RISK ASSESSMENT STUDY

TO SUPPORT SAFE CROSS-BORDER TRADE OF FMD-SUSCEPTIBLE LIVESTOCK FROM LAO PDR AND MYANMAR TO CHINA

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LIST OF ABBREVIATIONS

ARAHIS	ASEAN Regional Animal Health Information System
ASEAN	Association of South-East Asian Nations
CZ	Control Zone
DLD	Department of Livestock Development, Thailand
DLF	Department of Livestock and Fisheries, Lao PDR
FAO	Food and Agriculture Organisation of the United Nations
FMD	Foot and mouth disease
FMDV	Foot and mouth disease virus
GACC	General Administration of Customs of the People's Republic of China (new name of AQSIQ)
GMS	Greater Mekong Sub-Region
LBVD	Livestock Breeding and Veterinary Department, Myanmar
LNT	Luang Namtha Province of Lao PDR
MARA	Ministry of Agriculture and Rural Affairs (new name of MoA)
MoC	Ministry of Commerce
MOU	Memorandum of Understanding
OIE	World Organisation for Animal Health
OIE	SRR-SEA OIE Sub-regional representation for South-East Asia
PAE	Probability of agent entry
PDE	Probability of domestic exposure
PDR	People's Democratic Republic
PR	People's Republic
SEA	South-East Asia
SEACFMD	South-East Asia and China foot and mouth disease campaign
URE	Unrestricted risk estimate

EXECUTIVE SUMMARY

A study conducted in 2015 on live animal movement pathways in the Greater Mekong Sub-Region (GMS) (Smith, et al., 2015) estimated that at least one million large ruminants (cattle and buffalo) cross illegally from South-East Asia into China each year. This movement is driven by the high demand for livestock and their products within China, coupled with the ready supply of livestock in certain South, and South-East, Asian countries. Given that FMD is endemic throughout mainland South-East Asia and that regional epidemiological analyses have highlighted the important role of live animal movements in the spread of FMD, it is likely that FMD is dispersed along the livestock trade pathways, putting at risk those countries through which livestock transit as well as those to which they are destined.

During a SEACFMD Animal Movement Management Meeting held in August, 2015, approaches to facilitating safer trade in livestock were discussed. One of the initiatives raised at this meeting was establishment of export zones in border areas (referred to as Control Zones (CZ) throughout this report) of countries neighbouring China, namely Lao PDR and Myanmar, from which livestock of higher health status, compared to the country in which the zones are based, could be officially exported to China. The proposed CZs in Lao PDR and Myanmar are in Luang Namtha (LNT) Province and Muse, respectively. These areas were selected due to their location both on the border with China and within major pathways of livestock movement destined for China.

The current study, supported by funds donated by the government of PR China to the OIE World Fund, is a risk assessment for incursions of FMDV into the proposed CZs through movement of live, FMD-susceptible livestock. The objectives of this study are: to provide updated descriptions of FMD susceptible livestock movement pathways into the proposed CZs; to estimate the risk of FMDV incursions into the proposed CZs, based on current sources and volumes of livestock movement destined for these areas;

and to provide estimates of the potential impact of risk mitigation measures implemented along livestock movement pathways.

Quantitative risk assessment was the principle methodology applied in this study, with data sourced from: field data collected during a mission conducted as part of the current study; follow-up surveys of key stakeholders; published literature; expert opinion provided by people with knowledge and experience of animal health/livestock movement in specific geographical areas; reports of outbreak investigations in the region; regional meeting reports, serological surveys; and FMD outbreak reports made through the ASEAN regional animal health information system (ARAHIS). A stochastic quantitative risk model was developed to estimate the risk that FMDV infected livestock would enter the proposed CZs and to model the potential impact of risk mitigation measures.

The model is based on: estimated FMDV prevalence in livestock source countries; the volume of livestock being moved along each pathway; the species of livestock; and any risk mitigation measures already in place. These are combined in the model to estimate: the risk that livestock entering the proposed CZs are infected with FMD; the expected number of FMD infected animals entering per year; and the probability that at least one FMD infected animal will enter per year.

According to estimates provided during this study: up to 220,000 cattle and buffalo, 132,000 small ruminants and 50,000 pigs move through the proposed CZ of Muse each year; and up to 305,000 cattle and buffalo and 16,800 pigs move through the proposed CZ in LNT, Lao PDR each year. In addition to the livestock movement through the proposed CZs, there is an active livestock trade pathway from Northern Thailand, via the Mekong River, to Sob-Luay Port in Myanmar and then into China. While this pathway does not pass through the proposed CZs, up to 365,000 cattle and buffalo and 442,000 pigs were believed to move along this pathway each year and it is thus essential that this pathway is taken into account when determining the risk posed by live animal movements into China.

Results of the study indicate that there is a very high risk that FMDV infected cattle and buffalo will enter the CZs in Lao PDR each year. For pigs, the risk of FMDV incursions into the CZs, estimated in the current study, appears to be far lower, as a result of both lower estimated prevalence of FMD in pigs and the lower volume of movement, compared to large ruminants. Similarly, for the CZ in Muse, large ruminants represent the greatest risk for FMDV incursions, and pigs the lowest risk. However, more recent figures provided by Myanmar LBVD suggest that the volume of pig movement through the CZ in Muse has increased significantly in 2018 compared to the figures estimated in 2016. Thus, the risk of FMDV incursions through pig movement is likely to have increased during that time.

There is also movement of small ruminants through this zone which, according to the results of this study, represent a very high risk for FMDV incursions. It should be noted that considerable uncertainty and variability exist in the data used to furnish this model and the estimates should not be regarded as absolutes. It does, however, provide a useful estimate of the level of risk and a baseline against which to model the potential impact of risk mitigation measures. The model may be updated as more information becomes available, or where there are changes in pathways or volumes of livestock being traded.

The impact of various risk mitigation measures is discussed in this study. These include: reduction of FMD prevalence in livestock source areas (i.e. vaccination of susceptible livestock populations and/or improved detection/response to FMD outbreaks in key source areas); clinical examination of livestock at the point of entry to the CZ; use of government approved pre-quarantine prior to entry to the CZ; and maximising official cross-border movement versus unofficial movement of livestock. It is noted in this study that clinical examination is not a perfect test for FMDV and it is assumed animals incubating the virus, or those with sub-clinical infection will be missed. The impact of reducing prevalence in source countries would obviously depend upon the extent of the reduction, but in terms of targeting measures to reduce FMD prevalence, Central Myanmar would likely generate the greatest impact as this represents the major source of livestock to both of the proposed CZs included in this study. While India and Bangladesh are less significant in terms of the volume of livestock sourced from here, incursions from these countries could have significant consequences due to the risk of incursions of FMDV strains currently exotic to South-East Asia and China.

According to the results of this study, the use of pre-quarantine prior to livestock movement into the CZs, results in a significantly reduced risk that FMDV infected livestock will enter the CZs (approximately 99% reduction in the probability that cattle/buffalo or pigs entering the CZ will be infected with FMDV, and approximately 79% reduction in the risk that small ruminants entering the CZ will be infected with FMDV, compared to the baseline level of risk (i.e. where no regulatory measures are in place)). Examination of livestock at the point of entry to the CZ, has a far lower impact (approximately 40% reduction for cattle/pigs and 17% reduction for small ruminants), which is unlikely to provide an acceptable level of protection, if used in isolation. The report includes discussion about designing risk mitigation measures which are science-based, provide an acceptable level of protection for the CZ, while also aiming to encourage traders to use official pathways of movement in preference to unofficial pathways. Any mitigation measures imposed will fail if they are not supported by the livestock traders involved in these movements. The key message here is facilitation of safer livestock movement in consultation with stakeholders involved in that movement.

It should be noted that data on livestock movement pathways in South-East Asia has been limited, historically, due largely to the predominance of unofficial cross-border trade and lack of centrally recorded data. However, recent advances in development of official trade, such as that between Central Myanmar and Muse, may provide more accurate figures. The models developed in this study, and conclusions drawn from those models, are based on estimates of livestock movement (volumes and pathways) and on estimates of FMD prevalence in specific countries within the region. Despite the uncertainties that exist in the data used in this study, the results provide an insight into livestock trade through the proposed CZs and the potential impact of risk management measures applied along those pathways. The process of undertaking this study and building a quantitative risk model also helps to highlight areas where data is lacking and where future studies may focus to improve on our current knowledge of FMD in this region.

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BACKGROUND

A study conducted in 2015 on live animal movement pathways in the Greater Mekong Sub-Region (GMS) (Smith, et al., 2015) estimated that up to one million large ruminants (cattle and buffalo) cross illegally from South-East Asia (SEA) into China each year. This movement is driven by the high demand for livestock and their products within China, coupled with the ready supply of livestock in certain South, and South-East, Asian countries. Given that FMD is endemic throughout mainland SEA and that regional epidemiological analyses have highlighted the important role of live animal movements in the spread of FMD, it is likely that FMD is dispersed along the livestock trade pathways, putting at risk those countries through which livestock transit as well as those to which they are destined.

In addition to livestock movement from within SEA to China, Smith et al., 2015 also highlighted the recent emergence of unofficial trade in cattle and buffalo from the Indian Sub-Continent into SEA. This movement may pose a significant risk for incursions of previously exotic FMD strains into SEA and China. Indeed, since that study was conducted, a strain of FMDV with high similarity to viruses from the Indian Sub-continent (and believed to have originated from the Indian Sub-Continent) has been isolated from outbreaks in Lao PDR, Vietnam, Myanmar and Thailand (Qiu, 2016). While vaccines currently in use in SEA offered protection against this new strain, future incursions of exotic viruses may not be covered by vaccines or may behave in such a way that the impact on livestock and FMD control programs in SEA may be more significant.

Until recently, all movement of live, FMD-susceptible animals from mainland SEA, into China, was unofficial as Chinese law dictates that no live animals be imported from countries where FMD is endemic. Despite this, the financial incentives for moving livestock into China, and the necessity to meet the high demand for livestock products, continues to drive high volumes of unofficial trade from mainland SEA into China (Smith et al., 2015). Since October, 2017 the Myanmar Government have allowed the legal export of cattle and buffalo to China via the Muse border gate (Thiha Ko Ko, 2018) and while the import of such cattle is not officially recognised by China, the two countries are working towards signing a Memorandum of Understanding (MOU) to support this trade.

Addressing the movement of livestock in the region in order to facilitate safer trade in livestock and livestock products was the key objective of a regional SEACFMD animal movement meeting held on 25th August, 2015. A recommendation resulting from this meeting was to develop standardised protocols and procedures to support cross-border trade in livestock, including consideration of the development of control zones in key positions along the livestock trade pathways destined for China. The purpose of these zones (referred to throughout this report as Control Zones (CZ)) is to establish livestock populations of higher health status, within SEA, which may be exported to China through official pathways (as opposed to the un-regulated, unofficial movement currently taking place). There has also been further development in regional cooperation on livestock movement management through signing of a joint statement on Animal Movement Control in GMS countries, with the purpose of strengthening regional infrastructure to promote safe and rapid livestock trade between countries.

The current study represents an initial step in understanding more about the proposed CZ areas in Myanmar and Lao PDR and to provide estimates of the risk of FMDV entering these proposed CZs, based on livestock movement pathways and volume of livestock movement passing through these areas. The study provides a detailed and updated account of live animal movements destined for the CZs and, through discussion with key stakeholders, provides some estimates for the number of animals moving along each pathway. This study applies risk assessment techniques (both qualitative and quantitative) to estimate the risk of FMDV entering the proposed CZs and to compare the impact of different risk mitigation measures targeted at reducing the risk of FMD incursions into the CZs. The study is supported by the funds donated by the Government of PR China to OIE World Fund.

Most of the data presented in this study is based on information gathered from previous studies and from field research conducted as part of the current study. Some further amendments have been made to reflect certain significant changes in livestock movement patterns, volumes or regulation which have occurred from the time when the results of the study were originally collated in 2016, until its publication in 2019.

The Proposed Control Zones in Myanmar and Lao PDR

Establishment of CZs, with the purpose of managing the risk of live animal movements into China, was proposed by the government of Yunnan Province in 2015, following the SEACFMD Animal Movement Management Meeting held in Qingdao in August, 2015. In March, 2016, four Ministries in China (Ministry of Agriculture (MoA), General Administration of Quality Supervision, Inspection and Quarantine (AQSIQ), Ministry of Commerce (MoC), and General Administration of Customs) issued a document asking the government of Yunnan Province to further investigate this proposal (Song, 2016). As part of this process, a stakeholder workshop for cross-border safer animal trade was held on September, 12th to 13th, 2016 in Kunming, China. The workshop was jointly organised by the Veterinary Bureau of the MARA of China and Food and Agriculture Organization of the United Nations (FAO) and was attended by representatives from the Veterinary Bureau of the MARA of China, FAO, OIE, China GACC Phytosanitary Division, Department of Livestock and Fisheries (DLF), Lao PDR, Livestock Breeding and Veterinary Department (LBVD), Myanmar, relevant departments of Yunnan Province; municipal governments and members of the private sector.

During this stakeholder workshop, representatives from China, Lao PDR and Myanmar agreed, in principle, to carrying out a regional cross-border animal disease management pilot project, constructing FMD control zones, and promoting tripartite cooperation on animal diseases prevention and control in border areas (Draft report of stakeholder workshop, Kunming 12th to 13th September, 2016). The proposed CZs for the pilot project were thus identified: In China, the pilot project areas will include: Ruili City of Dehong prefecture, Jinghong City and Mengla County of Xishuangbanna prefecture; in Lao PDR, Luang Namtha Province (LNT); and in Myanmar, Muse (figure 1).

Figure 1

Figure1: Proposed area for CZs in Myanmar and Lao PDR

The CZs identified in Lao PDR and Myanmar were selected due to their position on major livestock movement pathways destined for China. Figure 2 (taken from the study by Smith et al., 2015) shows the pathways of large ruminant movement into China, together with the estimated volume of livestock moving along each pathway, based on figures estimated at the time of that study.

Figure 2

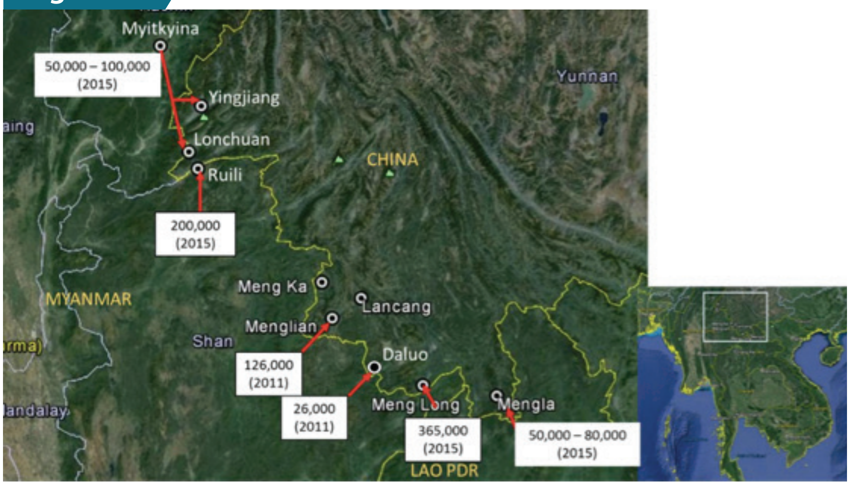

Figure2: Numbers of large ruminants entering China from Lao PDR and Myanmar based on results of previous studies (Huachun et al., 2011 and Smith et al., 2015)

The purpose of the proposed CZs in Lao PDR and Myanmar is to provide a safer source of livestock for import into China through development of harmonised approaches to disease prevention and control in the border areas to create zones containing livestock of a higher health status, compared to that of the countries in which the zones are located. While there have been some recent developments towards officially recognising the trade of livestock from Myanmar into China (Thiha Ko Ko, 2018), at the time of writing, China does not officially recognise import of livestock from any FMD endemic country. Therefore, all movement of livestock into China, from neighbouring countries, currently takes place illegally. This poses a potentially high-risk for China importing animals infected with FMDV, given that FMD is endemic in countries neighbouring China and that they are entering China without any form of regulation. However, while demand for livestock and livestock products in China remains high, and without alternative, legal pathways of movement, this illegal movement is likely to continue.

By establishing CZs within FMD endemic countries, which are approved by China as 'FMD-free', it is anticipated that a legal pathway for livestock movement, from neighbouring countries in South-East Asia, into China, may be established. There has been significant recent progress in establishing legal trade of livestock between Myanmar and China according to an article by Thiha Ko Ko, 2018. China has proposed that the zones will be established and managed according to OIE guidelines, with technical assistance provided by China, investment in infrastructure provided by the private sector, and with further technical support from international organisations: World Organisation for Animal Health (OIE) and FAO. The importance of engaging with the private sector when developing these zones has been acknowledged such that measures put in place may be mutually beneficial for the purposes of disease control as well as for the stakeholders involved in cross-border movement of livestock.

OBJECTIVES

The objectives of this study are:

- *To provide updated descriptions of FMD susceptible livestock movement pathways into the proposed CZs in North-West Lao PDR (LNT) and Northern Shan State of Myanmar (Muse).*
- *To estimate the risk of FMDV introduction into the proposed CZs based on current sources and volumes of livestock movement destined for these areas.*
- *To provide estimates of the potential impact of risk mitigation measures implemented along livestock movement pathways.*

METHODOLOGY

DATA COLLECTION

The data used for this study was sourced from: field data collected during a mission conducted as part of the current study; follow-up surveys of key stakeholders; published literature; expert opinion provided by people with knowledge and experience of animal health/livestock movement in specific geographical areas; reports of outbreak investigations in the region; regional meeting reports, serological surveys; and FMD outbreak reports made through the ASEAN regional animal health information system (ARAHIS).

Field data collection for the current study used a combination of stakeholder meetings, focus group discussions with livestock traders and semi-structured interviews with individual livestock traders and other stakeholders. This information was supplemented by observations made during the field missions to key trading areas, livestock trading routes, and proposed CZ areas in Lao PDR and Myanmar.

STAKEHOLDER MEETINGS

Three stakeholder meetings were held during the field mission: one in Myanmar (Nay Pyi Taw) on 29th September, 2016; and two in Lao PDR (Vientiane Capital and Luang Namtha Province) on 4th and 5th of September, respectively. Participants of the stakeholder meetings included various stakeholders in the livestock trade and animal health industries with representatives from both private and public sectors. The agendas for the meetings and presentations given at the workshops are provided in Annex II of this report. The purpose of the workshops were: to present the zoning project to participants; to gather feedback from stakeholders on the proposed CZ areas; to gather detailed and current information on livestock trade pathways (including species and volume of trade) into the proposed CZs; to gather estimates for some key parameters to be used in the quantitative risk model for this study; and to conduct some qualitative risk exercises to estimate and rank the level of risk represented by each pathway of livestock movement identified.

FOCUS GROUP DISCUSSIONS AND INDIVIDUAL STAKEHOLDER INTERVIEWS

The main purpose of these interviews was to gather information from livestock traders on the pathways of movement destined for the proposed CZs, the cost of moving livestock through these routes (with particular emphasis on the comparison between cost of moving officially, compared to unofficially), and identification of the stakeholders involved in the movement of livestock through these routes. The semi-structured interview technique was used to allow the interviewer to probe points of interest and to gather opinions, as well as facts, on livestock movements in these areas. The type of information required here is not easily gathered using a standard questionnaire approach, but requires a discussion approach whereby questions may be asked in a variety of ways in order to achieve the level of detail required for this study. The focus group discussions were approached in a similar way to the individual interviews, using the same interview checklist to conduct interviews with a small group of traders simultaneously.

The semi-structured interview checklist used for these interviews is provided in Annex III of this report.

FOLLOW-UP SURVEY IN BOKEO, LAO PDR

Following the field mission and stakeholder meetings conducted in Vientiane Capital and LNT Province of Lao PDR, some additional data requirements were identified for movement of livestock through Bokeo Province of Lao PDR. For collection of this information, a questionnaire was developed to gather data on livestock movement pathways identified during the field mission to Lao PDR where more data was required in order to validate previous data collected or to fill gaps where information was lacking. The main targets of this survey were livestock transport companies based in Lao PDR who arrange transportation of livestock from the Thai border (in Bokeo Province) to the Chinese border (near the Boten border checkpoint). Other targets included: livestock traders operating in Bokeo, quarantine staff and DLF officers from this Province. The questionnaire used for this purpose is provided in Annex IV of this report.

GATHERING EXPERT OPINION

Following the field data collection and follow up questionnaires, any further information required was gathered using collection of expert opinion from stakeholders with specific knowledge relevant to the information required. This method was used mainly to gather information to furnish parameters in the quantitative risk model, for estimation of prevalence of FMD in different source countries, and to triangulate some of the information on livestock movement pathways gathered by other means.

RISK ANALYSIS

Risk analysis is the main methodology used for analysis of data in this study: both qualitative and quantitative techniques were used to estimate the risk of FMDV infected livestock entering the proposed CZs through specific livestock pathways (qualitative risk estimates) and to quantify the overall risk of FMD entering the proposed CZs through movement of live animals of various species, and to estimate the impact of risk mitigation measures targeted at specific points along the livestock movement pathways (quantitative risk assessment).

Risk assessment, when applied to the importation of livestock and livestock products, is useful for facilitating trade while safe-guarding the animal health status of importing country (or zone) (Tameru et al., 2008). Often the methodology is applied by importing countries to examine the disease risks associated with importing a given commodity. Risk analysis provides scientifically-based information to decision makers on which they can base decisions of whether or not to allow imports of specific commodities and also what measures might be applied to reduce the risk to an acceptably low level.

For the current study, risk assessment will not be used to base a decision on whether or not to import live animals into the CZs, but rather as a tool to estimate the risk of FMDV entering the zones through current livestock movement pathways and then to model the potential impact of measures aimed at reducing that risk. As such, the methodology will be used to make decisions on how to facilitate trade in live animals through these areas while minimising the risk associated with that trade. The study will also take into account the impact that illegal (and therefore unregulated) movement of livestock has on the overall risk of FMDV incursions and how the proportion of livestock moving through unofficial channels might be affected by the risk mitigation measures applied.

The quantitative risk model developed for this study is based on the process of import risk analysis used by OIE (Murray, 2004) and utilising a modified version of a model presented by Morley (1993), whereby the FMD status in livestock source areas (exporting countries), together with volume of trade movement, is used to estimate the risk of FMD entering the proposed CZs. The quantitative risk model is also modified to model the impact of risk mitigation measures implemented at specific points along the pathways of livestock movement.

Although risk analysis combines a number of processes, namely: hazard identification, release assessment, exposure assessment, consequence assessment, risk management and risk communication, this study focuses specifically on hazard assessment, i.e. "what can go wrong" and risk assessment, i.e. "how likely is it to go wrong." There is also be some consideration of risk management measures.

It should be noted that there is very little centralised data on livestock movements throughout SEA, a situation exacerbated by the high volumes of unofficial movement of livestock which, by definition, is unregulated and largely unreported. Therefore, the data used for this study is largely collected through discussion with key stakeholders with knowledge and experience of livestock trade in the region and the data provided is, in the most part, in the form of estimates. For this reason, there is some uncertainty and variability in the estimates provided. Where possible, information collected from one source was also collected from other sources in an attempt to validate the information through triangulation of data. So, although every effort was made to gather detailed and accurate information on livestock movement, there remains some deficiencies in that data. The data used to furnish each of the parameters in the quantitative risk model is described in Annex I. This Annex provides details of any assumptions made, the probability distributions used to model each parameter, and the reasons for selecting those distributions.

Although the data available to furnish the quantitative risk model is currently limited, the quantitative risk model developed for this study could potentially be used as a framework for future models, when more data becomes available, or where there are changes in livestock movement pathways or volumes of movement.

HAZARD IDENTIFICATION

The risk questions answered by this study, are:

- *How likely is FMDV to be introduced to the proposed CZs in Lao PDR and Myanmar through existing pathways of livestock movement?*
- *What could be done to reduce this risk?*

The hazard of interest for this risk assessment study is FMDV. This section will describe FMDV with particular reference to its distribution and epidemiology in SEA (and other areas from which livestock destined for the CZs are sourced) and in those FMDV-susceptible livestock identified to be moving into the proposed CZs.

FMDV IN SOUTH-EAST ASIA, CHINA AND THE INDIAN SUB-CONTINENT

FMDV is a highly contagious viral disease of cloven hoofed animals. Foot and mouth disease is caused by an aphthovirus of the family Picornaviridae and it exists as seven immunologically distinct serotypes (A, O, C, SAT1, SAT2, SAT3, Asia1) between which there is no cross-protection following infection or vaccination with one serotype and infection with another (OIE, 2016). Within different serotypes are also sub-types (or topo-types) between which there is incomplete cross-protection. Epidemiological analysis of FMDV in SEA indicates that virus is spread along livestock trade pathways.

FMDV is transmitted by: direct (or close-indirect) contact between an infected animal and a susceptible animal; fomite spread on inanimate objects or vectors (people and non-FMD susceptible animals) or through windborne spread. Movement of live, infected animals represents the greatest risk for FMD transmission in the SEA context, particularly where this movement is un-regulated and therefore, by definition, is not subject to any formal controls.

Foot and mouth disease is endemic throughout mainland SEA, as well as in India and Bangladesh, from which some livestock, destined for the proposed CZs, are believed to originate (Smith et al., 2015). From countries in mainland SEA, FMDV serotypes O and A are commonly isolated, with O SEA/My-98, O/Cathay, O ME-SA/PanAsia and A Asia/Sea-97 being the topo-types isolated from the region in recent years (Kukreja, 2015). However, in 2015, there was an incursion of a new strain of serotype O (O-Ind2015) which was initially isolated in Lao PDR, and later, in Myanmar, Vietnam and Thailand. This strain is closely related to viruses from India (Lao and Vietnam isolates) or Bangladesh (Myanmar and Thailand isolates) (Qiu,2017) and demonstrates the vulnerability of SEA to incursions of exotic FMD strains from outside of the region.

Serotype Asia 1 was introduced into SEA, from South Asia before 1996 but it has not been isolated from outbreaks in SEA and China since 2009 (Wei, 2016). However, in the Indian sub-continent three FMDV serotypes (O, A and Asia1) are currently co-circulating (Mahapatra et al., 2015) with a re-emergence of Asia 1 viruses in Bangladesh in 2012 and 2013 (Ullah et al., 2014). Given the patterns of livestock movement from India and Bangladesh into SEA (Smith et al., 2015) there may be a risk that Asia 1 viruses could be re-introduced to the region from the Indian Sub-Continent through movement of live animals. However, more information on the FMD status, exact source, volume and movement pathways of livestock (and other FMD risk products) from the Indian Sub-Continent, moving into SEA would be needed to further understand this risk. The number of samples collected from FMD outbreaks in the region and, particularly the number characterized, remains limited. In 2015, around 40% of reported outbreaks did not have causative viruses identified and so it is difficult to draw conclusions about the epidemiology of specific strains of FMDV in the region.

The proposed locations for CZs have been selected because of their position along the main livestock movement pathways from SEA, destined for China. Therefore, by their very nature, these areas are highly vulnerable to incursions of FMD, given the high volume of livestock movement into them. There is potential that these zones (with high livestock density and high turnover of livestock originating from various sources) could result in amplification of virus and thus increase the risk of FMD spreading from these key points to other areas, namely China, if the risk of FMD entering the CZs is not effectively managed.

FMDV SUSCEPTIBLE SPECIES IN SOUTH-EAST ASIA AND CHINA

The major domestic livestock species susceptible to FMDV, namely: cattle, buffalo, sheep, goats and pigs are all present in SEA and China and, according to results from the current study, there is now significant trade in all of these livestock species from mainland SEA to China, with much of this movement occurring via the proposed CZs.

While previous livestock movement studies have focused predominantly on movement of cattle and buffalo (Smith et al., 2015) or on cattle, buffalo and pigs (Cocks et al., 2009; ACIAR, 2011), there has been limited emphasis on small ruminants. One of the reasons that these species have not been widely regarded in previous studies is that there was previously understood to be minimal trade-movement of small ruminants within the region. These species may also be somewhat neglected due to the subtle clinical signs they display when infected with FMDV (Burnett and Cox, 1999). However, the results of the current study indicate that there are now strong drivers (in terms of price and demand) for movement of small ruminants from SEA into China. This demand, combined with the high population of small ruminants in Central Myanmar, has resulted in an active trade developing in small ruminants between Central Myanmar and China (via the proposed CZ in Muse).

In addition to this newly identified small ruminant movement, pig movement has also undergone some relatively recent changes, when compared to results from previous studies (Cocks et al., 2009). Previously, pig movement tended to occur out of China, into neighbouring countries in SEA. However, results from the current study indicate a reversal in the direction of pig trade, with pigs now moving from SEA (namely, Thailand) into China, via the proposed CZ areas in LNT and Muse. More recently, figures for 2018 and 2019 indicate that the trade in pigs via Myanmar and Lao PDR, into China, continue to increase in volume.

The following section describes each of the FMDV-susceptible livestock species included in this risk assessment study in terms of their role in the epidemiology of FMD, with specific focus on the SEA and Chinese context.

Cattle and buffalo

Cattle and buffalo infected with FMDV will generally display obvious clinical signs of disease, characterised by fever and blister-like sores on the tongue and lips, in the mouth, on the teats and between the hooves (OIE, 2016). However, in endemic situations, local breeds will frequently show a degree of resistance to clinical disease, although there is no evidence that these animals have increased resistance to infection (CABI, 2016). Therefore, in the endemic settings of SEA and parts of the Indian Sub-Continent, infected cattle and buffalo may be more likely to be sub-clinically infected, compared to a naïve population of cattle in an FMD free country. As such, they may pose a greater risk for spreading FMDV, given that infected animals are more likely to go un-detected. Cattle are highly susceptible to infection with FMDV via the respiratory route, given their high inspiratory volume and will therefore be readily infected through direct (or close-indirect) contact with FMDV infected animals.

In SEA and China, cattle and buffalo are the species moved in greatest volumes, with cross-border movement of these species being largely un-regulated across much of the region. Cattle and buffalo movement from outside of SEA, namely from the Indian Sub-Continent, was also been identified (Smith et al., 2015) with the added risk of FMD strains, currently exotic to South-East Asia and China, entering the region through movement of infected cattle and buffalo.

Huachun (2016) described that 30.28% of cattle tested in border counties of Yunnan Province were positive for the 3ABC ELISA test for FMDV. Although this does not necessarily indicate current infection, it does demonstrate that a large proportion of cattle and buffalo moving into China have been exposed to FMDV. Given the vulnerability of cattle and buffalo to FMD infection, the FMD status of those countries from which cattle and buffalo originate (and transit) en-route to the proposed CZs, and the high volume of trade in these species, it is likely that they play a key role in the spread of FMD throughout the region (including into the CZs of LNT and Muse).

Pigs

The pig movement identified during the current study (from Thailand to China, via the CZ in LNT and from Thailand, via the CZ in Muse, to China) is likely to result from both the strong demand in China, due to the extremely high level of pork consumption, and the recently reduced domestic production, leading to dramatic increases in the price of pork in China over the past two years. According to a news report (The Pig Site, 2016a), Chinese pork imports escalated in 2016, due to insufficient domestic production and consistently high demand. China's pig population is currently reported to be at an historical low, following one of the largest culls on record during 2014 to 2015 (Rabobank, 2015), with a decline of almost 100 million head in China's pig herd and 10 million in its breeding herd (Rabobank, 2015). Recent flooding in some of the most prolific pig producing areas has placed additional pressure on domestic production (The Pig Site, 2016b). The discrepancy between domestic production and demand has led to marked increases in the price of pork in China, with prices as high as RMB20 (USD 2.9) per kg live-weight seen in June, 2016 (The Pig Site, 2016c). The price of pork may fall somewhat as domestic pork production in China begins to increase again, but as China's growing middle class continues to expand, the demand for meat is likely to remain high (The Pig Site, 2016a).

Given this very high demand for pork in China, and subsequent high prices, it is not surprising that over the last two years there has been an increase in unofficial trade in live pigs from SEA countries into China. According to results of the current study, pigs are being moved from commercial farms in Thailand, into China, via North-West Lao PDR or Myanmar. The volume of pigs moving through the proposed CZs appear to be high (several thousand per year) and are being sourced from a country where FMD is endemic. However, the risk posed by this movement of pigs, taking into account the husbandry systems and areas from which they originate, and the strains of FMD currently circulating in the region, may be lower compared to cattle and buffalo, but is explored further in the quantitative risk assessment described later in this report.

Some previous studies have indicated that pigs may not play an important role in outbreaks of FMD in parts of Thailand, where pigs appeared to be rarely involved in FMD outbreaks (even when livestock of other species were affected in the same village) (Chamnanpood et al.,1995). It was concluded by Chamnanpood, et al. (1995) that pigs did not commonly become infected when there were outbreaks of FMD in village cattle and buffalo in Northern Thailand, due to the pig feeding and housing practices employed by villagers that protected pigs from exposure to the virus.

According to outbreak reports made to ARAHIS, the number of outbreaks reported in pigs in Thailand is far lower than those reported in cattle and buffalo, suggesting that pigs are less frequently affected by FMDV in Thailand. While pigs may not commonly be involved in FMD outbreaks in Thailand, outbreaks in pigs are reported (ARAHIS, 2016), and the volume of pig movement identified by this study would suggest that there is a risk that FMD infected pigs could enter the proposed CZs, albeit relatively rarely. The fact that movement from farms in Thailand to the CZ in Lao PDR can be quite rapid, could further exacerbate this risk as pigs may be moved while incubating the disease and therefore show no outward signs of infection until after they have arrived at their destination. Once an infected pig is introduced to an area where there is a high density of FMD susceptible livestock (which would be the case in the proposed CZs) it is likely there will be viral spread from the pig to other susceptible species, given the high level of infectious units excreted by infected pigs (Kitching and Alexandersen, 2002). The role of pigs in the epidemiology of FMD in SEA and China, and the risk posed by pigs moving into China, may also be affected by the presence of pig adapted FMD strains, should they occur in Thailand in the future.

Sheep and goats

The role of sheep and goats in the epidemiology of FMD in SEA and China has not been fully elucidated, with FMDV being rarely reported in these species (ARAHIS, 2012-2016) and with relatively few epidemiological studies involving these species. Central Myanmar has a high population of small ruminants and represents the source of sheep and goats destined for China. In this area, small ruminants are often kept together with cattle and buffalo, with commingling in grazing areas or at water sources being common practice. In Central Myanmar, FMD is frequently reported in cattle and buffalo, but not in sheep and goats (ARAHIS, 2012-2016). However, according to a serological survey conducted in small ruminants in Central Myanmar, there is a high level of sero-conversion for FMD, with 35.02% in sheep and goats from Pyawbwe and 49.77% in Meikthila testing positive for FMD antibodies (Ma Ma Phyo, date unknown). Therefore, despite the low level of reports of FMD in small ruminants in Central Myanmar, it appears that they are being exposed to, and infected with, FMDV and may then represent a risk for transmission through trade-related movement. Experience in other regions (Kitching, 1998; Mansley et al., 2003), suggest that small ruminants can play an important role in spread of FMD across borders due to the fact that they display mild clinical signs of disease and infection of FMD may not be recognised. Although FMD in small ruminants is often clinically silent, the amount of FMDV excreted by infected small ruminants is significant, especially in the very early stages of infection (Donaldson, date unknown).

From information collected during the current study, transport of sheep and goats from their source in Central Myanmar to the proposed CZs is relatively rapid (usually approximately 24 hours). Therefore, even where sheep and goats do eventually display clinical signs of disease, they may not be recognized as infected if they are still incubating the disease during transit. The risk may be further exacerbated by mixing of goats from different areas immediately prior to transport. Once an infected goat is introduced to an area containing a high density of livestock (such as would be the case in the proposed CZs), it may readily lead to infection of susceptible livestock (particularly cattle), due to the fact that infected small ruminants excrete considerable quantities of FMD virus in their exhaled breath (from one day before they show signs of disease and for up to four to five days later) (Sellers and Parker 1969; Donaldson et al. 1970); and due to the fact that cattle are highly susceptible to infection by airborne FMD virus (Donaldson et al. 1988).

IDENTIFICATION OF RISK PATHWAYS: MOVEMENT PATHWAYS OF LIVESTOCK DESTINED FOR PROPOSED CONTROL ZONES

The following section outlines the livestock movement pathways destined for the proposed CZs in LNT in Lao PDR and Muse in Myanmar. The information presented here is based on information collected during stakeholder meetings, focus groups discussions, interviews and questionnaires, as outlined under the methodology section.

LAO PDR-CHINA BORDER CONTROL ZONE: LUANG NAMTHA PROVINCE

Movement pathways were identified for pigs and large ruminants (cattle and buffalo) moving through North-West Lao PDR, destined for China. No movement of small ruminants through this route was identified. The following section outlines the pathways identified for pigs and for cattle and buffalo. The information provided will focus on movement into (or through) LNT province given that this is the area of interest for this RA study.

Cattle and buffalo

Cattle and buffalo destined to pass through the proposed CZ in North-West Lao PDR originate from various sources, including: Central Myanmar (which represents the main source of these livestock), India, Bangladesh, Malaysia, Thailand and Australia. The movement pathway from the source of cattle and buffalo through North-West Lao PDR, to China, was described in detail by a previous study conducted in the region (Smith et al., 2015) and further validated by the results of the current study. All of the pathways taken by cattle and buffalo through the proposed CZ in Lao PDR, at some point, pass through Chiang Rai in Northern Thailand (figure 3). Therefore, the following section provides a description of the movement pathways taken by cattle and buffalo from their place of origin to Chiang Rai Province, and is then followed by descriptions of each pathway from Chiang Rai, into the proposed CZ.

The movement pathway from the source of cattle and buffalo (India/Bangladesh, Central Myanmar, Malaysia, Thailand and Australia) to Chiang Rai Province in Northern Thailand

Figure 3

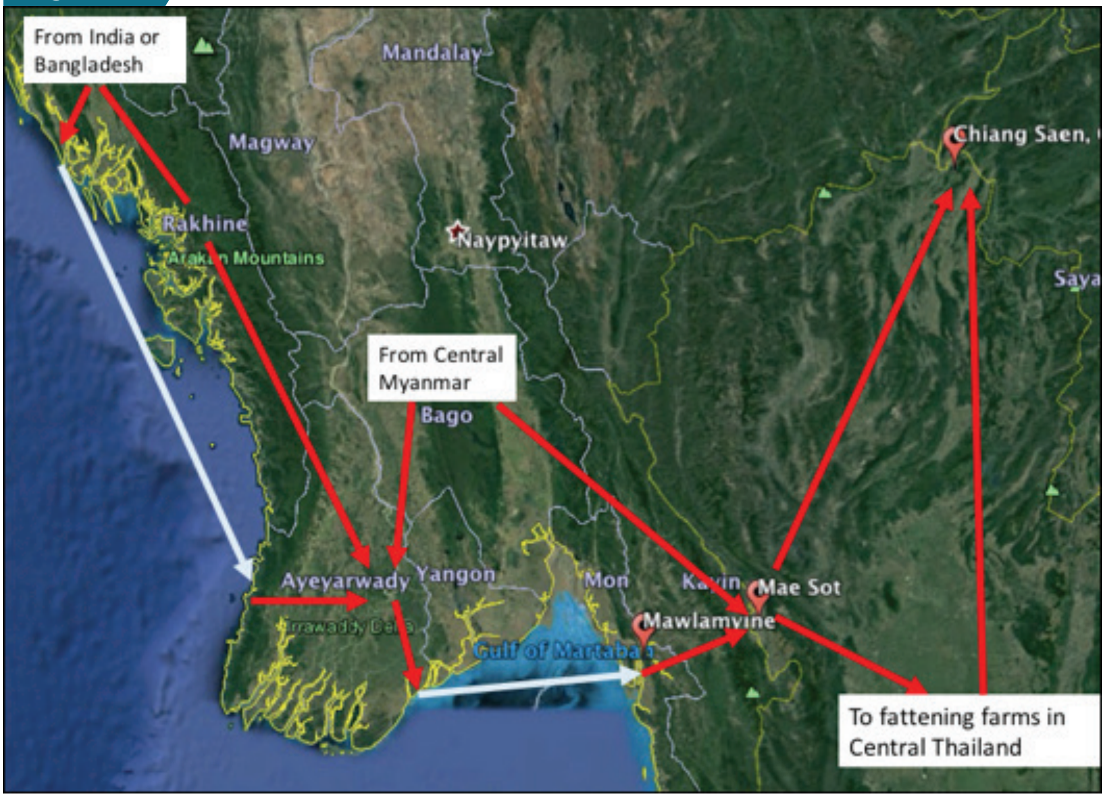

Figure 3: Map showing movement pathways for cattle and buffalo destined for Chiang Rai Province in Thailand before transiting through the North-West Provinces of Lao PDR to China. This map illustrates general directions of movement (from named source to destination) rather than exact routes. The white lines indicate movement by boat and the red lines, movement by road/foot (base-map source: Google 2016).

Most cattle destined for transit to China via the proposed CZ in LNT will originate from Central Myanmar (and to a lesser extent from India, Bangladesh, Thailand, Malaysia and Australia) (Smith et al., 2015). Cattle and Buffalo from Central Myanmar will be collected by traders either direct from the villages or from livestock markets in Central Myanmar before moving to the Myawaddy-Mae Sot border crossing into Thailand.

Those cattle and buffalo originating from India and Bangladesh, and passing to Chiang Rai, are believed to enter Myanmar in Rakhine State from where they are walked along mountain roads before passing into Ayerawaddy Division. From here, the pathways can vary but they are often taken by boat (together with animals that have originated from Ayerawaddy and from Yangon Divisions) to Mawlymine Port (figure 3). It is then a relatively short journey from Mawlymine Port to the border crossing at Myawaddy into Mae Sot, Thailand.

The export of cattle and buffalo from Myanmar is unofficial, so there is no regulation at this point. However, Thailand operates a system by which livestock entering from Myanmar are taken into private or public quarantine facilities and undergo vaccination, quarantine, individual identification and health certification before continuing their movement through the country (Smith, 2012). However, it is not known what proportion of livestock entering Thailand pass through these systems and what proportion circumvent these measures.

From Mae Sot, cattle and buffalo will either be transported directly to Northern Thailand (Chiang Rai Province) or they will be moved to farms within Thailand (usually in central and southern-central Thailand) for fattening. In general, cattle will be kept at these farms for approximately three months before moving to Chiang Rai Province. Livestock coming from Malaysia and Australia were reported by traders to spend some time in farms in Thailand, though it is possible that they may travel relatively directly to Northern Thailand for transit to China (via North-West Lao PDR).

Movement pathway CL1: Transit movement from Chiang Rai, Thailand, across the Mekong River by boat into Bokeo Province of Lao PDR, before moving into Luang Namtha Province, where cattle and buffalo exit Lao PDR for China near the Boten-Mohan border crossing.

Figure 4

Figure 4: Map showing movement pathway CL1. All pathways shown are approximate (base-map source: Google 2016).

This is a very active pathway of cattle and buffalo movement from Chiang Rai Province in Thailand to China. It represents the single highest volume of cattle and buffalo movement into LNT Province of all those described in this study.

A wide range of estimates for the actual number of cattle traded along this route were provided by different stakeholders: Stakeholders interviewed in Vientiane estimated 200-300 cattle per day; a Chinese businessman who is developing a quarantine station near to the

Boten-Mohan border ,described movement of 800 cattle per day; quarantine officers based near the border described movement of 100 to 300 per day; and a transport company in Bokeo described movement of 200 cattle/buffalo per day along this route. A livestock officer from Bokeo Province stated that 4953 cattle/buffalo entered Bokeo Province (officially) per month and travelled either to the Boten border checkpoint area or to Phongsali Province, before moving to China (see movement pathway CL3). Assuming that approximately 80% of cattle/buffalo entering Bokeo do so officially (according to transport companies operating in Bokeo), then this would suggest that 6,200 might enter Bokeo (combined official and unofficial) per month, or approximately 74,000 per year (approximately 200 head per day). The most recent figures provided by the Lao government suggest that 66,048 cattle and buffalo crossed from Lao PDR into China by this route in 2017, though there is no indication of the number unofficially crossing so the total number may be higher, possibly up to approximately 82,000 head of cattle and buffalo if official movement of livestock accounts for around 80% of the total movement across the border.

Live cattle and buffalo brought along this route are generally purchased by Chinese traders while still in Thailand, either direct from livestock markets (particularly from a market in Mae Sot, Tak Province which is located near the Myanmar-Thailand border) or from farms within Thailand. Thai traders are then employed by the Chinese traders to move cattle to Chiang Rai Province in readiness for transiting through Lao PDR to China. In Chiang Rai, Lao PDR agents or transportation companies are employed to take the cattle from Chiang Rai, Thailand through to the Lao-China border at Boten. The companies are paid by the Chinese traders to arrange all transportation, certification and taxation necessary for the transit of cattle and buffalo through Lao PDR. Some such companies were interviewed during this study and provided details of this process (see figure 5).

Figure 5

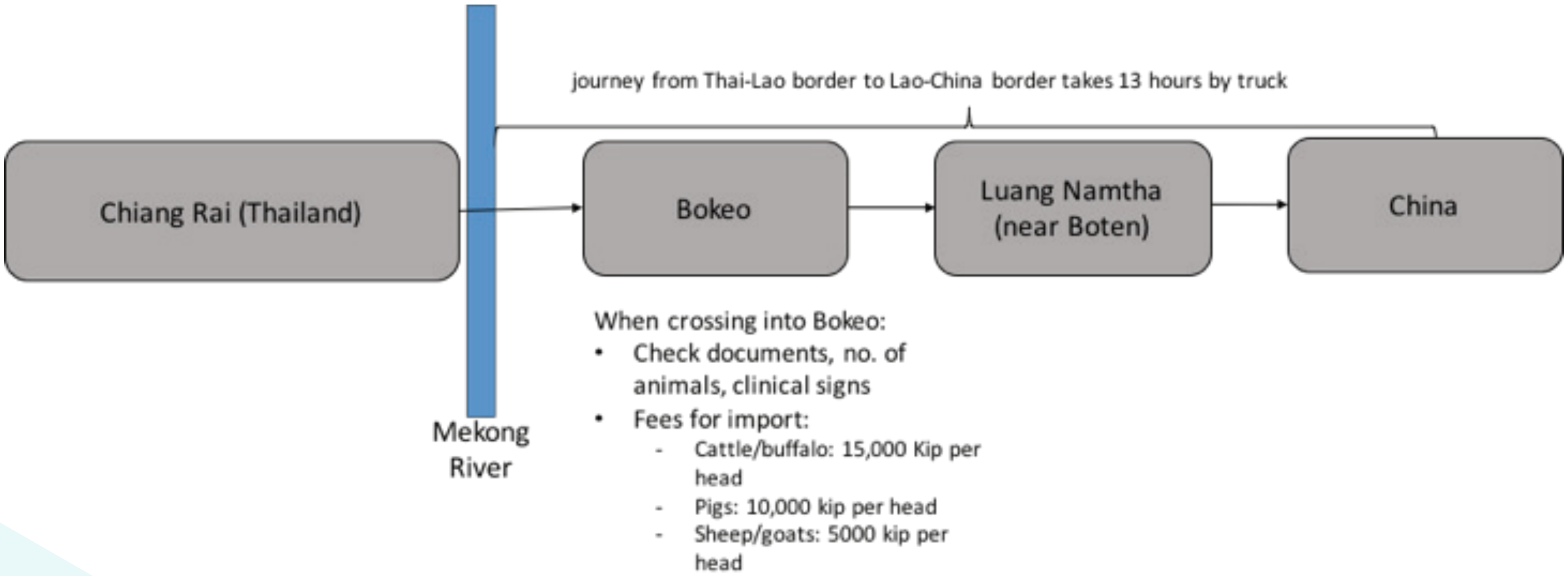

Figure 5: details of pathway CL1 (including journey times and taxes) from Chiang Rai (Thailand) to China (near the Boten-Mohan border checkpoint)

Cattle and buffalo arriving at Chiang Rai (usually Chiang Saen or Chiang Kong river ports) will be unloaded from trucks and cross the river by small boat (Smith et al., 2015) into Bokeo Province of Lao PDR. According to Lao veterinarians interviewed during the current study, this is the only point along the transit route where cattle pass through a checkpoint and are checked by a veterinary officer. When passing through this checkpoint, cattle should be examined by a veterinary officer for clinical signs of disease. If there are no signs of disease, then a certificate for onward movement will be issued. During the current study, it was described that there is a fee of 15,000 kip (approximately USD 2) per head of cattle/buffalo entering Lao PDR at Bokeo. According to information collected in 2015 (Smith et al., 2015), the Provincial Finance Office in Bokeo Province charged USD 15 per head of cattle and USD 20 per head of buffalo for transport through the Province. The cattle are loaded back onto trucks in the afternoon and usually arrive at the Boten border crossing area early the following morning (Smith et al., 2015). Transport companies operating in Bokeo Province that approximately 80% of cattle will enter Bokeo through the official pathway described above, whereas 20% will circumvent these processes and enter illegally, without any regulation.

Approximately 500 metres from the Boten border crossing there is a field where the cattle and buffalo are gathered before being taken over the border on foot (via small tracks) into China (figure 6 (A)). Local people are employed by Chinese traders to walk the cattle over the border. According to the study by Smith et al (2015), a fee of CNY (USD16) per 3 animals is paid to the local people. In addition to the payment to walk cattle over the border, one interviewee described an unofficial payment of CNY 40 (almost USD 6.5) per head of cattle or buffalo made to Lao quarantine officials in this area to allow movement over the border (this was only described by a single source and could not be further validated).

Figure 6

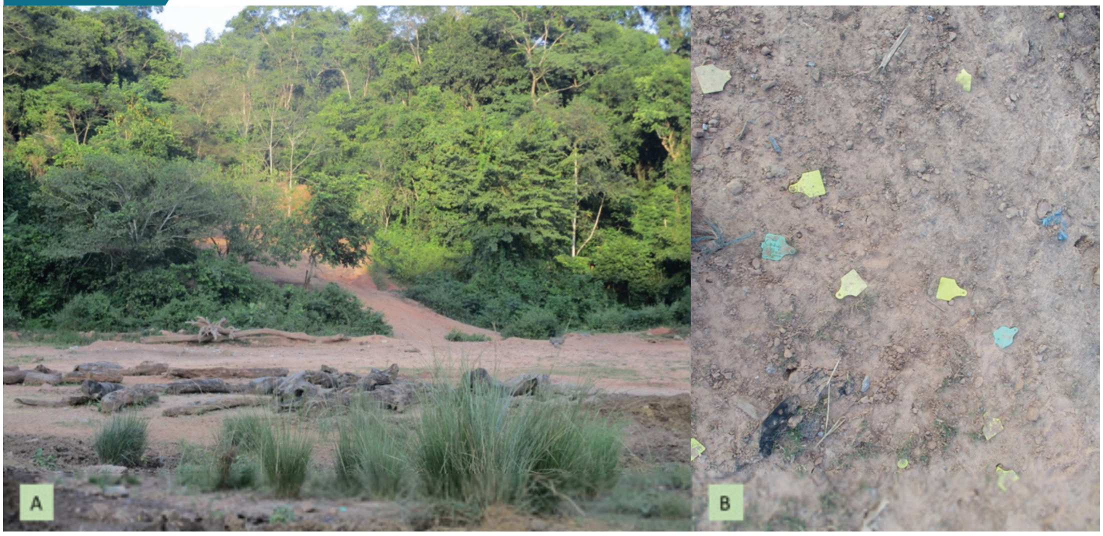

Figure 6: Collection area and track for movement of cattle and buffalo across the Lao-China border near the Boten-Mohan border crossing (A) and discarded cattle ear-tags found in this area (B).

The journey across the border, from this collection point, takes about two hours. However, one of the local people employed to move cattle along this pathway described an alternative, shorter pathway which may be used if animals are unable to walk a longer distance (it was described that this could include sick animals). However, the shorter route is not commonly used as it does not reach the established collecting area on the China side of the border. From the collection area on the China side of the border, cattle and buffalo are loaded onto trucks and taken to other destinations within China.

During the visit to this area, many discarded ear-tags were visible in the collection area (figure 6B). These tags were issued by the Department of Livestock Development (DLD) in Thailand, thus validating that cattle passing out of Lao PDR into China, near the Boten border crossing, have passed through Thailand. It also highlights how investments made in identification/vaccination in one area are being under-utilised due to the absence of a regionally recognised certification of livestock and absence of official cross-border movement.

Movement pathway CL2: Transit movement from Chiang Saen/Chiang Kong in Chiang Rai Province, Thailand, along the Mekong River by boat to Xieng Kok, Luang Namtha, to exit Lao PDR for China near the Panghai border checkpoint (Lao PDR)

Figure 7

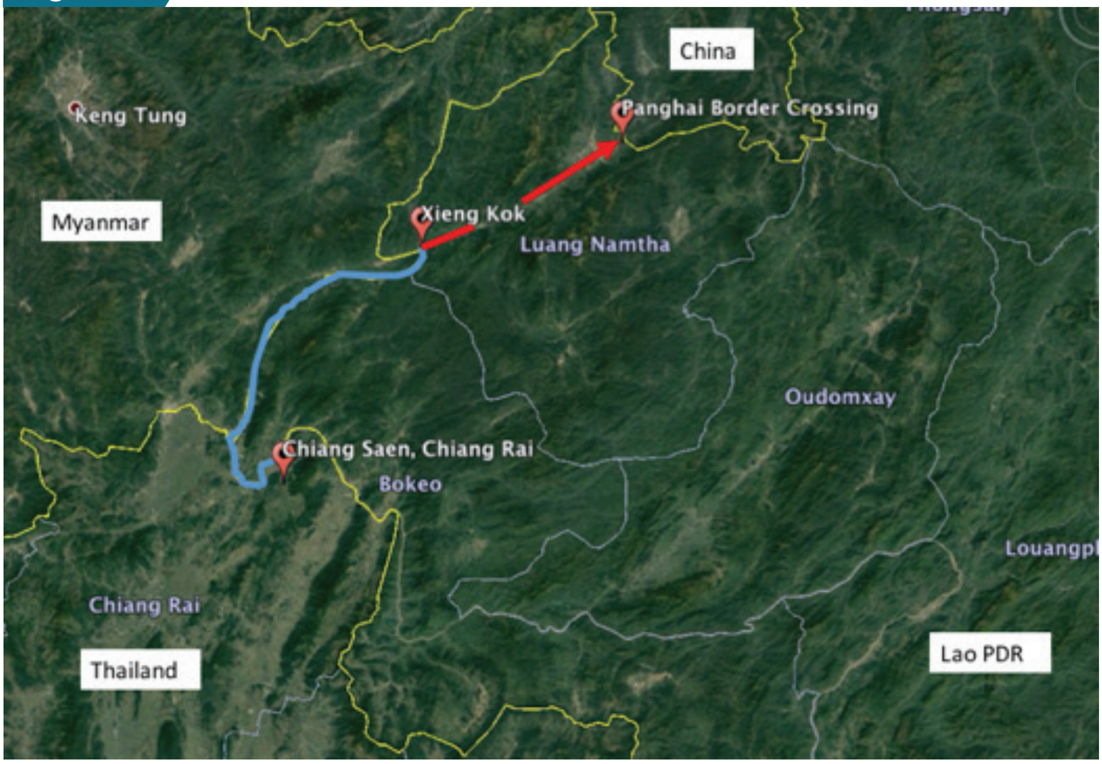

Figure7: A map showing the approximate routes of cattle and buffalo along movement pathway CL2 (base-map source: Google 2016).

A number of different routes of cattle and buffalo movement along the Mekong river from Chiang Rai Province in Thailand, destined for China, were described during data collection for the current study. The routes differed according to the location of the river port where livestock are unloaded and then the route they take from the port, into China. According to information gathered during the current study, livestock may either disembark from boats at Xieng Kok and then pass into Luang Namtha (figure 7), or stay on the boats until reaching Sob-Luay Port in Myanmar, or even Guanlei Port, China from where they can pass directly into China without passing through the North-Western provinces of Lao PDR (see movement pathway CL6). According to traders operating in North-West Lao PDR, cattle and buffalo rarely disembark at Xieng Kok but are generally moved further up the Mekong River to Sob-Luay or Guanlei Ports. This latter movement pathway is reportedly the major route (in terms of volume of trade) for livestock moving from Northern Thailand to China. The movement pathway described here, however, includes only the movement of cattle and buffalo through the proposed CZ of LNT Province (that is, the movement from the Mekong River, to Xieng Kok in Lao PDR, and then exiting via Panghai border crossing in Sing District, Lao PDR). Although local people interviewed near Panghai described very few cattle passing through this route, transport companies in Bokeo (interviewed as part of the current study) estimated that 3600 cattle per year pass along this route.

Movement pathway CL3: Transit movement from Chiang Rai, Thailand, through Bokeo, Luang Namtha and Oudomxay Provinces, to exit Lao PDR through Phongsali Province.

This pathway is described to have started in 2015. It was suggested that this new pathway may have become established due to demand in certain areas of China (though the reason could not be validated). Traders interviewed during stakeholder meetings in Lao PDR estimated that 250 cattle and buffalo move along this movement pathway each week (13,000 per year). Two transport companies in Bokeo estimated that they trade up to 10,530 head per year and 13,250 head per year, respectively along this route, giving a combined annual movement of 23,780 head of cattle and buffalo.

Figure 8

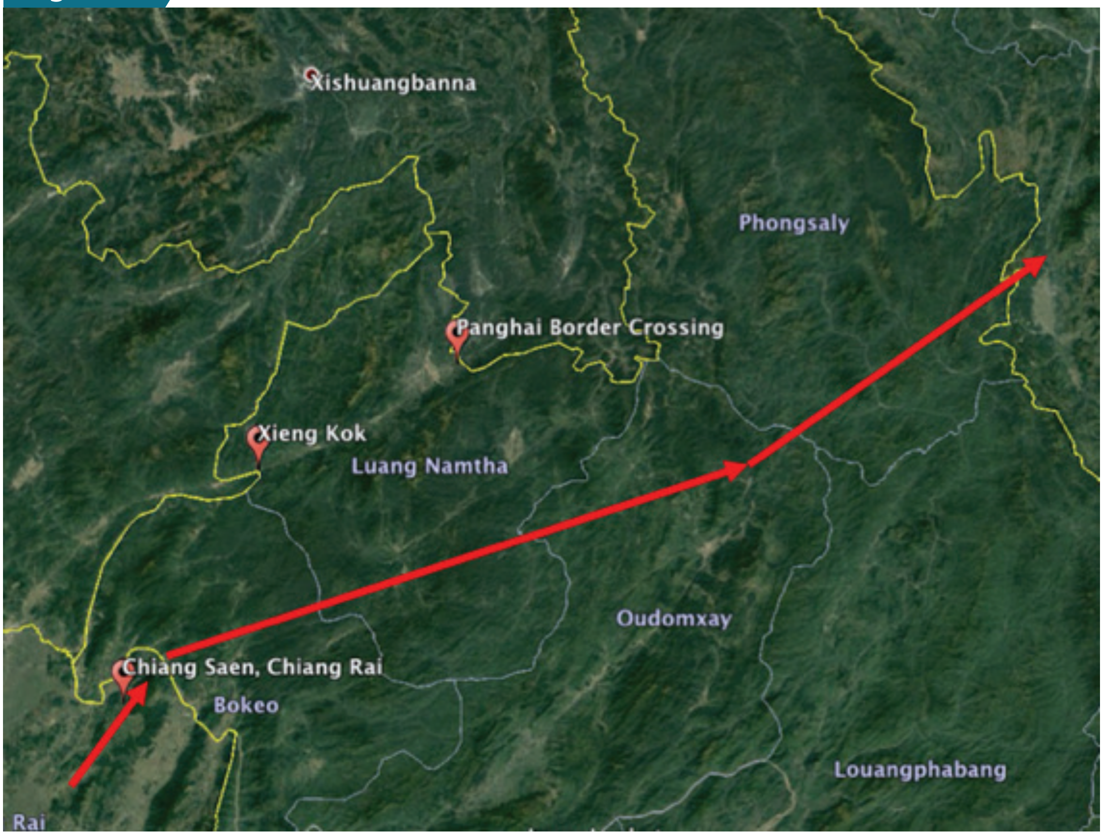

Figure 8: Map showing movement pathway (CL3) (the route shown on this map is only a guide as the exact pathway is not known) (base-map source: Google 2016)

Movement pathway CL4: Domestic movement of cattle and buffalo from other provinces in Lao PDR to Luang Namtha Province, exiting for China near the Boten-Mohan border crossing.

Figure 9

Figure 9: Map showing movement pathways (CL4) taken by cattle and buffalo from provinces within Lao PDR (Champasak, Xieng Kouang, Houphan, Luang Prabang and Bokeo) (based on information by Smith et al., (2015) and Phonvisay (personal communication) (note: the route shown on this map is only a guide as the exact pathway is not known) (base-map source: Google 2016)

Some movement of cattle and buffalo from other Provinces in Lao PDR to LNT Province was described during fieldwork for the current study. However, this is described in more detail by Smith et al. (2015) and is believed to have continued to the present day (figure 9):

According to Smith, et al. (2015) livestock traders from Vientiane, with connections in LNT, sourced large ruminants from the Southern Lao Provinces. Local traders operate this trading route, and source the animals from the Cambodian-Lao border area to Luang Namtha Province and then informally to China. These traders also sourced animals from other northern provinces such as Xieng Khouang, Luang Prabang and Huapanh to sell through the same route.

Smith et al. (2015) also described unofficial trade in local large ruminants from Bokeo Province to LNT Province prior to cross border movement into China. It was estimated that 20% of the total large ruminants traded in Bokeo were informally traded to China. This is equivalent to approximately 2,400 head per year.

According to Phonvisay (2014) traders from Xieng Khouang Province also sourced large ruminants, particularly buffalo, from within this Province, and near-by Provinces, to sell to China through the informal route near the Boten border check-point in LNT Province. Document fees for movement of large ruminants from Xieng Khouang to LNT cost 6-7 million Kip (USD 740 – 870) per truck and one truck can transport up to 30 buffalo (or 40-45 local cattle). It was estimated that approximately one truck of cattle per week was transported from Xieng Koung to LNT and then China. This equals approximately 2080 large ruminants per year.

Traders from Bokeo only described movement of cattle and buffalo from Bokeo to LNT at a very low volume (100 head per year). There appears to be significant uncertainty around the volume of cattle movement from provinces within Lao PDR.

Movement pathway CL5: Direct movement of cattle and buffalo from Myanmar to Xieng Kok, Luang Namtha Province, before exiting Lao PDR at Panghai border crossing.

Figure 10

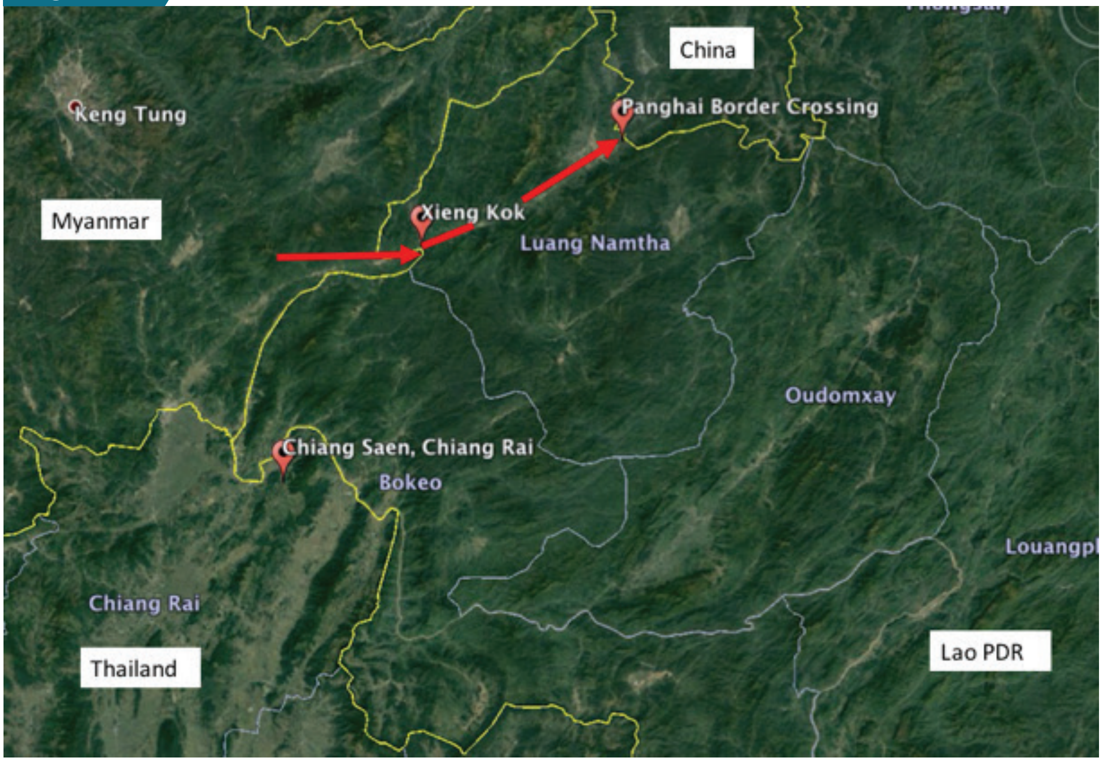

Figure 10: Map showing movement pathway (CL5) (note: the route shown on this map is only a guide) (base-map source: Google 2016)

This movement pathway was described by stakeholders in Vientiane Capital and in LNT Province, but relatively few details about the movement pathway was known. It is thought to have developed relatively recently, following construction of a bridge across the Mekong river from Myanmar to Lao PDR near Xieng Kok (figure 10). This bridge opened in 2015. However, traders in Bokeo Province described that no large ruminants pass along this route. This pathway has remained in the study, given that it was identified as some stakeholders as a potential pathway for cattle and buffalo movement. However, it is understood that this movement is not active at present.

Movement pathway CL6: Transit movement from Chiang Saen/Chiang Kong in Chiang Rai Province, Thailand, along the Mekong River by boat to Sob-Luay Port, Myanmar and then to China

Figure 11

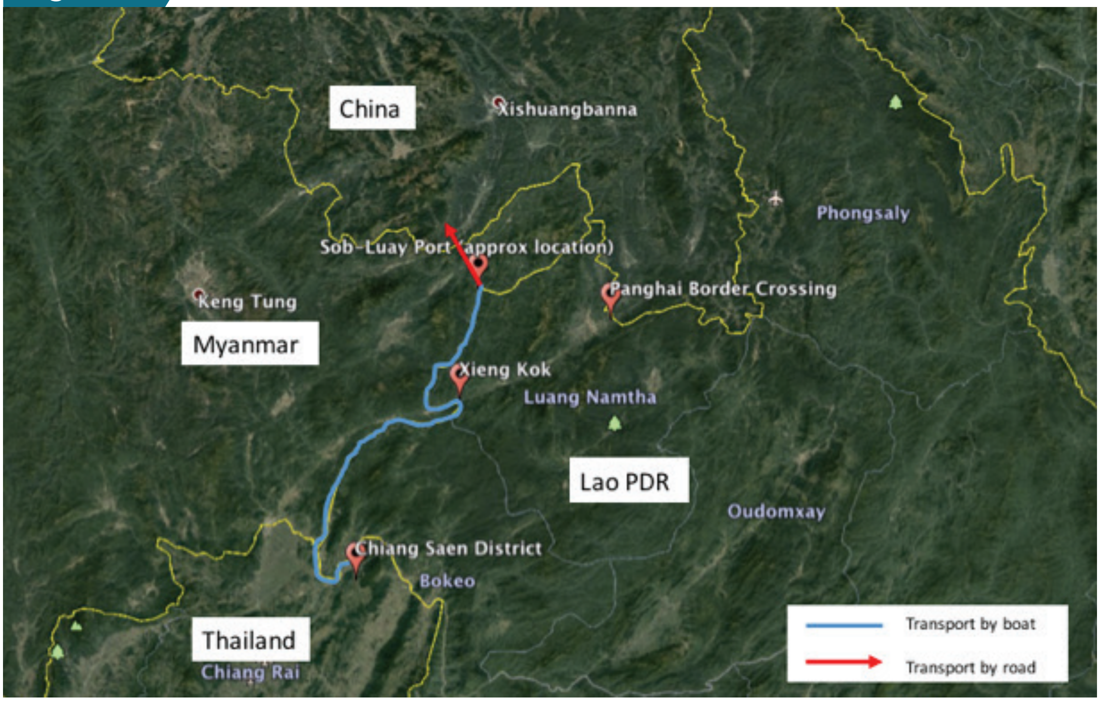

Figure 11: Map showing movement pathway (CL6) (note: the route shown on this map is only a guide) (base-map source: Google 2016)

This movement pathway is believed to be the most significant, in terms of volume of livestock movement, from Northern Thailand to China. Smith et al. (2015) described movement of cattle and buffalo by boat up the Mekong River from Chiang Saen in Chiang Rai Province of Thailand to Bokeo Province in Lao PDR to Xieng Kok District of LNT Province of Lao PDR to Sob Luay port in Myanmar. At Sob Luay Port, the cattle and buffalo are unloaded and moved directly into China. Although no estimates on the volume of cattle/ buffalo moving along this route were provided in the current study, Smith et al. (2015) provided various estimates of the number of animals moving along this route: from 36,000 head per year estimated by traders operating in Bokeo Province of Lao PDR; 39,000 head per year estimated by a livestock officer from Bokeo

Province Lao PDR; and 365,000 head per year (1000 per day) estimated by Chinese traders operating in the area at the destination of this route. Indeed, traders interviewed during the current study described that many more cattle/buffalo move via this route than via the pathway CL1 (estimated between 100 and 800 head per day) which would support the volumes described above.

News reports (dated July, 2016) describe closure of Sob-Luay Port in Myanmar, which was said to be impacting on trade along the Mekong River between Thailand, Lao PDR and China (Pooritanasorn, 2016). It is not clear how long the port will remain closed or how this is affecting movement of livestock along the river. However, livestock traders in Bokeo were asked to comment on whether they had noticed this impacting on movement of livestock up the Mekong River, and all answered in the negative. Therefore, it will be assumed that this movement is continuing despite reports of closures at Sob-Luay Port. This particular route of movement may be challenging in terms of controlling the risk of FMD entering China or, indeed the proposed CZ areas. At present, this movement pathway is used by Thai traders, supplying cattle to Chinese traders, with Lao boats providing a transportation service only. This route, according to a number of sources, is far cheaper than the alternative road route through the North-West Provinces of Lao PDR, to the Boten border checkpoint or to Phongsali Province (movement pathways CL1 and CL3, respectively) which appears to be the main driver for using this movement pathway. One boat carrying 200 cattle costs approximately 5 million Kip (USD 620), which equals USD 3.10 per head, compared to road transport costs of approximately 705,000 kip (USD 87) per head in tax and transportation costs (note that there may be some additional road transport after the animals are unloaded from the boat, but the river route would still be considerably cheaper).

The movement is unregulated and involves very high volumes of livestock. However, as it currently stands, this movement bypasses the proposed CZs and may not, therefore, be included in this risk assessment. However, given the proximity of this movement to the CZ and the fact that the main driver of the river route movement is low cost, then consideration should be given to the impact that opening up a legal movement channel for cattle and buffalo into China, via the CZ in LNT, may have on this river route if the legal channel offers a cheaper alternative. For this reason, further consideration will be given to this movement pathway in the quantitative risk assessment given that livestock currently using the pathway may transfer to alternative routes (i.e. through the CZ) if legal export channels become available or, if this is not achieved, then continuation of the river route outside of legalised pathways will continue to represent a significant risk for FMD infected livestock entering China. Consideration may also be given to establishing a CZ in a strategic place at the start of this pathway, such as in Chiang Rai Province, Thailand which could incorporate cattle and buffalo moving both through Bokeo and up the Mekong River.

Pigs

In the current study, pigs were described to be moving in relatively large volumes from Thailand, through Lao PDR to China. This movement was not identified in the previous animal movement study in the region (Smith, et al., 2015) which focused on movement of large ruminants. Earlier studies conducted in the region (Cocks, et al., 2009) identified pig movement, but at that time it occurred in the opposite direction: out of China to other SEA countries. According to Rousseau (2016), factors within China have led to a reduction in pig production in recent years with sow numbers shrinking to an historic low. Imports of pig meat are reported to be increasing significantly as a result of the reduced domestic production (Rousseau, 2016) and it may therefore be assumed that the demand for pig products will drive prices up and could attract illegal movement of live pigs into China from neighbouring countries. The movement channels described for pigs in this study are relatively similar to those described above for large ruminants. Figure 12 shows that the price of pig meat has almost doubled from 2009 to 2015.

From the perspective of the Lao PDR government, the transit movement of pigs through Lao PDR, from Thailand to China, is permitted and is therefore considered legal, providing the correct procedures are followed. These procedures include health checks and issuing of movement certificates, which are conducted at the point of entry into

Lao PDR (Bokeo Province). There are no further checks during domestic movement within Lao. However, illegal movement still occurs commonly and appears to be mainly due to avoiding the waiting period for health/movement certificates to be issued at the point of entry to Bokeo Province. If livestock enter Lao PDR illegally they can, at present, be moved more directly through to China. A DLF officer in LNT estimated that approximately 80% of pigs entering Bokeo, for transit purposes, do so illegally (that is, they do not undergo any checks on arrival at the Thai-Lao border crossing into Bokeo Province), whereas only 20% follow the official procedures.

Figure 13 shows the main movement pathways for pigs through LNT identified during the current study. Each pathway will be described in more detail below.

Figure 12

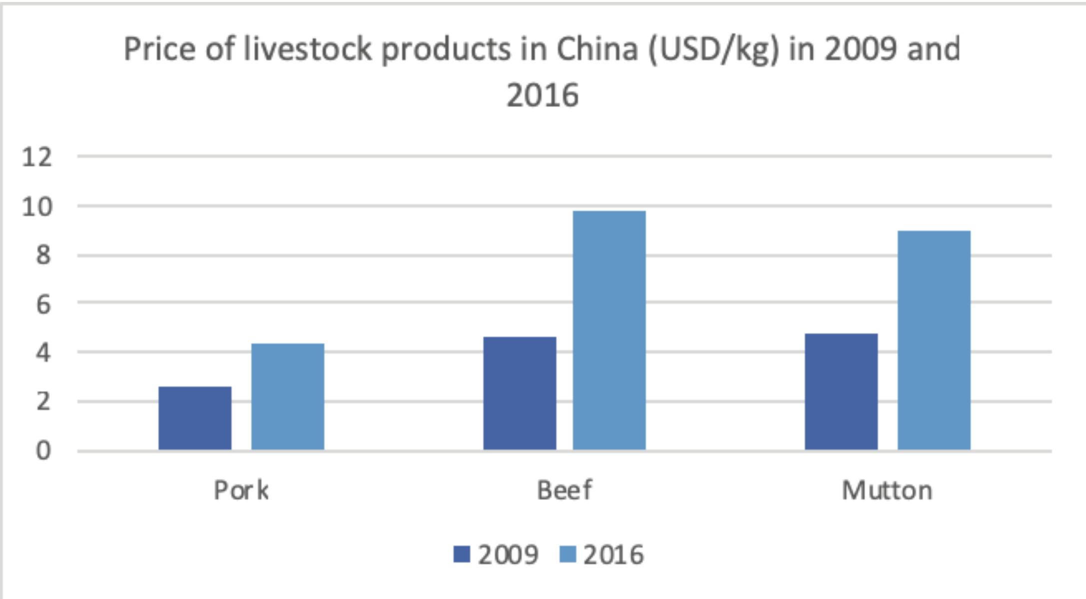

Figure 12: A graph showing the price of livestock products (meat) in China (USD/kg) for 2009 and 2016 (Wei, 2016)

Figure 13

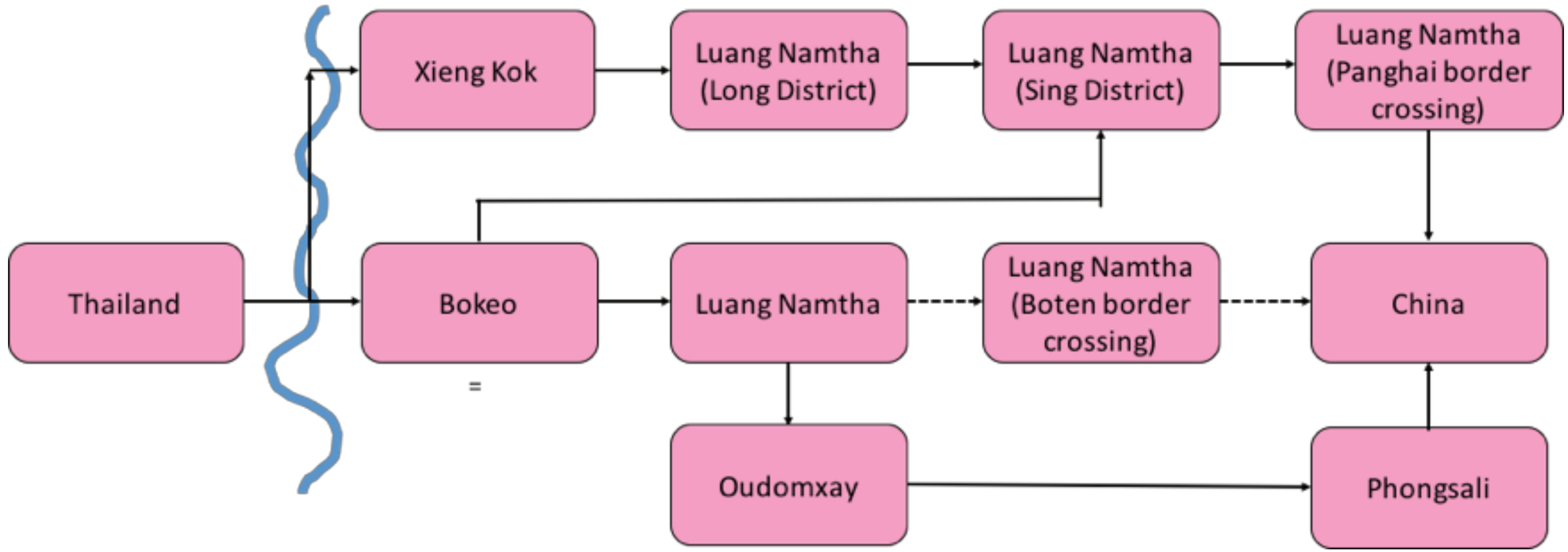

Figure 13: Movement pathways of pigs from Thailand to China, via LNT Province.

Movement pathway PL1: Transit movement from Chiang Rai, Thailand, along the Mekong River by boat to Xieng Kok, Luang Namtha, to exit Lao PDR for China at Panghai border crossing in Sing District.

This pathway of pig movement was described by several sources as one of the most active movement pathways for pigs moving from Thailand to China, via the proposed CZ in LNT (figures 14 and 15). However, transport companies operating in Bokeo estimated only 200 head per month (2400 per year) as passing through this route. Pigs are brought by truck, from commercial pig farms mainly located in central and northern Thailand, to the Mekong River in Chiang Saen District, Chiang Rai. From here, they are loaded onto boats and moved up the Mekong River to Xieng Kok. The journey from Prachuab Kiri Khan in Thailand (one of the source areas identified) is said to take 3 days and 2 nights, with each truck carrying 40 pigs. Thai companies are responsible for the cost of transportation and any taxes payable along the route. They hire Lao boats for the journey up the Mekong River but the pigs remain under the ownership of the Thai trader until reaching the border between Lao PDR and China, at which point the Chinese trader takes ownership (see figure 15). At Xieng Kok, a customs charge of THB 1500 (USD 43) per head is paid before the pigs can cross into Xieng Kok. There is not understood to be any veterinary checks at this point.

Figure 14

Figure 14: Map showing movement pathway (PL1). The blue line indicates movement by boat and the red line, movement by road (base-map source: Google 2016).

Traders and other stakeholders noted that this is a cheaper route for transportation of pigs compared to route PL2. However, it was noted that this route involves some risk given that there have been incidents where boats have sunk and all livestock lost at high cost to the trader/owner responsible. However, the cost of using this route appears to be such that traders and willing to take this risk.

When the pigs arrive in Xieng Kok they are moved directly by truck through Long District and into Sing District of LNT Province. On arrival near the border in Sing District the pigs will be unloaded from Thai trucks and loaded onto Chinese trucks before being moved through small, unofficial border crossings into China (figure 15). Documents may be checked when live pigs arrive in Sing District but clinical examination by a veterinary officer is not conducted.

Most of the journeys occur without the pigs being unloaded and so there is relatively little opportunity for traded pigs along this route to mix with local animals. However, there may be collection points at the river ports where mixing with local animals or other traded animals could occur.

Figure 15

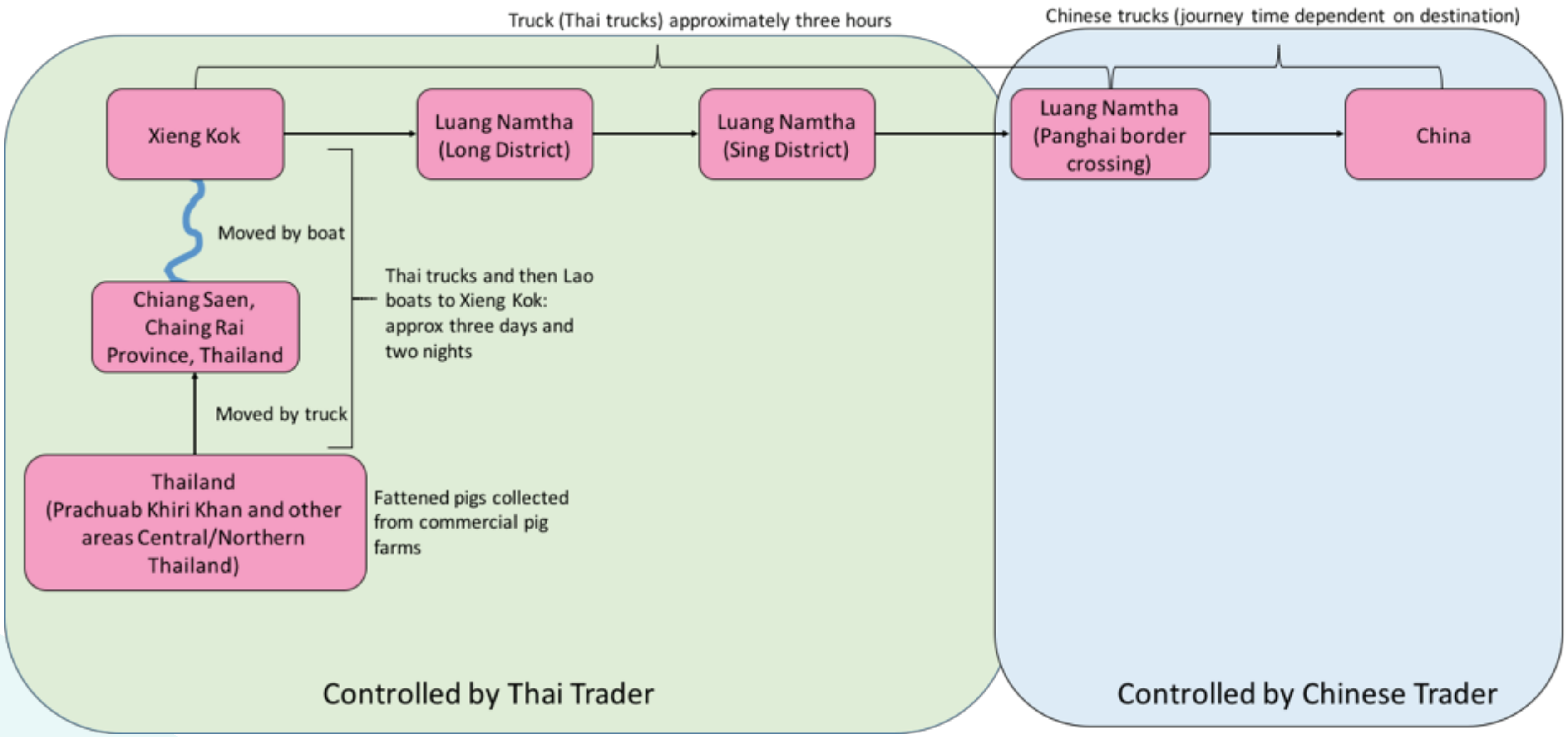

Figure 15: Detailed movement pathway for pigs along the river route from Thailand to China, via Xieng Kok and LNT, Lao PDR (some journey times estimated by traders, others from google maps).

Movement pathway PL2: Transit movement of pigs from Chiang Rai, Thailand, across the Mekong River by boat, to Bokeo Province, Lao PDR and then by road to Luang Namtha to exit Lao PDR at Panghai border crossing, Sing District.

Figure 16

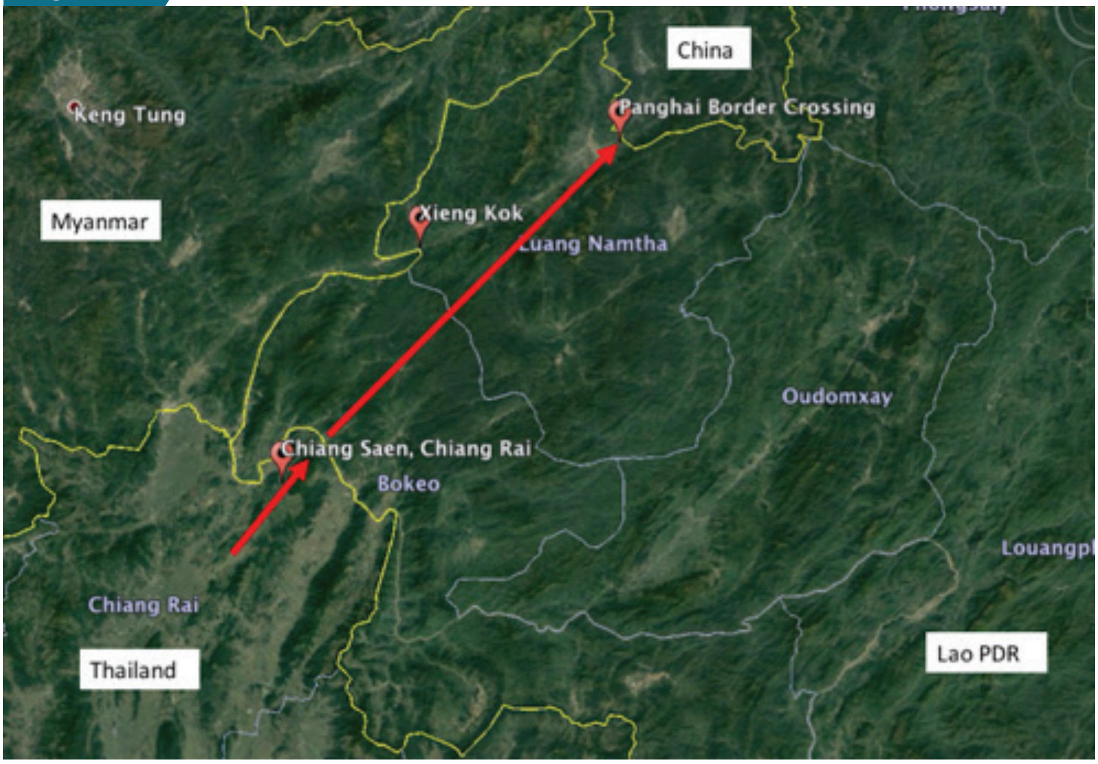

Figure 16: Map showing movement pathway (PL2) taken by pigs from Chiang Rai in Thailand to Yunnan Province in China, via Bokeo Province and LNT Province in Lao PDR (base-map source: Google 2016).

This movement pathway shares a common source with Movement pathway PL1, with pigs originating from commercial farms in northern and central Thailand before moving to Chiang Saen in Chiang Rai Province of Thailand (figures 16 and 17). Once there, the pigs are loaded onto small boats to cross the Mekong river into Bokeo Province, Lao PDR. The movement into Bokeo Province either occurs through legal routes (estimated by local livestock officer as 20% of all movement) or by illegal routes (estimated by local livestock officer as 80% of all movement). The number of pigs moving along this pathway was estimated by a number of sources, with estimates ranging from 5000 to almost 11,000 head of pigs per year.

For the legal movements, pigs will be checked on entry at the checkpoint in Bokeo on arrival to Lao PDR. At this time, the pigs are checked for clinical signs of disease by a veterinary officer. If no signs of ill-health are evident, a health certificate is issued and the pigs are allowed to continue on their journey (It can take from 2 to 7 days to issue certificates, during which time the pigs will wait in Bokeo). However, when stakeholders were asked, there did not seem to be official holding areas for pigs awaiting certification. According to a trader operating in this area, if any illness is detected at the checkpoint, only those animals with clinical signs of disease will be rejected, not the whole consignment.

The illegal pathway of pig movement into Bokeo Province from Thailand is much the same as that described for legal movement (above) the difference being that pigs are moved into Bokeo during the night/early hours of the morning, avoiding border checks, and are then moved directly to the Chinese border rather than waiting for certificates to be issued. These pigs do not, therefore, undergo any checks by veterinary officers on entering Lao PDR.

Once in Bokeo, movement of pigs to the China border will generally occur quite rapidly and without stops (apart from short rest stops during which pigs are not unloaded). According to Lao regulations, there should be no unloading of pigs along the transit route and other pigs should not be collected along the way. Even for pigs legally moved into Bokeo, there are no further checks required before reaching the Lao-China border area. As for Movement PL1, Chinese trucks would collect the pigs in Lao PDR near to the Panghai border gate before crossing via small roads into China.

Again, this movement is generally controlled by Thai and Chinese traders, with Lao companies providing logistical assistance during transit through Lao PDR.

In addition to the movement from Bokeo to Sing District in LNT, some interviewees described movement of pigs from Bokeo to Boten border checkpoint in LNT. However, several others (including large transport companies based in Bokeo) noted that pigs rarely use this pathway and are generally transported to China via Sing District. The Boten border area is, in contrast, a major transit area for cattle and buffalo.

Figure 17

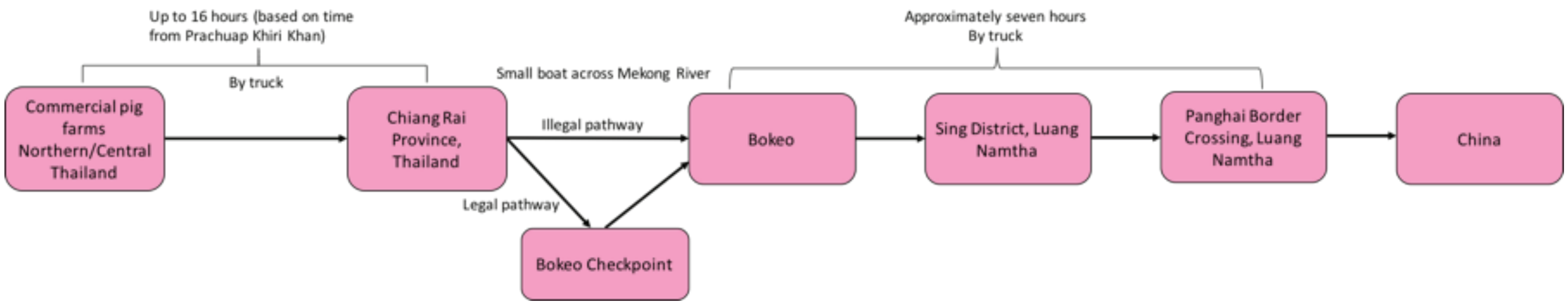

Figure 17: Movement pathway showing illegal and legal pathways of pig movement from Thailand to LNT, Lao PDR via road through Bokeo Province (journey times estimated from google maps)

Movement pathway PL3: Transit movement from Chiang Rai, Thailand, across the Mekong River by boat, to Bokeo Province, Lao PDR and then by road through Luang Namtha and Oudomxay Provinces, to exit Lao PDR for China in Phongsali Province.

Figure 18

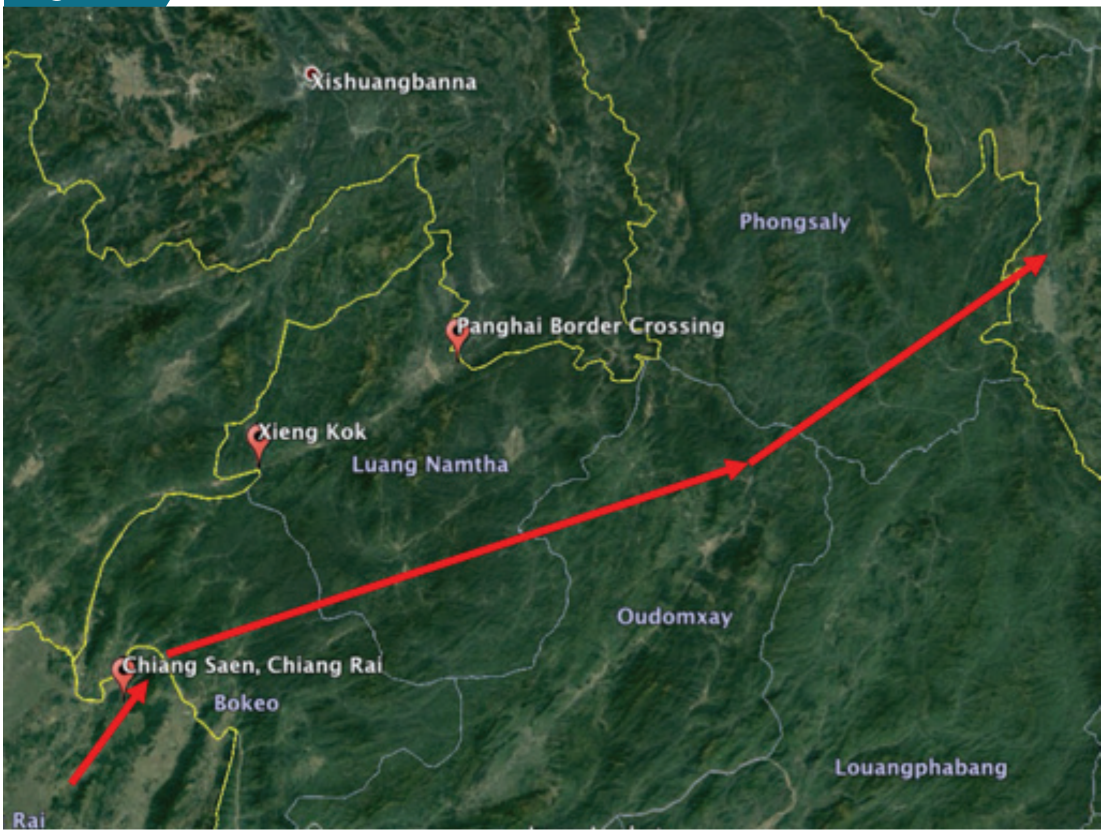

Figure 18: Map showing movement pathway (PL3) (note: the route shown on this map is only a guide as the exact pathway is not known) (base-map source: Google 2016)

Relatively little information was available on the traders involved in this movement pathway but the pathway itself was described by a number of different sources (both in Vientiane Capital and in LNT Province). One stakeholder estimated that 240 head of pigs are transported along this route each month (2,880 per year), with two traders interviewed in Bokeo describing that they each move 500 pigs per year by this route. It was not known why pigs are moved via this route in preference to other routes through Lao PDR to China, but was assumed to be due to demand on the China side.

As for pathway PL2, pigs are moved from Thailand (from Chiang Rai Province) over the Mekong River, into Bokeo. From here, pigs are taken by truck through Bokeo, LNT and Oudomxay Provinces of Lao PDR, to Phongsali Province. From Phongsali, pigs cross the border into China (figures 18 and 19). Though this pathway appears to be used by a smaller volume of pigs compared to PL1 and PL2, it could be important for China to consider given that there is some onward movement from LNT, within Lao PDR, before livestock move to China. For the purposes of the risk assessment, this pathway will be combined with PL1 given that these pigs take the same pathway into LNT Province (the proposed CZ).

Figure 19

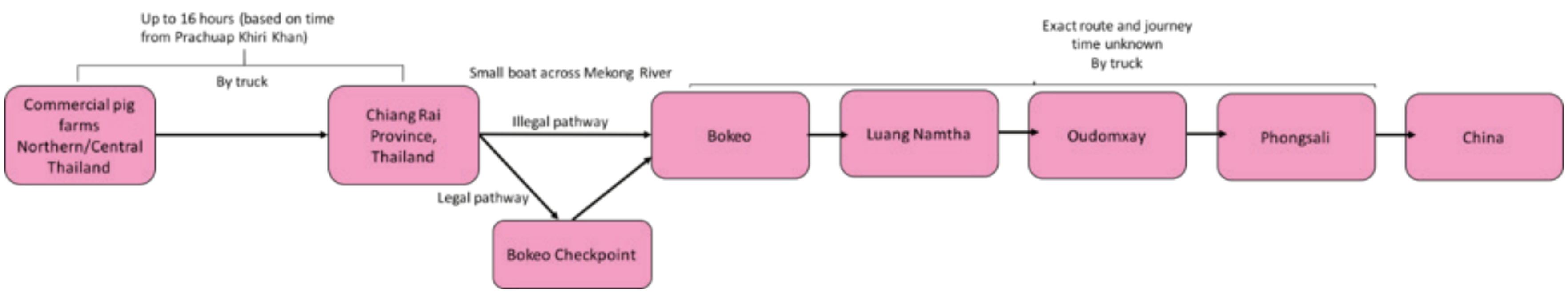

Figure 19: Movement pathway of pigs from Thailand to China via Bokeo, LNT, Oudomxay and Phongsali Provinces of Lao PDR

Movement pathway PL4: Import movement of pigs for breeding purposes from Chiang Rai, Thailand, across the Mekong River by boat, to Bokeo Province, Lao PDR and then by road to Luang Namtha Province.

Figure 20

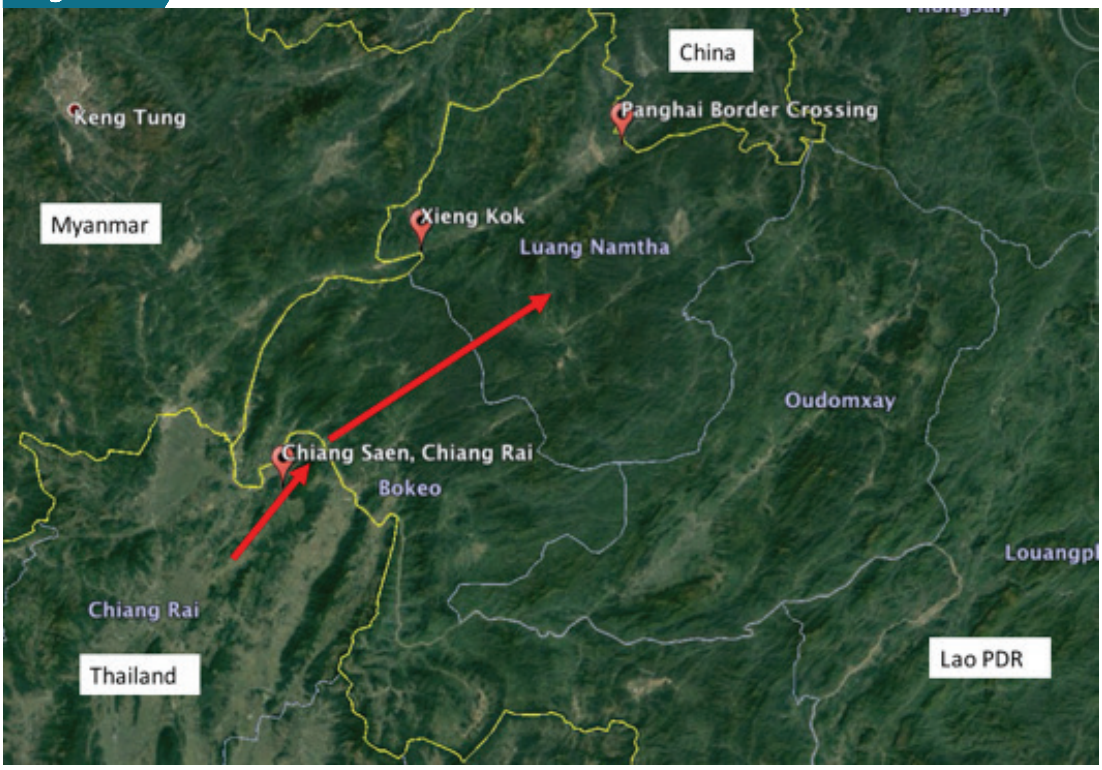

Figure 20: Map showing movement pathway (PL4) (note: the route shown on this map is only a guide as the exact pathway is not known) (base-map source: Google 2016).

This movement was specifically mentioned as an import to Lao PDR, rather than a transit movement. The pigs are imported for the purposes of breeding and come from commercial farms in Thailand. The route taken by the pigs is similar to other routes, from various areas of Thailand (mainly central and northern Thailand) to Chiang Rai Province, then across the Mekong River before moving by truck from Bokeo to their destination in LNT Province. It was estimated (by veterinary officers in Lao PDR) that between 100 and 500 breeding pigs per year and imported along this route.

Movement pathway PL5: Transit movement from Chiang Saen/Chiang Kong in Chiang Rai Province, Thailand, along the Mekong River by boat to Sob-Luay Port in Myanmar or Guanlei Port, China.

This movement pathway is believed to be the most active, in terms of the volume of pigs moving along it, of all the pathways described in this study. Some traders who attended stakeholder meetings held in LNT described several thousand pigs per day moving along this route, and a veterinary officer based in Bokeo Province of Lao PDR described that 36,869 pigs were recorded to be passing the port in Bokeo (en-route from Chiang Saen/Chiang Kong up the river to Sob-Luay Port in Myanmar or Guanlei Port, China) per month in 2016. This represented a significant increase compared to the movement of 7,751 pigs per month recorded in 2015. The movement of pigs along this route is believed to be conducted by Thai traders and, similarly to the movement of cattle and buffalo along this route, is unregulated and cheaper than alternative forms of transport through the North-West Provinces of Lao PDR. As with the cattle and buffalo movement, this pig movement also represents a potentially important risk pathway given that it bypasses the proposed CZ area of LNT Province and involves very high volumes of pigs moving into China. Careful consideration should thus be given to how to address this movement and how it might be affected when alternative, legal pathways become available. Further investigation into the future trends in pig imports to China should also be considered before significant investment in risk mitigation measures and infrastructure is developed specifically for managing trade in this species given that the very high imports are, at least in part, due to a significant reduction in pig production in China. However, when production in China increases again, this may impact on the demand of pigs from South-East Asia.

Figure 21

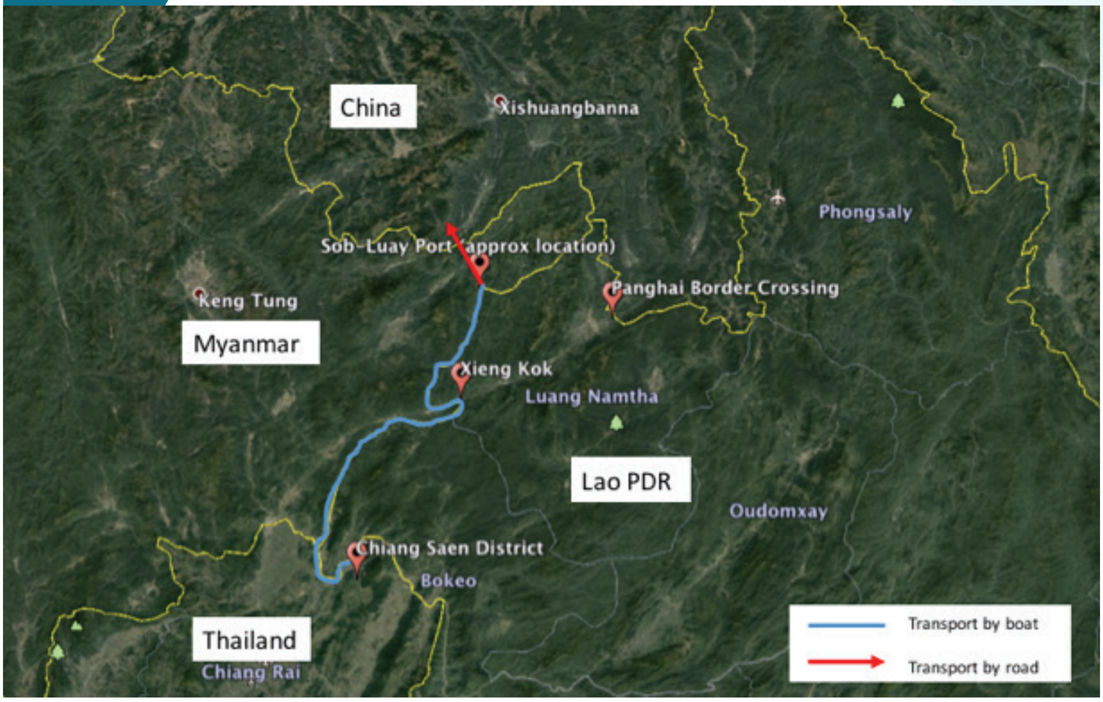

Figure 21: Map showing movement pathway (PL5) (note: the route shown on this map is only a guide as the exact pathway is not known) (base-map source: Google 2016).

Myanmar-China Control Zone

The results of the current study conducted in Myanmar demonstrate that there is an active trade in FMD-susceptible livestock from Myanmar to China, through Northern Shan State (particularly in the area of Muse) to Ruili in China. This trade pathway for cattle and buffalo has been previously identified in studies conducted in the region (Cocks, et al. 2009; Smith et al., 2015) with volumes of trade increasing through this pathway in recent years (Smith et al., 2015).

Previous livestock movement studies conducted in the region have predominantly focused on movement of large ruminants (Smith et al., 2015) or large ruminants and pigs (Cocks et al., 2009; ACIAR, 2011), with small ruminants being somewhat neglected from these studies due to the fact that there was believed to be minimal cross-border movement of these species at that time. The current study, however is the first to describe significant volumes of cross-border movement of small ruminants from Myanmar to China.

Although there is a high level of goat production in Yunnan Province of China, from 2009 to 2016, the price for mutton in China almost doubled (Wei, 2016), presumably reflecting that supply of mutton within China was unable to satisfy domestic demand (figure 12). This high price, coupled with the high population of sheep and goats in Central Myanmar (LBVD, 2015) (and relatively low demand of the local population), is likely to be the key driver behind the movement of these species from Myanmar to China.

In the last two to three years, the Myanmar Government has developed a system for official export of small ruminants to China using a quota system whereby the exported animals must be produced for the purpose of export, rather than procured from existing village production systems, and must undergo a period of quarantine in Muse area before crossing into China. The purpose of these stipulations were described as a measure to facilitate exports, while also aiming to protect food security and prevent price increases on Myanmar's domestic market for sheep and goats. It should be noted, however, that while the export of small ruminants is accepted as an official movement by the Myanmar Government, China does not recognise the import of sheep and goats from Myanmar and all movement into China of live animals from FMD infected countries remains unofficial.

A transit movement of pigs was also described whereby pigs are moved from Thailand, into Myanmar (via Tachilek) and then to China (via Muse). This movement pathway has not been described in previous studies and more details are included in the pathway descriptions that follow.

Movement pathway SM1: Movement of sheep and goats from Central Myanmar to China, via Muse.

Figure 22

Figure 22: Map showing movement pathway (SM1) (note: the route shown on this map is only a guide) (base-map source: Google 2016)

The movement pathway of small ruminants to the Chinese border (near Muse) is relatively simple, with sheep and goats originating from Central Myanmar (predominantly Magway, Mandalay and Sagaing Divisions) and then moving by truck to an area near the Chinese border (generally in, or near Muse) (figure 22). The same movement pathway was described by several different stakeholders and all stakeholders with knowledge of this pathway described an increase in this trade over the past two years. While the pathway of movement is similar for all sheep and goat movement from Myanmar to China (via Muse), there are a number of different methods used by different traders for procuring livestock, holding livestock and whether or not official export procedures are followed.

Figure 23

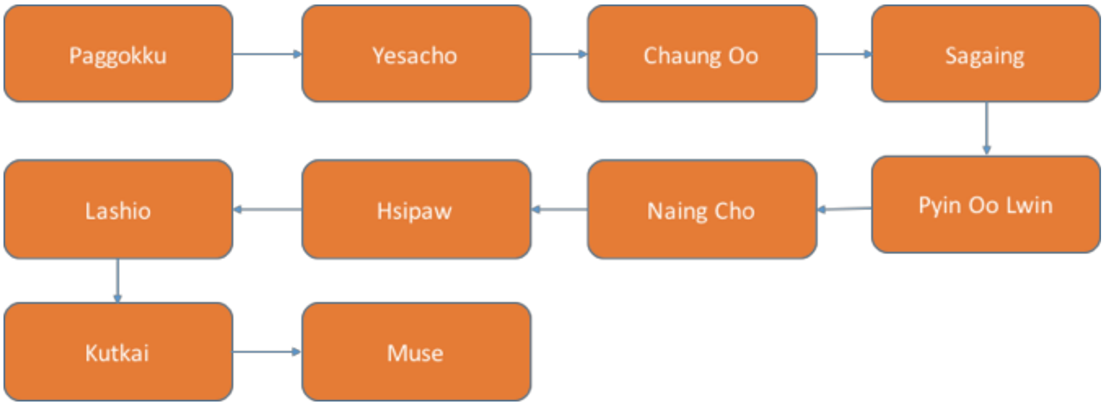

Figure 23: Movement route for sheep and goats described by stakeholders (including goat traders) during a workshop in Nay Pyi Taw.

Figure 23 outlines one pathway of movement for small ruminants from a major source of sheep and goats (Paggokku in Magway Division) to Muse. Some sheep and goats will also come from Mandalay Division, with Meikthilar described as a key source area. While this is just one example of the pathways described, all sheep and goat movement was described as following a similar route.

The locations listed in figure 23 represent the areas through which trucks pass, en-route from Central Myanmar to Muse. In general, trucks containing small ruminants are loaded in the source area (Magway or Mandalay Divisions) and are then moved directly to the border area with China. This journey takes 24 hours and, although they may stop for rests along the way, there is no unloading of animals and therefore no opportunity for mixing with other consignments or with local livestock along the journey.

According to estimates provided in 2016 by sheep and goat traders operating along this route, up to 11,000 goats are exported to China, via this pathway, each month (comprised of 1000 legal exports and 10,000 illegal exports of small ruminants per month). Other sources described movement of 2000 to 3000 small ruminants per month along this route. More recent data provided by LBVD suggest that in 2017, a total of 123, 987 head of small ruminants moved officially from Myanmar to China, via Muse, indicating significant increase in the official goat movements. Still, it was very likely that the unofficial movement of small ruminants still exist and may also increase alongside official movements. It should be noted that all cross-border movement of sheep and goats into China is considered illegal from the China side, but Myanmar recognises the export of some small ruminants (under specific conditions) to be official movement.

A number of different procurement systems were described by different traders (figure 24): one employed villagers local to their main farm site to keep goats for them. The villager would house the goat at their home, breed them and keep the kids until they reached a suitable size and age to enter the main farm, at which point they would be returned to the main farmer/trader (see box 1). Once in the main farm, the goats are kept here for approximately six to 12 months until they are of suitable size and weight for Chinese buyers. At this time the goats are transported to Muse for quarantine. Other traders use middlemen/agents to collect goats (already of suitable size for sale to China) from local villages in Central Myanmar and when there are enough to fill a truck, the truck is transported directly to the border area.

Some goat traders have a holding area near to the source of goats (see box 1) whereas others will collect goats from villages when they meet the market requirement in China and then transport them directly to Muse where they are to be held in a quarantine area for 21 days (see figure 24). While the officially exported animals must stay in a quarantine area for this period, it appears that the 'quarantine period' for some may be more like a holding period until a suitable price can be agreed between the buyer and seller. Some traders mentioned that they may spend less time in 'quarantine' if a good price is available in China.

The cost of transporting small ruminants from Central Myanmar to Muse differed slightly between traders, with truck hire described to cost from 1 to 1.2 million kyat (USD 770 to 930) to transport 200 goats and USD 1500 to transport 300 goats (approximately USD 4 to 5 per head). Some of the larger companies owned their own trucks and only hired additional trucks if they required more capacity. In addition to transporting goats, traders must also transport feed for goats to last for the whole quarantine period (21 days). It was estimated that the truck used to carry sufficient feed for 300 goats for the entire quarantine period would cost 200,000 kyat (USD 150 or USD 0.5 per head) and the feed itself approximately USD 10 per head for the whole quarantine period.

It was estimated by traders that the total cost of transporting small ruminants from Mandalay to Muse (including the cost of transport, labour costs and other charges) was 10,000 kyat (USD 8) when using legal channels and 50,000 kyat (USD 39) when using illegal channels. Therefore, the cost to move illegally is considerably higher than legal movement.

Once the goats arrive in the border area, Chinese traders come to Muse to buy animals. The goats are unloaded from Myanmar owned trucks and loaded onto Chinese trucks in Muse and then a ferry is used to move the Chinese trucks over the small river in that area. The cost of transport over the border is paid by the Chinese traders. The goat traders in Myanmar said that Chinese traders often don't request animals are vaccinated against FMD prior to sale, whereas some will request this is done during the quarantine period on the Myanmar side of the border. If vaccination is given, the cost of the vaccination is met by the Myanmar trader and is supplied by LBVD.

Figure 24

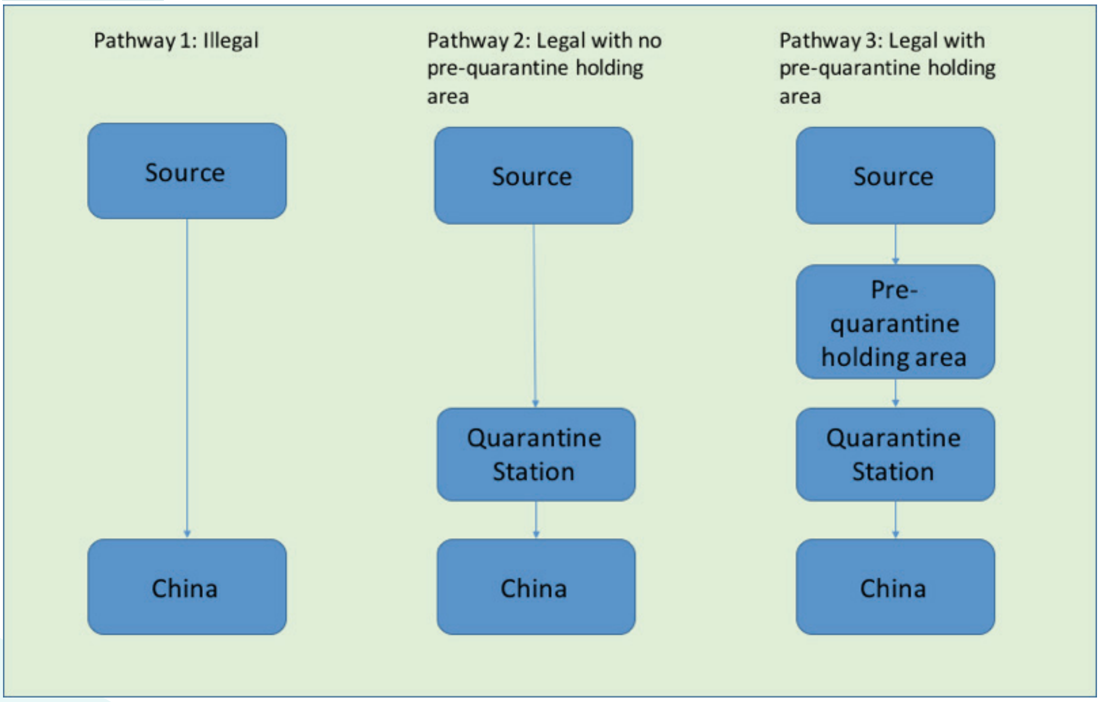

Figure 24: Pathways showing the three types of goat export systems operating from Central Myanmar to China, via Muse.

Box 1

A case study describing a Myanmar goat export business operating from sites in Mandalay Division and Muse

Myanmar goat exporter: A model for the future?

Trader profile: This goat exporter began his business two to three years ago and has established a holding (extending over 100 acres) in a relatively remote location in Mandalay Division. The holding has capacity for 3000 goats and is also used for production of high quality pasture. This businessman would also consider trading in cattle from this site in the future, should this trade become legalised.

Local villagers are employed by the goat trader to keep breeding goats (owned by the trader) and raise young goats up to approximately six months of age. At this time, the young goats are brought to the main farm area where they are raised and fed until they reach market requirements for China (usually at approximately 18 months of age).

Once goats are ready for export they are transported by truck to Muse, where this trader owns another property where the goats can be held for the quarantine period. Feed for the goats must also be transported from Central Myanmar to Muse. Once in Muse, LBVD staff come and inspect the animals, after which they remain in quarantine for 21 days before being released to the Chinese traders. A partner of this trader works in Muse and makes the connection with the Chinese trader in order to conduct the transaction.

Box 1 *(Continued)*

Potential as a pre-quarantine area: This farm is in a relatively isolated area and, although there is currently some potential for mixing with other livestock, the area would likely be suitable and relatively easily upgraded into a quarantine facility with some improvements in biosecurity.

At present, large volumes of feed and long waiting periods at the border can be costly for traders, so approval of areas like this as a pre-quarantine property prior to animals moving into the CZs would provide financial benefits to the traders as well as ensure a safer supply of livestock to the CZ (see section on risk mitigation measures).

By employing a pre-quarantine system, the CZs would be better protected against incursions of FMD, compared to the current system whereby livestock are brought from several different places and then mixed in the CZ areas, potentially leading to a situation where FMD outbreaks may be amplified by mixing large volumes of livestock from multiple sources of unknown FMD status. The potential for pre-quarantine systems is explored in more detail under the section on risk mitigation.

Movement pathway CM1: Movement of cattle and buffalo from Central Myanmar to China, via Muse.

Figure 25

Figure 25: Map showing movement pathway (CM1) (note: the route shown on this map is only a guide) (base-map source: Google 2016)

As for the sheep and goat movement, there is one major pathway for cattle and buffalo movement from Central Myanmar to Muse (and the surrounding areas). This pathway is shown in figures 25 and 26. However, unlike the movement of goats, when the current study was conducted, cattle movement along this pathway was complicated by the fact that movement was often not direct from source to destination and so there was considerable opportunity for mixing of traded livestock with other consignments of cattle and buffalo, as well as with local livestock.

The mixing of cattle was likely during movement from Central Myanmar to Muse because many cattle were walked for at least part of this journey in order to avoid detection. At the time of this study movement of cattle and buffalo, beyond the district level, for trade purposes was not legal in Myanmar. Traders get around this by arranging for people to walk cattle, on foot, in small groups and along small roads near to the main road from Mandalay to Muse. Along this route are several markets/collection areas where cattle and buffalo may be traded or where they can be loaded into trucks to continue the journey by road. Due to the need to walk cattle long distances, the trade takes a long time, costs traders additional money compared to more rapid transport (which could be possible under a legalised system of cattle and buffalo export), and cattle are more likely to arrive at their destination in poor condition. Recent developments in regulation of cattle and buffalo trade in Myanmar, however, are likely to impact on this movement through Myanmar, potentially reducing the need to walk cattle over long distances. Export of cattle and buffalo, under certain conditions, is now officially recognised as a legal movement by the Myanmar Government (Thiha Ko Ko, 2018). However, as no further study has been conducted on the actual impact of this change on the movement patterns, this study will present information on the movement pathways as they were described during the current study.

The main movement pathway for cattle as described during 2016 (shown in figure 26) passes from Mandalay to Pyin Oo Lwin, to Nan Cho, then to Hsipaw, Lashio, Kutkai and then Muse. There are markets near all of these places (though the small roads and markets/collection areas used by livestock traders are just outside the main towns through which the main road to the border passes). Some cattle will be walked as far as Lashio and will usually take small trucks from Lashio to Kutkai (though some cattle may be walked as far as Kutkai). Once in Kutkai, cattle are generally loaded onto larger trucks given that all movement to the border area is then within the Muse district (and is therefore legal).

Figure 26

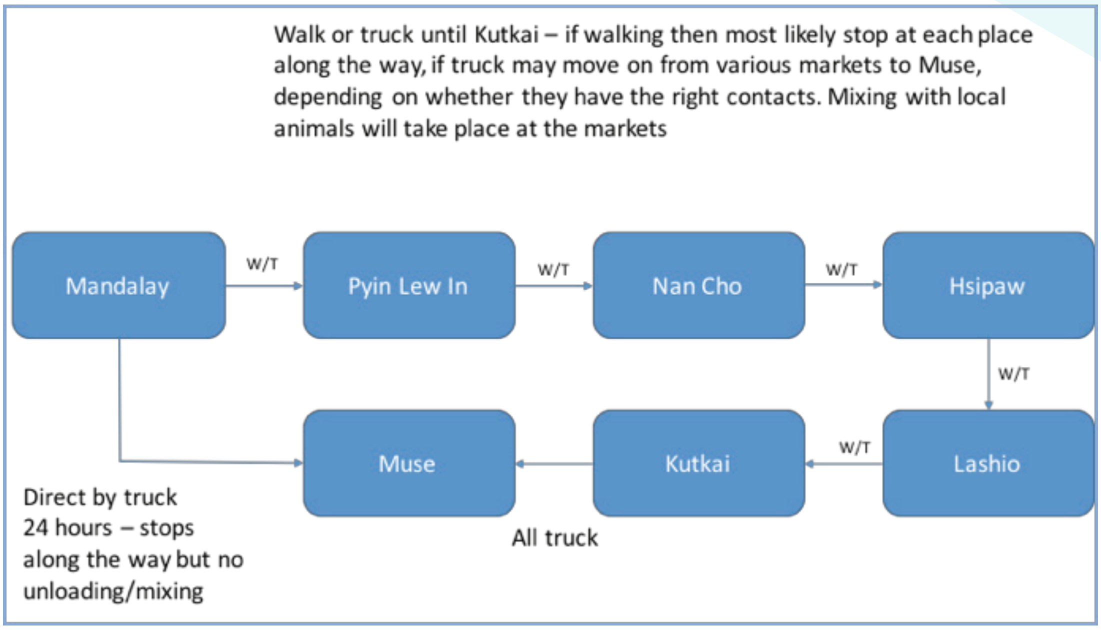

Figure 26: The main pathway of cattle movement from Central Myanmar to the Myanmar-China border.

This risk assessment will consider the major movement pathway leading to Northern Shan State in the area around Muse (also including those exiting through Shweli and Kyukok border areas) given that livestock passing through any of these places are likely to pass into/through the proposed CZ once legal trade is established in this area.

The major source of livestock entering this pathway is Central Myanmar. Throughout this field study little information was available about movement of cattle and buffalo originating from the Indian Sub-Continent, passing along this route, to Muse. This is supported by the study of Smith et al. (2015) whereby cattle and buffalo entering from the Indian Sub-Continent, through Rakhine State, generally move out of Myanmar via Myawaddy rather than Muse. However, a veterinary officer from Ruili, China described that some cattle passing across the border near Shweli in Kachin State may originate from India and Bangladesh, though was unable to estimate the number of animals from this source. Further investigation in Central Myanmar could help to validate the presence or absence of livestock from the Indian sub-continent using the pathway to Muse.

For animals coming from Central Myanmar, Meikthilar livestock market was described as the largest of the markets and the key market through which cattle pass before moving to Muse. However, traders interviewed in Meikthilar and in Muse described that the movement through this market has reduced in the past five years (from 300-400 every 5 days in 2011, to 200 every 5 days in 2016). The traders in Muse stated that more cattle are being sourced (using agents/middlemen) direct from villages without passing through a market, thus explaining the lower numbers. In Muse, the traders said that less traders buy from this market than previously, given that prices at this market have increased. However, they said that it remains the largest of all the livestock markets. Smith et al., 2015 also described a marked reduction in livestock numbers passing through livestock markets across Mandalay Division, according to official livestock market data provided by the LBVD.

Those cattle that are moved directly from Mandalay Division to Muse by truck were described as travelling direct (taking 24 hours) with no unloading of cattle along the way. A figure of 150,000 to 200,000 cattle and buffalo (extrapolated from daily estimates of 15-20 trucks, each carrying 28 cattle, assuming a constant rate of movement all year) was estimated as the volume of cattle moving by truck all the way from Mandalay to Muse per year. In addition to these animals that are transported all the way to Muse by truck, are those which are walked for at least some of the journey. Other traders estimated that 6000 cattle and buffalo move through Muse District per month (72,000 per year, assuming a constant rate of movement all year). A veterinary officer from Ruili estimated that 220,000 cattle and buffalo enter Ruili from Myanmar each year, providing some validation of the high numbers estimated by traders in Myanmar. Official figures provided by LBVD for the 12 months from December, 2017 to November, 2018 indicate movement of 207,561 head of cattle and buffalo into China from Myanmar, via Muse.

One of the major market areas along the route to Muse is located in Nan-Cho and another is Nampa market in Lashio. There are other market/collection points at all the towns listed in figure 26. Traders described that costs of moving cattle through Mandalay Division are relatively low but once in Shan State (and particularly in areas outside of central government control) the cost can be high, where payments must be made at several checkpoints along the way. It is not clear whether these costs have been affected by the recent legalisation of cattle trade from Myanmar to China.

According to traders in Muse, it cost 600,000 kyat (USD 460) per head to transport cattle and buffalo from Mandalay to Muse unofficially. According to other estimates, actual transport costs (truck hire) from Mandalay to Muse costs in the region of USD 70 per head. Although there would be other costs (labour charges, etc.), traders estimated that the cost of legal movement, were it available, would be far less than illegal movement. A number of stakeholders interviewed in 2016 stated that they would like to trade in cattle if it became legal and that they would rather use legal channels, if available, due to the high cost of moving animals unofficially. Given the recent commencement of legal trade, the financial implications of this on the traders has not, to the author's knowledge, been examined.

Movement pathway PM1: Movement of pigs from Thailand to China, via Muse.

Figure 27

Figure 27: Map showing movement pathway (PM1) (note: the route shown on this map is only a guide) (base-map source: Google 2016).

Relatively little information was found about this route of pig movement from Thailand, via Myanmar, to China. However, the movement may be of significance to the proposed CZ in Muse given that these pigs reportedly transit through the Muse area on their way to China. A trader interviewed during the field investigation work for the current study described this movement of pigs, but it was described as a possible future route of movement. However, the route was further validated by staff from LBVD who described current movement of pigs from Thailand, via Myanmar, to China. This movement was described as 'occasional' yet the annual volume was estimated as 20,000 to 50,000 head. At the time of this study, it was not clear how long this pig trade had been in operation. Recent figures provided by LBVD suggest that the number of pigs being moved into China via Muse has increased significantly with 92,775 head being moved during 2017 and 227,977 recorded to be taking the same route in the period from January, 2018 to November, 2018, inclusive.

FMDV RISK PATHWAYS

The FMD risk pathways shown in figures 28, 29 and 30 were developed based on the livestock movement pathways identified as passing into the proposed CZs of LNT (figures 28 and 29) and Muse (figure 30). The information presented in these risk pathways form the basis for the scenario trees developed for the quantitative risk model. Given the complexity of the livestock movement pathways and the lack of data available on the movement pathways at the lowest level (i.e. opportunity for individual animal mixing, proportion of livestock moving through one market or another market, the proportion of livestock moved by truck or by foot, etc.) there is insufficient data available to develop a meaningful model of disease spread through the movement pathways. Therefore, a relatively simple model was developed to estimate the risk of FMDV infected livestock entering the proposed CZs. This model is based on the following: the source of livestock destined for each pathway; the prevalence of FMD in those source areas; the number of animals (of each species) moving along each pathway; and any control measures already in place along those pathways.

It should be noted that two movement pathways (CL6 and PL5), which do not actually pass through the proposed CZs, have been included in the description of movement pathways and in the quantitative risk model, due to the high volume of movement along these pathways and therefore their significance, in terms of the risk they pose for FMD incursions into China. However, as these pathways do not actually pass through the proposed CZ, they are discussed separately in the results section of the quantitative risk assessment.

Figure 28

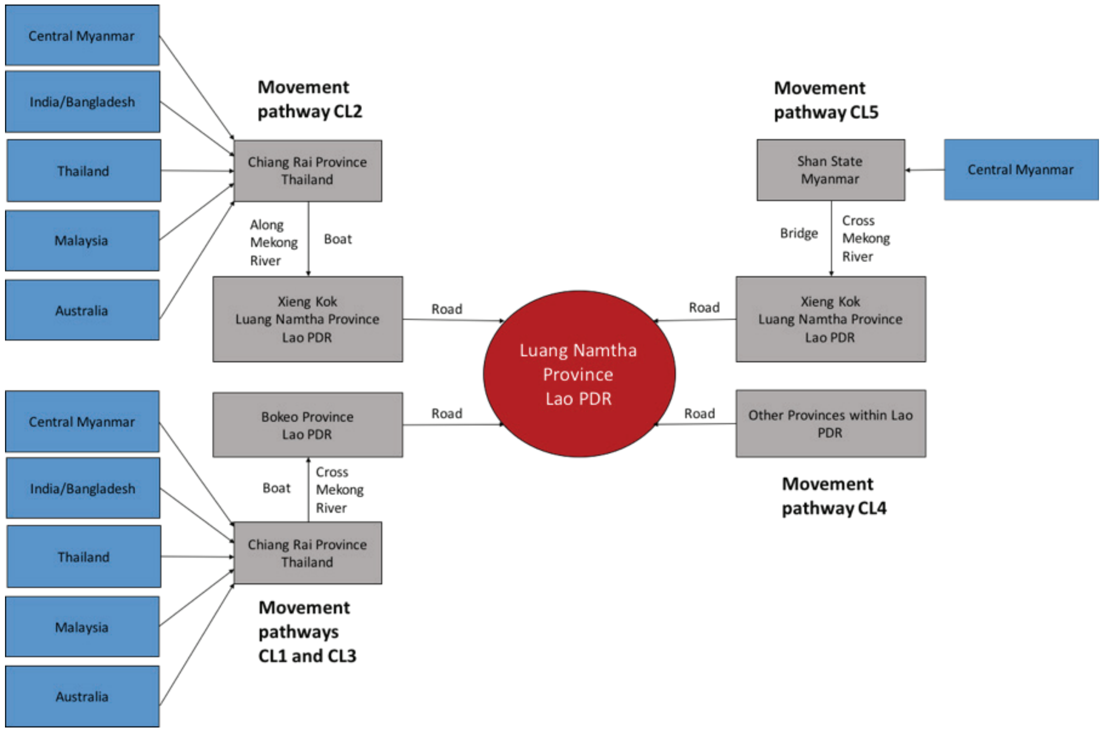

Figure 28: Risk pathways for introduction of FMD into the CZ of LNT Province in Lao PDR through movement of live cattle and buffalo.

Figure 29

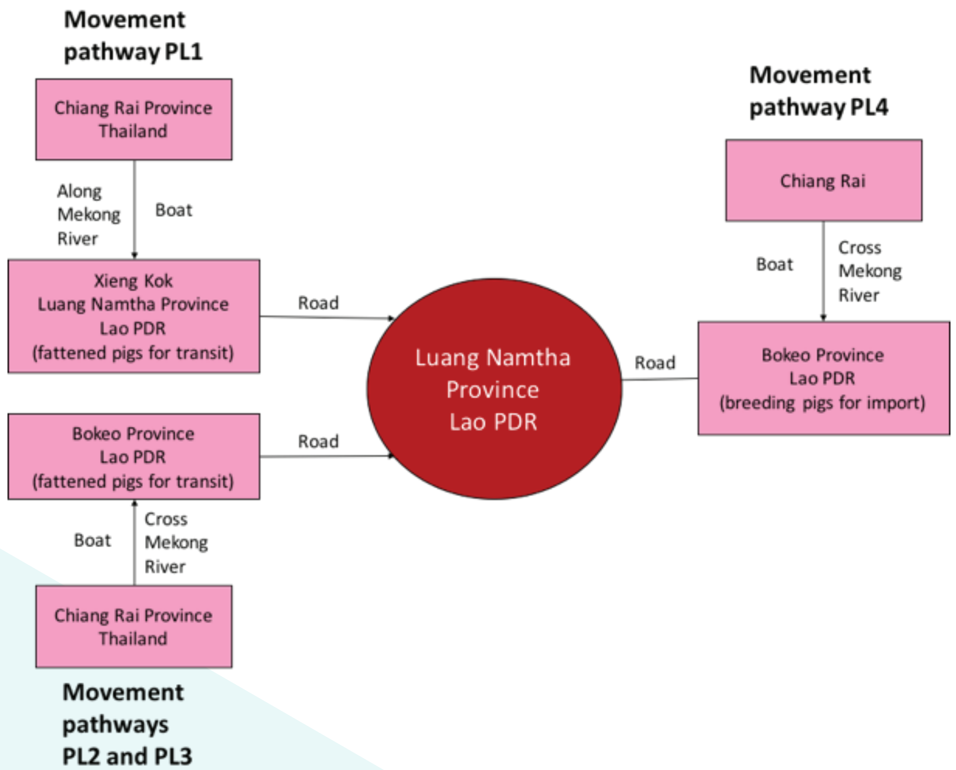

Figure 29: Risk pathways for introduction of FMD into the CZ of LNT Province in Lao PDR through movement of live pigs.

Figure 30

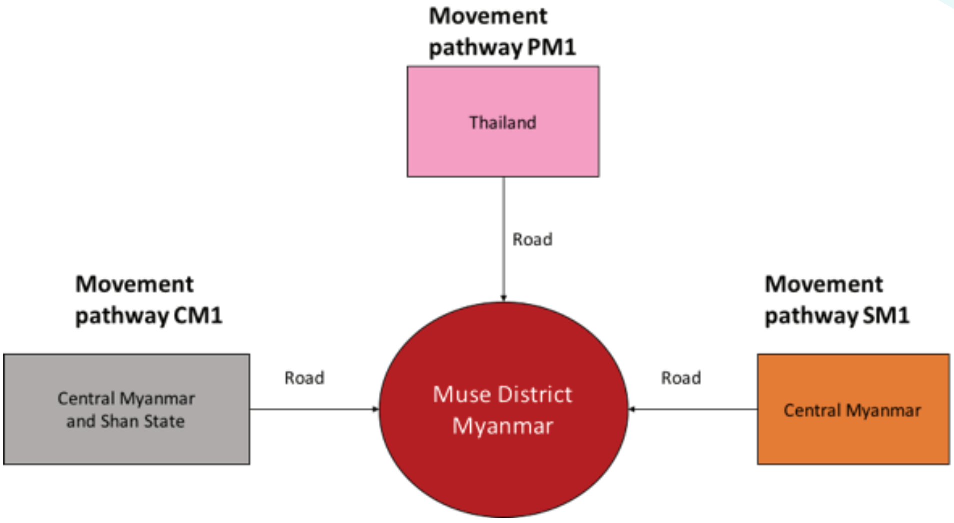

Figure 30: Risk pathways for introduction of FMD into the CZ of Muse District in Myanmar through movement of: live cattle and buffalo (movement CM1); live sheep and goats (movement SM1); and live pigs (movement PM1)

PRIORITISATION OF RISK PATHWAYS: QUALITATIVE RISK ASSESSMENT EXERCISE

As described in earlier sections of this report, several pathways of large ruminant and pig movements were identified leading to the proposed CZ in LNT Province of Lao PDR. During stakeholder meetings in Lao PDR, a workshop was conducted whereby stakeholders were asked to provide an overall, qualitative estimate of the risk that FMD would be introduced to the proposed CZ in LNT Province through each of the pathways identified. The purpose of this exercise was to prioritise the pathways identified and to decide which pathways, if not all, should be included in the quantitative risk model. The participants were asked to select from the list of risk categories shown in table 1. When estimating the level of risk for each pathway, the stakeholders were asked to consider the FMD status of the source country or countries, the route taken by livestock along the way, the volume of livestock traded along each pathway, and any controls in place.

This process was not conducted in Myanmar (for the Muse CZ) given that only one major route of movement for each species was identified and therefore it was not necessary to prioritise these pathways.

Table 1

Risk categories used for qualitative risk estimates of FMD being introduced to LNT Province through various livestock movement pathways.

Risk Category	Risk Category (number)
Negligible	1
Low	2
Medium	3
High	4
Very High	5

The results for each pathway are provided below (note that the risk category numbers shown in table 1 are used in the histograms to represent the qualitative risk categories). For each of the pathways, the risk category selected by the most participants (the mode) was taken to be the risk level assigned to that pathway. Answers were written on paper anonymously and without discussion. It was therefore assumed that participants provided their own judgment without influence from other participants.

Movement pathways CL1 and CL3

Figure 31 shows the risk estimates provided by the stakeholders for entry of FMDV into LNT through movement pathways CL1 and CL3. The overall risk category assigned to pathways CL1 and CL3 (combined) is 'very high':

Figure 31

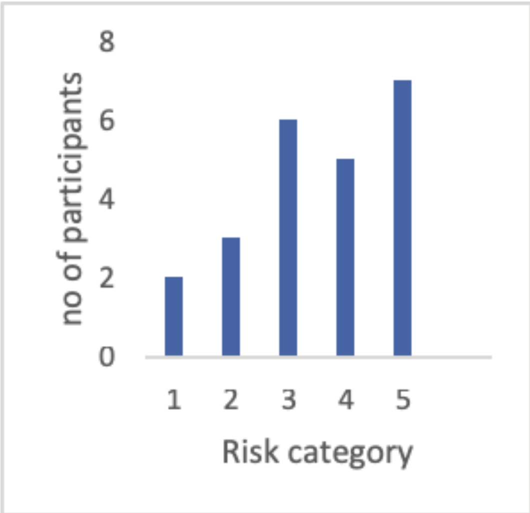

Figure 31: Risk estimates provided by the stakeholders for entry of FMDV into LNT through movement pathways CL1 and CL3

Movement Pathway CL2

Figure 32 shows the risk estimates provided by the stakeholders for entry of FMDV into LNT through movement pathway CL2. The overall risk category assigned to pathway CL2 is 'very high':

Figure 32

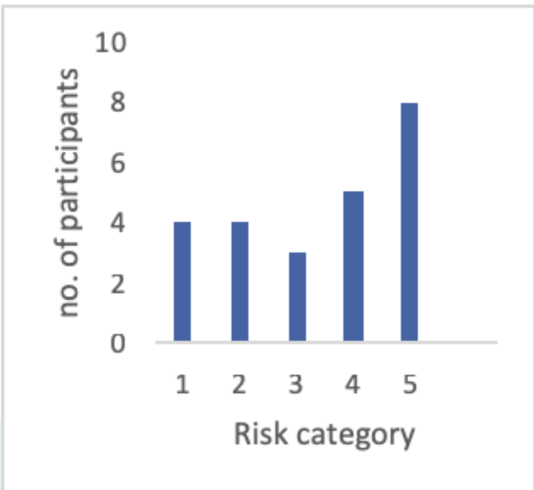

Figure 32: Risk estimates provided by the stakeholders for entry of FMDV into LNT through movement pathway CL2

Movement pathway CL4

Figure 33 shows the risk estimates provided by the stakeholders for entry of FMDV into LNT through movement pathway CL4. The overall risk category assigned to pathway CL4 is 'very high':

Figure 33

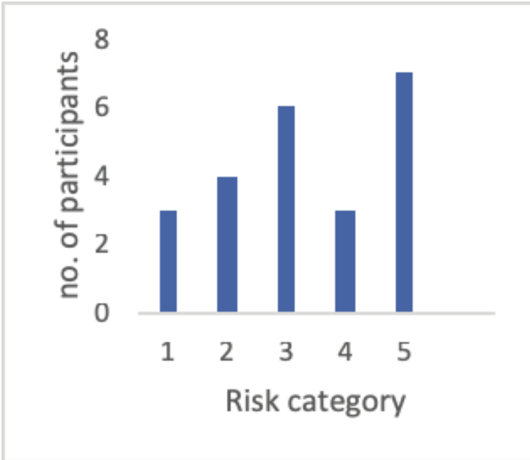

Figure 33: Risk estimates provided by the stakeholders for entry of FMDV into LNT through movement pathway CL4

Movement pathway CL5

Figure 34 shows the risk estimates provided by the stakeholders for entry of FMDV into LNT through movement pathway CL5. The overall risk category assigned to pathway CL4 is 'medium':

Figure 34

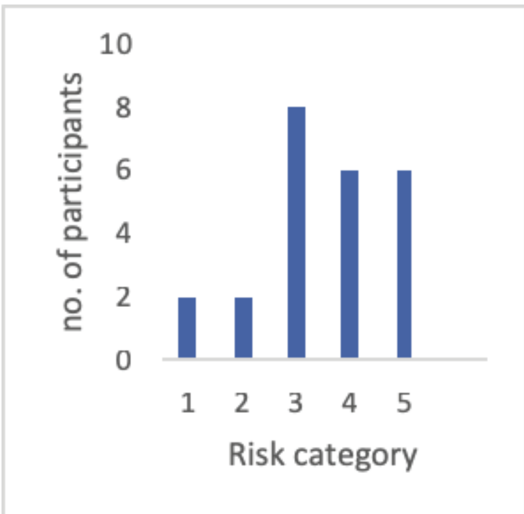

Figure 34: Risk estimates provided by the stakeholders for entry of FMDV into LNT through movement pathway CL5

Movement pathway PL1

Figure 35 shows the risk estimates provided by the stakeholders for entry of FMDV into LNT through movement pathway PL1. The overall risk category assigned to pathway PL1 is 'very high':

Figure 35

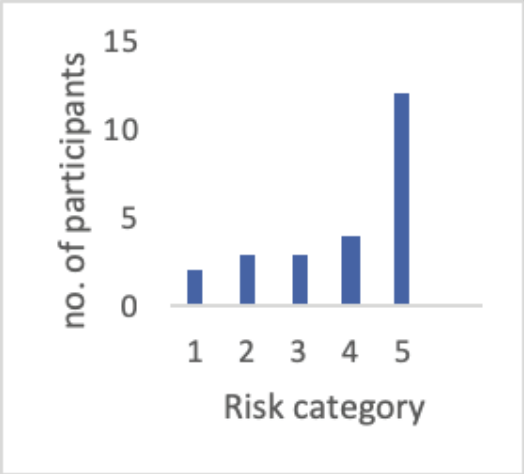

Figure 35: Risk estimates provided by the stakeholders for entry of FMDV into LNT through movement pathway PL1

Movement pathways PL2 and PL3

Figure 36 shows the risk estimates provided by the stakeholders for entry of FMDV into LNT through movement pathway PL2 and PL3. The overall risk category assigned to pathways PL2 and PL3 is 'high':

Figure 36

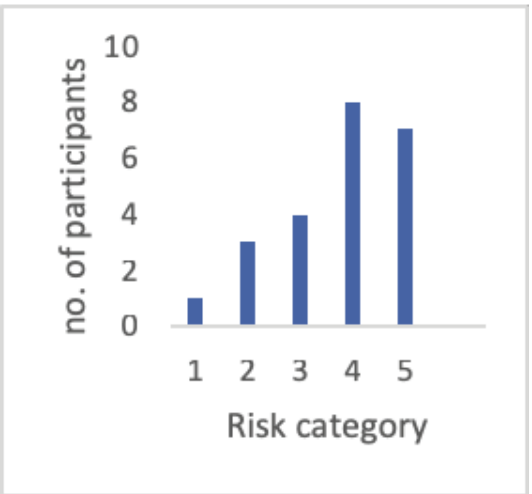

Figure 36: Risk estimates provided by the stakeholders for entry of FMDV into LNT through movement pathways PL2 and PL3.

Movement pathways PL4

Figure 37 shows the risk estimates provided by the stakeholders for entry of FMDV into LNT through movement pathway PL4. The overall risk category assigned to pathway PL4 is 'medium':

Figure 37

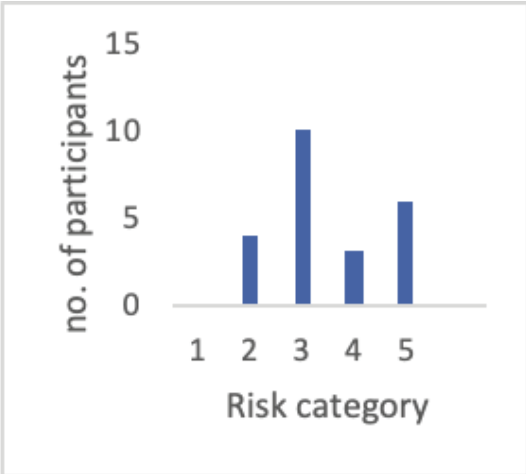

Figure 37: Risk estimates provided by the stakeholders for entry of FMDV into LNT through movement pathway PL4.

Results of the qualitative risk assessment exercise for introduction of FMDV into Luang Namtha Province through various pathways of livestock movement

Table 2 shows the mode risk estimates for each of the pathways described above. It can be seen from these estimates that stakeholders assigned high or very high risk categories to most pathways of livestock movement. The lowest risk category assigned was medium. Therefore, as all of these were considered greater than negligible risk, they were all included in the quantitative risk assessment (described in the next section of this report).

Table 2

Results of the workshop showing the mode risk category assigned for each of the pathways of livestock movement into LNT Province.

Movement Pathway	Mode risk category (no.)	Mode risk category
CL1 and cl3	5	Very High
CL2	5	Very High
cl4	5	Very High
CL5	3	Medium
pl1	5	Very High
pl2 and pl3	4	High
pl4	3	Medium

QUANTITATIVE RISK MODEL TO ESTIMATE THE RISK THAT FMDV WILL ENTER THE PROPOSED CONTROL ZONES

PURPOSE

The purpose of this quantitative risk assessment model is to estimate the risk of FMDV incursions into the proposed CZs in LNT, Lao PDR and Muse, Myanmar through trade movement of live, FMD-susceptible domestic livestock. The model will also form the basis of another exercise to estimate the impact of risk mitigation measures implemented at strategic points along the livestock movement pathways.

Given the relatively incomplete data currently available on livestock trade movements throughout much of the region, the uncertainty surrounding the exact pathways taken by individual animals, and the dynamic nature of livestock trade in this region, the model developed in this study is also intended to provide a framework on which to build as more data becomes available and/or when livestock movement patterns change.

THE QUANTITATIVE RISK MODEL

A stochastic quantitative risk assessment model was developed to represent movement of livestock through trade pathways identified during the current, and previous, studies of livestock movements in the region. For the purposes of this model, simplified versions of the livestock movement pathways were used to estimate the risk of FMDV incursion into the proposed CZs. The input for the model includes: calculated FMD prevalence (based on estimates of a number of parameters which, together provide an estimate of prevalence) for each of the source areas for livestock destined for the CZs; the number of livestock, of each species, coming from each source; the species of livestock moving through each pathway; and any control measures currently in place along those pathways.

Using the prevalence of FMD in the source area of livestock as a measure of the risk that animals arriving at the CZ are infected with FMD does assume direct movement from source to destination without transmission of FMD between traded livestock and local livestock, and vice versa. Although assuming direct movement from source to destination somewhat over-simplifies the pathway of livestock movement into the CZs (given that livestock can move through several places during transit and that this can, in some cases, take considerable time) the data available is insufficient to model more complex movement along the pathways, with meaningful results. Therefore, a simple model was used here with the purpose of providing an indication of the risk of livestock movement into the proposed CZs. It is important, however, to consider these limitations when interpreting the results of the model.

The parameters of the model were furnished with data obtained from: published literature; data collected during field research (stakeholder meetings, individual stakeholder interviews and questionnaires); reports presented at meetings by SEACFMD Member Countries; official records from Veterinary Authorities of participating countries; FMD outbreaks reported through ARAHIS; and expert opinion from people with field experience and knowledge of FMD in countries involved in the study. Given the degree of uncertainty and variability in many of the parameters, probability distributions were used to model many of the parameters in the model. Details of the data used to furnish each of the parameters, and the probability distributions used to model each parameter, are described in detail in Annex I of this report.

The risk assessment model and probability distributions were generated through use of the free-source software package: 'Poptools' version 3.2 (Hood, 2010) as an add-in to Microsoft Excel (2016). All other analyses were conducted using Microsoft Excel, data-analysis function.

Risk Scenario Trees

Scenario trees were developed for each of the livestock movement pathways (risk pathways) identified (and described above) into the proposed CZs. The scenario trees represent all of the events necessary for FMDV-infected animals to enter the proposed BCZs through each of the pathways identified, and form the basis of the quantitative risk model. In addition to the scenario trees for the risk pathways described in figures 28, 29 and 30, are two additional scenario trees for pathways CL6 and PL5. These represent the movement of large ruminants and pigs, respectively, from Northern Thailand, up the Mekong River to Sob-Luay Port in Myanmar and then into China. While these pathways do not actually pass through the proposed CZ in Lao PDR, the movement is highly significant in terms of the volume of livestock being moved by this route and it runs very close to the CZ and could, potentially impact on the zone if legal movement pathways are established, and alternative pathways become economically attractive to traders. For this reason, risk scenario trees have been developed for these risk pathways and they are included in the model to demonstrate the potential level of risk posed by these pathways.

The scenario trees include: the source of livestock destined to move along each of the pathways; the probability that an individual animal from that source area is infected with FMDV (the estimated prevalence of FMDV); the impact of any control measures already in place along each pathway; and the likelihood that livestock are subjected to those controls. Given that much of the animal movement included in this model takes place unofficially, the number of controls in place are minimal. There is insufficient information available to the author on the recent officially recognised trade in cattle and buffalo from Myanmar to China and so it is assumed that no additional measures have been implemented to mitigate the risk of FMD infected animals entering the CZ.

One scenario tree has been developed for each of the risk pathways described in figures 28, 29 and 30 (in addition to pathways CL6 and PL5). The scenario trees are shown in figures 38 to 49.

Figure 38

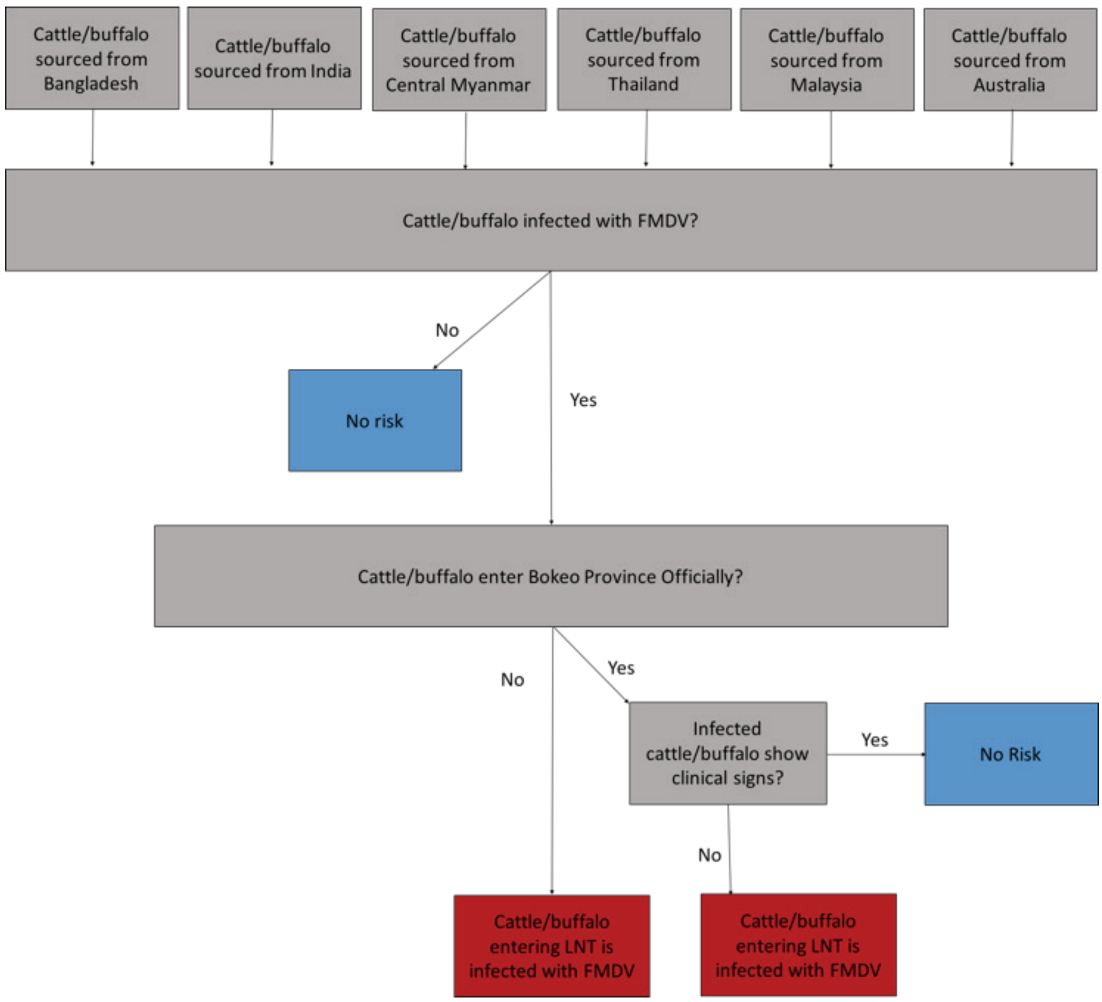

Figure 38: Scenario tree for entry of FMD infected animals to LNT CZ via risk pathways CL1 and CL3.

Figure 39

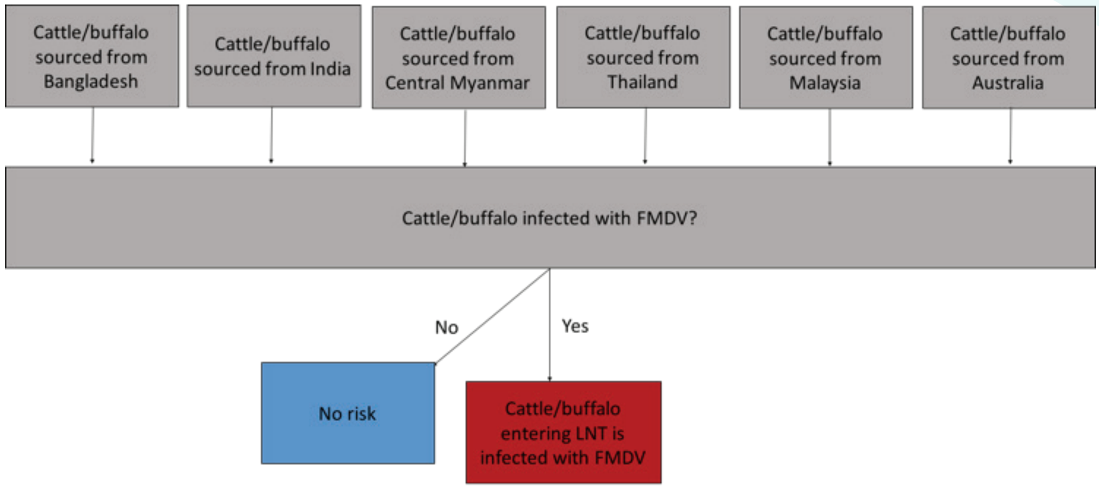

Figure 39: Scenario tree for entry of FMDV infected animals to LNT CZ via risk pathways CL2.

Figure 40

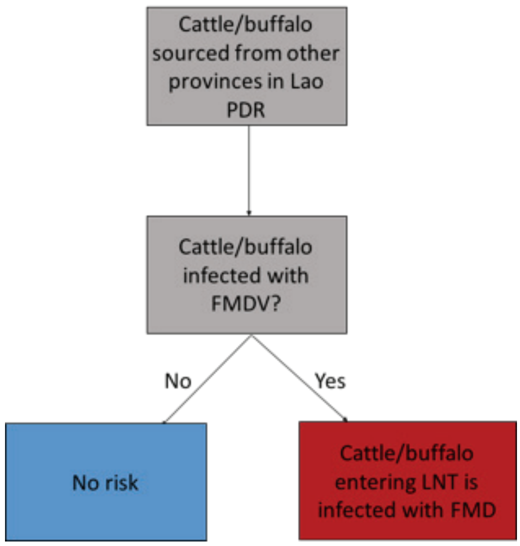

Figure 40: Scenario tree for entry of FMD infected cattle/buffalo to LNT CZ via risk pathway CL4

Figure 41

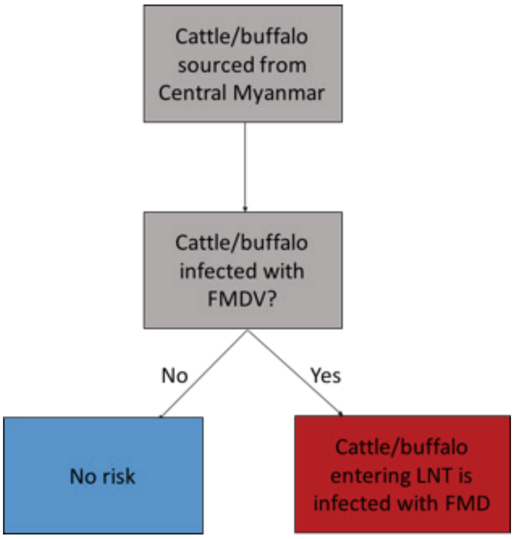

Figure 41: Scenario tree for entry of FMD infected animals to LNT CZ via risk pathway CL5

Figure 42

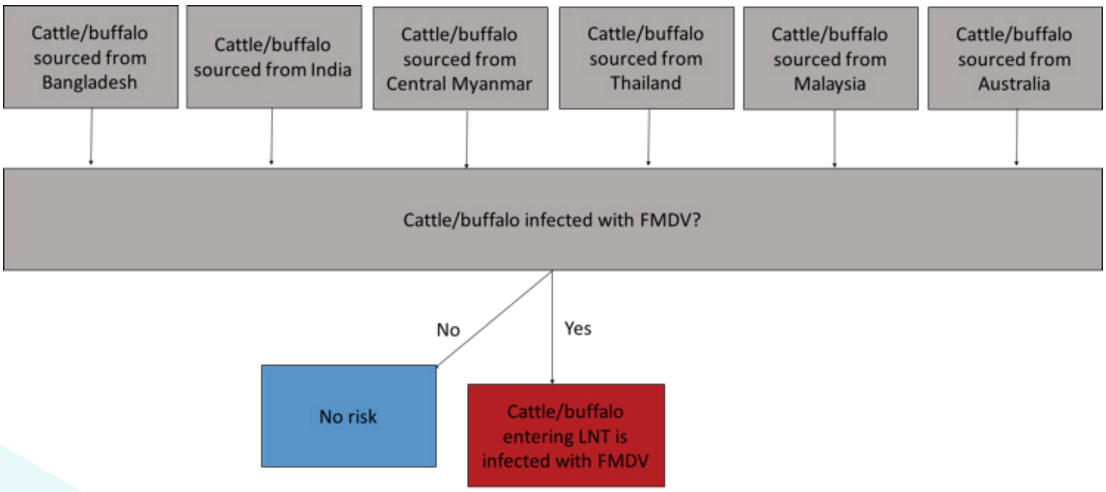

Figure 42: Scenario tree for entry of FMD infected animals to China via risk pathway CL6

Figure 43

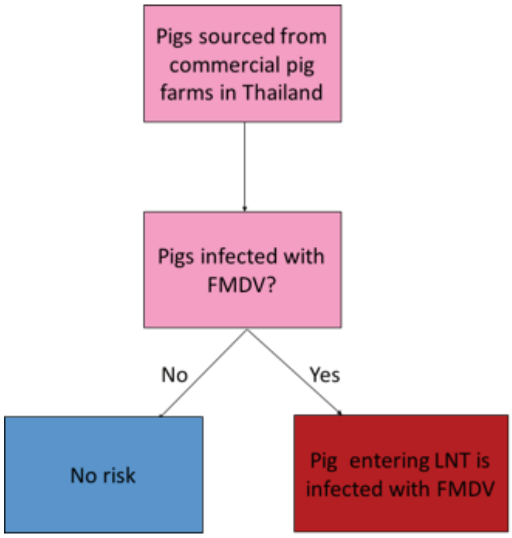

Figure 43: Scenario tree for entry of FMD infected pigs to LNT CZ via risk pathway PL1

Figure 44

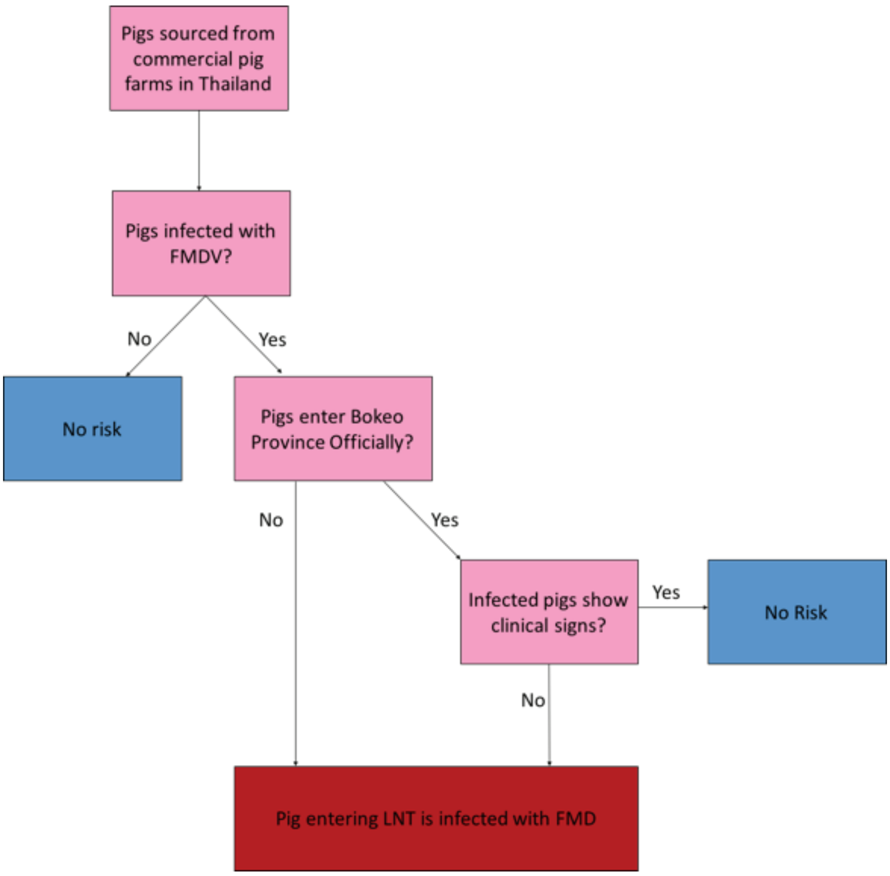

Figure 44: Scenario tree for entry of FMD infected pigs to LNT CZ via risk pathways PL2 and PL3

Figure 45

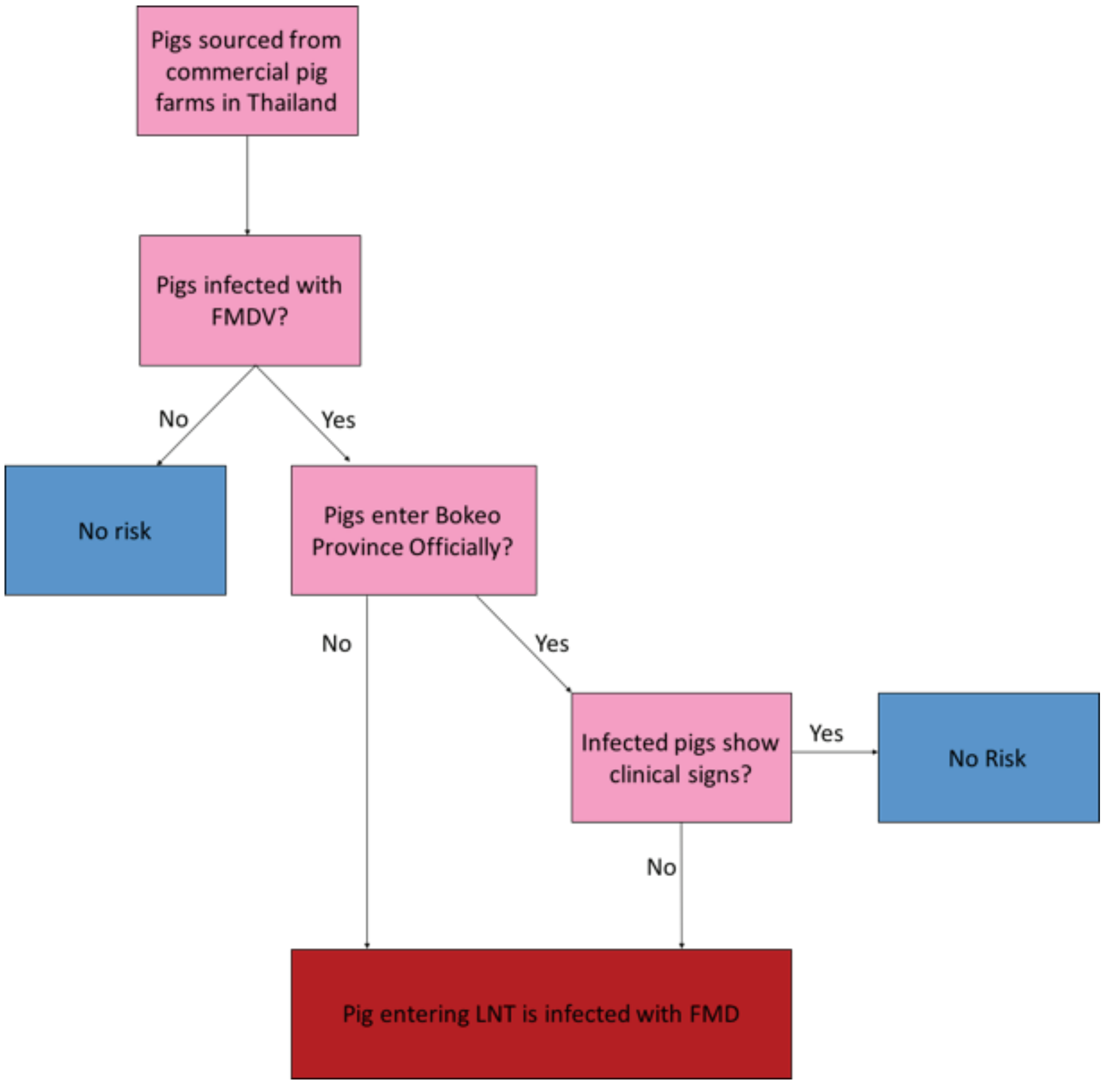

Figure 45: Scenario tree for entry of FMD infected pigs to LNT CZ via risk pathway PL4

Figure 46

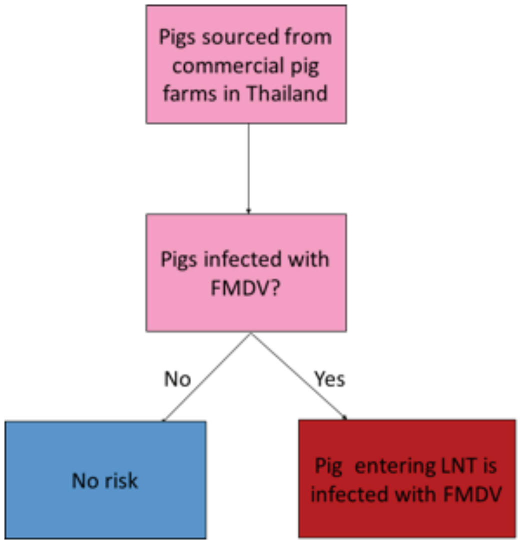

Figure 46: Scenario tree for entry of FMD infected pigs to China via risk pathway PL5

Figure 47

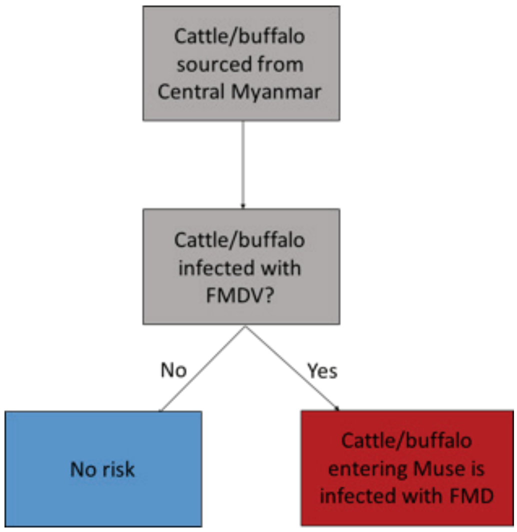

Figure 47: Scenario tree for entry of FMD infected cattle and buffalo into Muse CZ via risk pathway CM1

Figure 48

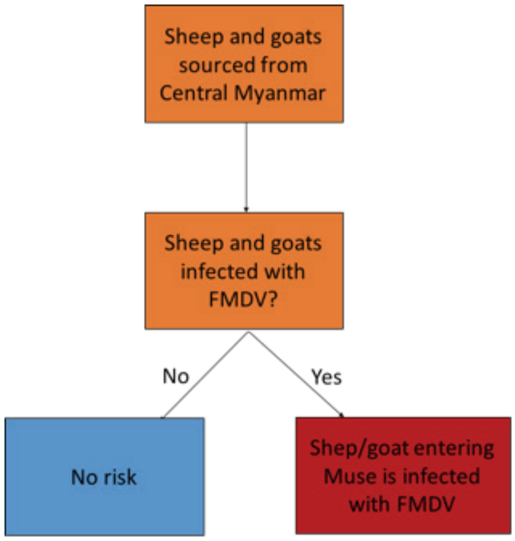

Figure 48: Scenario tree for entry of FMD infected sheep and goats into Muse CZ via risk pathway SM1

Figure 49

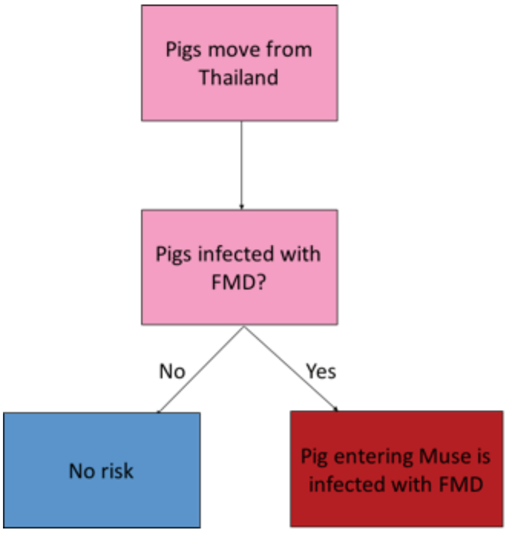

Figure 49: Scenario tree for entry of FMD infected pigs into Muse CZ via risk pathway PM1

Model Parameters

Tables 3 to 26 outline the parameters used in the quantitative risk model (and the probability distributions/ point estimates used to represent each parameter) and how these parameters are combined to estimate: the probability that animals entering the proposed CZs are infected with FMDV; the expected number of FMDV infected livestock entering via each pathway per year; and the probability that at least one FMDV infected animal will enter the CZ via that pathway each year. These 'probabilities of interest' are included in the results section of this report and are shaded in green in tables 3 to 14. The data used to furnish the parameters, any assumptions made when applying data to specific parameters, and the probability distributions selected are described in detail in Annex I.

Table 3

Parameters for simulation model of risk pathways CL1 and CL3

Parameter	Parameter description	Distribution/ formula
PBc	Probability that cattle/buffalo from Bangladesh are infected with FMDV	*See table 17*
Sb	Probability that cattle/buffalo in this pathway are sourced from Bangladesh	*Sb = 0.035*
Ib	Probability that cattle/buffalo are sourced from Bangladesh and have FMD	*Ib = PBc x Sb*
PIc	Probability that cattle/buffalo from India are infected with FMDV	*See table 16*
Si	Probability that cattle/buffalo in this pathway are sourced from India	*Si = 0.035*
Ii	Probability that cattle/buffalo are sourced from India and have FMD	*Ii = PIc x Si*
PMc	Probability that cattle/buffalo from Central Myanmar are infected with FMDV	*See table 15*
Scm	Probability that cattle/buffalo in this pathway are sourced from Central Myanmar	*Scm = 0.78*
Icm	Probability that cattle/buffalo are sourced from Central Myanmar and have FMD	*Icm = PMc x Scm*

Table 3 *(Continuted)*

Parameter	Parameter description	Distribution/ formula
PTc	Probability that cattle/buffalo from Thailand are infected with FMDV	*See table 18*
St	Probability that cattle/buffalo in this pathway are sourced from Thailand	*St = 0.08*
It	Probability that cattle/buffalo are sourced from Thailand and have FMD	*It = PTc x St*
PYc	Probability that cattle/buffalo from Malaysia are infected with FMDV	*See table 20*
Sm	Probability that cattle/buffalo in this pathway are sourced from Malaysia	*Sm = 0.03*
Im	Probability that cattle/buffalo are sourced from Malaysia and have FMD	*Im = PYc x Sm*
PAc	Probability that cattle/buffalo from Australia are infected with FMDV	*PAc = PTc (see Annex I for explanation)*
Sa	Probability that cattle/buffalo in this pathway are sourced from Australia	*Sa = 0.04*
Ia	Probability that cattle/buffalo are sourced from Australia and have FMD	*Ia = PAc x Sa*
Pbo	Probability that cattle/buffalo arriving at Bokeo are infected with FMDV	*Pbo = Ib + Ii + Icm + It + Im + Ia*
LCo	Probability that cattle/buffalo enter Lao PDR officially (at Bokeo)	*LCo = Uniform (0.8, 1)*
Px	Probability that cattle/buffalo have FMD and enter Lao PDR unofficially	*Px = Pbo x (1-LCo)*
Pcs	Probability that cattle/buffalo with FMD show obvious clinical signs	*Pcs = Pert(0, 0.77, 1)*
Py	Probability that cattle/buffalo have FMD, enter Lao PDR officially and don't show obvious clinical signs of disease (i.e. are assumed not to be detected on clinical examination)	*Py = Pbo x Lco x (1-Pcsl)*
Ppt	Probability that cattle/buffalo entering LNT Province via risk pathways CL1 and CL3 are infected with FMDV	*Ppt = Px + Py*
N3	Number of cattle/buffalo moving along risk pathways CL1 and CL3 (combined) each year	*N3 = Pert (36,500 , 73,000 , 292,000) + Uniform (13,000, 23,780)*
Npt	Expected number of FMDV infected cattle/buffalo entering LNT Province via risk pathways CL1 and CL3 each year	*Npt = Ppt x N3*
Ptz	Probability that at least one FMD infected cattle/buffalo will enter LNT Province via risk pathway CL1 and CL3 each year	$Ptz = 1-(1-Ppt)^{N3}$

Table 4

Parameters for simulation model of risk pathway CL2

Parameter	Parameter description	Distribution/ formula
PBc	Probability that cattle/buffalo from Bangladesh are infected with FMDV	*See table 17*
Sb	Probability that cattle/buffalo in this pathway are sourced from Bangladesh	*Sb = 0.035*
Ib	Probability that cattle/buffalo are sourced from Bangladesh and have FMD	*Ib = PBc x Sb*
PIc	Probability that cattle/buffalo from India are infected with FMDV	*See table 16*
Si	Probability that cattle/buffalo in this pathway are sourced from India	*Si = 0.035*
Ii	Probability that cattle/buffalo are sourced from India and have FMD	*Ii = PIc x Si*
PMc	Probability that cattle/buffalo from Central Myanmar are infected with FMDV	*See table 15*
Scm	Probability that cattle/buffalo in this pathway are sourced from Central Myanmar	*Scm = 0.78*
Icm	Probability that cattle/buffalo are sourced from Central Myanmar and have FMD	*Icm = PMc x Scm*
PTc	Probability that cattle/buffalo from Thailand are infected with FMDV	*See table 18*
St	Probability that cattle/buffalo in this pathway are sourced from Thailand	*St = 0.08*
It	Probability that cattle/buffalo are sourced from Thailand and have FMD	*It = PTc x St*
PYc	Probability that cattle/buffalo from Malaysia are infected with FMDV	*See table 20*
Sm	Probability that cattle/buffalo in this pathway are sourced from Malaysia	*Sm = 0.03*
Im	Probability that cattle/buffalo are sourced from Malaysia and have FMD	*Im = PYc x Sm*
PAc	Probability that cattle/buffalo from Australia are infected with FMDV	*PAc = PTc (see Annex I for explanation)*
Sa	Probability that cattle/buffalo in this pathway are sourced from Australia	*Sa = 0.04*

Table 4 *(Continuted)*

Parameter	Parameter description	Distribution/ formula
Ia	Probability that cattle/buffalo are sourced from Australia and have FMD	*Ia = PAc x Sa*
Ppo	Probability that cattle/buffalo entering LNT Province via risk pathway CL2 have FMD	*Ppo = Ib + Ii + Icm + It + Im + Ia*
N1	Number of cattle/buffalo moving along risk pathways CL2 each year	*N1 = 3600*
Npo	Number of FMD infected cattle/buffalo entering LNT Province via risk pathway CL2 each year	*Npo = Ppo x N1*
Poz	Probability that at least one FMD infected cattle/buffalo will enter LNT Province via risk pathway CL2 each year	$Poz = 1-(1-Ppo)^{N1}$

Table 5

Parameters for simulation model of risk pathway CL4

Parameter	Parameter description	Distribution/ formula
PLc	Probability that cattle/buffalo from other provinces in Lao PDR are infected with FMDV	*See table 19*
Ppf	Probability that cattle/buffalo entering LNT Province via risk pathway CL4 have FMD	*Ppf = PLc*
N4	Number of cattle and buffalo moved along risk pathway CL4 each year	*N4 = Uniform (4500, 10,000)*
Npf	Number of FMD infected cattle/buffalo entering LNT Province via risk pathway CL4 each year	*Npf = Ppf x N4*
Pfz	Probability that at least one FMD infected cattle/buffalo will enter LNT Province via risk pathway 4 each year	$Pfz = 1-(1-Ppf)^{N4}$

Table 6

Parameters for simulation model of risk pathways CL5

Parameter	Parameter description	Distribution/ formula
PMc	Probability that cattle/buffalo from Central Myanmar are infected with FMDV	*See table 15*
Ppn	Probability that cattle/buffalo entering LNT Province via risk pathway CL5 have FMD	$Ppn = PMc$
N2	Number of cattle and buffalo moving along risk pathway CL5 each year	$N2 = 0$
Npn	Number of FMD infected cattle/buffalo entering LNT Province via risk pathway CL5 each year	$Npn = Ppn \times N2$
Pnz	Probability that at least one FMD infected cattle/buffalo will enter LNT Province via risk pathway CL5 each year	$Pnz = 1-(1-Ppn)^{N2}$

Table 7

Parameters for simulation model of risk pathways CL6

Parameter	Parameter description	Distribution/ formula
Ppx	Probability that cattle/buffalo entering China via risk pathway CL6 have FMD	*Ppx = Ppo (assumed to be the same as the probability that cattle/buffalo entering LNT from Chiang Rai (via the Mekong River) will have FMD (pathway CL2)*
N10	Number of cattle/buffalo moving along risk pathways CL6 each year	*N10 = Uniform (36,000, 365,000)*
Npx	Number of FMD infected cattle/buffalo entering China via risk pathway CL6 each year	$Npx = Ppx \times N10$
Pxz	Probability that at least one FMD infected cattle/buffalo will enter China via risk pathway CL6 each year	$Pxz = 1-(1-Ppx)^{N10}$

Table 8

Parameters for simulation model of risk pathway PL1

Parameter	Parameter description	Distribution/ formula
PTp	Probability that pigs from commercial farms in Thailand are infected with FMDV	*See table 21*
Ppv	Probability that a pig entering LNT Province via risk pathway PL1 has FMD	*Ppv = PTp*
N5	The estimated number of pigs moving along risk pathway PL1 each year	*N5 = 2400*
Npv	Number of FMD infected pigs entering LNT Province via risk pathway PL1 each year	*Npv = Ppv x N5*
Pvz	Probability that at least one FMD infected pig will enter LNT Province via risk pathway PL1 each year	$Pvz = 1-(1-Ppv)^{N5}$

Table 9

Parameters for simulation model of risk pathways PL2 and PL3

Parameter	Parameter description	Distribution/ formula
PTp	Probability that pigs from commercial farms in Thailand are infected with FMDV	*See table 21*
LPo	Probability that pigs enter Lao PDR officially (at Bokeo) for transit	*LPo = 0.2*
Pj	Probability that pigs have FMD and enter Lao PDR unofficially	*Pj = PTp x (1-LPo)*
Pps	Probability that pigs with FMD show obvious clinical signs	*Pps = Pert(0, 0.88, 1)*
Pk	Probability that pigs have FMD, enter Lao PDR officially and don’t show obvious clinical signs of disease	*Pk = PTp x LPo x (1-Ppc)*
Pps	Probability that pigs entering LNT Province via risk pathways PL2 and PL3 are infected with FMDV	*Pps = Pj + Pk*
N6	Number of pigs moving along risk pathways PL2 and PL3 each year	*N6 = 2880 + Uniform (5000,11000)*
Nps	Number of FMD infected pigs entering LNT Province via risk pathways PL2 and PL3 each year	*Nps = Pps x N6*
Psz	Probability that at least one FMD infected pig will enter LNT Province via risk pathways PL2 and PL3 each year	$Psz = 1-(1-Pps)^{N6}$

Table 10

Parameters for simulation model of risk pathway PL4

Parameter	Parameter description	Distribution/ formula
PTp	Probability that pigs from commercial farms in Thailand are infected with FMDV	*See table 21*
LBo	Probability that pigs enter Lao PDR officially (at Bokeo) for breeding	*LBo = 1*
Pm	Probability that pigs have FMD and enter Lao PDR unofficially	*Pm = Ptp x (1-LBo)*
Ppc	Probability that pigs with FMD show obvious clinical signs	*Ppc = Pert(0, 0.88, 1)*
Pn	Probability that pigs have FMD, enter Lao PDR officially and don't show obvious clinical signs of disease	*Pn = Ptp x LBo x (1-Ppc)*
Ppe	Probability that pigs entering LNT Province via risk PL4 are infected with FMDV	*Ppe = Pm + Pn*
N7	Number of pigs moved along risk pathway PL4 each year	*N7 = Uniform (100, 500)*
Npe	Number of FMDV infected pigs entering LNT Province via risk pathway PL4 each year	*Npe = Ppe x N7*
Pez	Probability that at least one FMD infected pig will enter LNT Province via risk pathway PL4 each year	$Pez = 1-(1-Ppe)^{N7}$

Table 11

Parameters for simulation model of risk pathway PL5

Parameter	Parameter description	Distribution/ formula
PTp	Probability that pigs from commercial farms in Thailand are infected with FMDV	*See table 21*
Ppw	Probability that a pig entering China via risk pathway PL5 has FMD	*Ppw = PTp*
N11	The estimated number of pigs moving along risk pathway PL5 each year	*N11 = 442,400*
Npw	Number of FMD infected pigs entering China via risk pathway PL5 each year	*Npw = Ppw x N11*
Pwz	Probability that at least one FMD infected pig will enter China via risk pathway PL5 each year	$Pwz = 1-(1-Ppw)^{N11}$

Table 12

Parameters for simulation model of risk pathway CM1

Parameter	Parameter description	Distribution/ formula
PMc	Probability that cattle/buffalo from Central Myanmar are infected with FMDV	*See table 15*
Mci	Probability that cattle/buffalo entering Muse have FMD	*Mci = PMc*
N8	Number of cattle and buffalo moved along risk pathway CM1 each year	*N8 = Uniform (72,000 , 220,000)*
Nmi	Number of FMD infected cattle/buffalo entering Muse via risk pathway CM1 each year	*Nmi = Mci x N8*
Pmz	Probability that at least one FMD infected cattle/buffalo will enter Muse Province via risk pathway CM1 each year	$Pmz = 1-(1-Mci)^{N8}$

Table 13

Parameters for simulation model of risk pathway SM1

Parameter	Parameter description	Distribution/ formula
PMg	Probability that sheep/goats from Central Myanmar are infected with FMDV	*See table 23*
Mgi	Probability that cattle/buffalo entering Muse have FMD	*Mgi = PMg*
N9	Number of sheep and goats moved along risk pathway SM1 each year	*N9 = Uniform (30,000 , 132,000)*
Ngi	Number of FMD infected sheep/goats entering Muse via risk pathway SM1 each year	*Ngi = Mgi x N9*
Pgz	Probability that at least one FMD infected sheep/goat will enter Muse Province via risk pathway SM1 each year	$Pgz = 1-(1-Mgi)^{N9}$

Table 14

Parameters for simulation model of risk pathway SM1

Parameter	Parameter description	Distribution/ formula
PTp	Probability that pigs from commercial farms in Thailand are infected with FMDV	*See table 21*
Pmp	Probability that a pig entering Muse via risk pathway PM1 has FMD	*Pmp = PTp*
N12	The estimated number of pigs moving along risk pathway PM1 each year	*N12 = Uniform (20,000 , 50,000)*
Nmw	Number of FMD infected pigs entering Muse via risk pathway PM1 each year	*Nmw = Pmp x N12*
Pmz	Probability that at least one FMD infected pig will enter Muse via risk pathway PM1 each year	$Pmz = 1-(1-Pmp)^{N12}$

Table 15

Description of parameters for calculation of FMD prevalence in cattle and buffalo in Central Myanmar

Parameter	Parameter description	Distribution/ formula
Md	Number of FMD outbreaks reported over a one year period in Central Myanmar	*Pert (1, 9, 23)*
Mur	Probability that an outbreak in cattle and buffalo which occurs in Central Myanmar is not reported	*Mur = Pert (0.5, 0.6, 0.8)*
Mda	Adjusted number of outbreaks in cattle and buffalo over a one-year period in Central Myanmar	*Mda = Md/(1-Mur)*
Mv	Number of villages affected per outbreak	*Mv = Pert (5, 15, 40)*
Mcp	Population of cattle and buffalo in Central Myanmar	*Mcp = 8,519,909*
Mah	Average herd size of cattle and buffalo in Central Myanmar	*Mah = Pert (280, 500, 5000)*
Mar	Probability cattle/buffalo in an infected FMD herd will become infected	*Mar = Pert (0.006, 0.19, 0.4)*
cADI	Average duration of infection of FMDV (cattle and buffalo)	*See Annex I (table 22)*
PMc	Calculated prevalence for cattle and buffalo in Central Myanmar	*PMc=(Mda x Mv x Mah x Mar x cADI)/ Mcp*

Table 16

Description of parameters for calculation of FMD prevalence in cattle and buffalo in India

Parameter	Parameter description	Distribution/ formula
Id	Number of FMD outbreaks reported over a one year period in India	*Id = Pert (109, 454, 879)*
Iur	Probability that an outbreak in cattle and buffalo which occurs in India is not reported	*Iur = Pert (0.5, 0.6, 0.8)*
Ida	Adjusted number of outbreaks in cattle and buffalo over a one-year period in India	*Ida = Id/(1-Iur)*
Icp	Population of cattle and buffalo in India	*Icp = 299,606,000*
Inv	Number of (inhabited) villages in India	*Inv = 593,731*
Iah	Average herd size of cattle and buffalo in India	*Iah = Icp/Iv*
Iar	Probability cattle/buffalo in an infected FMD herd will become infected	*Iar = Pert (0.19, 0.27, 0.35)*
Iv	Number of villages/herds affected per outbreak	*Iv = Pert (1, 2, 10)*
cADI	Average duration of infection of FMDV (cattle and buffalo)	*See Annex I (table 22)*
PIc	Calculated prevalence for cattle and buffalo in India	*PIc = (Ida x Iv x Iah x Iar x cADI)/Icp*

Table 17

Description of parameters for calculation of FMD prevalence in cattle and buffalo in Bangladesh

Parameter	Parameter description	Distribution/ formula
Bd	Number of FMD outbreaks reported over a one year period in Bangladesh	*Pert (86, 130, 540)*
Bur	Probability that an outbreak in cattle and buffalo which occurs in Bangladesh is not reported	*Bur = Pert (0.5, 0.6, 0.8)*
Bda	Adjusted number of outbreaks in cattle and buffalo over a one-year period in Bangladesh	*Bda = Bd/(1-Bur)*
Bcp	Population of cattle and buffalo in Bangladesh	*Bcp = 25,100,000*
Bnv	Number of villages in Bangladesh	*Bnv = 87,310*
Bv	Number of villages/herds affected per outbreak	*Bv = Pert (1, 2, 10)*
Bah	Average herd size of cattle and buffalo in Bangladesh	*Bah = Bcp/Bv*
Bar	Probability cattle/buffalo in an infected FMD herd will become infected	*Bar = Pert (0.19, 0.27, 0.35)*
cADI	Average duration of infection of FMDV (cattle and buffalo)	*See Annex I (table 22)*
PBc	Calculated prevalence for cattle and buffalo in Bangladesh	*PBc = (Bda x Bv x Bah x Bar x cADI)/ Bcp*

Table 18

Description of parameters for calculation of FMD prevalence in cattle and buffalo in Thailand

Parameter	Parameter description	Distribution/ formula
Td	Number of FMD outbreaks reported over a one year period in Thailand	*Pert (27, 101, 179)*
Tur	Probability that an outbreak in cattle and buffalo which occurs in Thailand is not reported	*Tur = Pert (0.1, 0.15, 0.2)*
Tda	Adjusted number of outbreaks in cattle and buffalo over a one-year period in Thailand	*Tda = Td/(1-Tur)*
Tcp	Population of cattle and buffalo in Thailand	*Tcp = 5,805,063*
Tah	Average herd size of cattle and buffalo in Thailand	*Tah = Pert (143, 590, 2054)*
Tv	Number of villages affected per FMD outbreak	*Tv = Pert (1, 2, 10)*
Tar	Probability cattle/buffalo in an FMD infected herd will become infected	*Tar = Pert (0.06, 0.3, 0.77)*
cADI	Average duration of infection of FMDV (cattle and buffalo)	*See Annex I (table 22)*
PTc	Calculated prevalence for cattle and buffalo in Thailand	*PTc = (Tda x Tah x Tar x cADI)/Tcp*

Table 19

Description of parameters for calculation of FMD prevalence in cattle and buffalo in Lao PDR

Parameter	Parameter description	Distribution/ formula
Ld	Number of FMD outbreaks reported over a one year period in Lao PDR	*Pert (8, 21, 28)*
Lr	Probability that an outbreak in cattle and buffalo which occurs in Lao PDR is reported	*Lr = Pert (0.5, 0.75, 1)*
Lda	Adjusted number of outbreaks in cattle and buffalo over a one-year period in Lao PDR	*Lda = Ld/Lr*
Lcp	Population of cattle and buffalo in Lao PDR	*Lcp = 2,360,400*
Lv	Number of herds/villages affected by each FMD outbreak in Lao PDR	*Lv = Pert (1, 6, 12)*
Lah	Average herd size of cattle and buffalo in Lao PDR	*Lah = Pert (177, 272, 337)*
Lar	Probability that cattle/buffalo in an FMD infected herd will become infected	*Lar = Pert (0.001, 0.25, 0.94)*
cADI	Average duration of infection of FMDV (cattle and buffalo)	*See Annex I (table 22)*
PLc	Calculated prevalence for cattle and buffalo in Lao PDR	*PLc = (Lda x Lv x Lah x Lar x cADI)/Lcp*

Table 20

Parameters for calculation of FMD prevalence in cattle and buffalo in Malaysia

Parameter	Parameter description	Distribution/ formula
Yd	Number of FMD outbreaks reported over a one year period in Malaysia	*Pert (22, 40, 72)*
Yr	Probability that an outbreak in cattle and buffalo which occurs in Malaysia is reported	*Yr = Pert (0.8, 0.9, 0.95)*
Yda	Adjusted number of outbreaks in cattle and buffalo over a one-year period in Malaysia	*Yda = Yd/Yr*
Ycp	Population of cattle and buffalo in Malaysia	*Ycp = 876,182*
Yah	Average herd size of cattle and buffalo in Malaysia	*Yah = Pert (20, 200, 800)*
Yar	Probability cattle/buffalo in an infected FMD herd will become infected	*Yar = Pert (0.02, 0.09, 0.5)*
Yv	Number of villages/herds affected per outbreak	*Yv = Pert (2, 3, 5)*
cADI	Average duration of infection of FMDV (cattle and buffalo)	*See Annex I (table 22)*
PYc	Calculated prevalence for cattle and buffalo in Malaysia	*PYc = (Yda x Yah x Yar x cADI)/Ycp*

Table 21

Description of parameters for calculation of FMD prevalence in commercially produced pigs in Thailand

Parameter	Parameter description	Distribution/ formula
TPd	Number of FMD outbreaks reported over a one year period in pigs in Thailand	*Pert (0, 2, 5)*
TPr	Probability that an outbreak in pigs which occurs in Thailand is reported	*TPr = Pert (0.08, 0.33, 0.57)*
TPda	Adjusted number of outbreaks in pigs over a one-year period in Thailand	*TPda = TPd/TPr*
TPp	Population of commercially produced pigs in Thailand	*TPp = 9,510,000*
TPah	Average herd size of commercial pigs in Thailand	*TPah = Pert (14, 400, 8333)*
TPar	Probability pigs in an FMD infected herd will become infected	*TPar = Pert (0.07, 0.4, 0.83)*
TPv	Number of herds affected per FMD outbreak	*TPv = Pert (1, 2, 5)*
pADI	Average duration of infection of FMDV (pigs)	*See Annex I (table 23)*
PTp	Calculated prevalence for commercially raised pigs in Thailand	*PTp=(TPda x TPah x TPar x TPv x pADI)/ TPp*

Table 22

Description of parameters for calculation of FMD prevalence in pigs in Lao PDR

Parameter	Parameter description	Distribution/ formula
LPd	Number of FMD outbreaks reported over a one year period in pigs in Lao PDR	*Pert (0, 1, 2)*
LPr	Probability that an outbreak in pigs which occurs in Lao PDR is reported	*LPr = Pert (0.5, 0.77, 1)*
LPda	Adjusted number of outbreaks in pigs over a one-year period in Lao PDR	*LPda = LPd/LPr*
LPp	Population of pigs in Lao PDR	*LPp = 2,947,288*
LPv	Number of herds affected per FMD outbreak in pigs	*LPv = Pert (1, 2,5)*
LPah	Average pig herd size in Lao PDR	*LPah = Pert (1, 10, 600)*
LPar	Probability pigs from FMD infected herds are infected	*LPar = Pert (0.15, 0.17, 0.2)*
pADI	Average duration of infection of FMDV (pigs)	*See Annex I (table 23)*
PLp	Calculated prevalence for pigs in Lao PDR	*PLp = (LPda x LPv x LPah x LPar x pADI)/ LPp*

Table 23

Description of parameters for calculation of FMD prevalence in sheep/goats in Central Myanmar

Parameter	Parameter description	Distribution/ formula
MGda	Estimated number of outbreaks in sheep/goats over a one-year period in Central Myanmar	*MGda = Mda*
MGv	Number of villages affected per outbreak	*MGv = Pert (5, 15, 40)*
MGp	Population of sheep/goats in Central Myanmar	*MGp = 6,613,636*
MGah	Average sheep/goat herd size in Central Myanmar	*MGah = Pert (120, 250, 900)*
MGar	Probability sheep/goats from FMD infected herds are infected	*MGar = Pert (0.03, 0.29, 0.8)*
gADI	Average duration of infection of FMDV (sheep/goats)	*See Annex I (table 24)*
PMg	Calculated prevalence for sheep/goats in Central Myanmar	*PMg = (MGda x MGv x MGah x MGar x gADI)/MGp*

DATA ANALYSIS

Measuring the risk of FMDV entering the proposed Control Zones in Luang Namtha and Muse

The overall risk of FMDV entering the proposed CZs in LNT and Muse was calculated as the sum of the risk of FMDV entering the zones through each of the individual risk pathways, taking into account the relative volumes of livestock entering by each of the pathways. The probability that at least one infected animal will be introduced to the CZ each year, and the expected number of FMDV infected animals entering per year. Given that there is only a single pathway for each species entering the CZ in Muse, there was no need to combine results for this CZ. However, in Lao PDR where there are several pathways by which cattle or pigs enter the CZ, the results for each species were combined to given a total measure of risk (calculations are shown in table 28).

In order to generate these risk estimates, the stochastic risk model was run for 10,000 iterations using Monte-Carlo simulation (PopTools version 3.2 (Hood, 2011)) to provide a range of outputs from the model for each of the parameters of interest. A high number of iterations were used due to the significant variability in the results, due to uncertainty/variability in many of the parameters contained in the model. A mean (and 95% confidence intervals) are reported for each of these parameters in the results section of this report. These results provide a baseline risk level to be considered by decision-makers and also for the purposes of comparison with models where risk mitigation measures are simulated (reported under the risk mitigation section of this report).

The model was furnished using data collected during the study conducted in 2016. More recent figures provided for 2017 and 2018 have been included in each of the pathway descriptions and implication of these recent updates will be addressed in the results and discussion section of this study.

RESULTS

The results generated by the quantitative risk model described above, provide estimates for: the probability that FMD-susceptible livestock entering the proposed CZ in LNT and Muse are infected with FMDV (note that this is calculated as animals either incubating the virus or in the actual disease-phase of the virus, due to the likely low risk that so-called 'carriers' of FMD will transmit virus to other susceptible livestock, they were not included in this model); the expected number of FMDV infected animals entering the CZs each year; and the probability that at least one FMD infected animal will enter the CZ each year. These results are presented as a mean (and 95% confidence interval) for each of these output parameters. The results are presented below for both CZs.

RESULTS OF THE QUANTITATIVE RISK ASSESSMENT FOR INCURSIONS OF FMDV INTO THE PROPOSED CONTROL ZONE IN LUANG NAMTHA THROUGH MOVEMENT OF FMD-SUSCEPTIBLE LIVESTOCK.

The results for the CZ in LNT are presented as individual risk estimates for each pathway of livestock movement (table 29) and then the combined level of risk from all pathways (for each species of livestock) (table 30). Table 27 provides a reference to assist the reader in interpreting the source of the information used for the parameters in table 28, while table 28 shows how the risks from individual pathways are combined to give an overall level of risk for entry of FMDV infected livestock (of each species) into the CZ in LNT. Annex I provides further information on the data used to furnish the parameters outlined in tables 27 and 28.

Table 27

A table showing the relevant parameters for each of the pathways as a reference for the formulae used to calculate the total risk for FMDV entry into the zones (through combining the risk of each pathway)

Pathway	Probability animal entering by that pathway is infected with FMDV	Number of animals moving by that pathway
CL1/3	Ppt	*N3*
CL2	Ppo	*N1*
CL4	Ppf	*N4*
CL5	Ppn	*N2*
CL6 (river route)	Ppk	*N10*
PL1	Ppv	*N5*
PL2/3	Pps	*N6*
PL4	Ppe	*N7*
PL5 (river route)	Ppc	*N11*

Table 28

A table showing the formulae used to calculate the total risk for FMDV entry into the proposed CZ in LNT (based on results of the quantitative risk model)

Parameter	Description	Formula
NLc	Total number of cattle/buffalo entering the CZ in LNT per year (excluding river route)	*N3 + N1 + N4 + N2*
NLp	Total number of pigs entering the CZ in LNT per year (excluding river route)	*N5 + N6 + N7*
NLcr	Total number of cattle/buffalo entering the CZ in LNT per year (including river route)	*N3 + N1 + N4 + N2 + N10*
NLpr	Total number of pigs entering the CZ in LNT per year (including river route)	*N5 + N6 + N7 + N11*
ALc	Probability that an individual cattle/buffalo entering the CZ in LNT is infected with FMD (excluding river route)	*(Ppt x (N3/NLc)) + (Ppo x (N1/NLc)) + (Ppf x (N4/NLc)) + (Ppn x (N2/NLc))*
BLc	Probability that at least one FMDV infected cattle/buffalo will enter the CZ in LNT per year (excluding river route)	$1- (1-Alc)^{NLc}$
ALcr	Probability that an individual cattle/buffalo entering the CZ in LNT is infected with FMD (excluding river route)	*(Ppt x (N3/NLcr)) + (Ppo x (N1/NLcr)) + (Ppf x (N4/NLcr)) + (Ppn x (N2/NLcr)) + (Ppk x (N10/NLcr))*
BLcr	Probability that at least one FMDV infected cattle/buffalo will enter the CZ in LNT per year (including river route)	$1- (1-ALcr)^{NLcr}$
Tc	Total number of FMDV infected cattle and buffalo expected to enter the CZ in LNT per year (excluding river route)	*ALc x NLc*
Tcr	Total number of FMDV infected cattle and buffalo expected to enter the CZ in LNT per year (including river route)	*ALcr x NLcr*
ALp	Probability that an individual pig entering the CZ in LNT is infected with FMDV (excluding river route)	*(Ppv x (N5/NLp)) + (Pps x (N6/NLp)) + (Ppe x (N7/NLp))*
BLp	Probability that at least one FMDV infected pig will enter the CZ in LNT per year (excluding river route)	$1-(1-Alp)^{NLp}$
ALpr	Probability that an individual pig entering the CZ in LNT is infected with FMDV (including river route)	*(Ppv x (N5/NLpr)) + (Pps x (N6/NLpr)) + (Ppe x (N7/NLpr)) + (Ppc x (N11/NLpr))*
BLpr	Probability that at least one FMDV infected pig will enter the CZ in LNT per year (including river route)	$1-(1-ALpr)^{NLpr}$
Tp	Total number of FMDV infected pigs expected to enter the CZ in LNT each year (excluding the river route)	*ALp x NLp*
Tpr	Total number of FMDV infected pigs expected to enter the CZ in LNT each year (including the river route)	*ALpr x NLpr*

Table 29

Table showing the results for the quantitative risk model used to estimate the probability that livestock entering the proposed CZ in LNT are infected with FMDV, the expected number of FMDV infected animals entering the CZ each year and the probability that at least one infected animal enters the CZ per year for each of the risk pathways included in the model.

Risk pathway	Species	BCZ	Probability an individual animal entering CZ by this pathway is infected with FMDV (mean (95% CI))	Number of FMDV infected animals expected to enter CZ by this pathway per year (mean (95% CI))	Probability that at least one FMD infected animal will enter the CZ by this pathway per year (mean (95% CI))
CL1 and CL3	Cattle/buffalo	Lao PDR	0.0001 (1.50×10^{-5}, 0.0006)	19 (2, 78)	0.98 (0.78, 1)
CL2	Cattle/buffalo	Lao PDR	0.0004 (6.09×10^{-5}, 0.001)	1 (0, 5)	0.62 (0.19, 0.99)
CL4	Cattle/buffalo	Lao PDR	0.0003 (2.86×10^{-5}, 0.0008)	2 (0, 6)	0.71 (0.16, 1)
CL5	Cattle/buffalo	Lao PDR	0.0004 (1.90×10^{-5}, 0.0016)	0 (0,0)	0 (0,0)
CL6 (River Route)	Cattle/buffalo	None	0.0004 (6.09×10^{-5}, 0.001)	77 (6, 313)	1 (1, 1)
PL1	Pigs	Lao PDR	5.01×10^{-5} (1.32×10^{-6}, 0.0002)	0 (0, 1)	0.10 (0.0032, 0.42)
PL2 and PL3	Pigs	Lao PDR	4.26×10^{-5} (1.17×10^{-6}, 0.0002)	0 (0, 2)	0.29 (0.012, 0.88)
PL4	Pigs	Lao PDR	1.28×10^{-5} (1.45×10^{-7}, 7.17 x 10-5)	0.0037 (3.48×10^{-5}, 0.022)	0.0038 (3.77×10^{-5}, 0.022)
PL5 (River Route)	Pigs	None	5.01×10^{-5} (1.32×10^{-6}, 0.0002)	23 (1, 105)	0.95 (0.45, 1)

Table 30

Table showing the results for the quantitative risk model whereby the probability that FMDV infected animals (from each species) will enter the proposed CZ in LNT through all the different pathways combined.

Parameter	Description	Result: mean (95% CI)
ALc	Probability that an individual cattle/buffalo entering the CZ in LNT is infected with FMD (excluding river route)	0.0002 (2.53×10^{-5}, 0.0006)
BLc	Probability that at least one FMDV infected cattle/ buffalo will enter the CZ in LNT per year (excluding river route)	0.997 (0.952, 1)
Alcr	Probability that an individual cattle/buffalo entering the CZ in LNT is infected with FMD (including river route)	0.0003 (4.74×10^{-5}, 0.0011)
BLcr	Probability that at least one FMDV infected cattle/ buffalo will enter the CZ in LNT per year (including river route)	1 (1, 1)
Tc	Total number of FMDV infected cattle and buffalo expected to enter the CZ in LNT per year (excluding river route)	21 (3, 83)
Tcr	Total number of FMDV infected cattle and buffalo expected to enter the CZ in LNT per year (including river route)	99 (11, 392)
Alp	Probability that an individual pig entering the CZ in LNT is infected with FMDV (excluding river route)	4.32×10^{-5} (1.14×10^{-6}, 0.0002)
BLp	Probability that at least one infected pig will enter the CZ in LNT each year (excluding river route)	0.34 (0.016, 0.929)
Tp	Total number of FMDV infected pigs expected to enter the CZ in LNT each year (excluding the river route)	1 (0, 3)
Alpr	Probability that an individual pig entering the CZ in LNT is infected with FMDV (including river route)	4.96×10^{-5} (1.41×10^{-6}, 0.0002)
BLpr	Probability that at least one FMDV infected pig will enter the CZ in LNT each year (including the river route)	0.95 (0.482, 1)
Tpr	Total number of FMDV infected pigs expected to enter the CZ in LNT each year (including the river route)	22 (1, 100)

RESULTS OF THE QUANTITATIVE RISK ASSESSMENT FOR INCURSIONS OF FMDV INTO THE PROPOSED CONTROL ZONE IN MUSE THROUGH MOVEMENT OF FMD-SUSCEPTIBLE LIVESTOCK.

The results for Muse CZ are presented as individual risks posed by each pathway of livestock movement (table 31). As there is only one identified risk pathway for each species entering the CZ in Muse, there is just a single set of results showing: the probability that animals (from each species) which enter the CZ in Muse are infected with FMDV; the expected number of FMDV infected animals (from each species) to enter the CZ each year; and the probability that at least one infected animal (from each species) will enter each year.

Table 31

Table showing the results for the quantitative risk model used to estimate the probability that livestock entering the proposed CZ in Muse are infected with FMDV, the expected number of FMDV infected animals entering the CZ each year and the probability that at least one infected animal enters the CZ per year for each of the risk pathways included in the model.

Risk pathway	Species	BCZ	Probability an individual animal entering CZ by this pathway is infected with FMDV (mean (95% CI))	Number of FMDV infected animals expected to enter CZ by this pathway per year (mean (95% CI))	Probability that at least one FMD infected animal will enter the CZ by this pathway per year (mean (95% CI))
CM1	Cattle/ buffalo	Myanmar	0.0004 (2.00 x 10-5, 0.0016)	52 (2, 232)	0.99 (0.92, 1)
SM1	Sheep/ goats	Myanmar	0.0003 (3.2 x 10-5, 0.0013)	27 (2, 111)	0.99 (0.86, 1)
PM1	Pigs	Myanmar	4.91 x 10-5 (1.28 x 10-6, 0.0002)	2 (0, 9)	0.59 (0.044, 1)

SUMMARY OF RESULTS

CONTROL ZONE IN LUANG NAMTHA, LAO PDR

The results of the quantitative risk assessment indicate that there is an extremely high probability that at least one FMDV infected cattle/ buffalo will enter the CZ in Lao PDR each year, with a mean probability of 0.997 (95% CI: 0.95, 1). The probability that at least one infected pig will enter the CZ each year is lower, with a mean probability of 0.34 (95% CI 0.016, 0.93). According to these results, the probability is far greater for introduction of FMDV infected cattle and buffalo compared to pigs, with an estimated 21 (95% CI: 3, 83) FMD-infected cattle expected to enter each year. Based on the mean probability that at least one infected pig will enter each year, it may be estimated that one infected pig may enter approximated every 2.9 years, but, according to the model, this could be as high as 3 infected pigs per year. The lower risk that pigs will enter the CZ in Lao PDR is a function of the lower volume of pig movement, compared to cattle, as well as the lower estimated FMD prevalence in pigs in source countries, compared to cattle and buffalo (given that the probability that any individual pig entering the CZ is lower compared to cattle/buffalo with respective probabilities of 0.0002 (95% CI: 2.53 x 10-5, 0.0006) and 4.32 x 10-5 (95% CI: 1.14 x 10-6, 0.0002).

The results also indicate that the movement of livestock along risk pathways CL5 and PL5(the ‘river route’) could pose a significant risk for FMDV incursions into China, with an estimated 77 (95% CI: 6, 313) FMDV infected cattle and 23 (95% CI: 1, 105) infected pigs expected to enter China each year via these pathways. While these livestock do not currently pass through the CZ in LNT, the pathway is closely linked to movement pathways which do enter the CZ and, in the future, could re-direct through the CZ, should economically attractive alternative pathways become available to traders currently using the river route.

CONTROL ZONE IN MUSE, MYANMAR

The results of the quantitative risk assessment indicate that there is an extremely high probability that at least one FMDV infected cattle/buffalo or small ruminant will enter the CZ in Muse each year, with a mean probability of 0.99 (95% CI:0.92, 1) and 0.99 (95% CI: 0.86, 1), respectively. According to the model, the probability that at least one infected pig will enter the CZ in Muse each year is lower, compared to ruminants, with a mean probability of 0.59 (95% CI: 0.044, 1), which equates to a mean of one infected pig entering every 1.7 years, but according to the model, up to 9 infected pigs could enter the CZ in Muse each year (based on the upper CI). In comparison, it is estimated that 52 (95% CI: 2, 232) FMDV infected cattle/buffalo and 27 (95% CI: 2, 111) infected small ruminants could enter the CZ in Myanmar each year.

The probability that any individual animal entering the CZ in Muse is infected with FMDV is similar for large and small ruminants, at 0.0004 (95% CI: 2.00 x 10-5, 0.0016) and 0.0003 (95% CI: 3.2 x 10-5, 0.0013) with the difference in expected number of FMDV infected livestock from these different species being mainly a result of the lower volume of small ruminant trade into the CZ compared to that of large ruminants. The lower risk of FMDV infected pigs entering the zone compared to ruminants is a result of both the lower estimated prevalence of FMD in pigs in the source areas and the lower volume of pig trade through the CZ compared to ruminants. However, recently published figures by LBVD indicate that between January and November of 2018, 227,977 pigs passed from Myanmar to China officially, via Muse. This is significantly higher than the 20,000 to 50,000 head of pigs estimated during the current study, in 2016 and used to furnish this model. Therefore, the risk that at least one FMD infected pig will enter the Muse CZ would be assumed to have further increased more recently, based on these recent figures.

DISCUSSION

RISK AND CONSEQUENCES OF FMDV INCURSIONS INTO THE PROPOSED CONTROL ZONES

The results above indicate that there is a very high risk that FMDV infected animals will enter the proposed CZ in both Muse and LNT each year, with multiple introductions being highly likely. While this study does not include a quantitative assessment of the consequences of FMDV incursions into the CZs, some discussion is provided here on some of the possible consequences.

Given that the proposed CZ are likely to contain high quantities of livestock being held for periods of time (possibly up to 21 days) in quarantine (and likely at high stocking rates), incursions of FMDV into the CZ could have significant consequences for livestock within the zone and thus increase the risk of FMDV incursions into China (where FMD outbreaks occur within the proposed CZ). By bringing livestock, of unknown health status, from multiple sources and collecting them in a high stocking situation, there is a risk that the CZ areas could serve to amplify the virus, thus increasing the risk for viral incursions into China, rather than reducing that risk. Therefore, given the high risk of FMDV incursions into the proposed CZ, risk mitigation measures aimed at reducing the risk of livestock having FMDV when they arrive at the CZs is essential, rather than relying on measures applied within the CZ. This would likely involve some form of pre-quarantine, which will be explored further under the section on risk mitigation.

Although the model indicates that there is a lower risk of FMDV incursions occurring due to pig movement, compared to ruminants, the consequences of an FMDV infected pig entering the proposed CZs could be significant. Pigs excrete high quantities of virus in their exhaled breath (Kitching and Alexandersen, 2002) and could therefore pose a risk for transmitting virus to other susceptible livestock within the CZ. The significance of pig movements may be further exacerbated if pig adapted strains of FMDV occur in the region in the future. It should also be noted that the number of pigs being moved along certain routes have increased significantly from 2016, when the model was developed, to 2018 (LBVD, 2018) which would suggest the risk of FMD incursions through these routes may be far greater, based on the higher volume of movement.

In addition to the potential consequences of introductions of FMDV infected cattle and pigs from within South-East Asia, we know from information gathered during this study, and from the study by Smith et al., 2015, that livestock are also sourced from India and Bangladesh and that these livestock are reaching the CZ of LNT (and possibly also Muse). There are serotypes and strains of FMDV in the Indian Sub-Continent which are exotic to South-East Asia. Incursions of these exotic FMDV strains could potentially have severe consequences, particularly if vaccines currently used in the region don't convey protection against these strains. Qiu (2017) described the occurrence of Serotype O-Ind2015 which was identified in a number of countries in South-East Asia in 2016, and was closely related to strains circulating in the Indian Sub-Continent. This highlights the vulnerability of South-East Asia to incursions of exotic strains of FMDV from the Indian Sub-Continent.

LIMITATIONS OF THE QUANTITATIVE RISK MODEL

The model used to estimate the risk of FMDV incursions into the CZs of LNT and Muse has a number of limitations which should be taken into account when interpreting the results of the model. Some of these are outlined here, with further detail provided under each of the parameter descriptions provided in Annex I:

- The model is a simplified representation of livestock movements into the proposed CZs and does not take into account the affect of mixing of livestock during transit or the pathways taken by livestock, on the probability of them being infected when they arrive at the CZ. Given the level of uncertainty in the data available on the exact pathways taken by livestock, the proportion of livestock taking each pathway, and the potential for mixing with other livestock along the way, adding further complexity to the model would be unlikely result in a more meaningful result.
- The model is highly sensitive to changes in prevalence of FMDV in source countries (see section on risk mitigation measures) and therefore the uncertainty in the parameters used to estimate prevalence of FMDV in various livestock species in the source countries could impact significantly on the output of the model.
- Throughout much of SEA, there is some level of under-reporting of FMD outbreaks and, while the model has been adjusted to reflect this under-reporting, there is still considerable uncertainty surrounding the actual number of outbreaks occurring. Again, this is likely to impact significantly on the results of the model.

- Investigation of outbreaks and reporting on results is still quite limited across much of South-East Asia meaning that there is limited information available on attack rates and also on the extent of outbreaks (i.e. how many herds/villages are affected per outbreak), as well as on the strain of virus causing a specific outbreak. While SEACFMD uses a specific definition of an FMDV outbreak which member countries are recommended to use when reporting to ARAHIS, it is not clear that this is always followed. Therefore, the value of using ARAHIS data as an estimate of the number of outbreaks occurring in the country, is limited by uncertainty around what constitutes a single outbreak.
- It is assumed in this model that FMD-infected livestock will be traded in the same way as non-infected animals, that is, it does not account for any self-regulation which may occur, whereby traders are more or less likely to trade infected livestock.
- Small ruminants represent a major risk pathway into the CZ in Muse. However, the role of small ruminants in the epidemiology of FMD in SEA remains poorly understood with most previous livestock movement studies and serological surveys focusing on large ruminants. Further work is needed to better understand the role of small ruminants in the epidemiology of FMD in this region in order to better understand the risk posed by movement of these species and the potential impact of risk mitigation measures targeted at these species.
- The volume of livestock moving along the risk pathways identified by this study is based upon estimates provided by various stakeholders. Given that most of this movement is unofficial it is, by its nature, difficult to estimate given that there is no official reporting of movements. Estimates may also be biased by the fact that some stakeholders may have an interest in estimating higher or lower volumes moving through the different pathways.
- Some of the livestock movement into the proposed CZs are believed to originate in South-Asia, namely Bangladesh and India. Information about the FMD situation in these countries were based predominantly on extracting information from published reports or from extrapolating information gathered about FMDV in other countries. Therefore, there is uncertainty in many of the parameters used to model the FMD prevalence in these countries.

- The model does not specifically take into account the impact of any vaccination programs which may currently be taking place in source and transit countries included in this model. Within SEA, the extent of vaccination programs remains relatively low compared to the total population of susceptible livestock. If existing programs have contributed to reduced numbers of FMDV outbreaks in source countries, however, this would be reflected in the model given that the number of outbreaks constitutes one of the main input parameters for calculation of prevalence in source countries.
- The model does not take into account any amplification of the virus within consignments during transportation to the CZs. For example, where a single infected animal is taken from the source country, it is assumed that only a single infected animal will arrive at the destination. However, in reality it is likely that this animal will infect others in the consignment en-route to the zone, potentially resulting in a higher number of infected animals entering the CZ. By not taking this into account, the model may under-estimate the risk. However, if pre-quarantine processes are used, whereby livestock will be vaccinated near the source of the movements, the impact of this factor would be far less.

Despite the limitations outlined above, this model does provide some indication of the level of risk posed by different species and different risk pathways entering the CZ in Myanmar and Lao PDR, and while there is uncertainty in many of the parameters used to construct this model, triangulation of data was used to help validate information where possible. The risk estimates resulting from this model are such that it should be reasonable to conclude that the risk of FMDV incursions into the CZ is very high and that risk mitigation measures are required in order to reduce this risk to an acceptable level.

RISK MITIGATION MEASURES

Risk mitigation or management is the process of identifying, documenting and implementing measures to reduce identified risks and their consequences (FAO, 2002). The risks posed by FMD can never be completely eliminated, and when there is movement in FMD-susceptible animals or their products, there will always be some level of risk. The aim of risk mitigation measures is to adopt procedures that will reduce the level of risk to what is deemed to be an acceptable level (FAO, 2002).

This section will consider different risk mitigation measures which may be targeted along the livestock movement pathways identified by this study in order to reduce the risk of FMD incursions into the proposed CZs. The advantages and disadvantages of different measures will be discussed, with some use of quantitative risk modelling to quantify the potential impact of measures implemented at different points in the pathways. For some of the measures, one pathway might be used as an example to demonstrate the likely impact of a measure applied there, assuming that it could also be applied to other pathways.

The quantitative risk model used here as the baseline with which to compare different risk mitigation scenarios, is a modified version of the model used in the previous section. In this baseline model, all regulations are removed from the model to provide an estimate for the Unrestricted Risk Measure (URE) (defined by Morley (1993) as the risk before selecting and applying any risk reduction options, such as diagnostic testing, quarantine and further processing) of live FMD-susceptible animals entering the proposed CZs (results are shown in table 31). While Morley (1993) describes the URE as consisting of the product of two probabilities: the probability of agent entry (PAE) and the probability of domestic exposure (PDE), this study only takes into account the probability of agent entry given that it is assumed that the risk of exposure within the proposed CZs would be very high.

Table 31

A table showing the results of the quantitative risk model (with all regulation of livestock movement removed) to provide a baseline level of risk with which to compare the risk after implementation of various risk mitigation measures.

Risk pathway	Species	BCZ	Probability an individual animal entering BCZ by this pathway (with no risk mitigation measures in place) is infected with FMDV (mean (95% CI))	Number of FMDV infected animals expected to enter BCZ by this pathway per year (mean (95% CI))
CL1 and CL3	Cattle/buffalo	Lao PDR	0.0003 (6.02×10^{-5}, 0.0014)	46 (6, 173)
CL2	Cattle/buffalo	Lao PDR	0.0004 (6.09×10^{-5}, 0.001)	1 (0, 5)
CL4	Cattle/buffalo	Lao PDR	0.0003 (2.86×10^{-5}, 0.0008)	2 (0, 6)
CL5	Cattle/buffalo	Lao PDR	0.0004 (1.90×10^{-5}, 0.0016)	0 (0,0)
CL6 (River Route)	Cattle/buffalo	None	0.0004 (6.09×10^{-5}, 0.001)	77 (6, 313)
PL1	Pigs	Lao PDR	5.01×10^{-5} (1.32×10^{-6}, 0.0002)	0 (0, 1)
PL2 and PL3	Pigs	Lao PDR	4.98×10^{-5} (1.45×10^{-6}, 0.0002)	1 (0, 2)
PL4	Pigs	Lao PDR	5.04×10^{-5} (1.46×10^{-6}, 0.0002)	0.01 (0.0004, 0.073)
PL5 (River Route)	Pigs	None	5.01×10^{-5} (1.32×10^{-6}, 0.0002)	23 (1, 105)
CM1	Cattle/buffalo	Myanmar	0.0004 (2.00×10^{-5}, 0.0016)	52 (2, 232)
SM1	Sheep/goats	Myanmar	0.0003 (3.2×10^{-5}, 0.0013)	27 (2, 111)
PM1	Pigs	Myanmar	4.91×10^{-5} (1.28×10^{-6}, 0.0002)	2 (0, 9)
Total (ALc)	Cattle/buffalo	Lao PDR	0.0004 (6.70×10^{-5}, 0.0013)	50 (7, 187)
Total (Alp)	Pigs	Lao PDR	5.12×10^{-5} (1.17×10^{-6}, 0.0002)	1 (0, 3)

The potential impact of the following risk management approaches will be discussed in this section. A detailed analysis of the cost/benefit of different scenarios is beyond the scope of this study, and therefore this represents an initial assessment of the impact of risk mitigation measures on the risk of FMDV entry. However, the limitations in the data used to construct these models should be taken into account when interpreting the results and further feasibility/pilot studies will likely be needed prior to implementation of any such measures. While each of these measures will be addressed in isolation during this study, it is possible that two or more may be combined to optimally reduce the risk of FMDV incursions into the proposed CZs. Quantitative risk modelling is applied to most of the risk mitigation scenarios described in this section. However, where there is not considered to be sufficient information to model a mitigation measure, there will be a discussion of that measure with some qualitative analysis:

- ***Risk mitigation scenario A:*** *Reduction of FMDV prevalence in source areas (i.e. vaccination of susceptible livestock populations and/or improved detection/ response to FMD outbreaks in key source areas).*
- ***Risk mitigation scenario B:*** *Clinical examination of livestock at the point of entry to the CZ.*
- ***Risk mitigation scenario C:*** *Use of government approved pre-quarantine prior to entry to the CZ.*
- ***Risk mitigation scenario D:*** *Maximising official cross-border movement versus unofficial movement of livestock.*

RISK MITIGATION SCENARIO A: REDUCTION OF FMDV PREVALENCE IN SOURCE AREAS (I.E. VACCINATION OF POPULATIONS IN KEY SOURCE AND TRANSIT AREAS AND/OR IMPROVED DETECTION AND RESPONSE TO OUTBREAKS)

Addressing disease at its source is a key strategy in reducing the risk of FMD incursions through live animal movement. By reducing the risk that animals entering the movement pathway have FMDV, provided they are not infected along the pathway of movement, the risk of FMD entering the proposed CZ will be lower. Mitigation measures used to reduce the prevalence of FMDV in source countries might include, inter-alia: vaccination of susceptible livestock; more rapid detection of FMDV outbreaks; and more rapid and effective response to FMD outbreaks. The precise impact of different measures on the prevalence of FMDV in a given area is beyond the scope of this study. However, this section demonstrates how changes in the prevalence of FMD in source areas could reduce the risk of FMDV infected livestock entering the proposed CZ.

Due to limited data available on the source of viruses causing FMD outbreaks across the region, the prevalence of FMD in different source countries is assumed to be independent of each other. While this is unlikely to be the case in reality, there is insufficient data available to determine the extent to which the prevalence in one country is dependent upon the prevalence in another country. In reality, it is likely that reductions in prevalence in certain source areas, such as Myanmar, is likely to impact on the prevalence in other countries in the region, given that outbreaks in some countries through which livestock transit are likely to result from incursions of virus from those source countries. However, the proportion of virus likely to have come from strains endemic in the transit country, and circulating within that country, and the proportion resulting from incursions from neighbouring countries could not be quantified due to the low number of outbreaks from which samples are collected for serotyping, and the even lower number submitted for further characterisation necessary to determine the likely source of the outbreak.

Reducing FMD prevalence in source countries/areas from which the greatest proportion of livestock are sourced would be expected to have the greatest impact on the final risk of FMDV infected livestock entering the CZs. For the proposed CZ in Muse, it is assumed that all ruminants entering that zone originate in Central Myanmar and, therefore, the prevalence of FMD in Central Myanmar will be directly proportional to the risk that ruminants arriving at the CZ in Muse will be infected with FMDV.

The impact of reducing the prevalence of FMDV in Central Myanmar on the risk of FMDV incursions through movement of pigs from Thailand, through the BCZ in Muse or into BCZ in LNT is not known. While the model assumes independence between the prevalence of FMDV in ruminants in Central Myanmar and the prevalence of FMDV in pigs in Thailand, this may not be the case in reality. In order to understand this relationship better, more information would be needed on the source of virus causing FMD outbreaks in pig herds in Thailand.

For the CZ in Lao PDR, the fact that ruminants are sourced from a variety of different countries means that the impact of reducing prevalence of FMD in one source country/area, on the final risk of FMDV incursions into the CZ, is less than where there is a single source of livestock. However, as demonstrated in figure 50, those countries from which a greater proportion of livestock are sourced, will have the greatest impact on the risk of FMDV incursions into the CZ in LNT.

Figure 50

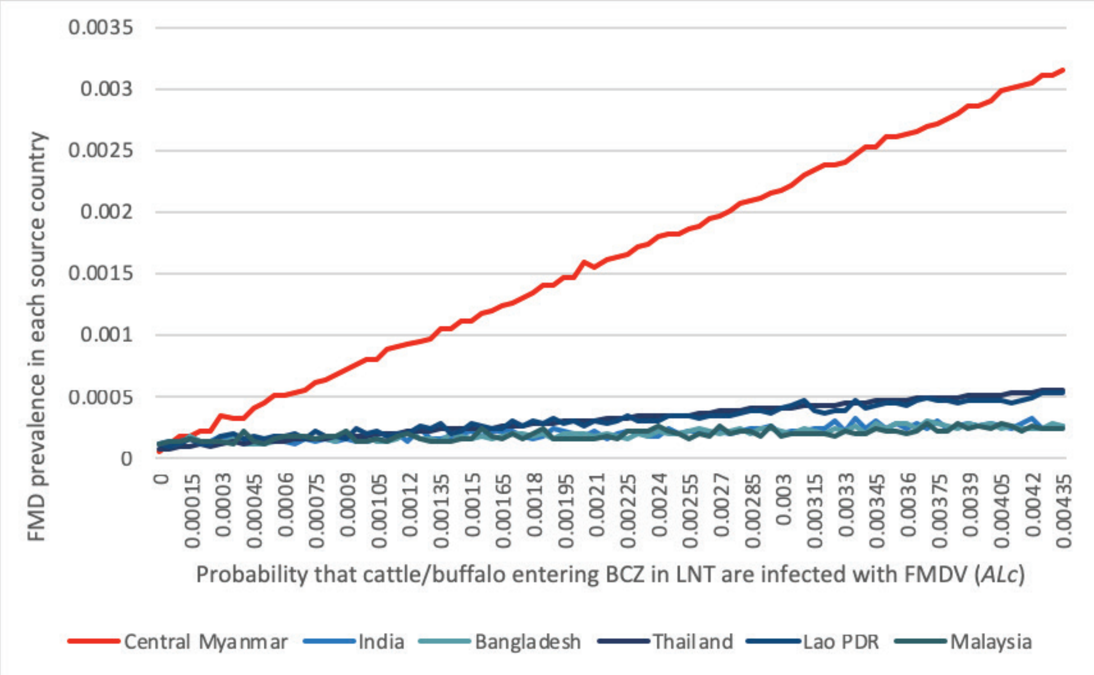

Figure 50: Graph showing the impact of changing the prevalence in different source countries on the overall risk that cattle/buffalo entering LNT CZ will be infected with FMD (ALc) (assuming independence between prevalence in different source areas). This graph was based on results from the quantitative risk model, but with all parameters fixed at their 'most-likely' value (where Pert distributions were used to represent the parameter in the original model), or at a mid-point of the data range (where Uniform distributions were used).

According to the results shown in figure 50, altering the prevalence of FMDV in Central Myanmar is likely to have the greatest impact on the risk of FMDV incursions into the CZ in LNT, compared to the other source countries. Together with the fact that the risk of FMD incursions into the CZ in Muse is dependent upon prevalence in Central Myanmar, measures aimed at reducing the FMD prevalence in Central Myanmar are likely to provide significant benefits to the whole region, in terms of the impact this would have on reducing the prevalence of FMDV in livestock being transported across the region and into the CZ.

While reduction in prevalence of FMDV in Central Myanmar may offer the greatest rewards in terms of reducing the risk of FMDV incursions through ruminant movement into the CZs, addressing FMDV prevalence in other areas must also be considered in order to reduce the risk to an acceptable level. Where there is limited opportunity to reduce prevalence in other areas, or where prevalence is not reduced to zero, other risk mitigation measures, such as those described below, may be used in combination with efforts to reduce FMDV prevalence at source in order to reduce the risk of FMDV incursions to the CZ to an acceptable level.

Reduction in FMDV prevalence in the source countries are likely to involve longer-term strategies, whereby results will not be immediate. Therefore, application of other risk mitigation measures and applying measures to reduce FMDV prevalence in the region should be applied simultaneously to achieve optimum level of protection for the CZs.

RISK MITIGATION SCENARIO B: CLINICAL EXAMINATION OF LIVESTOCK ON ENTRY TO THE ZONE

This risk mitigation scenario models the impact of examining livestock on entry to the CZ and rejecting any animals which are displaying clinical signs consistent with infection with FMD virus. For the purposes of this study, it is assumed that where livestock are suspected of having FMD, that only those livestock showing clinical signs are rejected (this is based on the approach used at certain border areas at present). The sensitivity of this measure to detect infected animals will depend upon the stage of infection of the animal (whether it is incubating the virus – and therefore assumed to be pre-clinical, or whether it is in the disease phase of infection, during which time it may or may not display obvious clinical signs) and the probability that an animal in the disease phase of infection will show obvious clinical signs of disease. The latter probability is based on estimates provided by different stakeholders during field data collection or by expert opinion gathered at a later date, for each FMD susceptible species. Further details of the source of data used to estimate the parameters included in this model are provided in Annex I of this report.

This scenario is modelled by adding additional regulatory systems (steps) to the baseline model (see the scenario tree in figure 51). This scenario assumes that infected animals will be either incubating the virus (during which time it is assumed that all animals are sub-clinical) or in the 'disease' phase of infection (noting that some of these animals may show clinical signs while others will be sub-clinical). The probability that an infected animal is in any particular phase of infection depends upon the relative length of the incubation period and the length of the disease phase. Those animals in the disease phase of infection are further sub-divided into those which display obvious clinical signs and those which do not, only those animals in the disease phase of infection and showing obvious clinical signs are assumed to be detected and rejected using this system, thus allowing entry of all those animals which are sub-clinically infected at the time of import.

Figure 51

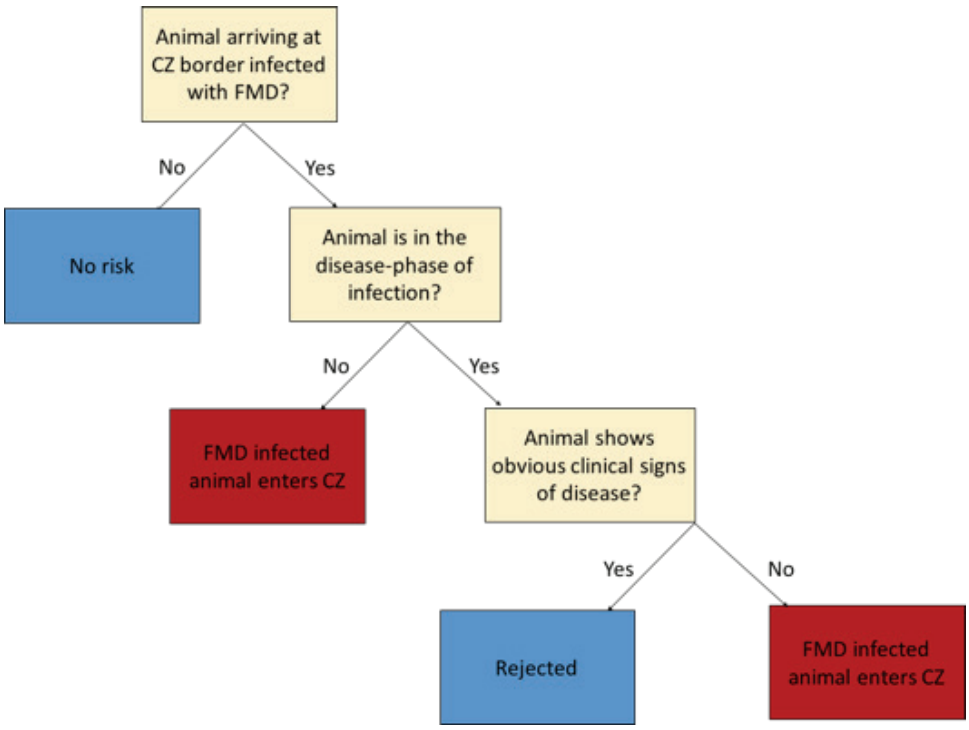

Figure51: A generic scenario tree illustrating the steps necessary for FMDV infected animals to enter the CZ when clinical examination of livestock is conducted on entry to the zone. Only those animals with clinical signs of FMDV will be rejected in this scenario.

Tables 32 and 33 provide examples of the parameters used to model Risk Mitigation Scenario B for cattle/buffalo and small ruminant movement into the Muse CZ, respectively. The same method was applied to other species and other pathways to provide an estimated level of risk for FMD incursions into the CZs in LNT and Muse, where Scenario B is applied. All parameters used to model this scenario are described in Annex I. The results of the models for Scenario B are presented in table 34.

Table 32

Parameters for estimation of the risk of cattle/buffalo entering Muse using clinical examination on entry to the zone

Parameter	Parameter description	Distribution/ formula
PMc	Prevalence of FMD in cattle and buffalo in Central Myanmar	*PMc (see table 15)*
IP	Incubation period for FMD in cattle/buffalo	*IP = Uniform (2, 14)*
DC	Disease duration for FMD in cattle/buffalo	*DC = Uniform (4, 11)*
PNi	Probability infected cattle are in the incubation period	*PNi = IP/(IP+DC)*
PNd	Probability infected cattle are in the disease phase of infection	*PNd = 1-PNi*
Pcs	Probability that cattle/buffalo infected with FMD will show obvious clinical signs of disease	*Pcs = Pert (0, 0.77, 1)*
Pu	Probability an animal allowed into the CZ is infected with FMD	*Pu = (PMc x PNi)+(PMc x PNd x (1-Pcs))*
Nu	Number of FMD infected animals allowed into the CZ per year in this scenario	*= Pu x N8*

Table 32: Parameters used to model the risk that cattle/buffalo entering Muse CZ will be infected with FMDV, when applying clinical examination of livestock on entry to the CZ Risk Scenario B).

Table 33

Parameters for estimation of the risk of small ruminants entering Muse using clinical examination on entry to the zone

Parameter	Parameter description	Distribution/ formula
PMg	Probability that small ruminants arriving at proposed CZ in Muse are infected with FMD	*See table 23*
IP	Incubation period for FMD in small ruminants	*IP = Uniform (2, 14)*
DC	Disease duration for FMD in small ruminants	*DC = Uniform (6, 10)*
PNi	Probability infected small ruminants are in the incubation period	*PNi = IP/(IP+DC)*
PNd	Probability infected small ruminants are in the disease phase of infection	*PNd = 1-PNi*
Pcg	Probability that small ruminants infected with FMD (in Myanmar) will show obvious clinical signs of disease	*Pcg = Pert (0.1, 0.55, 0.75)*
Pv	Probability an animal allowed into the CZ in Muse is infected with FMD	*Pv = (PMg x PNi)+(PMg x PNd x (1-Pcsl))*
N9	Total number of small ruminants entering the CZ in Muse per year	*See table 13*
Nv	Number of FMD infected small ruminants allowed into the CZ in Muse per year in this scenario	*Nv = Pv x N9*

Table 33: Parameters used to model the risk that small ruminants entering Muse CZ will be infected with FMDV, when applying clinical examination of livestock on entry to the CZ Risk Scenario B).

Table 34

Table showing baseline risk that animals entering the CZs are infected with FMD and the expected number of FMDV infected animals entering the CZ by each pathway, per year together with these same risk measurements after application of risk mitigation scenario B.

Pathway (BCZ)	Species	Baseline risk that animals entering BCZ are infected with FMD	Baseline number of FMD infected livestock entering BCZ each year	Risk that animals entering BCZ are infected with FMD for scenario B	Number of FMD infected animals entering BCZ each year for scenario B	% difference in risk between baseline and scenario B (based on different in means)
CM1 (Muse)	Cattle/buffalo	0.0004 (2.00 x 10^{-5}, 0.0002)	52 (2, 232)	0.00024 (1.29 x 10^{-5}, 0.0011)	35 (1, 166)	40%
SM1 (Muse)	Sheep/goats	0.0003 (3.2 x 10^{-5}, 0.0013)	27 (2, 111)	0.00026 (0.00019, 0.00032)	20 (2, 79)	13%
PM1 (Muse)	Pigs	4.91 x 10^{-5} (1.28 x 10^{-6}, 0.0002)	2 (0, 9)	3.2 x 10^{-5} (8.97 x 10^{-7}, 0.00015)	1 (0, 5)	35%
ALc (LNT)	Cattle/buffalo	0.0004 (6.7 x 10^{-5}, 0.0013)	50 (7, 187)	0.00024 (3.89 x 10^{-5}, 0.00088)	33 (5, 128)	40%
Alp (LNT)	Pigs	5.12 x 10^{-5} (1.17 x 10^{-6}, 0.0002)	1 (0, 3)	3.1 x 10^{-5} (7.96 x 10^{-7}, 0.00014)	0 (0, 2)	40%

The results of risk scenario B show that examination of livestock at the point of entry to the CZ might reduce the risk that animals entering the zone have FMDV by approximately 40% for cattle, buffalo and pigs but only about 13% for small ruminants. The lower risk reduction for small ruminants is due to the lower probability that infected small ruminants will display obvious clinical signs of disease. Therefore, fewer would be detected compared to cattle and pigs. While the reduction in risk is quite significant for cattle/buffalo and pigs, the results indicate that it is still highly likely that there will be multiple incursions of FMDV infected livestock into the zone, even where this measure is in place. It is unlikely that this would provide an acceptable level of protection for the CZs and would also be highly dependent upon the observational skills of individuals conducting the examinations.

RISK MITIGATION SCENARIO C: USE OF GOVERNMENT APPROVED PRE-QUARANTINE PRIOR TO ENTRY TO THE PROPOSED CONTROL ZONE

The risk mitigation scenario modelled here is for the use of government approved pre-quarantine establishments where livestock may be kept for a specified period of time and undergo specific treatments and health certification before being released to enter the proposed CZs in Muse and LNT. The exact form these pre-quarantine establishments take might vary, but it is likely that approval of private facilities where livestock may be simultaneously raised and quarantined would be an attractive approach for the livestock traders rather than paying for quarantine services at other government or private establishments.

FOCUS ON: QUARANTINE

(the following extract is taken from the SEACFMD roadmap toolkit manual on animal movement management and quarantine)

According to the OIE, a quarantine station is defined as:

an establishment under the control of the Veterinary Authority where animals are maintained in isolation with no direct or indirect contact with other animals, to ensure that there is no transmission of specified pathogen(s) outside the establishment while the animals are undergoing observation for a specified length of time and, if appropriate, testing and treatment.

Figure 52

Figure 52: Private quarantine station in Thailand

How and where quarantine is undertaken should be decided jointly by the exporting country and the importing country. Each country should be able to provide sufficient evidence to the other country that the quarantine facilities in place are fit for purpose. This should be documented such that the veterinary authority of the importing country has confidence in the systems implemented in the exporting country, and that certification issued or signed by the competent authority of the exporting country is accurate and accepted by the importing country (and any transit countries).

Quarantine stations may be run by the government or owned and managed by the private sector (with approval of the governments of the importing country and/or the exporting country).

It is likely that the standards for pre-quarantine would be agreed jointly by the governments of countries in which the quarantine facilities are based and the country to where the livestock are destined (i.e. China). While the details of the arrangement will be decided between these countries, it may be that the Veterinary Authority of the country where pre-quarantine takes place is responsible for ensuring that the pre-quarantine requirements are met.

The model used in this scenario is based on clinical observation of consignments of livestock during the pre-quarantine period (assumed to be at least 21 days and therefore it is assumed that any FMD infected animal entering the quarantine will progress beyond the incubation period of disease during quarantine, as will livestock infected within the first few days of quarantine). If one or more livestock within the consignment show clinical signs consistent with FMDV, it is assumed that the whole consignment will be rejected (prevented from entering the CZ). This is a relatively simple model to demonstrate the principle of pre-quarantine as a means of reducing the risk that FMDV infected livestock enter the CZ. As livestock leaving pre-quarantine would be vaccinated against FMDV and certified as higher health status, there would be less risk of transmitting FMD along livestock movement pathways, thus not only reducing the risk of FMD incursions into the destination country/zone but also making livestock movement safer for those countries through which livestock transit.

Given that livestock would generally be pre-quarantined at the same time as growing/fattening and within the traders own facilities, then a 21-day quarantine period should not be onerous in terms of additional cost/inconvenience when compared to long quarantine periods elsewhere, where traders might have to pay a daily rate for quarantine facilities and also transport livestock feed to cover the quarantine period.

The model used to represent this scenario assumes that animals held in pre-quarantine establishments, in a single consignment, are likely to be held at a high stocking density and so the opportunity for contact between infected and susceptible animals will be high. Therefore, if at least one infected animal enters the consignment, it is assumed that FMD will spread to a relatively high proportion of the other animals within that consignment (though the extent of intra-herd spread will depend upon the species in question (details of the parameters used to model this are in Annex I)). The data used to model this process assumes that all animals within the consignment are susceptible to FMD, but does take into account the potential for livestock in endemic settings, such as Central Myanmar, to have mild or sub-clinical infection. The effect of vaccination at the start of quarantine is not taken into account in this model, but would need to be considered when establishing the pre-quarantine standards and procedures.

This model also assumes that there would not be opportunity for pre-quarantined livestock to mix with other livestock between leaving pre-quarantine and entering the CZ. This could be achievable through use of official seals on trucks and more rapid transit of livestock, where mixing with livestock during transit is not permitted. As part of the pre-quarantine process is likely to involve vaccination of livestock against FMD, the traded animals would be further protected during transit.

The scenario tree shown in figure 53 illustrates the model used to represent pre-quarantine of livestock prior to entry into the CZs and table 35 outlines the parameters which make up the model (details of the source of data and probability distributions used to represent each parameter are provided in Annex I). While the scenario tree and model shown in figures 53 and table 35, respectively, use cattle and buffalo as an example, the model is run for the three different species of livestock which enter the CZ in Muse. It is assumed that they are pre-quarantined at source. However, the principle would be the same if pre-quarantine were undertaken in an approved area along the route of transit, provided the same standards were met. The results for the impact of pre-quarantine on the risk of cattle/buffalo, small ruminants or pigs which enter the CZ in Muse being infected with FMDV are shown in table 36.

Figure 53

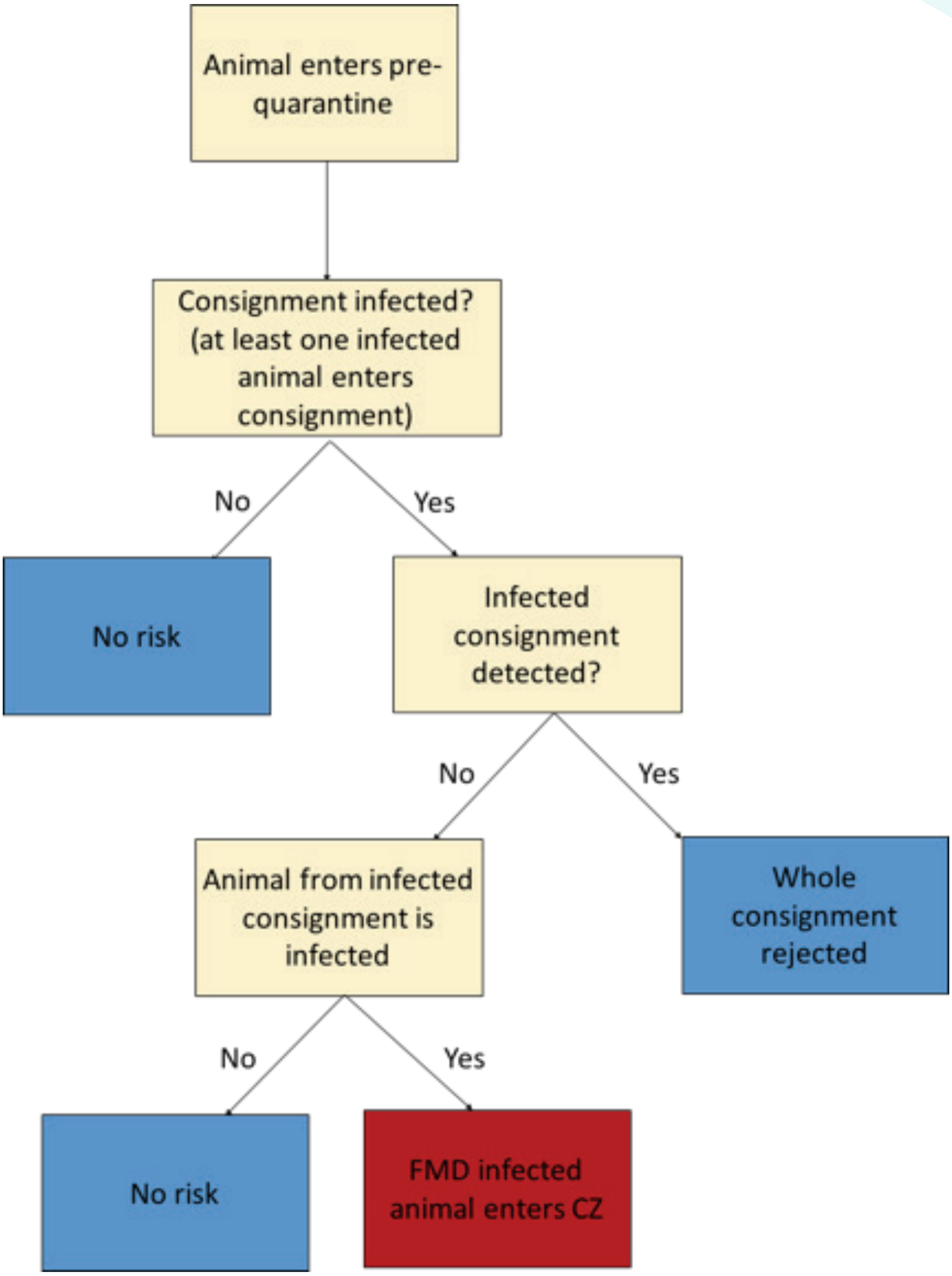

Figure 53: A generic scenario tree illustrating the steps necessary for FMDV infected animals to enter the CZ following a pre-quarantine period under approved conditions. This assumes that if one or more animals in a consignment are detected as infected (by observation of clinical signs)

Table 35

Parameters for estimation of the risk of FMDV infected cattle/ buffalo entering the CZ at Muse following pre-quarantine at source

Parameter	Parameter description	Distribution/ formula
PMc	Prevalence of FMD in Central Myanmar (probability cattle/buffalo entering pre-quarantine have FMD)	*PMc (see table 15)*
Nc	Number of animals in a consignment	*Nc = Uniform (10,100)*
Ptt	Probability at least one animal in a consignment is infected with FMDV	*Ptt = 1-(1-PMc)Nc*
Ps (min)	Minimum prevalence in a consignment where at least one infected animal enters the consignment (assumes entry of a single animal)	*Ps(min) = 1/^{Nc}*
Ps (most-likely)	Most likely prevalence in a consignment where at least one infected animal enters the consignment	*Ps(most-likely) = 0.4*
P (max)	Maximum prevalence in a consignment where at least one infected animal enters the consignment	*Ps(max) = 1*
Ps	Probability that an animal from an infected consignment is infected with FMDV during quarantine	*Ps = Pert ((Ps(min), Ps(most-likely), Ps(max)*
Ni	Number of infected animals in an infected consignment	*Ni = Ps x Nc*
Pcs	Probability infected cattle/buffalo will show clinical signs during quarantine period	*Pcs = Pert (0.1, 0.75, 1)*
Px	Probability an infected consignment is detected (at least one infected animal in the consignment shows clinical signs)	*Px = 1-(1-Pcs)^{Ni}*
Pq	Probability an infected consignment is not detected	*Pq = 1-Px*
Pz	Probability an animal entering the CZ comes from an infected consignment, is infected and that consignment is not detected	*Pz = Ptt x Pq x Ps*
N8	Number of animals imported per year through this system	*N8 = Uniform (72,000 , 220,000)*
Nz	Number of infected animals accepted into CZ following pre-quarantine per year	*Nz = Pz x N8*
Pzi	Probability at least one infected animal will be accepted into the CZ following pre-quarantine per year	*Pzi =1-(1-Pz)N8*

Table 35: Parameters used to model the risk that cattle/buffalo entering Muse CZ will be infected with FMDV, following pre-quarantine.

Table 36

Table showing results of a model to determine the risk that livestock entering the CZ in Muse are infected with FMD, showing both the baseline level of risk and the level of risk following pre-quarantine at source.

Pathway (BCZ)	Species	Baseline risk that animals entering BCZ are infected with FMD	Baseline number of FMD infected livestock entering BCZ each year	Risk that animals entering BCZ are infected with FMD for scenario C	Number of FMD infected animals entering BCZ each year for scenario C	% difference in risk between baseline and scenario C (based on difference between means)
CM1 (Muse)	Cattle/ buffalo	0.0004 (2.00 x 10-5, 0.0002)	52 (2, 232)	5.4 x 10-6 (1.77 x 10, 4.96 x 10-5)	1 (0, 7)	99%
SM1 (Muse)	Sheep/ goats	0.0003 (3.2 x 10-5, 0.0013)	27 (2, 111)	6.35 x 10-5 (3.99 x 10-10, 0.00034)	5 (4, 30)	79%
PM1 (muse)	Pigs	4.91 x 10-5 (1.28 x 10-6, 0.0002)	2 (0, 9)	3.11 x 10-7 (0, 1.77 x 10-6)	0.01 (0, 0.08)	99%

The results shown in table 36 demonstrate that pre-quarantine should have a significant impact on the risk of FMDV infected livestock entering the CZ in Muse. The results of this model can also serve as an example of how similar pre-quarantine systems could work for the CZ in LNT. Though the situation in Lao PDR is complicated by the fact that livestock come from multiple sources, alternative measures such as establishing pre-quarantine in a strategic area within Myanmar to take in cattle and buffalo entering from India/Bangladesh or pre-quarantine in Thailand for cattle coming from Malaysia and Myanmar (if not already pre-quarantined in Central Myanmar), could be considered.

It can be seen from the results of this scenario that the risk reduction from pre-quarantine is more effective in cattle/buffalo and pigs than in small ruminants. This is likely a result of two factors: first, that small ruminants are less likely to demonstrate obvious clinical signs of disease if infected with FMD and second, that the intra-herd spread of FMDV in herds of small ruminants is likely to be less and, therefore, where less animals are infected (and where less of those animals show obvious clinical signs) the probability that at least one animal in a consignment will demonstrate clinical signs (and therefore result in rejection of that consignment) will be lower than for the other species. Therefore, additional testing may need to be considered to further reduce the risk that small ruminants with sub-clinical infection are imported into the CZ.

RISK MITIGATION SCENARIO D: MAXIMISING USE OF LEGAL VERSUS ILLEGAL PATHWAYS OF LIVESTOCK MOVEMENT

This section examines the potential impact of maximising official (legal) movement over unofficial (illegal) movement of livestock for trade purposes. Many of the traders interviewed during this study stated that legalising cross-border trade into China would benefit their business. In China, traders described that legalisation of the trade would enable them to use larger trucks and larger roads for transportation of livestock and a reduction in payment of unofficial taxes along the route (Smith et al., 2015), which would make their business more profitable. In general, stakeholders were of the opinion that if legal channels of movement were available then they would use them, due to the high cost and inefficiency of illegal movement. However, this would obviously depend upon the legal channels being sufficiently streamlined to provide a more efficient, lower cost option for the traders, compared to unofficial pathways.

Risk mitigation scenario D is not an alternative to the other risk mitigation measures described above but, rather should underpin the other scenarios. The estimated impact of scenarios A to C all assume that livestock entering the CZs are doing so through official channels and are therefore subject to the mitigation measures imposed. This section will look at how the potential for unofficial movement of livestock can impact on the effectiveness of other risk mitigation measures (where strict measures can encourage more unofficial movement) and also look at some of the other benefits of facilitating legal cross-border trade in livestock.

Establishing an acceptable level of protection for the proposed Control Zones while facilitating legal livestock trade

As the current, and previous, studies have demonstrated, there is an established cross-border trade in livestock throughout South-East Asia, of which the vast majority occurs unofficially. This movement is driven by the significant price differentials which exist across the region as a result in the very high demand for livestock products in countries such as China and Vietnam, and the high supply and low demand for livestock in countries such as Myanmar and India. As described by Widders (2015), the regulatory procedures currently in place for cross border movement of livestock across much of South-East Asia are prohibitively strict and, in some cases, impossible for livestock traders to follow.

While importation of livestock will always pose some risk to the importing country, what this section seeks to demonstrate is the importance of establishing official cross-border pathways for livestock which minimise this risk, while taking into consideration the impact that import requirements might have on the probability that livestock will follow those procedures, or will be moved illegally in order to avoid them. In the words of Heuston et al. (2011): Optimal risk mitigation on a national scale requires scientifically sound, yet flexible mitigation strategies that can address the competing risks of formal and informal trade.

When designing risk mitigation strategies to minimise the risk that FMDV infected livestock will enter the CZs in Muse and LNT, it is essential that the potential for unofficial trade is taken into account and that governments work in consultation with other stakeholders (including livestock traders) when developing these measures. They should aim to effectively reduce the risk of FMDV incursions while also being sufficiently attractive to traders to prevent them seeking alternative, unofficial routes of movement.

Legal movement needs to streamline the cross-border movement process to ensure that animals can be moved efficiently and at the lowest possible cost, while minimizing the disease risks associated with this movement. Where official pathways are time-consuming and there are more efficient and cheaper unofficial pathways, the latter is bound to predominate (assuming that enforcement is not sufficient to prevent unofficial pathways of movement). Take, for example, the current movement of pigs through Bokeo Province in Lao PDR: unofficial movement allows for direct transit from the Mekong River, through Bokeo and LNT Provinces in Lao PDR, to the Chinese border. This movement could take as little as 7 hours (estimate: google maps) with minimal opportunity for the consignment to mix with other animals. The legal pathway, however, takes far longer, as certification procedures are time-consuming, and while the animals wait for permission to continue their journey (up to 4 days) there is greater opportunity for mixing with other livestock, thus providing a potential opportunity for disease spread. It is also costly for the traders to keep the pigs for additional time and to delay sale of the pigs.

According to information gathered during the current study, there is a high level of support, amongst livestock traders, to establish an official trade in livestock within the region and, particularly into China. At present, almost all of the movement takes place unofficially and traders describe this as a key restraint to their business. For example, in Myanmar, goat traders described that to trade goats into China officially (though this movement is only recognised by the Myanmar government and not the government of PR China), the cost is approximately 5 times less than when trading them illegally. Similar accounts were described for the movement of cattle and buffalo, whereby the use of small vehicles, small roads, the need to walk cattle over long distances and the payment of 'unofficial taxes' puts significant pressure on the traders' business. Therefore, it is likely that, where mitigation measures and import regulations are implemented which facilitate this trade (while also minimising the risk) it is likely they will be supported by traders.

This concept of managing a balance between optimal risk mitigation and minimising unofficial livestock movement has been discussed previously by both Hueston et al. (2011) and Smith (2012) and should be taken into account when designing measures as part of this safer trade initiative. The diagram shown in Figure 54 (taken from the SEACFMD Roadmap Toolkit) illustrates this point, whereby a very strict measure to prevent entry of FMD infected livestock (for example, a very long quarantine period) may be counter productive where it discourages traders from using the official route of cross-border movement. In this scenario, a less strict alternative, whereby more livestock use the official route of entry, may offer a lower overall risk for FMD infected animals entering the zone.

Figure 54

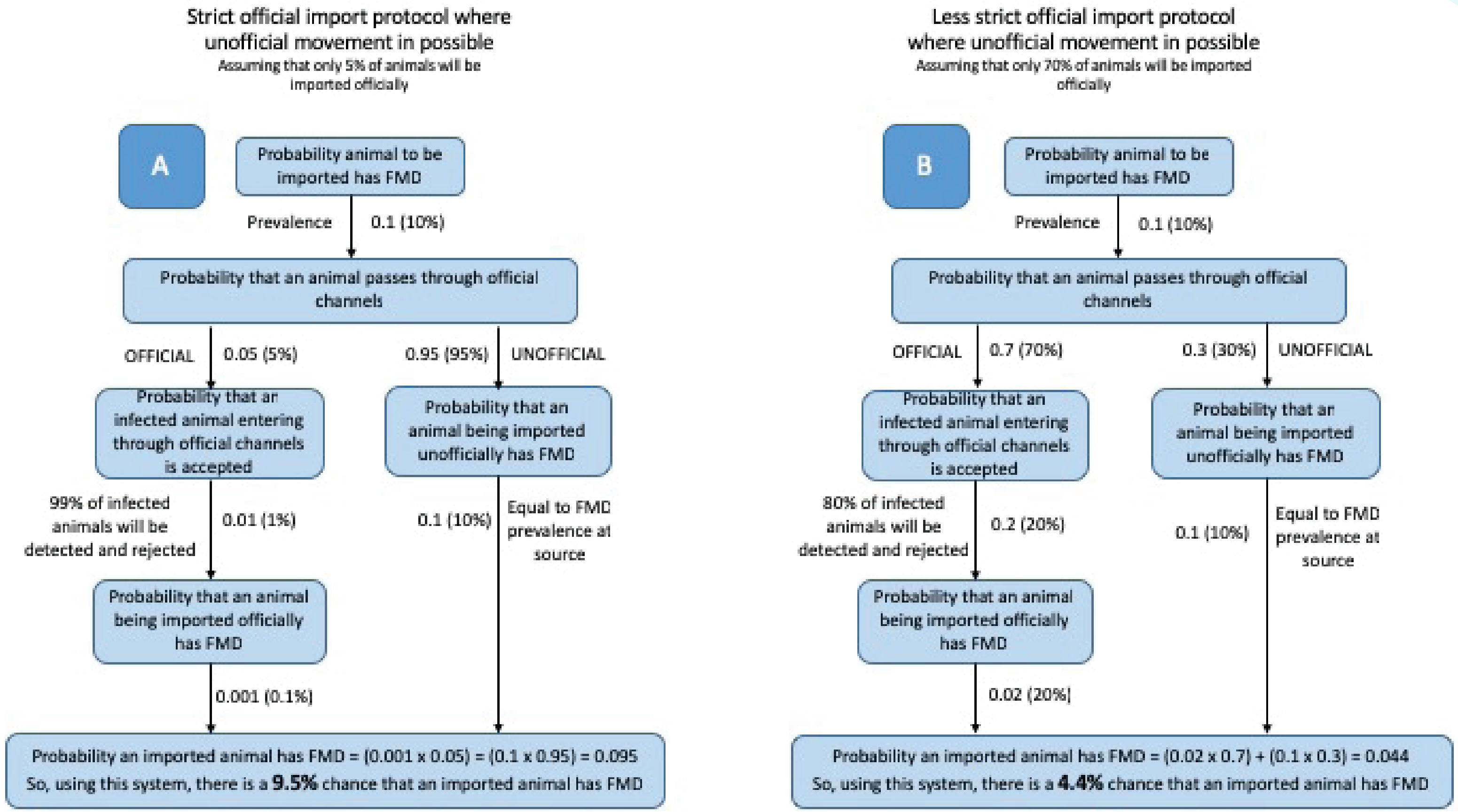

Figure 54: Scenario trees demonstrating how the overall risk of importing infected livestock might be affected when taking into account unofficial movements as well as official movements (taken from SEACFMD Roadmap Toolkit).

A major cost of legal trade are the time delays and cost resulting from quarantining of livestock. Therefore, the length of the quarantine period is likely to impact on the cost to the traders and therefore the likelihood that they will use these pathways. While the total cost of illegal movement will need to be investigated in order to know what cost limits are on the legal movement processes, reducing quarantine to a time where it is still effective at reducing the risk to an acceptable level, while minimizing the cost to traders, should be carefully considered. A 21-day period has been raised as a possible duration for quarantine prior to entry to China, from the CZs. While this might be optimum for reducing the risk of FMD infected animals entering China, it may be too costly for the traders to use it and the advantage, in terms of risk reduction, of each additional day of quarantine above, say 14 days, may not be sufficient to justify the additional cost of quarantine or the additional risk that traders will seek to avoid the quarantine system altogether.

Further investigation to establish the optimum quarantine period (both at pre-quarantine and quarantine within the CZ) should be conducted, in consultation with stakeholders, and with further information about the cost of quarantine. It might be possible, where pre-quarantine is used, to implement longer periods of pre-quarantine (prior to entry to the CZ) and then much shorter periods of quarantine, within the CZ. During pre-quarantine, the livestock are at the trader's own holding and therefore the cost of quarantine is lower and the animals are simultaneously being prepared for sale (growing or fattening). The pre-quarantine measures would also include vaccination, thus creating a safer source of livestock to enter the CZ. Once arriving at the CZ, the risk that animals have FMD would already be significantly reduced due to pre-quarantine, and a much shorter time in this quarantine facility may provide an acceptable level of protection for China, while still encouraging traders to use the official system. As described above, the economic feasibility and effectiveness of different quarantine periods and other measures will require a more detailed analysis of costs and consultation with other stakeholders, but this section functions to highlight the paradox that very strict measures can actually lead to increasing the risk of FMDV incursions due to encouraging more unofficial movement of livestock.

More direct movement of livestock from source to destination, reducing gathering and mixing of animals during trade and protecting resident livestock in transit areas.

During this study, particularly when tracing the pathway of large ruminant movement from Central Myanmar, the complexity of unofficial livestock movement pathways was striking, with livestock frequently being moved in small consignments, on foot over long distances in order to avoid detection. Due to the need to walk over distances and to change modes of transport at times, there were established areas for resting, gathering and even trading of livestock along the movement pathways. These areas could represent critical points for transmission of FMD through gathering and mixing of livestock from different sources. Therefore, due to the fact that movement is illegal, livestock tend to take longer to move over a particular distance and, during that journey, they have more opportunity for mixing with other FMD susceptible livestock.

Figure 55 shows a scenario tree representing movement of cattle and buffalo through Myanmar, destined for the BCZ in Muse. The model compares the risk that livestock passing directly from Central Myanmar to the CZ, without contacting other livestock, will be infected with FMDV, with the risk that livestock passing through a market (or other gathering of livestock) en-route to the CZ, will be infected with FMD. The parameters used to construct the model are shown in table 37, with descriptions of the data used to furnish the parameters provided in Annex I.

The model described in figure 55 and table 37 is a simple representation of livestock trade movements destined for the CZ in Muse, but the same principle will apply along other livestock movement pathways in the region.

Figure 55

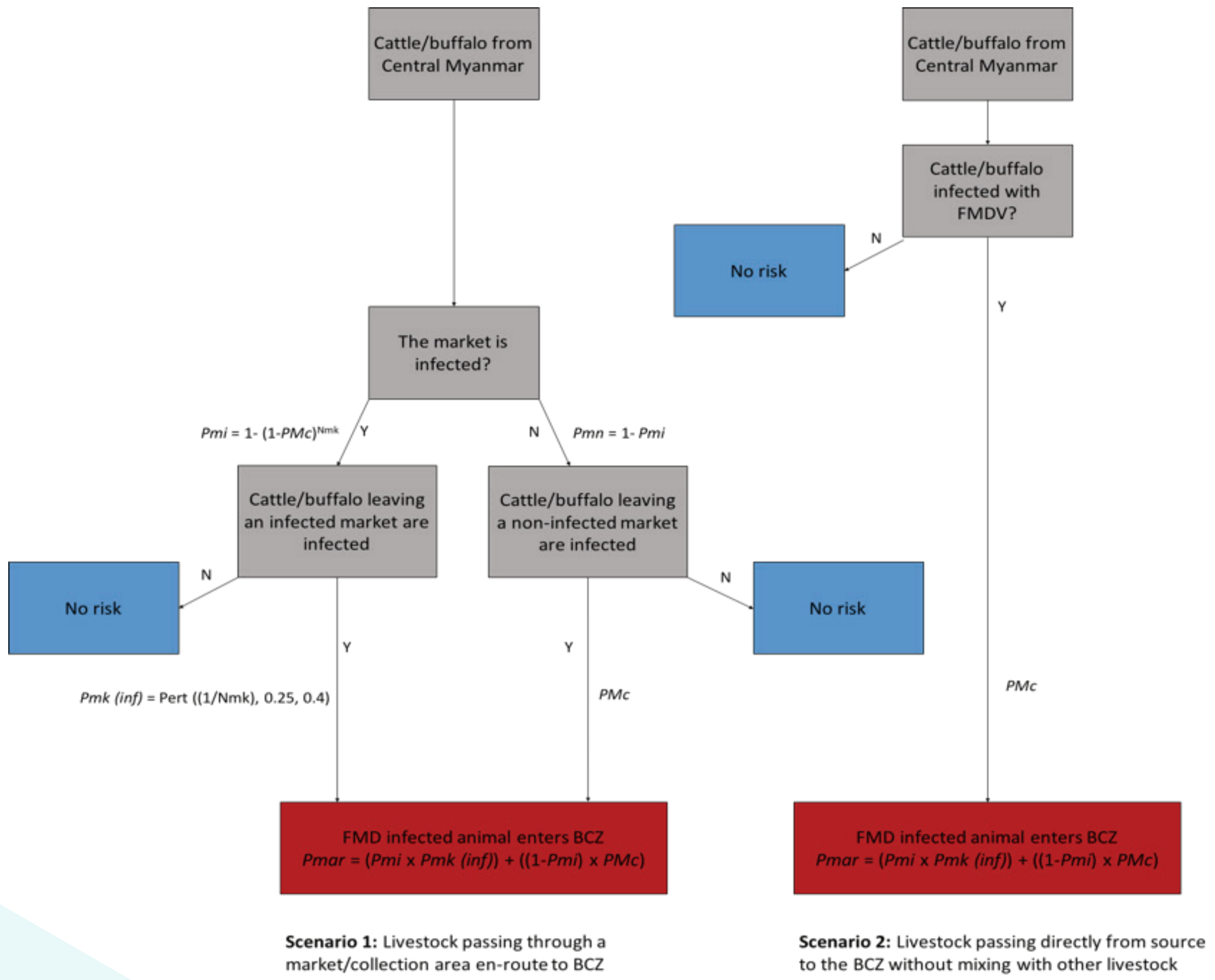

Figure 55: Scenario trees for livestock passing through a market en-route to CZ in Muse and for livestock travelling directly from their source in Central Myanmar to the CZ. These trees show the parameters used for calculation of the risk in each pathway.

Table 37

Parameters for estimating the impact of mixing livestock in markets/holding areas on the risk of FMD entering the CZ (using Muse as an example)

Parameter	Parameter description	Distribution/ formula
PMc	Prevalence of FMD in Central Myanmar (probability cattle/buffalo entering pre-quarantine have FMD)	*PMc (see table 15)*
Nmk	Number of animals in market 1	*Nmk = Uniform (100, 200)*
Pmi	Probability the market is infected (at least one animal entering the market is infected with FMDV)	$Pmi = 1\text{-}(1\text{-}PMc)^{Nmk}$
Ps (min)	Minimum prevalence in the market where at least one infected animal enters the market (assumes entry of a single animal)	*Pk(min) = 1/Nmk*
Pk (most-likely)	Most likely prevalence in the market (where at lease one infected animal enters the market)	*Pk(most-likely) = 0.25*
Pk (max)	Maximum prevalence in a market (where at least one infected animal enters the market)	*Pk(max) = 0.4*
Pk	Probability that an animal in an infected market is infected	*Pk = Pert ((Pk(min), Pk(most-likely), Pk(max)*
Lmi	Probability an animal arriving at CZ, via a market, is infected	*Lmi = (Pk x Pmi) + (PMc x (1-Pmi))*

Table 37: Table showing the parameters for the model used to estimate the difference in risk between moving animals directly from their source in Central Myanmar to the CZ in Muse and moving animals via a market/holding area.

The results of this model are shown in table 38, where they are displayed to compare the mean probability that: cattle moving direct to the CZ; cattle moving through a market/ gathering of 25 to 50 animals; and cattle moving through a gathering of 100 to 200 animals, will be infected with FMDV on arrival at the Muse CZ. According to the results of this model, there is a significant increase in the risk of cattle being infected with FMDV after they have passed through a market (or other gathering) rather than moving directly, with a 10-fold and 33-fold increase in the mean risk (when compared to direct movement (without mixing)) for livestock moving through small (25-50 head) and larger (100-200 head) markets, respectively.

Table 38

Table showing the results of the model for comparison of livestock mixing at markets compared to moving directly from source to destination (based on 5000 iterations of the model)

Scenario	Mean (95% CI) probability an animal arriving at the BCZ/ quarantine area is infected with FMD	% difference (of means) compared to baseline
Cattle/buffalo moved directly from Central Myanmar to CZ	0.00036 (1.89 x 10-5, 0.0016)	0% (baseline)
Cattle/buffalo passing through market (25-50 head)	0.0035 (0.00017, 0.0153)	872% increase compared to baseline (9.7-fold increase compared to baseline)
Cattle/buffalo passing through one market (100-200 head)	0.012 (0.00056, 0.054)	3233% increase compared to baseline (33.3 fold increase compared to baseline)

The model used in this scenario applies a number of assumptions, including that there are sufficient susceptible animals within a market to allow significant spread of FMD through that market, should an infected animal enter. In reality, if livestock being traded through the market have already been vaccinated near the source of those livestock then the intra-market spread of FMD would be expected to be far lower and the impact of trading through markets reduced. However, what this model does demonstrate is that, given a susceptible group of animals, the risk that any individual animal will become infected is significantly increased where there are opportunities for mixing of livestock, particularly in areas where animals are held at high stocking rates (allowing for rapid intra-herd transmission of FMDV). While a market is used as an example here, other gathering points along the trade route are likely to have a similar impact.

At present, the regulations on trade in some areas are encouraging greater use of livestock markets and mixing of livestock along trade routes as animals are moved by indirect and slow means which is a feature of unofficial movement of livestock.

In addition to facilitating legal trade in livestock within the region (South-East Asia and China), consideration should also be given to facilitating trade in livestock from FMD free countries, thus meeting at least some of the demand for livestock and livestock products from 'safe' sources, into China. At present, it is understood that there is no official importation of live cattle from Australia into China. However, according to information presented by Smith et al. (2015) Australian cattle are being imported into other countries in the region (namely, Vietnam and Thailand) and many of these cattle will eventually reach China, via unofficial pathways. During this transit period, however, the cattle may be exposed to FMDV and, therefore, when they enter China they could present a risk for incursions of FMDV. If a legal pathway of movement was available whereby cattle could be moved directly from Australia to China, the risk would be negligible.

RISK MITIGATION MEASURES: DISCUSSION

A number of risk mitigation measures have been presented and discussed in this section, using some simple models to demonstrate various principles and to model the potential impact that these measures could have on the risk of FMDV incursions into the proposed CZs.

A key conclusion of this section is the need to establish scientifically based mitigation strategies which function both to minimise the risk of FMDV incursions while encouraging use of official movement channels. As described earlier, the success of risk mitigation scenarios A, B and C are completely dependent upon the success of achieving official movement of livestock through gaining support from the livestock traders involved in animal movements in the region (risk mitigation scenario D).

While this study only provides examples based on simple models, it demonstrates the potential effectiveness of addressing disease at source, identifying Central Myanmar as a key target where measures to reduce FMDV prevalence could have greatest impact on the risk of FMDV infected animals entering the CZs in both LNT and Muse. A number of studies have already highlighted the importance of Central Myanmar as a source of livestock in the region (Cocks et al., 2009; Smith, 2012; Smith et al., 2015) and this study serves to update and validate some of the material presented by earlier studies.

Implementing pre-quarantine of livestock prior to entry to the CZ is demonstrated, by the models used in the study, to significantly reduce the risk that livestock entering the CZs will be infected with FMDV. In addition to establishing pre-quarantine areas at the source of livestock (i.e. at trader's premises in Central Myanmar) some other areas may be established to handle livestock entering from other countries, where quarantine at source is not possible. Further investigation should be conducted into the feasibility of establishing pre-quarantine areas within Myanmar to handle livestock entering from South-Asia, or in Northern Thailand to handle livestock entering from other areas (Myanmar, Malaysia, Thailand, etc.). This system might resemble the private quarantine station system employed in Thailand to handle livestock entering unofficially from Myanmar (Smith, 2012).

The various risk mitigation strategies described in this study are shown to be least effective at reducing the risk of FMDV-infected small ruminants entering the CZs, compared with other FMD susceptible species. This is predominantly due to the fact that the measures presented here are largely based on observation of clinical signs as the primary method of detecting infected animals, and small ruminants are frequently sub-clinically affected or only show subtle clinical signs. These species, therefore, pose a particular risk for the silent spread of FMDV, as has been demonstrated in outbreaks in other parts of the world (Barnett and Cox, 1999; Donaldson, date unknown). There is a need to conduct further studies on sheep and goats in the region, in order to understand more about the prevalence of FMDV in these species and their role in the epidemiology of FMD (particularly in Central Myanmar).

CONCLUSIONS AND RECOMMENDATIONS

The following list includes conclusions drawn from this study as well as recommendations for future investigation or action. Throughout this study, and in the conclusions below, there is a focus on facilitating safer trade in livestock destined for China (via the proposed CZs in LNT and Muse). Therefore, emphasis is not on stopping or 'banning' trade, as this would not be feasible and would lead to continuation of illegal movement, such is the demand and the price of livestock products in China.

CURRENT MOVEMENT PATHWAYS AND RISK OF FMDV INCURSIONS INTO THE PROPOSED CONTROL ZONES

There is a high volume of livestock movement into China, via the proposed CZs: The results of this study indicate that large-scale movement of cattle and buffalo, originating from SEA and the Indian Subcontinent, into China (as previously described by Smith et al., 2015) continues to occur. A large proportion of this movement transits through the proposed CZ areas of LNT and Muse.

Recent data suggests a marked increase in pig trade entering China from neighbouring countries from 2016 to 2018. This is likely to increase the risk of FMD incursions into the CZs compared to the risk estimated based on the volume of pig movement estimated in 2016.

Almost all cross-border movement of livestock en-route to China, via the CZs, is unofficial and unregulated: While some specific pathways of live animal trade are officially recognised in some countries, the vast majority of cross-border movement occurring in the region remains unofficial. In 2018, the Myanmar Government established a legal trade of cattle out of Myanmar, into China. While not yet officially recognised by China, the countries are working towards an MOU recognising this trade as official.

Movement of cattle, buffalo, small ruminants and pigs into the proposed CZ areas was identified: In addition to cattle and buffalo trade previously identified (Smith et al., 2015), this study also highlights an active trade in pigs (passing through the CZs in LNT and Muse) and small ruminants (passing through the CZ in Muse), en-route to China.

Cattle and buffalo movement represents the highest risk of FMDV incursions into the proposed CZs, followed by small ruminants and then pigs: The results of the quantitative risk assessment suggest that there is a very high risk that at least one FMD infected cattle/

buffalo will enter the CZ in Muse and in LNT each year. There is also a very high risk that FMD infected small ruminants will enter the BCZ in Muse each year, again with multiple incursions highly likely. Indeed, the frequently sub-clinical nature of FMD in small ruminants could mean that the movement of sheep and goats actually pose a greater risk for FMD incursions into the zone, as infection is more likely to go undetected.

While the risk of FMDV infected pigs entering the CZs may be lower than other species, the consequences could be significant: Although the results of this risk assessment model indicate that pigs represent the lowest level of risk for FMD incursions amongst all the species, the consequences of introduction of an FMDV infected pig could be significant given the high quantity of virus excreted by infected pigs (particularly where a whole consignment of pigs become infected) and the expected high livestock density within the CZ areas. The role of pigs may also become more important, should pig adapted strains of FMDV enter the region. In addition, recent increases in the volume of pig trade through the CZs make this trade increasingly important in terms of risk of FMD incursions into the CZ.

While little is known about the role of sheep and goats in the epidemiology of FMD in the region, the frequently mild or subclinical infection represents a specific risk for undetected spread of FMDV: The role of sheep and goats in the epidemiology of FMD in the region is still relatively poorly understood, with very few outbreaks reported in these species. However, serological surveillance studies conducted in the region suggest a high level of sero-conversion in goats in Central Myanmar (the main source of small ruminants entering the CZ in Muse). This suggests that while sheep and goats are becoming exposed to FMDV, these infections are not being detected/reported. Therefore, small ruminants could represent a particular risk to the CZ areas if infected animals are not detected and are allowed to enter the proposed CZ areas. Further investigation into the role of small ruminants in the epidemiology of FMDV in SEA is needed.

The movement of livestock from Chiang Rai Province, Thailand to Sob-Luay Port, Myanmar (along the Mekong River) requires special consideration as this bypasses proposed CZ areas: The movement of livestock up the Mekong River to Sob-Luay Port in Myanmar, previously described by Smith et al., (2015), remains active with volumes of livestock reportedly exceeding that of the road route which passes through Bokeo to the proposed CZ in LNT. If measures applied to encourage legal trade through the CZ do not take this movement pathway into account, it could remain active and thus bypass any risk mitigation measures applied at, or prior to, the CZ.

Addressing the 'River route' will be a question of economics and engagement of stakeholders: According to traders interviewed under the current study, the river route is used because it is much cheaper to transport livestock by this route, compared to other routes from Northern Thailand to China. It is expected that directing livestock movement away from the river route and through the CZ would be a question of economics, ensuring that the benefit/cost ratio of using the official route is favourable compared to using the unofficial river route. Further investigation of, and engagement with, the stakeholders using this route is needed in order to better understand the factors driving this movement and to explore ways to encourage movement of livestock through official channels.

Livestock entering SEA from the Indian Sub-Continent represents a risk of FMDV incursions (including of FMDV strains exotic to South-East Asia) into the whole region, as well as the proposed CZs. Cattle and buffalo are reportedly entering SEA from the Indian Subcontinent and are passing into the proposed CZ in LNT. While the volume of livestock entering via this route is uncertain, identification of this movement of livestock from India and Bangladesh by the current study, provides additional verification of information previously reported by Smith et al., (2015). Further investigation of this movement, and the risk it poses to the region should be considered.

Improved data needed on volumes of livestock movement and measures of prevalence: The models developed in this study are highly sensitive to changes in FMD prevalence and the volume of livestock being moved into the CZ. The process of developing these models has highlighted the need to more accurately estimate prevalence and livestock movement volumes in order to more accurately estimate the risk of FMD incursions into the CZs. Under-reporting of FMD remains a major constraint to understanding and quantifying the occurrence of FMD in the region and the predominance of unofficial livestock trade precludes accurate recording of livestock movements in the region.

RISK MANAGEMENT/ MITIGATION MEASURES

Risk mitigation measures should be applied before animals enter the proposed CZs. If uncontrolled movement of livestock occurs into the CZ, these areas could function as amplifiers of virus, due to high livestock density within the CZ and mixing of livestock from multiple sources: The risk assessment conducted in this study indicates that it is highly likely that FMDV infected livestock will enter the CZ if no regulatory measures are applied prior to entry to the zone. This, coupled with the high density of livestock expected in the CZs, could mean that the CZ become foci for disease transmission and thus amplify the level of virus. Therefore, risk mitigation measures should be applied prior to entry to the CZs in order to protect these areas and provide an additional level of protection for China.

The use of Pre-quarantine could significantly reduce the risk of FMD infected livestock entering the CZ. Approving private facilities for pre-quarantine could potentially provide a cost-effective measure for livestock traders: Of the risk mitigation methods modelled in this study, the use of pre-quarantine at source, or in key locations prior to entry to the CZs, appears to be the most effective method for reducing the risk of FMD infected animals entering the zone. By applying strict clinical examination and by managing livestock in consignments (i.e. rejecting a whole consignment based on observation of clinical signs of infection in at least one animal in that consignment) the risk of FMD infected livestock entering the zone significantly reduced (by approximately 99% in cattle, buffalo and pigs and almost 80% in small ruminants), compared to a baseline scenario. The success of pre-quarantine would depend upon preventing infection of livestock during transit from pre-quarantine areas to the CZs (vaccination during pre-quarantine and use of official seals applied to trucks may be used for this purpose).

A number of areas might be considered as locations for pre-quarantine establishments: Central Myanmar (already discussed above); a strategic area in Myanmar into which livestock entering Myanmar from South-Asia might be collected; Farms in Central Thailand (noting that many of these may previously have been approved as private quarantine establishments for export of livestock to Malaysia; farms in Chiang Rai Province; commercial pig farms in Thailand. The feasibility of establishing and approving private or government pre-quarantine establishments in these areas should be examined further. Pre-quarantine should, ideally occur as close to the source of livestock as possible, in order to minimise the risk of FMD transmission through movement of livestock prior to vaccination/ quarantine.

Reducing FMD prevalence at source could be a key, but long-term, approach to reducing the risk of FMD entering the CZs: Reducing FMD prevalence at source remains a key approach to reducing the risk of FMD entering the CZs in LNT and Muse, and would serve to reduce the risk that animals presenting to pre-quarantine stations are infected with FMD. Central Myanmar remains the most important source of livestock entering the CZs. Therefore, expansion of the pilot vaccination campaign, if successful, may significantly reduce the overall risk of FMD incursion into the CZs.

Risk mitigation measures should be designed to minimise the risk of FMD incursions through live animal movement while facilitating official livestock trade: Of major concern to the safety of livestock trade in this region is the extent of unofficial movement of livestock. At present, there are very few official pathways available to traders and it is therefore necessary to open up official routes of movement in order to facilitate trade. Engaging traders in this process and basing measures on a compromise of achieving an acceptable level of protection for the CZ, while encouraging traders to follow official routes will be an important consideration.

The unofficial nature of livestock movement causes increased transit times, greater opportunity for mixing of livestock and therefore is higher risk in terms of FMD transmission between traded livestock and resident livestock during transit: Under the current system, where cross-border movement of livestock largely takes place unofficially, livestock movement pathways are, in the most part: complex; involve numerous stops where there is significant potential for mixing of livestock; and take significantly longer than movement by official routes. Much of the mixing of livestock and use of alternative forms of transport/ small roads, etc. takes place due to the need to evade detection whilst transporting livestock unofficially. The increased transit times and mixing of livestock during transit is likely to increase the risk of transmission of FMD.

Engaging stakeholders and regional cooperation is essential to the success of facilitating safer trade in livestock: The cornerstone of facilitating safer livestock trade in the region, is to engage with stakeholders in the livestock trading industry and to cooperate with other governments within the region, to develop standardized and practical approaches to manage the risk of livestock movement. This may be achieved in such a way that it will benefit not only governments (through reduced costs of disease control and increased revenues from official taxes) but also livestock traders and producers (through price premiums for livestock of higher health status and more efficient/ cheaper transportation of livestock through official routes).

The impact of legalising the trade would need to be considered for stakeholders along the length of the market chain for livestock entering China: Note that further work on the incentives to use official pathways for livestock movement will need to be examined within China given that the costs incurred by the Chinese traders (in moving animals unofficially) impacts on the price they will pay to the traders in South-East Asian countries. Therefore, the costs and benefits to traders all along the market chain will need to be considered when designing new cross-border protocols for livestock movement. To ensure that the official pathways are supported by traders while also minimising the risk of FMD incursions into the CZs.

The length of the quarantine period in the CZ should aim to optimise risk reduction through preventing entry of FMD infected livestock to China while encouraging traders to use official pathways: Quarantine within the CZ needs to be a balance between achieving an acceptable level of protection against FMD incursion for China, while encouraging livestock traders to use official pathways. The use of pre-quarantine, if successful, should significantly reduce the time needed for livestock to be held within the CZ. This would have economic benefits for traders and would reduce the cost of infrastructure in the zones, as shorter quarantine periods would allow for lower holding capacity in the quarantine stations within the CZs. More detailed studies will be needed to determine the optimum pre-quarantine and quarantine times and requirements.

Optimizing the benefits of sourcing livestock from FMD-free countries/ zones: Based on estimates gathered during this study, many cattle and buffalo passing into China (via the CZ and the river route to China) each year originate from Australia. Although these livestock originate from an FMD-free country, due to lack of an official pathway directly into China from Australia, these livestock enter the region via neighbouring countries (most likely Thailand, Malaysia or Vietnam). They are then moved, via the various trade routes described in this study, into China. This process effectively takes livestock from an FMD-free area, mixes them with livestock in countries where FMD is endemic and then imports them to China, thus creating a higher risk source of livestock compared to the originally FMD-free livestock. By establishing a direct and official trade in livestock between FMD free countries and China, a greater proportion of the demand for livestock in China could be met from 'safe' sources, thus reducing the overall risk of FMD incursions.

Exploring the potential to increase the proportion of China's meat demand met by imported product rather than live animals: Despite the risk management measures applied to live animal movement, wherever there is importation of live animals from an area where FMD occurs, there will be a risk for importing FMD (and other diseases). Therefore, importing countries (such as China) should continue to explore options to increase imports of animal products over live animals. While there is likely to still be a demand for live animals, slaughter nearer to source and movement as product, provided the product is adequately processed to minimize the risk of transmitting FMD, would significantly reduce the risk compared to movement of live animals. The benefits of this would also extend to transit areas, through which livestock currently travel and spread FMDV.

Consider inclusion of additional key countries in the safer livestock trade initiative: While the current project on establishing safer trade is underpinned by a tri-partite agreement between China, Lao PDR and Myanmar (due to a proposal to establish CZ in those countries), it is recommended that consideration be given to inclusion of other countries (particularly Thailand) into this agreement, given the central position of Thailand as a transit country for cattle and buffalo moving towards the CZ in LNT and the source country of pigs destined for the CZs in Muse, LNT and China.

Regional recognition of identification systems and certification: Thailand has already implemented an individual identification system for FMD susceptible livestock and invests significant funds in this system. Gaining regional recognition of identification systems, and certification of health measures, such as vaccination, could optimize the benefits gained from these systems. However, this would require mutual confidence in the health measures applied and certified in different countries. Again, by including key countries in the safer trade project could help to align these systems and build agreement of protocols for safer cross-border movement.

SUITABILITY OF THE PROPOSED CONTROL ZONES IN LUANG NAMTHA AND MUSE

While this study does not focus specifically on assessing the suitability of the proposed CZ areas, observations were made during the field mission which could offer insight into selection of suitable areas for establishing the CZs.

- **Availability of feed:** The proposed CZ in Muse appears to be highly productive in terms of crop production (therefore, one would expect ample feed supply for quarantining livestock). Currently, legal goat traders are bringing their own forage from Central Myanmar to Muse, which incurs considerable transport costs. Identifying quarantine areas where feed may be purchased at a reasonable price will be important. Similarly, in Lao PDR, a large quarantine area is already being established near the Boten-Mohan border crossing and this includes an area where improved pasture will be grown solely for use in the quarantine station.
- **Situated within major pathways of livestock movement:** Stakeholders interviewed in both Muse and Nay-Pyi-Taw, in Myanmar, described that Muse would be the most suitable area for establishment of a CZ. However, an alternative area identified was in Namhkan District which has the benefits of large pasture areas which are continuous across the border between Myanmar and China (and thus make movement easier), has good transport links to other areas within China, and has some geographical features which may limit un-regulated movement of livestock into this area (two rivers running along two sides of the area). However, the road to reach this area, within Myanmar, is very poor and journey times would be significantly increased compared to movement directly to Muse, unless significant investment was made in the transport infrastructure in the area.

- **Consideration of the impact of governance issues in certain areas in Myanmar:** The issue of control over livestock movement in some border areas in Myanmar may also require further clarification, given that some areas within (or near) the proposed CZ areas may be outside of Myanmar Central Government's control. It was described by stakeholders that livestock movement might be controlled by other groups in some areas. Whether this would impact on establishing zones in any particular area, and what that impact would be, would need to be determined as traders operating in these areas noted that a large proportion of the cost of moving animals was due to payments made to these groups. It would be useful to know that if legal movement of livestock was established by the central government, whether traders would still need to pay additional 'unofficial fees' to different groups along the movement pathway.
- **Investment in quarantine stations is already underway near the Boten border checkpoint in LNT:** In the proposed CZ in LNT, there is already a large quarantine station being established with Chinese investment, near the Boten border crossing. Given that this is the major area for cattle trade, it is likely that this will be a suitable area for establishment of the CZ. There appears to be potential for growing crops for feed near to the quarantine areas proposed here.
- **Investigating potential of a dedicated CZ for pigs in Panghai:** An additional area which may be considered for establishment of a CZ for pigs, is near the Panghai border crossing in Sing District of LNT. This appears to be the main route through the LNT CZ for pig movement into China (noting that a far higher volume of pigs move up the Mekong River, circumventing the CZ). However, if movement is facilitated through Boten, the pig movement may transfer to this route. Further engagement with pig traders in LNT is needed to understand the factors driving movement through Panghai compared to Boten. Currently, much of the pig trade into China appears to be driven by the recent reduction in domestic pig production in China, together with the ever-growing demand for pig meat. As production in China recovers, as it is expected to do (the pig site, 2016) there may be less demand for pigs/pork from outside of China and this trade might reduce.

- **Exploring the feasibility of establishing pre-quarantine areas or slaughter facilities along the Bangladesh/Myanmar and India/Myanmar border (or in areas under central government control near to these borders):** Investigating the feasibility of establishing holding areas within Myanmar, near to the Myanmar/Bangladesh and Myanmar/Indian borders should be conducted. These establishments may be government owned or privately owned and could be approved for holding livestock which has entered from India or Bangladesh (see above discussion on pre-quarantine). The livestock could be vaccinated, identified (through application of eartags) and fattened during the quarantine period, prior to transit to the CZs. Establishment of slaughterhouses in this border area (approved by the Chinese Government) and movement of these animals as 'product' would further reduce this risk. Again, the feasibility of this option would need to be further investigated. If establishment near the border area is not feasible due to terrain or political constraints in these areas, establishment of a pre-quarantine zone/slaughter facilities may be established elsewhere in Myanmar, but should be selected to minimise opportunity for livestock entering from the Indian Sub-Continent contacting local cattle prior to entering the quarantine area, and preferably in an area with low density of resident FMD susceptible livestock.

RELATED RISKS

Monitoring of drug residues in imported livestock: Pre-quarantine would not only reduce the risk of FMD entering the proposed CZ but may also allow for more controlled use of drugs/vaccines and recording of health status. At present, there is no monitoring of drug residues in meat in Myanmar and, although it was stated that the meat withholding period is printed on any bottle of medication provided to farmers, there is no process to ensure that this is followed or to monitor the level of drug residues in meat. However, it was noted that the proposed quarantine period within the CZ of 21 days would cover the withholding period of many drugs. This would be further extended if pre-quarantine was used, during which drug administration could be strictly recorded and controlled.

Identification of other hazards: This risk assessment focuses only on the risk of FMD entering the CZ through movement of live animals and does not consider other disease risks. Importing countries may need to also consider other hazards which may be relevant to importing high volumes of livestock and whether additional risk assessments may be necessary to cover those hazards identified.

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