

Question 1: Demographics
Firstly, please state your name, current workplace, your job scope, and your working experience (duration in years)
Question 2: Veterinary human resources
What are your views on the number of staff and the changes in labour costs during the management of the LSD outbreak, compared to the current situation or before the LSD outbreak? If there were constraints, what contingency plans were implemented? Did these constraints lead to changes in management strategies or approaches to workflow?
Question 3: Specific cases
What control measures and policies were implemented by the Department of Veterinary Services (DVS) to control, prevent, and eradicate LSD? Are there any additional approaches you think are relevant, such as farm-level control, vector/potential carrier control, movement restrictions, or biosecurity measures? In your opinion, how does DVS analyse the spread of LSD from an epidemiological perspective?
Question 4: Current outbreak situation
As a Veterinary Officer or coordinator during an outbreak, mental and physical challenges are significant issues. Firstly, could you share how you personally managed the situation? Secondly, how did you support your officers or staff to motivate them in carrying out their duties? Thirdly, how was the management approach toward livestock owners? Additionally, could you share strategies for convincing uncooperative farmers, particularly when the disease affects high-value livestock breeds? Were these approaches beneficial to the farmers?

Table 1. (*continued*)

Question 5: General impact of LSD
During the endemic phase of LSD (2021–2022), infected cattle may have experienced changes in production and productivity, indirectly affecting the national ruminant industry in terms of food security, food safety, and industry sustainability. From your perspective, how did LSD impact industry players, the public, authorities, and the country economically and socially? What are your views on employment opportunities at different levels of the industry (farmers, traders, and private veterinary services)?
Question 6: Cost of disease management
It is understood that each disease incurs varying costs depending on the control and eradication measures discussed in Question 3. Basic costs such as consumables and diagnostics are essential. Based on your experience, what percentage increase in annual expenses occurred during the LSD outbreak for operational and development budgets? This comparison can refer to the differences in costs before and during the outbreak, which may vary by issues, location, or state.
Question 7: Trade system
Malaysia's reliance on imported cattle remains a means of meeting self-sufficiency levels. However, the presence of LSD in Asian countries, particularly Thailand (April 2021) and Myanmar (2020), raises concerns not only about disease preparedness but also about the impact on the trade system. In your opinion, what significant effects on the national trade system might influence the industry based on supply and demand across industry players and the public? If possible, list the costs associated with importation activities.
Question 8: Perception
While implementing veterinary services in the field, what are your observations on farmers' acceptance regarding their readiness and responsibility toward their livestock industry? If yes, to what extent is awareness of LSD among farmers and the general public? If not, what steps can be taken to increase this awareness?
Question 9: Way forward
How do you view opportunities to reduce management costs while simultaneously increasing productivity in the livestock industry?

Focus Group Interview (FGI) session

A pilot study was conducted with six officers to test the focus group interview (FGI) procedures and refine the interview guide. The participants included three state-level veterinary officers, one officer from a regional laboratory, and two officers from the federal headquarters involved in decision-making. The pilot study aimed to ensure that the questions were clear, understandable, and relevant to the study objectives, as well as to identify any logistical issues in conducting the FGIs.

Following the pilot, the main FGI sessions were conducted with 24 participants, divided into four groups of six. Each group was carefully balanced to include officers from the laboratory, state, and federal levels. The study did not conduct one-on-one interviews with all 24 participants due to time constraints and resource intensity. Therefore, the FGIs were conducted in person at the DVS headquarters in Putrajaya, Malaysia, on 1 November 2023, allowing comprehensive data collection in a shorter period [27] and achieving a response rate of 100%. This approach saved time, reduced financial and logistical demands, and minimized officers' workload by consolidating interviews and meetings into a single session. It also encouraged participants to interact and exchange ideas, stimulating in-depth responses and insights. Before the session, a simulation was held to ensure that the moderator and transcribers were aware of their respective roles and responsibilities and adhered to the established timeline. A trial run of the questions was also conducted prior to the interview.

Each group was facilitated by an interviewer who served as the moderator and was either the author or a co-author of this study. Additionally, each group was accompanied by three transcribers to record verbatim responses. Each transcriber was assigned to transcribe information from two participants' FGI sessions, allowing for accurate capture of data while minimizing information loss. Every session was recorded using a voice recorder on the transcriber's mobile phone as well as a main portable audiotape recorder (Sony ICD-PX470 Digital) to capture the entire session. The recorder, equipped with a USB connection, allowed seamless transfer of verbatim content to a PC or laptop. It also features 4GB of internal memory with MicroSD expansion, providing ample recording capacity for up to 1,000 hours.

Verbatim transcripts were repeatedly reviewed, with participants reporting consistent themes and no new information emerging. Data collection was concluded with 24 participants, as thematic saturation had been reached.

Statistical analysis

Thematic analysis was used to identify themes and patterns from the interviews. The transcripts were translated into English and managed using computer software Atlas.ti [28]. This software facilitated the organization, transcription, storage, and retrieval of data, which was particularly important given the large database and extensive information collected. The thematic analysis followed the six steps outlined by Creswell [28]. First, an inductive approach was employed to develop concepts or theories from specific raw data into abstract categories. Codes were then grouped into categories and subcategories based on their similarities and differences. These categories and subcategories were refined to form the final themes and subthemes, which reflected participants' views and experiences regarding the costs of LSD. The themes and subthemes were supported by participants' quotes and interpreted in relation to the study objectives and relevant literature. Finally, the themes were reviewed by the research team to ensure that each was distinct, accurate, meaningful, and relevant to the aims of the study.

Atlas.ti also supported intercoder reliability by allowing comparisons of codes across verbatim transcripts to ensure consistency and minimize bias. Any discrepancies were discussed among the authors until consensus was reached, ensuring that interpretations accurately reflected participants' experiences in managing LSD outbreaks. This process further strengthened the trustworthiness of the findings through prolonged engagement and triangulation with official LSD case reports from the DVS.

RESULTS

Participant demographics

A total of 24 participants took part in the FGI sessions. Of these, 20 participants were directly involved in managing the LSD outbreak that occurred from 2021 to 2022. The remaining four participants were not directly involved due to factors such as study leave or assignment in different units (Table 2).

A significant majority of participants—70% (17/24)—have served for over a decade in various sections of the DVS at both the national and state levels. These participants hold leadership positions and were directly involved in managing the LSD outbreak at both state and national levels. It is noteworthy that most participants had been at their current workplace for less than two years during the LSD outbreak, with only eight participants having served at their current location for three to five years during this period.

Table 2. Demographic profile of participants in the focus group interviews

ID	Current job scope	Years of service in current position (Year)	Previous experience/ workplace during the LSD outbreak	Total years of service (Year)
FG1-1	Head of the State Veterinary Services (Health) Division	2	Served in the Poultry Technology Institute (ITU)	13
FG1-2	Head of the State Veterinary Services (Health) Division	2	Served in DVS, State of Terengganu	9
FG1-3	Regional Laboratory Director	2	Served in the Veterinary Research Institute (VRI)	15
FG1-4	Veterinary Enforcement Officer, DVS Malaysia	1	Served in DVS, State of Pahang	28
FG1-5	Veterinary Officer in Surveillance, DVS Malaysia	1	Served in DVS, State of Selangor	14
FG1-6	Head of the Ruminant Disease Section; Coordinating Disease Control for Ruminant Diseases in Malaysia	2	Served in DVS, State of Negeri Sembilan	18
FG2-1	Veterinary Officer (Disease Investigator)	1	Study leaves	15
FG2-2	Head of the State Veterinary Services (Health) Division	1	Served in the Veterinary Regional Laboratory	>10
FG2-3	Head of the State Veterinary Services (Health) Division	1.5	Study leaves	15
FG2-4	Veterinary Officer in Regional Laboratory (Pathology Section)	4	Served in the Northern Veterinary Regional Laboratory	14
FG2-5	Veterinary Officer in the Import/Export Section	5	None	<10
FG2-6	Head of the State Veterinary Services (Health) Division	2	Served in DVS, State of Penang	11
FG3-1	Head of Veterinary Extension Section, DVS Malaysia	2	Served in Veterinary Extension Services Center (Terengganu)	28
FG3-2	Officers in the Quarantine Control Division, MAQIS	4	Served in MAQIS	4 (<10)
FG3-3	Head of the State Veterinary Services (Health) Division	2	Served in DVS Malaysia	20
FG3-4	Regional Laboratory Director	5	Served in the Regional Laboratory	15
FG3-5	Head of Abattoir Management and Inspection Section	3	Served in the Regulatory Division	23
FG3-6	Head of Veterinary Extension Section, DVS Malaysia	<1	Served in DVS, State of Kelantan	14

Table 2. (*continued*)

FG4-1	Head of the State Veterinary Services (Health) Division	2.2	None	<10
FG4-2	Deputy Director of the Disease Control and Biosecurity Division	2	Served in DVS Malaysia	22
FG4-3	Head of Veterinary Extension Section, DVS Malaysia	2	Served in the Poultry Technology Institute (ITU)	<10
FG4-4	Assistance Veterinary Officer in the Epidemiology and Surveillance Unit	3	None	<10
FG4-5	Veterinary Officer in Pathology	3	Served in the Regional Laboratory	<10
FG4-6	Head of Veterinary Extension Section, DVS Malaysia	4	Served in DVS Malaysia	12

Note: FGx-y refers to FGI participants, where the first digit (x) indicates the FGI group number (1–4) and the second digit (y) indicates the participant number within that group (1–6). For example, FG1-3 refers to Group 1, Participant 3.

Challenges in managing LSD

Findings on challenges in LSD management were categorized according to the components of the epidemiological triad within the LSD strategic interventions theoretical framework (Figure 1): (i) knowledge gaps in disease emergence, (ii) systemic and socio-economic barriers to effective LSD control, and (iii) governance and policy limitations in disease control, including issues related to culling policies and inadequate border control (Table 3).

Table 3. Codebook of challenges (themes and subthemes) faced by Malaysian authorities in managing the LSD outbreak from 2021 to 2022

Themes	**Sub-themes**
Knowledge gaps in disease emergence	Lack of knowledge and expertise on new emerging diseases
Systemic and socio-economic barriers to effective LSD control	Industry and farmers' perceptions and awareness of good animal husbandry practice
	Socio-economic consequences
	Vector control measures
	Physical constraints (i.e., time, budget allocation, human resources)
Governance and policy limitations in disease control	Culling policy
	Improper border control (i.e., Illegal animal movement), The impact of bureaucratic procedures
	Lacking clarity in LSD protocol development

First theme: Knowledge gaps in disease emergence

Lack of knowledge and expertise on new emerging diseases

Although most participants were aware of outbreaks in neighboring countries at the national level, they needed time to adapt to the situation and to acquire knowledge about LSD and the corresponding control measures.

> FG3-6: *"Actually, many veterinarians and para-vets find it challenging to recognize LSD nodules because lumps can also be associated with other diseases… Consequently, confirming an LSD diagnosis can be quite difficult. To address this, I gathered our team and explained the nature of LSD, its control measures, and the necessary sampling procedures. Interestingly, even skin scraping can help detect the LSD virus."*

> FG1-2*: "Staff members can be influenced by farmers if they lack a strong foundational understanding of LSD. For instance, when the DVS policy involves culling LSD-affected cattle, some staff members may feel uncertain about this action."*

Second theme: Systemic and socio-economic barriers to effective LSD control

Industry or farmers' perceptions and awareness of good animal husbandry practices

Farm management systems and industry stakeholders' perceptions were identified as key external factors contributing to challenges in LSD management. Several participants noted that most cattle farms in their respective states were operated by small-scale farmers who practiced free-grazing. Additionally, many farmers lacked proper animal husbandry practices, which contributed to an increased number of LSD cases on their farms.

> FG3-6: *"It is difficult for us to deal with farmers who have these local cattle. For them, the symptoms of LSD are trivial because they don't sell the cattle. They think this disease can be cured without treatment if the lump breaks and festers, and that, once treated, it will be cured. Why does DVS need to quarantine and dispose of their cattle? This is a challenge for us to convince and explain to farmers."*

Socio-economic consequences

The enforcement of laws and regulations resulted in additional costs for traders, particularly at quarantine stations. Several participants noted that these costs included expenses for feed, animal care, and medication during the quarantine period, as well as official fees payable to MAQIS for permits, holding yards, and inspections.

> FG3-2: *"The costs involved in the quarantine station; I give an example of 300 cattle imported from Thailand. Let's take the LSD quarantine period to be 56 days. The cost that the importer must bear is the cost of feed, cattle care and medicine. Meanwhile, the importer must pay to MAQIS the fee for permit, holding yard, and inspection as per animal."*

Participants reported that the market prices of cattle and beef increased during the LSD outbreak period. This increase was attributed to factors such as reduced cattle supply following import and movement restrictions, as well as decreased consumer demand, reportedly linked to concerns about the zoonotic potential of LSD. Several participants also noted that revenue losses occurred due to carcass condemnation associated with LSD lesions.

Vector control measures

Climate change, resulting from both direct and indirect human and animal activities, significantly alters the composition of the global atmosphere [25]. In regions with high humidity and abundant rainfall, such climatic changes enhance arthropod breeding [2], posing challenges for vector control and highlighting the need to identify effective mitigation strategies.

> FG1-1: *"It is challenging to manage vectors in our country. Although we implemented vector control measures, I am uncertain about their effectiveness. Malaysia experiences a seasonal tropical climate characterized by unpredictable environmental changes, high temperatures, and humidity. Improving farm security could be a crucial step".*

Physical constraints (i.e., time, budget allocation, human resources)

The DVS comprises various divisions and sections with distinct responsibilities; therefore, targeted training is required, which subsequently entails budget allocation.

> FG4-1; FG3-3; FG3-6: *"The position remains vacant, and there is no replacement for retired officers. We have requested the filling of the vacant post, but the process is time-consuming. During the outbreak, we acted by pooling staff from the Regulatory, Industry, Laboratory, and District sections to manage and eradicate LSD in the affected area. This step was necessary due to insufficient staffing in the Health and District Departments."*

Participants explained that budget allocation in government agencies is typically based on requests from the previous year, and obtaining additional funding for new disease outbreaks requires formal applications to the Department of Finance (DOF) or the relevant ministry, with approval and procurement processes often being time-consuming.

> FG3-4: *"The costs in the laboratory were quite high in 2021. When faced with the LSD outbreak, we also had to manage existing diseases. We needed to develop new diagnostic procedures for LSD, and it had to be done quickly. At the same time, we were technical experts and advisors to top management, with field staff covering the technical aspects and criteria of LSD. This situation had a great economic and social impact."*

Participants also reported increased workloads, including conducting inspections, managing LSD vaccinations at quarantine stations, and performing additional testing at regional laboratories.

> FG4-1: *"MAQIS only had 500 staff throughout Malaysia. When the LSD outbreak occurred, it significantly impacted the workforce and management. We had to inspect animals at the quarantine station every day. Since daily inspections were necessary, staff worked in shifts, for example, from morning until night, so overtime had to be paid. Overtime at MAQIS was indeed the highest cost during this period."*

Third theme: Governance and policy limitations in disease control

Lacking clarity of the LSD protocol development and culling policy

Most participants reported that the culling process posed considerable challenges for staff and required the implementation of effective risk management strategies.

> *FG1-2: "For compensation, you must have evidence of culling, such as a photo of the lesion and the culling process. In the state, we used the Animal Act 1953 (Sec 18) and Sec 1 because we didn't have*

time to make a state gazette. We developed a 'persuasion' strategy to obtain the owner's consent to cull his infected cattle. We also brought the Veterinary Enforcement Officer together with the VO to report the matter. Enforcers and VOs need to be present in this situation."

The impact of bureaucratic procedures

Rapid decision-making must be implemented efficiently and clearly to enable field staff to take timely action. Collaboration across all levels of federal, state, and local government should be coordinated to support the effective implementation of these measures. Delayed responses and bureaucratic procedures create pressure not only on field staff but also on industry stakeholders.

FG4-6: *"...There are some directors who do not want to declare or are slow to declare illness. In a disease situation, we all know that if the laboratory results are positive, we need to make a quick decision. The action is like wanting to eradicate under what section? Only the state director can give instructions. If the decision is delayed, the disease control process will be delayed, and the disease will worsen. The decision involves the law (act). We must be firm in making decisions. The signature is necessary for the decision."*

Improper border control (i.e., illegal animals' movement)

Participants also noted that inadequate border controls create opportunities for the illicit movement of animals through alternative entry points.

FG4-2: *"Why do I say that illegal movement or illegal import has increased? Let's compare the quarantine data from the MAQIS with the cattle registration data from Kelantan and the border states. By doing so, we can identify several potential instances of illegal movement."*

LSD strategic interventions: multifactorial approaches

While most participants reported that Malaysia adopted mitigation measures recommended by the World Organization for Animal Health (WOAH), such as LSD vaccination, animal movement restrictions, and culling of LSD-affected cattle, implementation faced practical challenges. Based on the difficulties encountered by participants in managing the LSD outbreak, several strategic interventions were identified, reflecting a multifactorial approach. These include: (i) improving communication and rapid decision-making, (ii) enhancing emergency preparedness for disease outbreaks (e.g., surveillance and investigation strategies, mitigation, and response), (iii) strengthening government interventions (e.g., collaboration with relevant agencies and farmers, logistics management, human resource management, budget allocation including incentives for farmers, and training and simulation exercises), and (iv) addressing socio-economic considerations (Figure 2).

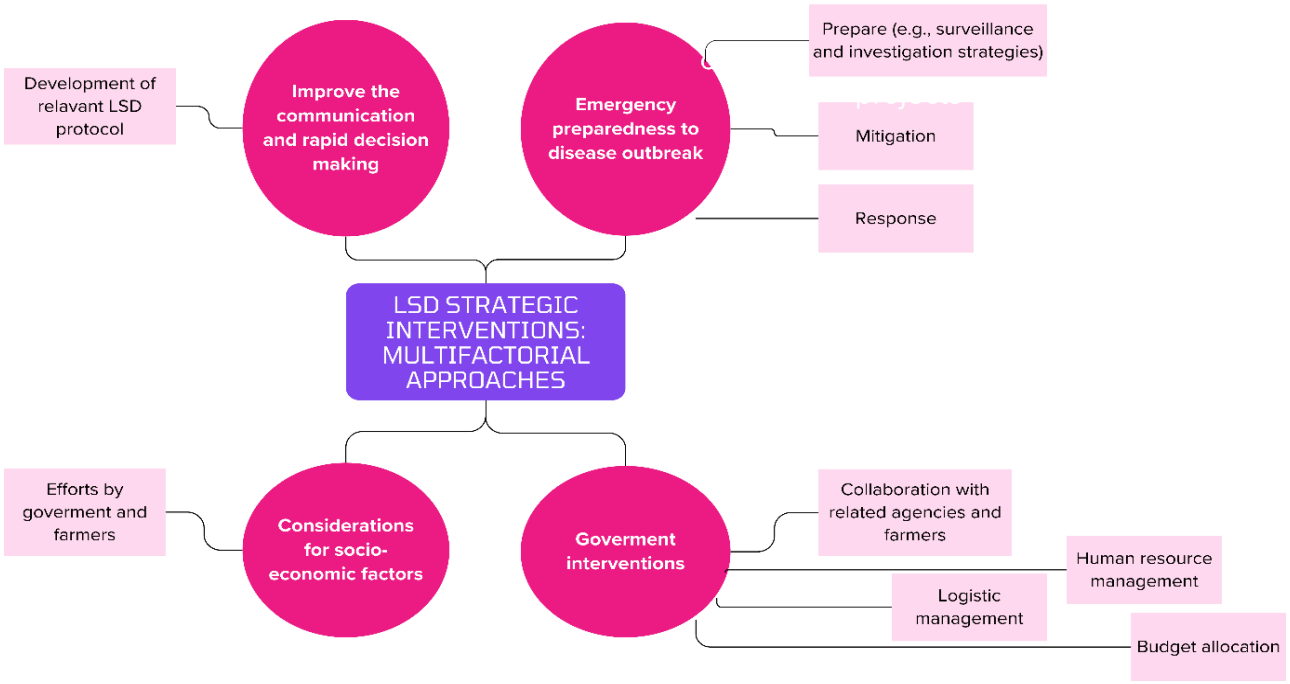

Figure 2. Strategic interventions for LSD control: A multifactorial approach.

Improve the communication and rapid decision-making

Participants emphasized that effective communication and rapid decision-making are critical for managing animal disease outbreaks. Accurate and timely information flow among authorities, farmers, and inter-agency stakeholders facilitated prompt responses. Streamlined decision-making, supported by relevant standard operating procedures (SOPs), laws, and regulations, enabled the effective implementation of containment measures.

> FG4-6: *"In terms of readiness, I'd say we were prepared and willing to make decisions. At the state level, the decision was made by the State Director. Sometimes, delays happened—some directors were slow to declare the disease. When that happened, management costs rose, and the disease spread further. But when decisions were made quickly, actions were taken faster, diagnostic results came in sooner, and we could respond immediately. Of course, every decision had to follow laws and regulations, so it had to be firm."*

Development of a relevant LSD protocol

Participants reported that movement restrictions and internal control measures under the Federal SOP were implemented even before LSD was officially gazetted as a notifiable disease. Once LSD was officially gazetted in certain states (e.g., Pahang in 2022), full enforcement of cattle movement restrictions, premise quarantine, and eradication measures was carried out.

> FG4-6: *"First, we imposed movement restrictions on cattle or animals that tested positive. Second, we implemented internal control measures in accordance with the Federal SOP. To facilitate these controls while waiting for the state to gazette LSD as a notifiable disease officially, we operated under Sections 36, 18, and 19 of the Animals Act. Once the state officially gazettes LSD, for example, in Pahang in 2022, we were able to fully enforce cattle movement restrictions, affected premise quarantine and eradication measures under the state's LSD control regulations."*

Emergency preparedness to disease outbreak (i.e., prepare, mitigation, response)

From the FGI sessions, several points related to emergency preparedness for disease outbreaks were identified that could be applied to future LSD or other disease outbreaks. For example, active surveillance was highlighted as an effective tool for early detection.

> FG4-2: *"DVS staff had a tough job. They needed to actively check farms for LSD-positive animals and quickly report any lesions found. At the same time, we created pamphlets and posters about LSD and shared them on YouTube, making it easier for both staff and farmers to understand the disease."*

> FG3-4: *"Our approach had to be fast—everything needed to move quickly. Even the lab staff went to the field to help the state DVS with active surveillance on farms. We were always on video calls to guide sampling if any lesions were spotted in the field."*

In addition, coordination with industry stakeholders is essential for communicating the importance of LSD control and promoting enhanced farm biosecurity, including environmental management measures.

> FG4-2: *"The first step was to work with the ruminant industry and educate them on the importance of proper livestock care and farm biosecurity."*

> FG1-1: *"For us, how do we even control the vectors? Our country has seasons with lots of rain and mosquitoes…Surveillance can be done, but vector control isn't 100% in our hands."*

Collaboration with farmers

In risk management contexts, participants reported that establishing trust and maintaining communication with farmers prior to outbreaks improved compliance and enhanced the effectiveness of interventions.

> FG3-1: *The key thing was communication with farmers because disease outbreaks could happen anytime. Usually, we only met them when there was a disease, but we should have known them earlier. If we had built a good relationship before, it would be much easier to work together when a problem happened. In my view, we needed to connect with farmers even before any outbreak. That way, when a disease came, they would trust us, and we could handle things more smoothly."*

> FG1-2: *"We used a 'persuasive' approach with cattle farmers affected by LSD, and thankfully, it went smoothly as they cooperated well."*

Collaboration with related agencies

DVS must maintain close communication with the MAQIS regarding border control at entry points.

> FG3-2: *"MAQIS periodically notified the Deputy Secretary-General of the nation about LSD outbreaks through the official platform of the Technical Committee on Trade Facilities. We provided detailed information to facilitate import procedures and raise awareness of the stricter import requirements for livestock (especially in live cattle importation from DVS) entry at border points."*

Logistic management

Participants reported that affected farmers received compensation for culled animals, and that infected carcasses and organs were properly disposed of. Opinions differed regarding which party should bear the costs

of transport and disposal. Logistical responsibilities were shared across multiple divisions, encompassing surveillance, monitoring, diagnostics, and sample transportation.

> FG1-1: *"I would have preferred if the management costs, especially transportation and culling expenses at the slaughterhouse, were covered by the farmers instead of DVS. Right now, we're paying for logistics just to get farmers to agree to culling. But in future SOPs, disposal costs should be the farmer's responsibility."*

> FG2-3: *"DVS fully handled the outbreak management, as it was our responsibility. We provided compensation to affected farmers whose cattle had to be culled, but they were still allowed to sell the meat."*

Human resource management

The LSD outbreak occurred during the COVID-19 pandemic, which imposed multiple constraints, including increased workloads, the emergence of new diseases, limited resources, and workforce shortages. Several participants discussed potential actions based on their experiences in managing the LSD outbreak, such as providing training, issuing guidelines, implementing staff shifts or rotations, and recruiting personnel from other departments or sections.

> FG3-4: *"I had a limited number of staff, so I recruited and organized shift schedules, including for non-technical personnel. This meant that administrative staff also had to take shifts—not for testing or diagnostic technical work, but to help ease the workload by handling tasks like lifting, labelling, and washing. Implementing shifts was necessary to prevent staff from becoming too exhausted, and it also had a positive impact on motivation."*

Budget allocation

Participants reported that budget allocations supported disease management activities, including LSD awareness programs, consumables, transportation, overtime salaries, vaccine procurement, and compensation.

> FG2-1: *"We had to buy supplies like medicine, supplements, and vaccines. On top of that, there were transport costs, overtime pay for staff, farmer awareness programs, and staff training. Managing this disease costs a lot in many ways."*

Participants suggested that compensation policies should be reviewed, as the current amounts are insufficient and may hinder the implementation of eradication measures, including the culling of affected cattle.

> FG2-3: *"However, the amount of compensation that is said is not commensurate with what should be given."*

> FG4-1: *"If it were a hybrid cattle ('sado' cattle), the minimum compensation should have been MYR 12,000. But the usual rate was only MYR 800. Considering the actual cost, how was that fair?*"

Considerations for socio-economic factors

As noted in the Challenges section under socio-economic consequences, one emergency LSD control measure involved extending the quarantine period for imported live cattle. However, participants reported

that prolonged quarantine increased costs for importers, including expenses for feed, vaccination, labor, and quarantine management.

> FG3-1: "*The impact on the cattle trade was significant, and I think the biggest burden fell on importers. Previously, cattle from Australia didn't need quarantine, but now they had to be quarantined for 45 days. That's not a short period—importers had to bear the costs* of feeding, vaccination, labour, and of course, the quarantine expenses."

DISCUSSION

In the context of Malaysia's first experience with LSD, no prior research has identified the epidemiological origin or initial source of the outbreak. As illustrated in the theoretical framework (Figure 1), the incursion of LSD can be understood through the interactions among disease transmission dynamics, farming practices, and the policy environment, providing a conceptual lens for interpreting the outbreak. The complex transmission dynamics of LSD occur primarily via blood-sucking vectors (indirect contact) [4] and through animal movement, as LSD sheds the virus via skin lesions, nasal, and ocular discharges (direct contact) [29]. These dynamics were further complicated by cattle farming practices that lacked adequate animal husbandry and farm biosecurity, coupled with reliance on imports and illegal animal movements. The risk of LSD spread was exacerbated by the policy, legal, and regulatory environment, which inadvertently facilitated disease transmission through bureaucratic procedures that created opportunities for rule-breaking by farmers and traders. This framework highlights how governance, laws, and regulations may unintentionally amplify disease spread, aligning the findings with socio-ecological and risk management theories.

Comparisons with prior studies reveal similar associations between LSD transmission dynamics and farming practices, including high vector presence and biosecurity challenges observed in Thailand and other Asian contexts [30], suggesting consistent patterns across Asian outbreaks. Moreover, systematic reviews of LSD in Asian countries report significant variations in prevalence that correlate with differences in management and control practices, reinforcing the importance of the multifactorial risk factors identified in this study [5,31].

The current findings indicate that early interventions prior to outbreak onset are critical. While LSD vaccination has emerged as a key measure for mitigating disease impact, with widespread evidence supporting its effectiveness [1,31], implementation challenges such as limited financial resources for vaccine procurement and distribution, and the illegal use of unregistered vaccines, have hindered control efforts. Comparative studies suggest that although live attenuated vaccines provide effective protection, their side-effect profiles and logistical requirements vary across contexts, highlighting the importance of vaccine strategy and delivery mechanisms for global control programs [32,33].

These observations support the application of implementation science theory, emphasizing that policy, institutional capacity, and stakeholder engagement directly influence intervention outcomes. Streamlining bureaucratic processes, such as digitizing vaccination registration and budget applications, can reduce delays while maintaining compliance with regulations. Simplified procedures and timely gazettement of LSD as a notifiable disease facilitate rapid, evidence-based decision-making, consistent with contingency theory in organizational management. Furthermore, dual vaccination strategies (e.g., for FMD and LSD) may be considered, targeting high-risk areas to maximize impact without overburdening the system or increasing vulnerability to other diseases.

As a newly emerging disease in Malaysia, LSD triggered public concern due to its perceived zoonotic potential, resulting in decreased livestock sales and demand [20,34]. According to participant reports, cattle farmers were aware of the severity of the disease and were willing to pay high vaccination fees charged by private veterinarians, which subsequently caused financial strain (personal communication). This underscores the need for stronger regulatory measures to ensure safe and effective vaccines, as well as to improve

affordability and accessibility for affected farmers [35]. Collaboration with private veterinary companies can help expand herd immunity and achieve more comprehensive vaccination coverage. However, the cost of vaccination services remains high, particularly for traditional or small-scale farmers. Therefore, a cost-sharing mechanism through public-private partnership (PPP) programs is recommended. PPPs provide practical mechanisms to improve herd immunity, expand coverage, and distribute costs between farmers and government agencies, operationalizing the theoretical principle of shared governance and collective action. This aligns with global recommendations emphasizing that integrated stakeholder engagement and economic support mechanisms enhance control program uptake and sustainability [36,37].

Recognized as a transboundary disease [37,38]—with risk of transmission via direct contact from contaminated to non-contaminated populations through vectors, animals, equipment, vehicles, or carcasses—a major challenge during the outbreak was the extensive movement restrictions imposed to control LSD spread. These measures affected both domestic trade and international cattle imports. Extended quarantine periods, up to 56 days, placed additional financial burdens on farmers and traders, including costs for livestock feed, worker salaries, and maintenance of quarantine facilities [39,40]. These measures are governed by the Animal Act 1953, which mandates the quarantine of affected premises and disposal of infected cattle, with penalties for non-compliance of up to MYR 5,000 (USD 1,124) at the federal level and MYR 15,000 (USD 3,371) at the state level [41]. The financial burden was compounded by revenue loss from delayed cattle sales and reduced market value of LSD-affected animals [29].

Implementing culling policies in Malaysia proved particularly challenging, especially in small-scale farming operations, where resistance to such measures was strong. Experts participating in the FGI reported that farmers incurred direct financial losses due to livestock culling, with compensation rates insufficient to cover the full economic impact. Compensation for condemned animals ranged between MYR 800 (USD 180) and MYR 2,000 (USD 449), depending on the type of animal and severity of infection. Delays in payment, often contingent on government approval, further strained farmers' finances. While compensation mitigated some losses, it remained inadequate, particularly for smaller herds or hybrid cattle known locally as "sado" (double-muscle) cattle. In a previous study reported that farmers derived more profit from selling LSD-infected live cattle compared to meat, despite a drop of up to 47% in the price of live cattle relative to pre-outbreak values [42]. The culling policy can significantly impact countries with small cattle or buffalo populations, potentially affecting food security [35]. Beyond immediate financial losses, culling also influences long-term herd structure and productivity [42].

During disease outbreaks, supply chain risks and animal health management functions are often inadequately monitored or overlooked in outbreak planning. Therefore, comprehensive planning for logistics, human resources, budgeting, and coordination with relevant agencies is critical. Establishing a contingency fund dedicated to animal disease emergencies can facilitate rapid decision-making and resource allocation without disrupting existing budgets. This enables timely provision of essential materials and support to personnel, including staff and affected farmers, as well as to facilities during an outbreak.

Leaders and department heads must proactively identify, mobilize, and manage support teams, as well as track, record, and allocate critical resources before a disease occurs. Operational continuity planning should prioritize high-probability risks that could disrupt activities [43]. An organization's capacity to act effectively during an outbreak is heavily influenced by its operating environment, highlighting the importance of preparedness and resilience in disaster management [10]. Key considerations for planners include: (i) enhancing agency resilience during catastrophic events, (ii) strengthening relationships between government and private ruminant industry stakeholders by incorporating diverse perspectives, and (iii) addressing gaps and challenges in current strategies to prevent future shortfalls.

Barriers to emergency preparedness include unclear roles and responsibilities, insufficient resource allocation, ineffective coordination, and limited knowledge of inter-agency support mechanisms. A crucial component of crisis mitigation involves fostering inter-agency relationships before outbreaks occur [10].

Effective collaboration enables stakeholders to define roles and responsibilities clearly, ensuring that essential societal functions are maintained.

To address these challenges, the development of clear and consistent standard operating procedures (SOPs) for LSD as a transboundary animal disease (TAD) is essential. Such SOPs should provide a multi-year strategy to optimize resource allocation, including budgets and human resources, while remaining compliant with existing laws and regulations. Malaysia has well-established policies and regulatory frameworks for managing animal diseases, similar to other countries that emphasize proper vaccination, strict border controls on animal imports, stamping out or culling infected cattle, and early detection through surveillance programs to control the emergence, re-emergence, and incursion of LSD [44]. However, maintaining balance among these regulatory imperatives requires continuous and coordinated efforts.

Educational campaigns and training for both industry stakeholders (farmers) and authorities (government officers) on relevant laws and Good Animal Husbandry Practices (GAHP) can effectively disseminate knowledge and build trust within the farming community. Incentive programs are critical drivers for compliance, including industry subsidies for affected farmers, certification schemes to recognize disease-free farms, and acknowledgment of farms that adhere to regulations. Simplifying policy on a case-by-case basis can make compliance more manageable, reduce time burdens for both farmers and authorities, and strengthen adherence to disease control measures.

The economic burden of LSD encompasses production losses [1], additional costs for interventions, reduced livestock productivity [45,46], expenditures for culling infected cattle, supportive treatment, diagnostics, and labor. These impacts affect both farmers and government authorities [43]. This study highlights additional economic burdens specific to LSD, including reduced market value due to nodular lesions that damage hide quality, decreased carcass value from meat condemnations, lower consumer demand for meat arising from public health concerns, and extended quarantine periods.

These distinctive burdens differentiate LSD from other livestock diseases and underscore the need for tailored interventions and policies. Reported economic losses have been substantial, estimated at USD 21 million in the Balkans [39] and approximately USD 91 million in Bangladesh [5]. Consequently, developing cost-benefit analyses for various LSD interventions is necessary to inform policy decisions. Tools such as partial budgeting and stochastic simulations can assess the impact of interventions; for example, the economic benefits of vaccination are evident, with studies showing an 11.6% reduction in herd losses [33] and positive financial returns [37], albeit at higher initial costs. Similar challenges were observed in Serbia, where logistical constraints initially delayed vaccination and culling strategies [32].

Some limitations of the current study stem from its reliance on expert opinions, primarily from government officers. Consequently, the discussion emphasizes regulatory improvements, standard operating procedures, and law enforcement. Future studies could expand to farm-level approaches, providing a more holistic perspective on LSD management. Additionally, indirect costs affecting the broader economy—such as mitigation measures by the government, impacts on importers, butchers, farmers, and consumers—could be explored. At the same time, direct costs related to animal production at the farm level, including milk yield, body weight, and reproductive losses, could be investigated to validate the current findings.

CONCLUSIONS

This study examined the challenges encountered during the LSD outbreak in Peninsular Malaysia from 2021 to 2022 using a qualitative approach, highlighting the socio-economic and operational impacts on both farmers and government authorities. The findings indicate that delays in decision-making, limited human and financial resources, gaps in regulatory SOPs, and difficulties in inter-agency coordination significantly affected the effectiveness of disease control measures.

Based on these results, several evidence-based recommendations are proposed. Strengthening early detection and rapid response mechanisms is critical to minimize outbreak escalation, as participants reported

that delayed disease declaration and intervention amplified economic and operational burdens. Enhancing stakeholder engagement, particularly with farmers and private veterinary providers, is essential to improve compliance with vaccination programs and culling procedures. Improving budgetary allocation, logistics support, and resource management can alleviate bottlenecks during outbreak responses, while standardized, context-specific SOPs aligned with legal and operational realities can guide consistent and practical field actions.

Implementing these measures can facilitate more timely, efficient, and sustainable management of LSD outbreaks. Moreover, the lessons learned from this study may inform strategies for managing other transboundary animal diseases, contributing to improved preparedness and resilience in the livestock sector.

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Availability of data and materials

All the generated data are included in the manuscript.

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Authorship contributions

NAT contributed to the conceptualization, methodology, software, formal analysis, investigation, resources, data curation, writing of the original draft, and visualization. SSZ was involved in validation, formal analysis, investigation, writing—review and editing, visualization, and funding acquisition. NMN supervised the study and contributed to project administration and funding acquisition. MB participated in resources, data curation, and visualization. All authors have read and approved the final manuscript.

Conflicts of interest

The authors declare that they have no financial or personal relationships with other individuals or organizations that could inappropriately influence or bias the content of this paper.

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