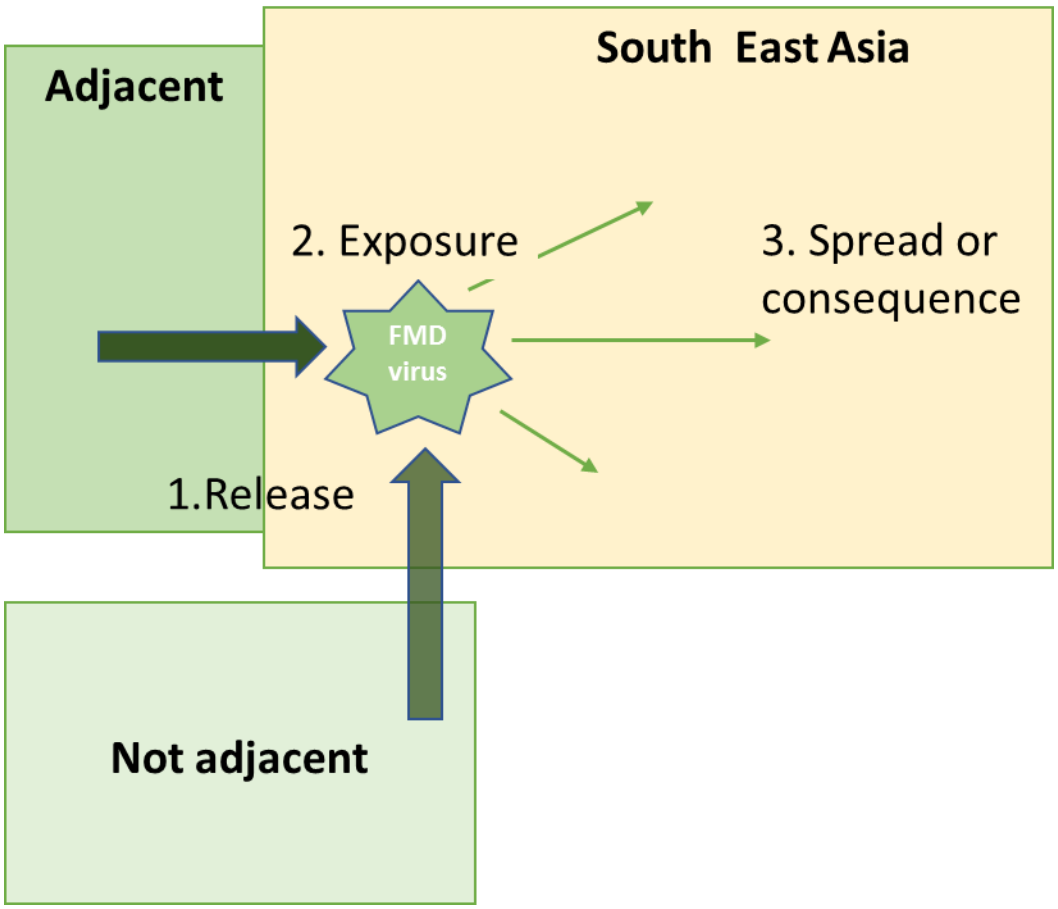
Risk analysis on incursion of exotic FMD viruses into South-East Asia



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Executive summary

At the 19th SEACFMD National Coordination Meeting in 2016, it was recognized that foot and mouth disease viruses (FMDV) of the lineages O/ME-SA/Ind2001 and A/Asia/G-VII present in other FMD-endemic regions of the world potentially pose serious risks to SEACFMD Member Countries, including the Association of South East Asian Nations (ASEAN) member states (AMS).

To help understand and mitigate these risks, a formal Regional Risk Analysis study was recommended. The study conducted for this report took the form of a qualitative risk assessment of the possible incursion of exotic FMD viruses and provides recommendations to mitigate risks of such an incursion.

The likelihood of release of exotic FMDV into SEA and exposure to susceptible domestic livestock were assessed to provide an estimate for the likelihood of occurrence of the undesired event. The assessment of the consequences followed through the exploration of different scenarios. In combining the likelihood of occurrence with consequences, a risk estimate was obtained.

The study relied on data gathered in a short period time (8 March – 28 April 2017) from published studies, grey literature and expert opinion. Although collection of primary data was out of scope, short 'site visits' to Myanmar, Lao PDR, Vietnam, Thailand and Bangladesh were conducted. Following the site visits, a workshop was conducted to validate the findings as well as to make use of the expertise of participants on the relative importance of the risks for release, exposure and consequence.

Results from the study indicate that there is a high likelihood of future incursions of exotic strains of FMD virus into SEA. The most likely risk pathways involve imports of live animals and animal products. Most countries in the region conduct these importations, surprisingly even countries with a FMD-free status. Additionally, several other pathways with a non-negligible likelihood of being the route of incursion were identified, including movements of vehicles, people and wildlife. When developing a strategy to minimize the risk of an incursion, these pathways must also be considered.

The consequences of an incursion of an exotic FMD strain into SEA are likely to be high. The consequences are related to compromised animal health and welfare causing production losses, cost of control and, in some cases, loss of valuable trading markets. For FMD-free countries, the loss of a recognized FMD-free status will negatively impact trade for an extended period of time. For the FMD-endemic countries, an incursion of an exotic FMD virus is likely to result in extensive regional spread as a result of intense intra-regional livestock trade, weak surveillance and response capacities of the national veterinary services and lack of harmonization of well-integrated and risk-based national FMD strategies.

Overall, we conclude that the risk for incursion of an exotic FMD virus is 'high'. Results indicate that the risk of further incursions of exotic FMD viruses is not a matter of 'if' but rather 'when'. The reality of this is underlined by the detection of FMD serotype Asia1 in Myanmar as recently as January 2017.

Available data suggest that South Asia is a particularly risky source area, especially India and Bangladesh. A significant number of large ruminants are informally imported from India and Bangladesh to supply the demand for animal products in markets in countries including China, Thailand, Malaysia and Vietnam. These animals are known to pass through livestock markets in which they are in close contact with

susceptible livestock, allowing them to easily transmit diseases such as FMD. In addition, data show that several SE Asian countries also source animal products from India, legally and, most likely, informally.

Apart from India, animal products are also imported from several other FMD-endemic countries. These include countries in the Middle East and North Africa. This is important because it puts SEA at risk of an incursion from all of the diverse FMD viral strains circulating in these regions, including SAT2, A/Asia/G-VII, A/Africa/G-IV, Asia 1 and O/EA-3.

Since the study was proposed, the O/ME-SA/Ind2001 lineage has spread extensively in the region, and has been detected in Lao PDR, Myanmar, Thailand and Vietnam. Results from viral genotyping sequencing suggest that this was not due to a single incursion, rather there have been several "escapes" from the Indian sub-continent through suggested routes such as the importation of high-risk buffalo products (offal from India) or spread from Bangladesh through cross-border movements of livestock and humans (Qui et al., 2017). Global surveillance reports suggest that there has been further onward spread of this lineage to China, Russia and the Republic of Korea after incursion in SEA (King et al., 2017).

In contrast, lineage A/Asia/G-VII has not yet been detected in SEA. Also, originating in the Indian sub-continent, this lineage is currently known to circulate in Saudi Arabia, Turkey, Iran, Armenia and Israel as recent as May 2017. This lineage has caused alarm at a global level, due not only to the spread to-date but also because of poor *in vitro* matching results with many commercial vaccines (King et al., 2017).

A regional approach is key to reducing the risk of incursion of exotic FMD virus. There is a need for strengthening of countries' surveillance and response capacities, particularly in Myanmar, Malaysia, Lao PDR, Thailand and Vietnam given the high risk of introduction and/or spread in these countries. As all countries in the region, including China, would benefit from mitigating the risk of an incursion of exotic FMD virus, they are recommended to support this capacity building. Regional coordination and support range from relatively simple mechanisms for instant information sharing between countries to developing contingency plans and conducting simulation exercises, to revising current laws and regulations to facilitate the legal and safe import and trading of livestock and animal products. Additionally, the individual countries in the region may further work on a risk-based approach to FMD control. It is noteworthy that many of the changes needed relate not just to FMD but apply to improving disease control in general.

However, FMD is not a disease 'owned' by the veterinary services only. We stress the importance of consulting with and involving key stakeholders from the private and other public sectors. For example, it is recommended to make better use of the 'boots on the ground' such as private-acting veterinarians and community animal health workers in matters regarding surveillance, control of FMD and also in raising awareness on disease prevention and building trust between livestock owners and the veterinary services. It is important to ensure that these activities include women as they are often the most important decision makers in the household (Paris, 2000) and involved in care of livestock. However, it often are men that are generally invited to attend trainings and talk with extension workers (Distefano, F., Colverson, K., & Deka, R. (2013).

Concurrently, it is critical to start discussion with key traders on measures and regulations that will motivate them to comply with these. Roles and responsibilities of the private sector need to be discussed in relation to how best the public veterinary services may support these. For example, the veterinary services has a role in making good quality FMD vaccine more widely available for the private sector, while

the private sector needs to comply with registration in matters such as import documentation and training of their personnel on biosecurity.

Gaps in data and knowledge were encountered throughout the study, as indicated by the high uncertainty associated with most of the pathways (Tables 8 and 10). This supports the need for a continued regional approach to further elucidate gaps in data and knowledge.

As both trade routes and the epidemiology of FMD are highly dynamic, the specific results of this study may only be valid for a limited time (months). However, several of the recommendations will be useful even if the nature of the risks change. Further, the framework presented here should be suitable to review and update the study as needed in the future.

In conclusion, this study found that there is a high risk of further incursions of exotic FMD viruses into SEA. Such incursions may result from a number of risk pathways, all associated with significant consequences in terms of production losses, costs of control and trade implications. Results of this study should guide decision makers and support the implementation of risk mitigation measures.

Reader to this report

This report consists of a main report and a number of annexes. In the main report, the reader can find the scope and limitations of this study under Chapter 1 – Introduction. In Chapter 2 – Materials and methods, the reader will find the risk assessment model used, with 10 risk pathways for release and 6 pathways for exposure. In Chapter 3 - Results, the reader will find an analysis with regard to FMD situation, use of FMD vaccination, and trading relations followed by results of our assessment. For details on the elaborated risk pathways and assessment of consequences, the reader is referred to annexes 2 to 4. Finally, in Chapter 4 – Discussion and Recommendations, our findings are discussed and recommendations are given to mitigate the risk of incursion of exotic FMD virus. We categorized recommendations by regional and national level and by short versus long term application.

Glossary

CAHW	Community Animal Health Worker
DFAT	Australian Government Department of Foreign Affairs and Trade
DLD	Department of Livestock Development (Thailand)
DLD-RRL	Department of Livestock Development Regional Reference Laboratory (for FMD)
EFSA	European Food Safety Authority
FAO stats	Food and Agriculture Organization Statistics
FMD	Foot-and-Mouth Disease
FMDV	Foot-and-Mouth Disease Virus
OIE	World Organisation for Animal Health
OIE SRR-SEA	OIE Sub-regional Representation for South-East Asia
PVS	Performance Veterinary Services
SE	South-East
SEA	South-East Asia
SEACFMD	South-East Asia and China Food-and-Mouth Disease
VS	Veterinary Services

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Contents

Introduction

At the 19th South East Asia and China Foot and Mouth Disease (SEACFMD) National Coordinators Meeting held in Bangkok, Thailand, on 17-19 August 2016, it was recognized that foot and mouth disease viruses (FMDV) of the lineages O/ME-SA/Ind2001 and A/Asia/G-VII potentially pose serious risks to SEACFMD Member Countries, including the Association of South East Asian Nations (ASEAN) member states (AMS). To help understand and mitigate these risks, it was recommended to conduct a formal Regional Risk Analysis study.

At least two distinct incursions of the emerging FMDV sub-lineage O/ME-SA/Ind2001d were detected in 2015 in Lao PDR, Vietnam and Myanmar. This is likely due to changing trade patterns along livestock supply chains from India to SEA, and driven by demand for beef and buffalo meat in China (Smith et al., 2015).

Further, very recently in January 2017, an incursion of FMD Asia1 was detected in cattle in Rakhine state in Myanmar. Preliminary genotyping results from the Regional Reference laboratory in Pak Chong, Thailand indicated that this virus is unrelated to any known FMD Asia1 virus from the last 10 years while analysis by the World Reference Laboratory in Pirbright, England analysis showed this Asia 1 isolate is most similar to viruses circulating in Bangladesh in 2012 and in India in 2013. As further investigations are under way, this appears to be another example of incursion of exotic FMD into SEA.

There is concern about another South Asian lineage of the FMDV spread to Turkey and Saudi Arabia in 2015 (A/Asia/G-VII). Although this virus lineage is not yet believed to be present in South-East Asia (SEA), its detection could have significant impact, given present vaccines are unlikely to protect animals and the virus has potential to lead to widespread outbreaks (King et al., 2017).

Scope

The aim of the study was to conduct a qualitative risk assessment of the possible incursion of exotic FMDV member countries of the SEACFMD Campaign and provide recommendations to mitigate risks.

The regional FMD risk analysis has been implemented by OIE, including the OIE Sub-Regional Representation for South East Asia (SRR-SEA), utilizing SRR-SEA technical expertise, regional knowledge and consultants to undertake a desk review of data and research, engage with country officials and experts, to collect and analyze information on the trade in livestock, livestock products and other risk materials from South Asia. This study builds on the Australian Department of Foreign Affairs and Trade (DFAT) funded analysis of safe animal movement in the region.

In consultation with the OIE-SRR-SEA, it was decided to limit the risk assessment to the countries of Myanmar, Laos, Thailand, Malaysia, Singapore, Cambodia, Vietnam, Philippines, Brunei Darussalam and Indonesia. Thus, this study excludes China, primarily as the time provided for this study was short however is was considered as a potential source of introduction to the other countries.

Challenges of this assessment study

This assessment study had a well-defined objective and time frame. The study was conducted in less than two months, including country visits, a workshop with stakeholders in Bangkok and delivery of the final report. Under these time constraints, in-depth data collection and thus analysis was hampered. Five countries were visited to conduct interviews with representatives of the Veterinary Services and key actors on the production and trade of livestock and animal products and to collect additional data needed for the assessment. However, there was little time for preparation on the side of the countries visited. As a result, it was not possible to interview a large variety of stakeholders. Further, the time for follow-up after the missions was very limited; on several occasions, we were promised that further data would be forwarded as soon as possible, however, often these did not materialize.

The findings and recommendations of this study are possibly best seen as a broad framework to monitor and mitigate the risk of incursion of exotic FMD virus strains over time. Nonetheless, we believe that the results will facilitate decision making about measures to mitigate the risk of introduction of exotic FMD viruses.

Follow-up

Findings and recommendations will be disseminated and reviewed by SEACFMD Campaign partners including AMS, for incorporation in national FMD plans.

Materials and methodology

Data sources

This study relied on data gathered from published studies, data bases (FMD notifications shared by OIE SRR-SEA, import and export databases provided by veterinary services of some countries), grey literature (reports on animal trade, value-chain analyses and newspaper articles) and expert opinion through in-country visits. These 'site visits' were conducted in Bangladesh, Lao PDR, Myanmar, Thailand and Vietnam and consisted of interviews and discussions with representatives and technical staff (laboratory, quarantine, field veterinarians, disease control, contingency planning) of the veterinary services, and with representatives of private sectors ranging from farmers, traders to livestock company directors. Expert opinion was assessed through a consultative workshop on 5 April 2017 with representatives of Cambodia, China, Laos, Thailand and Vietnam, and staff of OIE SRR-OIE.

Study components

Under the agreement of this study, the following study components were defined (see also Annex 1 – Terms of References):

1. Study design, under the guidance of the OIE SRR-SEA;
2. Desktop review including collection and analysis of information on the trade in livestock, livestock products and other risk materials from South Asia into SEA;
3. Workshop with representatives from Cambodia, China, Lao PDR, Thailand, and Vietnam to verify the desktop review findings and identify and analyse any additional risks.
4. Site visits for data collection through semi-structured interviews with stakeholders from both public and private sector in Bangladesh, Lao PDR, Myanmar, Thailand and Vietnam (agreed after consultation with OIE) to verify the desktop review and workshop findings and identify and analyse any additional risks;
5. Analysis of the collected and compiled data; and production of the final report.

In discussion with OIE SRR-SEA, the workshop mentioned under point 3 was conducted after site or in-country visits (point 4) as a means to validate the findings of desktop and in-country visits.

Risk assessment

We developed a risk-assessment model to estimate the risk of incursion for new FMDV strains based on a release assessment, an exposure assessment and a consequence assessment, according to established methods (Dufour et al., 2011, Figure 1; Moutou, Dufour, & Ivanov, 2001; Murray, 2004).

For the risk assessment evaluation, a qualitative terminology describing likelihood was adopted as shown on Table 1.

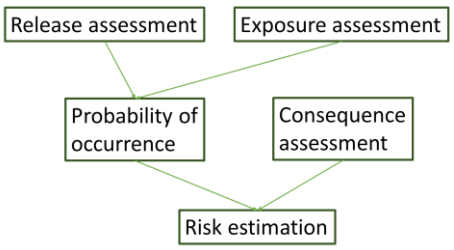


Figure 1. The risk assessment model (Dufour et al, 2001)

Table 1. Different levels of likelihood and corresponding interpretation (adapted from Moutou et al. 2001).

Risk level	Descriptive meaning
N = Negligible	Likelihood of event is sufficiently low to be ignored, or if the event is possible only in exceptional circumstances
L = Low	Event is a possibility in some cases
M = Moderate	Occurrence of the event is a possibility
H = High	Occurrence of the event is clearly a possibility.

For the release and exposure assessments, risk pathways were identified based on the literature relating to incursions of foot and mouth disease virus to non-endemic countries globally (Wooldridge, Hartnett, Cox & Seaman 2006; McLaws & Ribble, 2007; Collineau, McLaws, Dubé, Stärk & Sumption, 2015). Scenario trees were developed for each risk pathway. The qualitative likelihood of each step of the scenario tree was then estimated using information collected from the desktop review, country visits and workshop. The overall likelihood estimate for each pathway was based on the step with the lowest likelihood, because each step is dependent on the outcome of the preceding steps.

The likelihood estimates were based on the analysis of available data. When the level of completion and/or accuracy of the data was low, there was a resulting uncertainty around the outcomes. Understanding the level of uncertainty allowed for a correct and well-informed reading of the results provided by this assessment. The reported levels of uncertainty also highlight knowledge gaps that hampered a more detailed and precise analysis, and hopefully will motivate investigations to fill in the missing information.

Table 2 provides a summary of the different levels of uncertainty considered for this assessment as well the corresponding interpretation.

Table 2. Uncertainty levels and corresponding interpretation (Fournié et al., 2014).

Uncertainty level	Interpretation
Low	There are solid and complete data available; strong evidence is provided in multiple references; authors report similar conclusions. Several experts have multiple experiences of the event, and there is a high level of agreement between experts.
Moderate	There are some but not complete data available; evidence is provided in a small number of references; authors report conclusions that vary from one another. Experts have limited experience of the event and/or there is a moderate level of agreement between experts.
High	There are scarce or no data available; evidence is not provided in references but rather in unpublished reports or based on observations, or personal communication; authors report conclusions that vary considerably between them. Very few experts have experience of the event and/or there is a very low level of agreement between experts.

The likelihood of occurrence for each pathway was assessed by combining the results of the release and exposure pathways using an approach adapted from Moutou et al, 2001 (Table 3). It is important to note that the combination of the release and exposure pathways followed a different approach to the likelihood assessment of a single pathway, as the latter reflects a sequence of events, versus a merging of risk parameters.

Table 3. Results table for combination of risk parameters Release and Exposure into the likelihood of occurrence (adapted from (Moutou et al., 2001)).

		Parameter 1: Release			
	Level	Negligible (N)	Low (L)	Moderate (M)	High (H)
Parameter 2: exposure	Negligible (N)	N	L	L	M
	Low (L)	N	L	M	M
	Moderate (M)	N	M	M	H
	High (H)	N	M	H	H

For the consequence assessment, the consequences of an FMD incursion were considered at household/farm, national and regional level. Factors influencing the extent of spread were identified and evaluated.

A risk estimation for each pathway was determined by combining the likelihood of occurrence with the consequences, using the matrix presented in Table 3. Finally, the overall risk estimation for the incursion of exotic FMD virus strains was summarized into one estimate, reflecting the highest level of risk assessed based on one or more risk pathways.

Results

Situation analysis

FMD situation in South-East Asia

The region has both FMD-endemic (Cambodia, China, Lao PDR, peninsular Malaysia, Mongolia, Myanmar, Thailand, and Vietnam) and free areas (East Malaysia (Sarawak and Sabah), Brunei Darussalam, Indonesia, Philippines and Singapore). Of the outbreaks reported in 2016, 34% were due to serotype O and 5% were due to serotype A. The rest (61% of all outbreaks) are reported as untyped or with results pending (Table 4).

Table 4. FMDV strains detected in SEACFMD Member Countries in 2015-2016, as characterized by World and/or Regional Laboratory for FMD (from presentation by Yu Qiu, 23rd SEACFMD Sub-Commission Meeting, 9-10 March 2017, Siem Reap, Cambodia).

Country	No. outbreaks reported in 2016	Serotype O Topotype				Serotype A Topotype Asia/Sea-97
		SEA/ Mya-98	ME-SA/ PanAsia	ME-SA/ Ind-2001d	Cathay	
Cambodia	71	+	+			+
China	4	+		+	+	+
Lao PDR	36	+		+		+
Myanmar	21	+		+		+
Malaysia	71	+				+
Mongolia	1	+	+			+
Thailand	262	+	+	+		+
Vietnam	54	+	+	+	+	+

+: the FMDV lineage present in the country.

The use of vaccination to control FMD in South-East Asia

During the 23rd SEACFMD Sub-Commission Meeting in Siem Reap, Cambodia 2017, country representatives presented their current FMD control activities, including the application of FMD vaccines (Table 5). For Cambodia, Lao PDR, Myanmar, the number of FMD vaccine doses reportedly applied represent a low coverage of the total FMD-susceptible population and were related to short-term donor-funded projects. From these numbers, it can be assumed that the objective of vaccination is not intended to prevent the risk of FMD at a national scale. It may have been applied for emergency purposes in order to contain a local FMD outbreak or target specific geographic areas or productions systems.

For Thailand and Viet Nam, there are national strategies. In Thailand, vaccines are produced in-country by the DLD RRL. National strategies do require large quantities of FMD vaccines as well as the infrastructure of keeping the vaccines under cold conditions and the manpower to apply vaccination appropriately in the intended livestock populations. Post vaccination monitoring and vaccination coverage results are needed to provide accurate measures of vaccine-induced immunity in the target populations. However, for most countries investigated no information was available about the extent to which vaccination levels

were in accordance with target levels or on post-vaccination monitoring to assess the level of vaccine-induced immunity in risk populations. The post-vaccination monitoring studies conducted in Thailand demonstrated that the vaccine induced titers are short-lived and potentially protect only for a limited period of time.

Table 5. Compilation of FMD vaccination strategy in 2016 (and 2017 if provided) presented by national representatives at the 23rd SEACFMD Sub-Commission Meeting, 9-10 March 2017, Siem Reap, Cambodia).

Country	Vaccine doses	Serotype	Coverage	Notes
Cambodia	164,000			
Lao PDR	190,000			
Myanmar	2016: 300,000 2017: 600,000	2016: O 2017: O and A		STANDZ Australian support, in hotspots and high risk areas in central Myanmar
Malaysia	300,000		65% in hotspots	
Thailand	?		90%	2x/year in beef, 3x in dairy cattle
Vietnam	1.5 million doses 1.9 million	O O and A		In control zones along border with Cambodia and Lao PDR

Trading relations between South-East Asia and other FMD-endemic regions

We have made use of FAO-STATS and the in-country visits to collect information about the importation of livestock, animal products and byproducts, volumes and route of import (legal versus informal) (Table 6).

Trading relations within South-East Asia

Based on FAO stats data bases (FAO, 2013), reports and in-country visits, a matrix of inter-regional trade in livestock and animal (by-) products was developed, see Table 7.

It was used to categorize countries with respect to the extent of their trading relations. It shows that Cambodia, Lao PDR, Malaysia, Myanmar, Thailand and Vietnam have extensive trading relations with countries in the region, based on livestock and/or animal (by-)products.

It should be noted that the data retrieved from Stats was through the detailed trade matrix. For this sort of data Lao PDR, East-Timor, Myanmar and Vietnam were not available as reporting countries.

During the workshop conducted 5 April, participants were asked to map trading routes of livestock. Although the time to assess the trading routes was limited and the participants may not have been the persons most appropriate to elicit this information, the outcome of that exercise supported the report written by Smith et al. (2015). The livestock pathways identified appeared to be largely shaped by the high demand for beef in China. That demand seems to continue to grow as the supply in China cannot keep up with the increasing demand.

Table 6. Trading relations of SE Asian countries with other FMD-endemic regions of the world.

From	To	Brunei	Cambodia	East Timor	Indonesia	Lao PDR	Malaysia	Myanmar	Philippines	Singapore	Thailand	Viet Nam	Source of information
Bahrain									P				FAO Stats
Bangladesh								A			P		FAO Stats, Reports and Field data
China, mainland		P	P		A P		A P			A P	P	A	FAO Stats, Reports and Field data
Egypt							P						FAO Stats
India		P	P		P		A P P	A	P	P	P		FAO Stats, Reports and Field data
Israel										P			FAO Stats
Pakistan							A P			P	P		FAO Stats
Republic of Korea			A P				P			P	P		FAO Stats
Saudi Arabia							P				A		FAO Stats
Sri Lanka											P		FAO Stats
Tunisia											P		FAO Stats
United Arab Emirates										P			FAO Stats

A	Live animals
P	Animal products and/or by-products
Text in Red	Informal Trade
Text in Black	Legal trade
Text in Bold, underlined	Extensive trade

Table 7. Trading relations between SE Asian countries by categories.

From	To	Brunei	Cambodia	East Timor	Indonesia	Lao PDR	Malaysia	Myanmar	Philippines	Singapore	Thailand	Viet Nam	Source of information
Brunei							P						FAO Stats
Cambodia						A					**A P**	A	FAO Stats, Reports and Field data
East Timor					A								FAO Stats
Indonesia		P					A P		P	**A** P	P		FAO Stats
Lao PDR			A								A	A	FAO Stats, Reports and Field data
Malaysia		A P				A			A P	P	A		FAO Stats, Reports and Field data
Myanmar						A	A				**A A**		FAO Stats, Reports and Field data
Philippines		P					P			P	A		FAO Stats
Singapore		P	P		P		P		P		P		FAO Stats
Thailand			**A P**			A	**A** P		P	**P**			FAO Stats, Reports and Field data
Viet Nam			**P A**			A	A P			P	P		FAO Stats, Reports and Field data

A	Live animals
P	Animal products and/or by-products
Text in Red	Informal trade
Text in Black	Legal trade
Text in Bold, underlined	Extensive trade

As a result, some countries outside the SE Asian region have emerged as new sources of large ruminants, in particular India and Bangladesh, adjacent to Myanmar and with importation of cattle and buffalo by boat to Mawlamyine (Myanmar) and then by road into Thailand. Additionally, increasing numbers of cattle are imported from Australia, particularly into Vietnam and Malaysia. The purpose of these imports may be primarily for consumption in these countries, however highly Australian may well be livestock prior to being slaughtered. If that occurs, clinical FMD may potentially have a greater impact due to higher morbidity mortality. It is estimated that between 13,000-50,000 heads of cattle travel through Vietnam to China each year (Qui et al., 2017).

Release assessment

The release component of the risk assessment refers to the introduction of an exotic strain of FMDV into SEA. Ten pathways were considered for this stage (Table 8 and Annex 2).

Eight of the ten pathways considered were assessed to have a non-negligible risk as the route of incursion for an exotic strain of FMDV into SEA. The highest risk pathways were found to be the informal importation of live animals and the import of animal products (legal and informal). There was a moderate-to-high level of uncertainty associated with many of the assessments due to lack of data. A full description of each pathway is included in Annex 2.

It is important to understand which countries would be the most likely origin of an incursion of an exotic strain of FMD, in order to monitor the FMD situation there and assess the protection that available vaccines would provide. In this analysis, India and Bangladesh were most frequently implicated as potential source areas for an incursion into SEA. This is not surprising due to their proximity to the region. However, it is important to highlight that, for informal trade of animals and animal products as well as human movements, the origin of the animals/people entering SEA was unknown and may well arise from more distant countries. Indeed, it was interesting to discover the extent of countries from which animal products are imported to SEA – which include countries in the Middle East and North Africa.

As the primary direction of trade is into China to supply the growing demand for meat, it is at risk for incursions of exotic FMD virus as well. However, China should also be considered a potential source of exotic FMD virus incursion into SEA. Extensive trade of China with SEA as well as with countries to the North, West and East (Russia, Kazakhstan, Mongolia, South Korea) can act as a bridge of FMD virus transmission from these regions into SEA. With the currently available information on FMD occurrence and genotyping in these countries, there is no obvious risk. However, it seems appropriate to closely follow the FMD situation in China.

The introduction of exotic FMD virus through biologicals (eg. vaccines) was not considered in this study. The reason for this was that FMD vaccines make use of killed FMD virus and imported vaccines are from renowned vaccine-producing companies applying strict vaccine manufacturing procedures.

The virus strains known to be circulating in countries associated with the risk pathways are listed in Table 8 and based on the EuFMD Global Monthly Report, February 2017 (EuFMD, 2017). Several viral strains are circulating in these countries that are believed to be absent from SEA. Of these A/Asia/G-VII and Asia1 are perhaps the most concerning, as they are circulating in neighbouring India and (probably) Bangladesh, and the vaccines currently used in SEA will not provide protection against these strains. However, the other strains identified in this analysis (namely A/Asia/Iran-05, O/EA-3, O/ME-SA/Sharqia-72, and SAT2) could also pose a threat and should not be ignored.

Table 8. Overview of likelihood of release for each of ten risk pathways, assessment of level of uncertainty and additional notes.

	Pathway	Likelihood	Uncertainty	Notes
R1	Legal import live animals	Moderate	Moderate	Small number of live animals are imported from FMD endemic countries including: - China (Malaysia, Singapore, Indonesia) - Saudi Arabia (Thailand) - Pakistan (Malaysia) - Republic of Korea (Cambodia) - India (Malaysia)
R2	Informal import of live animals	High	High	Main route believed to be animals smuggled from India and Bangladesh to Myanmar, then onto consumers in China and Thailand. Goats and pigs are being informally exported from China to Vietnam.
R3	Legal import of animal products and/or by-products	Moderate	Moderate	Animal product are imported from several FMD-endemic countries including: Bahrain, China, Egypt, India, Iran, Israel, Pakistan, Republic of Korea, Saudi Arabia, Sri Lanka, Tunisia and the United Arab Emirates. Largest importers are Malaysia, Philippines and Thailand
R4	Informal import of animal products and/or by-products	High	High	Evidence from the field visits supported that there are informal imports of animal products into SEA, however the origin of these imports was largely unknown. An exception was anecdotal evidence of informal imports from India to Malaysia
R5	Wildlife	Low	High	This pathway is plausible for release of FMDV from countries that share a land border with SEA (China, India, Bangladesh)
R6	Communal grazing	Negligible	High	Information from field visits indicated that communal grazing with foreign livestock on pastures that bridge national borders does not occur although there were noted contradictions between interviews and evidence that co-grazing and cross-border movement is extensively practiced under other circumstances
R7	Human movements	Moderate	High	Pathway considered Moderate risk because of limited viability of virus on humans. The most common origin of people traveling to SEA is likely from neighbouring countries (China, India, Bangladesh)
R8	Feed/fodder	Low	High	According to available information, fodder is imported from China to Malaysia
R9	Vehicle	Moderate	High	This pathway is a plausible for release of FMDV from countries that share a land border with SEA (China, India, Bangladesh)
R10	Genetic Material	Negligible	Low	Genetic material is only imported from FMD-free countries

Table 9. Compilation of circulating FMDV in countries that have a trading relation with SEA.

Country	Release risk pathway(s)	Viruses circulating			
		Serotype O	Serotype A	Serotype Asia 1	Serotype SAT2
India	1 2 3 4 5 7 8 9	ME-SA/Ind-2001d	**ASIA/G-VII***	**Asia1**	
Bangladesh	2 3 4 5 7 8 9	ME-SA/Ind-2001d	**ASIA/G-VII**	**Asia1**	
China	1 2 3 5 7 8 9	SEA/Mya-98 CATHAY	ASIA/SEA-97		
Bahrain	3	ME-SA/PanAsia-2 (2014) ME-SA/Ind2001d (2015)			
Egypt	3	**EA-3** **ME-SA/Sharqia-72** ME-SA/PanAsia-2	**ASIA/Iran-05** **AFRICA/G-IV**		**SAT2**
Iran	3	ME-SA/PanAsia-2	**ASIA/Iran-05** **ASIA/G-VII**	**Asia1**	
Israel	3	**EA-3**			
Pakistan	1 3	ME-SA/PanAsia-2	**ASIA/Iran-05** **ASIA/G-VII (?)**	**Asia1**	
Republic of Korea	1 3	ME-SA/Ind2001d	ASIA/SEA-97		
Saudi Arabia	1	ME-SA/PanAsia-2 ME-SA/Ind2001d	**ASIA/G-VII**		
Sri Lanka	3	ME-SA/Ind-2001d ME-SA/PanAsia-2 (2014)			
Tunisia	3	ME-SA/Ind-2001d (2014)	**AFRICA/G-IV** (2017)		
United Arab Emirates	3	ME-SA/Ind-2001d			

*Bold indicates FMD serotypes and strain exotic to SEA

Exposure assessment

The exposure assessment identified the pathways by which livestock in SEA could be exposed to an exotic FMDV, following its release. Six exposure pathways were assessed (Table 10 and Annex 3). Of these, the most likely were found to be direct animal contact between imported livestock and susceptible SE Asian livestock, as well as exposure of SE Asian livestock to contaminated animal products.

For the direct animal contact, information from the desktop review (Smith et al., 2015) and field investigations indicated that there is extensive mixing of animals at livestock markets in Myanmar, Thailand and Vietnam, particularly of animals destined for China. In most situations, these animal markets deal with either large ruminants, small ruminants or pigs. However, it is possible that different species are mixed. As a result, markets represent an ideal opportunity for disease transmission through direct animal and inter-species contact.

Ingestion of contaminated animal products also was found to represent a high-risk pathway by which SE Asian livestock could become infected with an exotic strain of FMDV. This ingestion is most likely, though not only, to occur through swill feeding. Given that the majority of animal production in SEA is based upon small-holdings, there is evidently close contact between pigs and ruminants. Small holders often have various FMD-susceptible species on their premises, or these will be present in the village. Once virus is in swill-fed pigs, it is likely to spread widely from there, as pigs are known to act as virus amplifiers. Notably, swill feeding will be uncommon in countries with few pigs, such as Malaysia.

Additionally, susceptible livestock may also be exposed to contaminated animal products by other routes such as scavenging at landfills, inappropriate disposal (i.e. litter) and environmental contamination (Woolridge et al, 2006). Although these are indirect routes of transmission, the likelihood of susceptible livestock becoming infected should be considered.

It is important to note that there is a high level of uncertainty in many of these assessments. This uncertainty related to the specific route followed by imported animals, the use of imported animal products, the extent to which people contaminated with exotic viruses contact livestock in SEA and details of vehicle use for livestock trade.

Table 10. Overview of likelihood of exposure for each of six risk pathways, assessment of level of uncertainty and additional notes

	Pathway	Likelihood	Uncertainty	Notes
E1	Direct animal contact	High	High	Associated with pathways R1 and R2 Known to be most effective mode of FMD transmission At least some animals imported to SEA are known to enter live animal markets (e.g. en route from India to more lucrative markets in China, Thailand), where there would be ample opportunity for contact with naïve animals
E2	Exposure to animal products	High	High	Associated with pathways R3 and R4 Exposure may occur through swill feeding (most effective), scavengers at landfills, inappropriate disposal (i.e. litter) and environmental contamination
E3	Exposure to Wildlife	Low	High	Associated with pathway R5 Little information is available regarding the FMD status of wildlife along the border regions, nor about the movement patterns of susceptible wildlife species. However, encounters between wild boar and livestock were reported during the field investigations.
E4	Human movements	Moderate	High	Associated with pathway R7 Moderate likelihood due to some risk groups such as trader having frequent contact with livestock but taking into account the limited viability of virus over time
E5	Feed/fodder	Moderate	High	Associated with pathway R8 Virus can survive up to 15 weeks in this product Contaminated straw has been implicated in other FMD incursions (outbreak in Japan in 2000; (McLaws & Ribble, 2007))
E6	Vehicle movements	Moderate	High	Associated with pathway R9 Exposure may be associated with environmental contamination (relatively inefficient transmission) or direct

	contact with animals (eg during transport), which would result in more effective transmission

Likelihood of occurrence

To assess the overall likelihood that exotic strains of FMDV will be imported to SEA, the release and exposure pathways were combined as per Figure 2, with the resulting likelihood of occurrence summarized in Table 11. It is apparent that informal imports of live animals and animal products are associated with a high likelihood of incursion. However, it cannot be ignored that 6 further pathways represent a non-negligible likelihood of causing an incursion of exotic FMDV into SEA. Taken overall, there is a high likelihood of further incursions of exotic strains of FMDV into SEA.

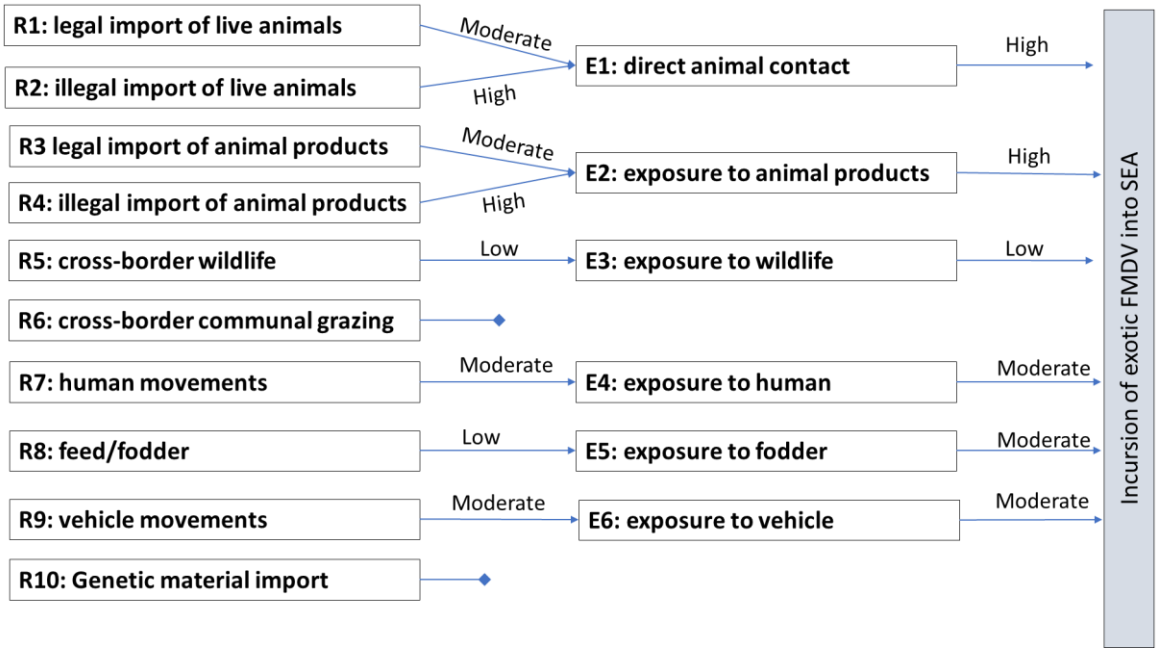


Figure 2. Combining Release and Exposure pathways.

Table 11. Compilation of likelihood of Release and Exposure into likelihood of Occurrence and level of uncertainty.

Risk pathway		Likelihood			Uncertainty
		Release	*Exposure*	*Occurrence*	
Import of live animals	Legal	Moderate	High	High	High
	Informal	High	High	High	High
Import of animal products	Legal	Moderate	High	High	High
	Informal	High	High	High	High
Wildlife		Low	Low	Low	High
Human movements		Moderate	Moderate	Moderate	High
Feed/fodder		Low	Moderate	Moderate	High
Vehicle movements		Moderate	Moderate	Moderate	High

Consequence assessment

An incursion of an exotic strain of FMD into SEA has consequences at several levels: animal, farm/household, national and regional. The consequences that arise may be categorized as relating to i) animal health and welfare, and production losses; ii) cost of control; and iii) trade losses. These are well described elsewhere (Knight-Jones & Rushton, 2013), and so are only briefly summarized below.

Animal health and welfare, and production losses: Infection with FMDV typically results in decreased milk production, anorexia leading to decreased weight gain, lameness leading to loss of draught power, mortality (particularly in young animals) and decreased fertility.

Cost of Control: Control of an incursion of FMD typically involves vaccination (purchase of vaccines and delivery costs), movement controls, diagnostic tests and possibly costs related to treatment and care (Nampanya et al., 2015), culling and compensation.

Trade losses: Infection with FMD can result in denied access to local, national and regional markets. Currently, 3 SE Asian countries (Indonesia, Brunei Darussalam and Philippines) have obtained official recognition of FMD-free status without vaccination, and Malaysia has a recognized FMD-free zone. An incursion of FMD into any of these countries or zones would be particularly devastating.

In the case of an incursion of an exotic strain of FMD into SEA, the extent of the consequences will be determined by several key factors:

1. *Time to detection:* The time to detection of a new strain is critical, as no targeted response will be mounted until it is detected. The capacity of the surveillance system in each country to detect an incursion of a new FMDV strain was assessed (see Annex 4), and generally found to be very low to moderate. Therefore, there is a moderate to high likelihood that detection of a new strain would be delayed. This finding is supported by the events surrounding the detection of viral genotype O/ME-SA/Ind-2001d, in which the virus characterization results were not available for 6-10 months following the sample collection (Qui et al., 2017).

2. *Effectiveness of response:* Once an incursion has been detected, the quality of the response will determine its effectiveness to limit further spread. Examining the results of the OIE Performance of the Veterinary Services (PVS) Assessment provides one measurement of the capacity of the veterinary services to mount an effective response. A selection of PVS critical competencies deemed relevant to assess the capacity of the Veterinary Services for early detection and rapid response was used to categorize countries according to the strength of their veterinary services (Annex 4). As no PVS evaluation was available for Brunei Darussalam, Malaysia and Singapore we assessed the quality of the VS in Malaysia and Singapore as 'Moderate' and 'Good' respectively, based on the level of economic development of each country. The results of this analysis are summarized in Table 13, and it can be seen that several countries likely have limited capacity to implement an effective response to an incursion of FMD. It is additionally concerning that several of the countries with weak VS are at a high risk of an incursion due to the patterns of legal and informal trade in animals and animal products (e.g Myanmar and Vietnam - see release assessment).
   An additional consideration in the effectiveness of the response is the availability of vaccine that provides adequate protection against the strain causing the incursion. Vaccine may be available

through existing national stocks, through a regional vaccine bank or an emergency procurement. The level of protection provided will depend on the potency of the vaccine and the antigenic characteristics of the viral strain. Based on studies by WRL Pirbright, commonly used vaccine strains such as O1/Manisa and O/3939 seem to provide sufficient protection against the O/ME-SA/Ind2001d field virus however for O1/Manisa, it is recommended to use a potency of 6PD50 or above. However, at present, most commercially available vaccines do not provide adequate protection against the emerging virus A/Asia/G-VII. Therefore, if this strain was to enter SEA it is likely that it would spread rapidly without a vaccine available to provide protection.

3. *Susceptibility of livestock population to the virus causing the incursion*: The susceptibility of the livestock population to a new viral strain will depend on i) the immunity of the animals, due to prior infection or vaccination and ii) the characteristics of the virus strain and extent of any cross-protection. Animals in FMD-free countries or zones will be completely naïve and the strain will spread rapidly before control is imposed, particularly in areas of high density or with a lot of animal movements. On the other hand, animals in FMD-endemic countries may be fully or partially protected against an incursion due to immunity.

4. *Contact structure of animals and farms:* FMDV is most effectively spread through animal movements, and the virus can therefore spread quickly through the trading network and in areas with high animal density. At the regional level, it is useful to consider the trading relationships within SEA to consider how the virus could spread if it entered different countries. In the situation that a country has very limited trading relations with other SE Asian countries, there is a higher likelihood that an incursion of exotic FMDV would be limited to local/national livestock production. However, if the incursion occured in a country with an extensive SE Asian trading network there is a greater likelihood that the whole region would become rapidly infected.

Three scenarios were identified to further explore the consequences of an FMDV incursion: i) only 1 farm/village infected; ii) spread within the country and iii) spread within the region (Table 12).

In the event that the incursion is contained to one farm, the consequences will be limited to farm-level animal health, welfare and production losses. Given the highly infectious nature of FMDV, this scenario is considered very unlikely, and would only occur if the virus was to enter a very isolated population or one with pre-existing immunity (due to vaccination or previous infection).

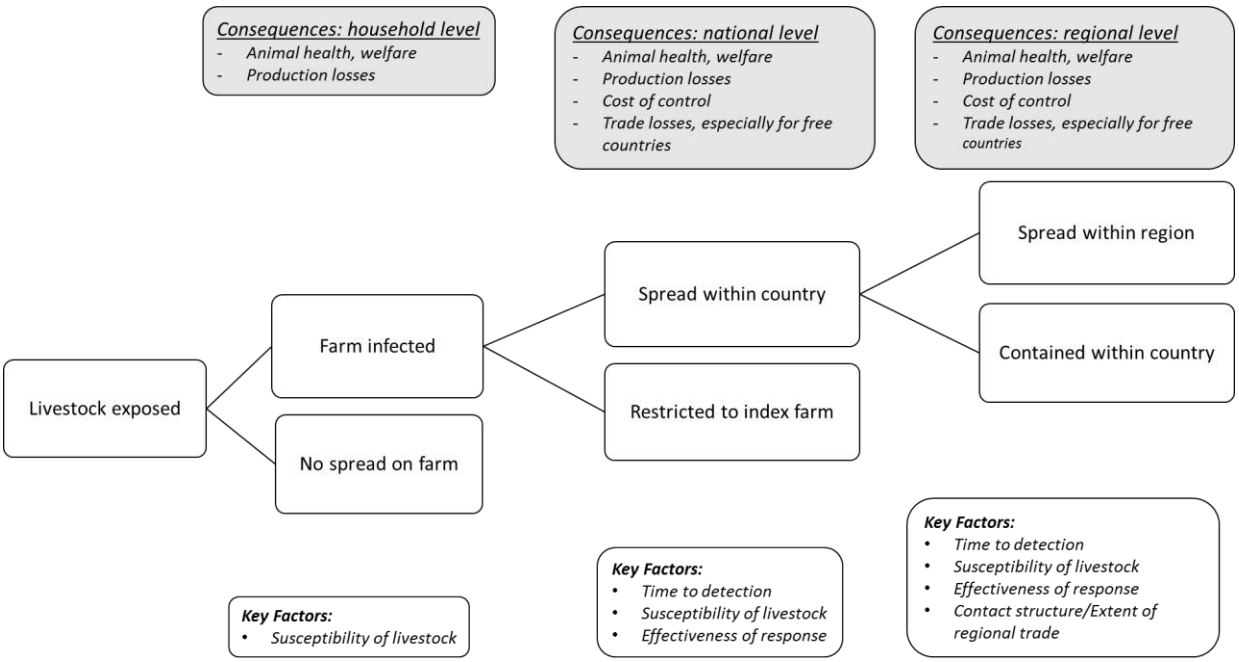


Figure 3. Scenarios for Consequence at household, national and regional level with key factors

If an exotic virus strain spreads within the affected country there may be additional consequences associated with cost of control (if the country engages in control) and trade losses. Trade losses would be especially important if the incursion occurred in a free country or zone (Figure 3). Given that vaccination coverage is low in most SE Asian countries plus the domestic animal movements are usually not regulated, it is considered highly likely that an exotic virus strain incursion would spread within the affected country.

Table 12. Overview of the likelihood of scenario, the type, likelihood and magnitude of the consequence for three scenarios

Scenario	Likelihood of scenario	Type of consequence	Likelihood of consequence	Magnitude of consequence at national and regional level:
Only farm infected	Very low	- Animal health, welfare - Production losses	Very high	-*EC*:* negligible -*FA:* very high if detected
Spread within country	High	- Animal health, welfare - Production losses - Cost of control - Trade losses, especially for free countries	Very high	-EC: depends on extent of production losses and control effort -FA: very high
Spread beyond index country to wider region	Low to high	- Animal health, welfare - Production losses - Cost of control - Trade losses, especially for free countries	Very high	-EC: depends on extent of production losses and control effort -FA: very high

**according to if incursion is in endemic country (EC) or officially free area (FA)*

The final scenario considered spread beyond the index country to the wider region. The likelihood of this scenario will vary with the quality of the veterinary services (influencing early detection and effective response) and the extent of legal and informal trade with other countries in the region (see Annex 4 and Table 13). The characteristics of the viral strain will also influence the likelihood of this scenario, in terms of its propensity for spread and the protection provided by available and used vaccines.

With respect to the likelihood of consequences, spread of an exotic strain of FMDV within a country and/or a region is almost certain to cause production losses as well as result in significant costs associated with control efforts. Should FMD-free areas be affected, then significant trade losses will certainly result.

Table 13. Assessed quality of the Veterinary Services, FMD situation, level of trade within the region and the risk of FMD spread within the region, by country.

	Quality VS	FMD Situation	Level of trade with countries in region	Risk of FMD spread into region
Brunei Darussalam	unknown	free	limited	.
Cambodia	poor	endemic	extensive	High
East Timor	moderate	unknown	no information	.
Indonesia	poor	free	limited	Moderate
Lao PDR	poor	endemic	extensive	High
Malaysia	moderate	endemic	extensive	Moderate
Myanmar	poor	endemic	extensive	High
Philippines	good	free	limited (low volumes)	Negligible
Singapore	good	free	extensive (animal products)	Negligible
Thailand	good	endemic	extensive	Moderate
Vietnam	poor	endemic	extensive	High

Consequences associated with specific risk pathways are explored in Table 14. Depending on the risk pathway, some countries may be at higher risk than others and this will influence the consequences. It is notable that FMD-free areas import animals and/or animal products from FMD endemic countries. This trade puts them at high risk for an incursion of FMD and loss of their free status. The risk of deboned beef from India, imported by Brunei Darussalam, Indonesia, Malaysia and Philippines, has recently been underlined with the FMD outbreak in Mauritius.

This table also highlights that Myanmar is particularly vulnerable to an incursion from South Asia due to its proximity to Bangladesh and India, which has resulted in it being the point-of-landing for animals en route to satisfy the demand of markets in China and other SE Asian countries. Vaccination coverage in Myanmar is very low except in OIE vaccination project areas, and the PVS evaluation suggests that the country is not well equipped for early detection and response to an outbreak. An exotic strain of FMD is therefore likely to spread through the country with little control. Myanmar is also extensively connected with the rest of the region by trading networks, making it likely that the incursion would affect the wider region, as likely occurred with O/ME-SA/Ind2001d.

Table 14. Consequences assessment for each of the risk pathways.

Risk pathway	Consequence	Notes on consequences
Legal import of live animals	High	Key importers are Malaysia, Singapore, Indonesia and Thailand. Consequences of an incursion in Indonesia and Singapore would be high due to loss of free status. Malaysia and Thailand have extensive trade with other countries in the region, which could cause spread
Informal import of live animals	High	Applies in particular to Myanmar, believed to be the site of many imports and assessed with a high risk of spread exotic FMD across the region
Legal import of animal products	High	For largest importers (Malaysia, Philippines and Thailand), the risk for spread within regions was assessed negligible to low. However, the consequences would be high for Philippines as it would lose its free status.
Informal import of animal products	High	Insufficient information as to which countries are receiving these products. However, risk assessed as high as it is likely to cause either loss of FMD-free status or spread within the region.
Wildlife	High	Lao PDR, Myanmar, Vietnam are at highest risk from this pathway due to their border regions. Spread within the region is highly likely from these countries.
Human movements	High	Lao PDR, Myanmar, Vietnam are at highest risk from this pathway due to their border regions. Spread within the region is highly likely from these countries.
Feed/fodder	Low	Importing country (Malaysia) was assessed as having a low risk to spread exotic FMD into the region.
Vehicle movements	High	Lao PDR, Myanmar, Vietnam are at highest risk from this pathway due to their border regions. Spread within the region is highly likely from these countries.

Risk Estimation

We have demonstrated that an incursion of an exotic strain of FMDV into SEA may occur through several different routes, and that there is a high likelihood of this event occurring through one of more of these pathways.

Regardless of the pathway responsible for an incursion, the consequences are likely to be high due to spread within the region and/or loss of free status.

The overall risk estimation consisted of two steps. Firstly, we combined the likelihood of occurrence with the consequence of the occurrence for each of the risk pathways. Secondly, the overall risk for incursions of exotic FMD virus into SEA was defined by the highest risk outcome of any of the risk pathways. For all risk pathways except 'Wildlife', the likelihood of consequence was assessed to be moderate or high. When combined with the consequence (high for all pathways, except for 'Feed/fodder'), the risk estimation of these risk pathways was 'high' using Table 3.

Discussion and Recommendations

Discussion

Findings from this study suggest that there is a high risk of incursion of exotic FMDV strains into SEA. Importation of animals and animal products pose the greatest risk, largely due to the potential for virus to survive and effectively be transmitted to susceptible livestock in SEA.

Available data suggest that South Asia is a particularly high-risk source area, especially India and Bangladesh. A significant number of large ruminants are informally imported from India to fill the demand for animal products in markets in countries including China, Thailand and Vietnam. These animals are known to pass through livestock markets in which they are in close contact with susceptible livestock, allowing them to easily transmit diseases such as FMD.

It is noteworthy that many of these Indian livestock first enter SEA in Myanmar, due to its geographical proximity to S. Asia. Due to low vaccination coverage, livestock in Myanmar are likely to be highly susceptible to any incursion. Further, the PVS analysis reveals that Myanmar lacks capacity to minimize the impact of an incursion through early detection and response. It is therefore likely that an incursion of an exotic FMD virus will be amplified in markets in Myanmar and spread onward to other countries in the region.

In addition to importation of live animals, data show that several SE Asian countries also source animal products from India, legally and, most likely, informally. Data from FAO (2013) show that Brunei Darussalam, Malaysia, the Philippines, Singapore and Thailand imported boneless meat from India. A recent incursion of FMD into Mauritius has been attributed to the importation of frozen meat from India, demonstrating the potential risk posed by these products (Hamuth-Laulloo, Sibartie, & Andre, 2017). It is important to note that 4 of the countries importing meat from India are officially recognized as free of FMD (Brunei Darussalam, Indonesia, Philippines, Singapore); an incursion of FMD into any of these countries would mean immediate loss of the coveted free status and the associated privileged trading status.

Apart from India, animal products are also imported from several other FMD-endemic countries. These include countries in the Middle East and North Africa. This is important because it puts SEA at risk of an incursion from all of the diverse FMD viral strains circulating in these regions (see Table 9 with viral strains), including SAT2, A/Asia/G-VII, A/Africa/G-IV, Asia 1 and O/EA3.

Although the importation of animals and animal products are the most likely pathways for an incursion, several other pathways were identified with a non-negligible likelihood of being the route of incursion. The risk posed by these pathways will mostly involve neighboring countries due to cross-border movements of humans, wildlife and vehicles. It is important to consider these lower-risk pathways when developing measures to minimize the risk of an outbreak.

Gaps in data and knowledge were encountered throughout the study, as indicated by the high degree of uncertainty associated with most of the pathways. Some of this lack of knowledge is inherent to the nature

of informal trade and the associated risks. However, in several places there is scope to collect further data to better characterize the risk, as indicated in the recommendations below.

As both trade routes and the epidemiology of FMD are highly dynamic, the specific results of this study may only be valid for a limited time (months). However, several of the recommendations below will be useful even if the nature of the risks change. The risk framework provided should also be suitable to review and update the study as required.

Trying to capture the many variables associated with the risk of incursion of exotic FMDV into a defined number of risk pathways and generating an overall estimate of risk is an oversimplification of the reality. However, it is hoped this study informs decision makers and supports prioritization of risk mitigation measures in an environment of limited resources.

Recommendations

In this chapter, we have grouped national level recommendations by the risk pathways studied and the approach at the regional or national level. Although the recommendations are written with the intention to prevent and better manage incursion of an exotic FMDV, many of the recommendations also apply to mitigating the emergence of other infectious diseases of livestock into SEA.

We do acknowledge the existing initiatives and strategies already in use in the region, such as the SEACFMD Campaign, the PCP framework and collaborative research projects (e.g. ACIAR, AAHL). However, within the limited time and scope of this study, we have not been able to assess to what extent our recommendations may already be addressed through these initiatives.

Of the 41 recommendations described here, some require a long-term vision and are best taken up in regional strategic framework plans. Other recommendations however, may be achieved in the short term, and are the so-called low-hanging fruits: these are the recommendations to start with to make a first step in mitigating the risk of incursion of exotic FMD virus. These are indicated by a note [Short-term].

The highest impact can be expected from facilitating legal animal transports and trading across SEA and into China. When such transports become more transparent, these will be easier to monitor and may even be channeled in such a way that the contact between traded and local livestock is minimalized. However, this will certainly be a long-term process and may not be easily feasible.

Strengthening national passive surveillance sytems including farmers' and CAWHs' willingness to report, in-depth outbreak investigation, proper sampling, swift and complete diagnostics will have impact on early detection and thus allow for appropriate and rapid response. Activities in these directions are certainly feasible.

A short-term, feasible recommendation is by expanding regional collaboration including information sharing on FMD occurrence and developing plus testing contingency plans for incursion of exotic FMD virus, or similar emerging diseases. The OIE SRR-SEA and the regional FAO office may continue to play an active role in these.

Overarching

At a **regional level** it is recommended to

1) Continuously monitor the FMD situation globally, with particular attention to S. Asia, and ensure that the regional vaccine bank has access to vaccines to protect against high risk strains circulating in S. Asia and elsewhere **[Short-term]**
2) Ensure that training and awareness-raising activities include women. This is important for effective knowledge transfer because studies have shown that women are often the most important decision makers in the household (Paris, 2000). In smallholder systems, women play an important role in feeding, cleaning and management of livestock, especially pigs, backyard poultry and small ruminants, apart from undertaking other routine day-to-day activities related to their reproductive role in the household. Unlike many other regions, women in SEA are also involved in retailing of livestock products, especially fresh meat (Distefano, Colverson, & Deka, 2013) **[Short-term]**
3) Strengthen intra-regional collaboration to:
    a. share information on the FMD situation in real-time, even in situations where diagnostic results are not fully confirmed **[Short-term]**
    b. speed up genetic identification of FMDV samples **[Short-term]**
    c. continue to provide support coordinated activities (such as through OIE SRR-SEA) to strengthen the capacity of high-risk countries and support any countries impacted by an incursion to minimize the regional impact.
4) Define measures to enforce a temporary international animal movement standstill in case of detection of an exotic FMDV in SEA **[Short-term]**
5) Coordinate a regional vaccine stock by defining arrangements with vaccine producer(s) to deliver a matching vaccine in case of an exotic FMD strain that is not protected by the FMD vaccines used in routine programs and agreeing on a vaccine reserve stock to be timely and effectively used for emergency vaccination to contain spread of exotic FMDV between SE Asian countries **[Short-term].** This may be an expansion of the current initiatives of the OIE vaccine bank.
6) Apply all available measures to combat FMD:
    a. Apply the various control options (awareness, movement controls, border controls, biosecurity, communication and vaccination) in such a manner that most effective use is made of each option in relation with other options, while accounting for the limited availability of each **[Short-term]**
    b. Define roles and responsibilities for all key actors on FMD control. This requires realization that livestock owners, traders, private vets and community animal health workers, dairy cooperatives, all have a role to play in FMD control **[Short-term].**

At a **national level**, with regional support, it is recommended to

7) Reduce the impact of an incursion of an exotic strain by continuing to improve and progress risk-based control strategies, considering the routes of exotic FMD virus release and exposure discussed in this report as well as endemic FMD virus circulation. As a result, risk-based vaccination programs may target specific border areas, key animal markets, fattening farms and other high risk populations on the trading routes
8) Include specific contingency plans within the current National FMD Control Plans, for the immediate response to an incursion of an exotic strain of FMDV in consultation with private stakeholders (livestock owners, traders, animal market managers, cooperatives (dairy or beef). This includes:
    a. preparedness to investigate FMD outbreaks in more detail when suspicion of an exotic FMD virus incursion arises, preparedness for immediate actions and

b. conducting simulation exercise to test the contingency plans
c. last but not least, allocate necessary funds/resources to manage emergence of exotic animal diseases

9) Strengthen the capacity of outbreak investigation not only by training and equipping field-level veterinarians, para-vets and community animal health workers but also by provision of continued technical backstopping and regular information sharing about results of previous outbreak investigations **[Short-term]**
10) Strengthen the flow of information between local and central levels of the veterinary services. This may be facilitated by digitalizing routine reporting or establishing syndromic surveillance and zero-reporting **[Short-term]**
11) Conduct campaigns to raise awareness on the risk of an FMD incursion, and biosecurity measures to protect livestock. Involve community leaders, successful farmers and traders on these issues and use success stories of situations where farmers have been able to keep out disease while disease was around
12) Study the sensitivity of passive surveillance with a view to identifying specific actions to improve the early detection of an incursion. Such actions may include providing incentives for reporting, facilitating reporting (eg through dedicated telephone/sms number), training and technical backstopping of veterinarians and animal health workers **[Short-term].** On the side of diagnostic capacity building, there is already support for the Labnet-Epinet through SEACFMD
13) Strengthen the relationship between livestock owners and animal health service providers (public and private) to motivate livestock owners to actively consult them when livestock become diseased
14) Include private sector initiatives to increase vaccination coverage in risk-hotspots by contracting out vaccination and surveillance activities to certified and accredited private vets and community-animal health workers, equipping them with materials to maintain an appropriate cold-chain for vaccination

Relating to import of livestock (legal and informal)

At a **regional level** it is recommended to

15) Establish incentives for key livestock traders to import livestock legally instead of informally. This is the most obvious approach with the highest impact on mitigating the risk of exotic FMD virus incursion while at the same time, it may seem an almost impossible, far-reaching ideal. Nonetheless, it is necessary to start discussions with key traders to identify the facilities needed to reduce the volume of informally traded livestock and animal products, see also recommendation 21
16) Develop a system to continuously monitor the trends of livestock movements (legal and informal) into and through the region, with respect to the origin, destination and route followed. Monitoring of meat and livestock prices in SEA, India and China may be explored as a measurable proxy measure for livestock movements based on the work by Madin (2011)
17) Advocate with the Chinese authorities to review its regulations prohibiting the importation of livestock. This regulation is an important driver for extensive and ever increasing informal trade of livestock from Myanmar, Lao PDR and Vietnam into China by routes that are changing regularly. Formalizing this livestock trade will allow for better control of livestock movements by having the trade channeled and thus easier monitored and surveyed
18) Explore cost-effective approaches to implement active surveillance for exotic strains FMDV in livestock at entry points and at large animal markets. These approaches may use environmental sampling or pooling swab samples **[Short-term]**

19) Discuss and design the requirements for refurbishing large (inter-provincial) animal markets considering segregation of species and livestock from different regions, provision of cleaning and disinfection for livestock trucks and establishing visual veterinary inspection **[Short-term]**
20) Consult with the key players of the private sector (traders and beef-fattening companies) in SEA about incentives or facilitation needed for them to change their approach on informal importation of livestock **[Short-term].**

At a **national level**, it is recommended

21) Facilitate the legal importation of livestock from South Asia into Myanmar by means of legalizing imports, reducing the paper work and entry fees. Concurrently, establish quarantine and vaccination procedures at the border to have imports comply with these preventive measures
22) For Myanmar to develop a contingency plan for incursion of exotic FMDV (and other emerging diseases) and request support from other SE Asian countries to strengthen capacity for surveillance and response **[Short-term].** There may be a coordinating role for SEACFMD here
23) For Malaysia, Myanmar and Thailand to raise awareness with traders on the risks of importation of livestock
24) For Cambodia, Lao PDR, Myanmar, Thailand and Vietnam to build trust with livestock owners and service providers (in particular women and Community Animal Health Workers) to report outbreaks of disease swiftly. As such initiatives have started in Lao PDR and Cambodia under ACIAR funded projects, monitor and evaluate the impact of such programs and use this to expand an well-tested approach
25) With facilitating measures in place (as suggested above), enforce control and regulation of livestock trade and importation by increase fines and sentences for non-compliance.

Relating to import of livestock products (legal and informal)

At a **regional level** it is recommended to

26) Develop a system for ongoing monitoring of the animal products imported to the region (legally and informally), the corresponding origin countries and the disease risks (FMDV and other) associated with the origin countries
27) Conduct a specific risk assessment with respect to the potential release for FMDV for the range of products being imported from FMD-endemic countries such as boneless meat, offal, bone crush **[Short-term]**
28) Follow this up with visits to production plants in exporting countries to audit the production and storage procedures in accordance with the scientific literature and technical guidelines such as the OIE Terrestrial Animal Health Code
29) Under the EpiNet support, strengthen the national capacities to implement risk-analysis with a primary focus on import risk assessment based on the OIE guidelines through training of public veterinary officials (OIE, 2015).

At a **national level**, it is recommended to

30) Use the results of recommendations 26 and 27 to raise awareness about the risks of introducing emerging diseases with the public officials (responsible for animal product import regulations) and key importers in the private sector of animal (by-)products

31) Find an agreement with the private sector to comply with rules and regulations to mitigate the risk of importing exotic infectious diseases and food-safety related pathogens
32) Raise awareness of the risk of imported meat products with livestock producers, in particular swine producers to treat swill before feeding it to pigs
33) Enforce control and regulation of import of animal (by-)products when these recommendations are in place.

Relating to wildlife

At a **regional level**, it is recommended to

34) Coordinate studies on the FMD status and behavior (especially migration patterns) of susceptible wildlife in the border areas of Myanmar, Lao PDR and Vietnam. The results of these studies should be used to inform national strategies on risk mitigation practices, as appropriate. These may include establishing protocols with public institutes related to wildlife conservation and border control

Relating to human movements

At a **regional level** it is recommended to to

35) Develop training and communication material to raise awareness with people that have close contact with livestock or deal with fresh and frozen animal products travelling into the region about the risk of transmitting diseases between countries and regions, as well as biosecurity measures that can reduce the risk **[Short-term].**

At a **national level**, it is recommended to

36) Use the training material to raise awareness and improve biosecurity in high risk groups, such as traders, truck drivers, service providers (veterinarians, para-vets and community animal health workers, inseminators, milk collectors).

Relating to the risk associated with vehicles

At a **national level**, it is recommended to

37) Register vehicles that are involved with the cross-border transport of livestock and animal (by-) products, manure, feed or fodder
38) Implement cleaning and disinfection at border posts, animal collection points such as large (inter-national) animal markets.

Relating to feed/fodder

At a **regional level** it is recommended to

39) Conduct a specific risk assessment with respect to the potential release for FMDV from feed/fodder imported to SEA **[Short-term]**
40) If warranted by the risk assessment, develop a system for ongoing monitoring of feed/fodder imported to the region, the corresponding origin countries and the disease risks (FMDV and other) associated with the origin countries.

At a **national level**, it is recommended to

41) Apply strict regulations for products that carry a higher risk of being contaminated with FMDV (bone meal, straw, manure).

References

Alexandrov, T., Stefanov, D., Kamenov, P., Miteva, A., Khomenko, S., Sumption, K., . . . Depner, K. (2013). Surveillance of foot-and-mouth disease (FMD) in susceptible wildlife and domestic ungulates in Southeast of Bulgaria following a FMD case in wild boar. *Veterinary microbiology, 166*(1), 84-90.

Callis, J. (1996). Evaluation of the presence and risk of foot and mouth disease virus by commodity in international trade. *Revue scientifique et technique (International Office of Epizootics), 15*(3), 1075-1085.

Collineau, L., McLaws, M., Dubé, C., Stärk, K., Sumption, K. (2014). Risk Analysis Framework to compare the importance of source regions for FMDV entry into Europe. Presentation at the Open Session of the Standing Technical and Research Committees of the EuFMD, Cavtat, Croatie, 29-31 October 2014. Retrieved April 29, from http://www.fao.org/fileadmin/user_upload/eufmd/Open_Session_2014PPTS/Plenary30oct/Tplen1.pdfDavies, G. (2002). Foot and mouth disease. *Research in veterinary science, 73*(3), 195-199.

Di Nardo, A., Knowles, N., & Paton, D. (2011). Combining livestock trade patterns with phylogenetics to help understand the spread of foot and mouth disease in sub-Saharan Africa, the Middle East and Southeast Asia. *Revue Scientifique et Technique-OIE, 30*(1), 63.

Distefano, F., Colverson, K., & Deka, R. (2013). Report of the FAO-ILRI Training Workshop "Gender, Livestock and Livelihood in Southeast Asia" (June 2013), Bangkok, Thailand. Retrieved April 29, 2017, from https://cgspace.cgiar.org/bitstream/handle/10568/35737/Gender%20Livestock%20and%20Livelihood%20in%20Southeast%20Asia%20-%20FAO-ILRI%20Training%20Workshop%208%208%2013.pdf?sequence=1.

Dufour, B., Plee, L., Moutou, F., Boisseleau, D., Chartier, C., Lancelot, R., . . . Toma, B. (2011). A qualitative risk assessment methodology for scientific expert panels. *Revue Scientifique et Technique-Office International des épizooties, 30*(3), 673-681.

EFSA. (2006). Risk Assessment on Foot and Mouth Disease (Vol. 313, pp. 1-34).

EuFMD. (2017). EuFMD global monthly report. Retrieved April 26, 2017, from http://www.fao.org/fileadmin/user_upload/eufmd/docs/FMD_monthly_reports/2017/Feb2017.pdf

FAO. (2006). World Reference Laboratory for Foot-and-Mouth Disease Cumilative Report for 2006. Institute for Animal Health, Pirbright Laboratory, Working, Surrey GU24 0NF.

FAO. (2013). FAO stats: Trade of crops and livestock products and live animals. Retrived 26 April, 2017, from http://www.fao.org/faostat/en/#data.

Fournié, G., Jones, B. A., Beauvais, W., Lubroth, J., Njeumi, F., Cameron, A., & Pfeiffer, D. U. (2014). The risk of rinderpest re-introduction in post-eradication era. *Preventive Veterinary Medicine, 113*(2), 175-184.

Hamuth-Laulloo, B., Sibartie, D., & Andre, A. (2017). Report of the Fact Finding Committee on the Outbreak of Foot and Mouth Disease (March 2017). Retrieved April 29, 2017, from http://agriculture.govmu.org/English/Documents/Report/full%20report.pdf

King, D., Mioulet, V., Knowles, N., Ludi, A., SWisden, G., Armson, B., . . . Belgrave, S. (2017). *Global FMD surveillance report. In 42nd General Session of EuFMD, April 20-21, 2017, Rome, Italy. Retrieved April 27, 2017, from http://www.fao.org/fileadmin/user_upload/eufmd/General_sessions/42GS2017/Item_2.WRLFMD_Global_Update_King.pdf*.

Knight-Jones, T., & Rushton, J. (2013). The economic impacts of foot and mouth disease–What are they, how big are they and where do they occur? *Preventive Veterinary Medicine, 112*(3), 161-173.

Madin, B. (2011). *Understanding and predicting the influence of animal movement on the spread of transboundary animal diseases.* (Thesis for the degree of Doctor of Philosophy), Murdoch University.

Mardones, F., Perez, A., Sanchez, J., Alkhamis, M., & Carpenter, T. (2010). Parameterization of the duration of infection stages of serotype O foot-and-mouth disease virus: an analytical review and meta-analysis with application to simulation models. *Veterinary research, 41*(4), 45.

Mclaws, M., Motta, P., & Sumtion, K. (2017). Confidence in the early detection of foot and mouth disease (FMD) – when is passive surveillance sufficient and what are the options for increasing confidence in disease freedom? Presentation at 42nd General Session of EuFMD, 20-21 April 2017. Retrieved April 27, 2017, from http://www.fao.org/fileadmin/user_upload/eufmd/General_sessions/42GS2017/GS42Complete_meeting_document.pdf

McLaws, M., & Ribble, C. (2007). Description of recent foot and mouth disease outbreaks in nonendemic areas: Exploring the relationship between early detection and epidemic size. *The Canadian Veterinary Journal, 48*(10), 1051.

Moutou, F., Dufour, B., & Ivanov, Y. (2001). A qualitative assessment of the risk of introducing foot and mouth disease into Russia and Europe from Georgia, Armenia and Azerbaijan. *Revue scientifique et technique (International Office of Epizootics), 20*(3), 723-730.

Murray, N. (2004). *Handbook on import risk analysis for animals and animal products: Introduction and qualitative risk analysis* (Vol. 1): Office Internationa des Epizooties.

Nampanya, S., Khounsy, S., Abila, R., Young, J., Bush, R., & Windsor, P. (2015). Financial Impacts of Foot-and-Mouth Disease at Village and National Levels in Lao PDR. *Transboundary and emerging diseases*.

OIE. (2015). Foot and Mouth Disease, Chapter 8.5., In: Terrestrial Animal Health Code 2015. Retrieved 29 April, 2017, from http://www.oie.int/international-standard-setting/terrestrial-code/access-online/

Paris, T. (2000). *Bringing women from the margin to the mainstream of rice research and technology development: Strategies and lessons learned* (Unpublished Ph.D thesis)

Paton, D., Sinclair, M., & Rodriguez, R. (2010). Qualitative Assessment of the Commodity Risk for Spread of Foot-and-Mouth Disease Associated with International Trade in Deboned Beef. *Transboundary and emerging diseases, 57*(3), 115-134.

Qui, Y., Abila, R., Rodtian, P., King, D., Knowles, N., Ngo, T., . . . Widders, P. (2017). Emergence of exotic O/ME-SA/Ind-2001d Foot and Mouth Disease Virues in South-East Aisia in 2015. *Transboundary and Emerging Diseases (under review)*.

Ramos-Onsins, S., Burgos-Paz, W., Manunza, A., & Amills, M. (2014). Mining the pig genome to investigate the domestication process. *Heredity, 113*(6), 471-484.

Scudamore, J. (2002). Origin of the UK foot and mouth disease epidemic in 2001. *Department of Environment, Food and Rural Affairs, London, United Kingdom*.

Sinkala, Y., Simuunza, M., Pfeiffer, D., Munang'andu, H., Mulumba, M., Kasanga, C., . . . Mweene, A. (2014). Challenges and economic implications in the control of foot and mouth disease in sub-Saharan Africa: Lessons from the Zambian experience. *Veterinary medicine international, 2014*.

Smith, P., Luthi, N., Huachun, L., Oo, K., Phonvisay, A., Sith, P., . . . Miller, C. (2015). Report on movement pathways amnd market chains of large ruminants in the Greater Mekong Sub-Region. World Organization for Animal Health, Sub-Regional Representation for South-East Asia.

Sorichetta, A., Bird, T. J., Ruktanonchai, N. W., zu Erbach-Schoenberg, E., Pezzulo, C., Tejedor, N., . . . Sedda, L. (2016). Mapping internal connectivity through human migration in malaria endemic countries. *Scientific Data, 3*.

Tekleghiorghis, T., Moormann, R. J., Weerdmeester, K., & Dekker, A. (2014). Foot-and-mouth Disease Transmission in Africa: Implications for Control, a Review. *Transboundary and emerging diseases*.

Weaver, G. V., Domenech, J., Thiermann, A. R., & Karesh, W. B. (2013). Foot and mouth disease: a look from the wild side. *Journal of wildlife diseases, 49*(4), 759-785.

Wooldridge, M., Hartnett, E., Cox, A., & Seaman, M. (2006). Quantitative risk assessment case study: smuggled meats as disease vectors. *Revue Scientifique et Technique-Office International des épizooties, 25*(1), 105.

Annexes

Annex 1: Terms of Reference

Regional risk analysis for incursions of exotic strains of foot and mouth disease in South-East Asia

Background

At the 19th South East Asia and China Foot and Mouth Disease (SEACFMD) National Coordinators Meeting held in Bangkok, Thailand, on 17-19 August 2016, it was recognized that foot and mouth disease viruses (FMDV) of the lineages O/ME-SA/Ind2001 and A/Asia/GVII potentially pose serious risks to SEACFMD Member Countries, including the Association of South East Asian Nations (ASEAN) member states (AMS). To help understand and mitigate these risks, it was recommended to conduct a formal Regional Risk Analysis study.

At least two incursions of the emerging FMDV sub-lineage O/ME-SA/Ind2001d have been detected in 2015 in Laos, Vietnam and Myanmar. This is likely due to changing trade patterns along livestock supply chains from India to SE Asia, and driven by demand for beef and buffalo meat in China. Another South Asian lineage of the FMD virus has already spread to Turkey and Saudi Arabia in 2015 (A/Asia/GVII). Although this virus lineage is not yet believed to be present in SE Asia its detection could have significant impact, given present vaccines are unlikely to protect animals and the virus has potential to lead to widespread outbreaks.

The aim of the study is to conduct a qualitative risk assessment of the possible incursion of exotic FMD viruses (specifically O/ME-SA/Ind2001 and A/Asia/G-VII) to AMS and member countries of the SEACFMD Campaign and provide recommendations to mitigate risks. The regional FMD risk analysis will be implemented by OIE, including the OIE Sub-Regional Representation for South East Asia (SRRSEA), utilising SRR-SEA technical expertise, regional knowledge and consultant(s) to undertake a desk review of data and research, engage with country officials and experts, to collect and analyse information on the trade in livestock, livestock products and other risk materials from South Asia. This will build on the Australian Department of Foreign Affairs and Trade (DFAT) funded analysis of safe animal movement in the region, and develop recommendations for regional risk mitigation. Findings and recommendations will be disseminated and reviewed by SEACFMD Campaign partners (including preliminary presentation at the SEACFMD Sub-Commission Meeting, March 2017), including AMS, for incorporation in national FMD plans.

The study will be supported by funds granted by Australia's DFAT to the OIE World Fund, and in collaboration with Australia's Department of Agriculture and Water Resources (DAWR).

Scope

This study will rely on data gathered from published studies, grey literature and expert opinion. Gathering of primary data (e.g. surveys of animal or animal product movements) is out of scope, however short 'site visits' to conduct interviews and hold discussions with key people in targeted countries is in scope. This study will also assess and make recommendations associated with socio-economic and inclusive development risks, including but not limited to gender issues (women's organisations), disability inclusive development (disabled peoples organisations), private sector and civil society engagement.

A consultant who has experience in risk analysis and specific knowledge and experience of South and SE Asia (region and/or country level) will be hired to lead this study. The roles of the consultant are to:

- Design the study under the guidance of the OIE SRR-SEA;

- Perform a desktop review including collection and analysis of information on the trade in livestock, livestock products and other risk materials from South Asia into SE Asia;
- Facilitate a workshop to verify the desktop review findings and identify and analyse any additional risks. The workshop will be attended by representatives from SEACFMD member countries;
- Conduct site visits in selected countries (up to 5 in South and/or SE Asia in consultation with OIE) to verify the desktop review and workshop findings and identify and analyse any additional risks;
- Analyze the collected and compiled data; and
- Write the final report.

Deliverables

1. Study design and work plan (including a breakdown of proposed costs and delivery date against each proposed deliverable) finalised and agreed by the OIE;
2. Desktop review of literature, documents and initial analysis of secondary data;
3. SEACFMD Sub-Commission presentation (outline and preliminary desktop data/findings) by 8 March 2017;
4. Facilitate workshop and pre-workshop questionnaire;
5. Analysis of desktop review data, workshop and site visits;
6. Provide a draft report (no more than 20 pages, not including annexes and executive summary) by 21 April 2017 and final report to OIE by 1 May 2017.

Total budget available

The total budget available for consultancy costs (including professional fees, site visits, travel and associated costs) is EUR 35 000.

Required skills/expertise

The Consultant should demonstrate the following skills/qualities and adhere to the highest review standards and code of ethics expected by OIE and its partners:

- Excellent technical/analytical/risk assessment skills including; practical experience of risk assessment in complex animal health/international development programs; and the ability to present and use relevant quantitative and qualitative evaluation tools to achieve review objectives;
- Excellent technical knowledge and experience of FMD and related animal health issues;
- Exceptional report drafting skills, including the ability to convey complex issues and ideas in simple easy-to-understand forms;
- Have a practical and realistic approach to risk assessment and technical recommendations;
- Strong cross-cultural and interpersonal skills; as well as specific knowledge and experience of South and SE Asia (region and/or country level); and
- Good understanding of socio-economic and inclusive development risks, including but not limited to gender issues, disability inclusive development private sector and civil society engagement;
- Previous experience of OIE regional programs, review standards and procedures preferred, but not essential.

Annex 2: Release pathways

The release component of the risk assessment refers to the introduction of an exotic strain of FMDV into SEA. Ten pathways were considered for this stage

1. Legal import of live animals
2. Informal import of live animals
3. Legal import of animal products and by-products
4. Informal import of animal products and by-products
5. Wildlife
6. Cross-border communal grazing
7. Human movements
8. Feed/Fodder import
9. Vehicle movements
10. Genetic material import

For the introduction of an exotic strain of FMDV into SEA it is necessary that the pathogenic agent circulates in the country of origin for animals, animal products/by-products and/or fomites moving or being moved to SEA. Table 9 presents a short summary of the most recent FMDV strains circulating in countries from where the SE Asian region imports animals, goods and products.

In the following, each pathway will be described and analysed with regards to the risk it posed to the introduction of FMDV into the SE Asian region.

Legal import of live animals

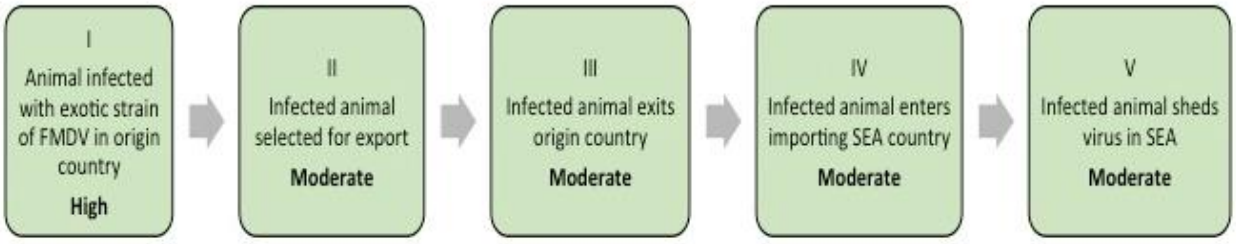


Figure 4. Risk pathway for the release of FMDV into SEA through the legal import of live animals (bold text refers to likelihood).

The movement of live animals constitutes one the major risk pathways for the incursion of FMD. Selecting the trading partners/zones for the importation of livestock based on their FMD epidemiological status is key for preventing disease introduction into national territory. However, analysis of data retrieved from FAO on live animal trade in 2013 concludes that SE Asian countries are importing livestock from FMD-infected countries. Cattle are imported from China, India and Pakistan, mainly to Malaysia but also to Singapore. China is also exporting pigs to Indonesia and sheep to Malaysia. Thailand is importing sheep from Saudi Arabia. Cambodia imports goats from Korea (Table 15).

As these countries are not free of FMD, and FMD is endemic in some of them (eg. Pakistan, India, Saudi Arabia), there is a high probability that an animal may be infected with FMD in the origin country (Step I). Several of the viruses that circulate in these countries are exotic to SEA (table 9).

Table 15. Number of live animals imported to SEA in 2013 (colour code for different species at the bottom of the table).

SEA country	Non free-from-FMD country				
	China, mainland	India	Pakistan	Republic of Korea	Saudi Arabia
Cambodia				1	
Indonesia	20				
Malaysia	220 26	1436	254		
Singapore	81				
Thailand					132

Cattle Sheep Pig Goat

However, the very low volumes presented in the official data may not represent the actual volumes traded. In addition, given underreporting of FMD is considerable in some of the exporting countries, the probability of exported animals being infected is difficult to quantify, but is likely to be higher than probabilities calculated from formal reports. With that we concluded that there is moderate probability that an animal infected with FMD would be selected for export (Step II).

Based on the in-country visits and the workshop conducted on 5 April, veterinary officials confirmed that control measures to reduce the risk of importing an infected animal are in place in the importing countries, namely quarantine, animal inspection and vaccination. However, mild and subclinical disease, frequent in small ruminants and vaccinated animals, make it harder for disease to be detected (Mclaws, Motta, & Sumtion, 2017). Thus, even with the implemented control mechanisms, there is a moderate probability that the disease will go unnoticed and the animal will exit origin country and enter SEA (Steps III and IV).

Although the time of virus shedding is limited (3.9 to 4.7 days for a 95% CI according to Mardones et al. (2010), with some variations depending on species and serotype), one still needs to take into consideration that animals are traded in groups and that within a group animals could be in different stages of disease. Nevertheless, the risk mitigation measures in place should reduce the probability of an infected animal releasing the virus into SEA (Step V). Note that we have not taken into consideration the role of the carrier state for this assessment. The role of animals persistently infected with FMD is controversial and it has been stressed that most transmissions occur from an acutely infected animal to a susceptible one (Tekleghiorghis, Moormann, Weerdmeester, & Dekker, 2014; Weaver, Domenech, Thiermann, & Karesh, 2013).

Provided that each step in the pathway above must occur for the virus to be released into SEA, **the risk of incursion of FMD by the legal trade of live animal into SEA is considered to be Moderate.** From all SE

Asian importing countries, Malaysia is the one posing the greatest risk considering the trading relations with different FMD-infected countries, the higher volumes and different species traded.

Although known to be reliable, the data available on the FAO Stats platform was from 2013. Also, there is little data on the actual prevalence of the disease in the exporting countries, so the perception of the likelihood of selecting an infected animal is not well supported. **Thus, there is a moderate level of uncertainty on this estimate.**

Informal import of live animals

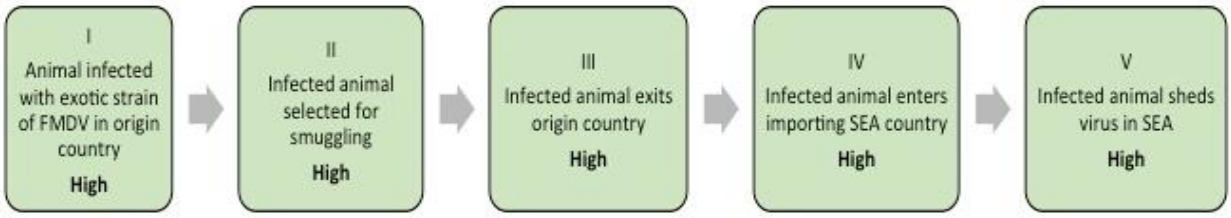


Figure 5. Risk pathway for the release of FMDV into SEA through the informal import of live animals (bold text refers to likelihood).

Unfortunately, due to its unofficial nature, little data are available on the informal trade of live animals. Additionally, it's not a comfortable theme to be discussed. Nevertheless, data collected during the fieldtrip mission allowed some insights on this risk pathway. Additionally, some studies have been done on animal trade in the Greater Mekong Sub-region.

Previous studies have reported that live animals are smuggled into SEA from India and Bangladesh (Di Nardo, Knowles, & Paton, 2011; Smith et al., 2015). There is a strong motivation for unofficial trade to take place because of the demand for meat in the region (China, Bangladesh, Thailand and Malaysia) coupled with surplus supply in India, especially as cattle trade and slaughter is forbidden by law. The trade is facilitated because India shares land borders with Myanmar, which is known to have informal trading routes to China and Thailand. Vietnam is another concern as reports of informal imports of goats and pigs from China are known (Smith et al., 2015).

These findings are supported by genotyping results from outbreaks caused by the O/ME-SA/Ind-2001d lineage in Myanmar, which highlighted the phylogenetic proximity of the responsible FMDV with those from Nepal, Bangladesh, India, Bhutan and other countries (WRLFMD report on Myanmar FMD 2016 outbreak batch WRLFMD/2016/00033) (FAO, 2006; Qui et al., 2017). The investigation of the Myanmar - Rakhine FMD outbreak in 2015 suggested that infection had been introduced through the import of cattle from Bangladesh.

Nepal, India and Bangladesh are endemic for FMD, with circulating strain O/ME-SA/Ind-2001d. Additionally in India and Bangladesh both A/Asia/G-VII and Asia1 strains circulate (Table 9). The probability an animal being infected with FMD is relatively high due to the believed high prevalence of FMD in these countries (countries' reports from the 3rd SAARC Roadmap meeting) (Step I).

Thus, the trading relation, the FMD situation in exporting countries and genotyping evidence indicates an epidemiological link and a gateway for FMDV from South Asia to SEA. The volume of informal trade of cattle is considerably high as suggested in Smith et al. (2015) – according to the report around 365 000

cattle and buffalo heads are informally traded via Chiang Rai (Thailand) to Menglong (China), most of which originate from Myanmar or India/Bangladesh. This results in a high probability of an animal infected with an exotic strain of FMD entering the informal trade route (Steps I and II).

As there are no border controls or veterinary checks with informal movements, smuggled, infected animals have a high probability of entering the country (Steps III and IV). The risk of shedding is limited by the infectious period, but given the lack the control measures that exist in the legal trading routes and the higher volumes traded the risk of viral shed is considered high (Step V). **Thus, the overall risk for this pathway is considered high, but with a high level of uncertainty,** as few data are available. Myanmar seems to be the main gateway for the introduction of disease for this pathway given its informal trading relation with neighbouring countries, specifically India and Bangladesh.

Legal import of animal products and by-products

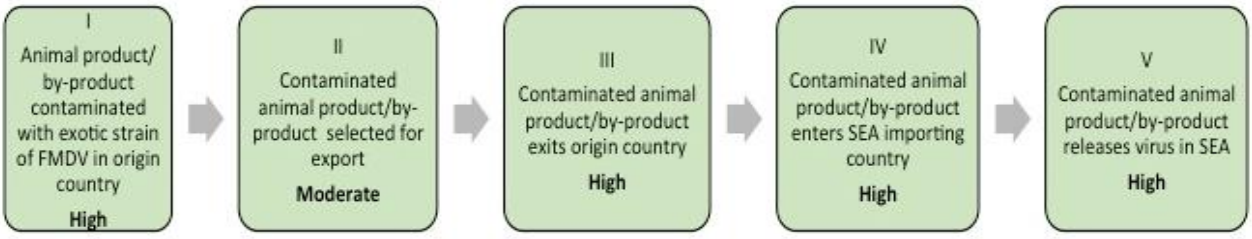


Figure 6. Risk pathway for the release of FMDV into SEA through the legal import of animal products and/or by-products (bold text refers to likelihood).

Again, the risk of introduction of an exotic strain of FMDV depends on whether there is such a virus in the countries exporting animal products or by-products to SEA. Based on data on animal products and by-products in 2013 retrieved from FAOSAT (FAO, 2013), and after excluding the countries that are free-from-FMD or have a free-from-FMD zone (using vaccination or not), we are left with the following table 16 that represents the trading relations between SEA importing countries and exporting partner.

Table 16. Trading relations of animal products and by-products of importing SE Asian countries in 2013 (volumes traded in tonnes).

SEA importing Country	Brunei Darussalam	Cambodia	Indonesia	Malaysia	Philippines	Singapore	Thailand
Bahrain					307 17		
Bangladesh							54
China, mainland	1 101	16 52	404	312 1 2		70	29 655 119
Egypt				18 3			
India	1 774	308 16		142 111 036 5 864	28 27 580 74	75 747	1 447 6 793 2 223
Iran				9			
Israel						1	
Pakistan				121		13	342

				287
Republic of Korea	622	8	64	8 521 68
Saudi Arabia		42		
Sri Lanka				3
Tunisia				2 488
United Arab Emirates			172	

Food wastes Beef Boneless meat (beef and veal) Offal (cattle) Milk (whole fresh cow)

It is clear that animal products and by-products are being exported to SEA from FMD-infected countries, where exotic FMDV strains circulate (Table 9). Data collected from fieldwork trip showed that a company in Vientiane - Lao PDR imported 217 tonnes of boneless meat from non-SE Asian countries, mainly from India. It also indicated that three companies in Ho Chi Minh – Vietnam imported boneless beef and offal, mainly from India (21,040 tonnes in 2016). The risk of disease introduction will vary according to the products/by-products imported and transformation processes it undergoes which will influence ability of the virus to survive. Scientific studies show that FMDV can remain viable after slaughter of an infected animal. The onset of rigor mortis is known to inactivate the virus in bovine carcasses due to a drop in the muscle pH during maturation. However, the virus will still be present in lymph nodes and bone marrow, which is the reason some FMD-free countries allow for the importation of deboned beef from countries with free-from-FMD zones, even if vaccination is practiced. In pigs the maturation process isn't reliable to inactivate the virus, as pH levels might stay above 6.0 (EFSA, 2006) (Step V).

Deboned beef is being imported to SEA, mainly from India. Although the maturation process and deboning would reduce the risk of incursion of FMDV into the region, investigation of recent FMD outbreaks have implicated Indian deboned beef as the source of the virus (Hamuth-Laulloo et al., 2017).Report from the Investigation Committee for the FMD outbreak in Rodrigues - Mauritius in 2016). This raises questions as to the effectiveness of the processes in place in India to mitigate the risk of importation of FMDV through the trade of animal products and by-products. A paper by Paton et al. (2010) cautioned that deboned meat can still pose a risk of FMD introduction, even if maturation and deboning processes are correctly undertaken. Additionally, Qui et al. (2017) denotes that an outbreak investigation of FMD in Vietnam concluded that offal and deboned meat had been imported previous to the outbreak.

Food wastes are being exported from FMD-infected countries in large quantities. Although little is known about how these products are processed and their final destinations, the importation of these products does present a biosecurity risk. Unpasteurized milk can also constitute a risk for disease introduction, as does offal when not properly treated (OIE Terrestrial Animal Health Code recommends a boiling or soaking for more than 48h in solutions with high or low pH) (EFSA, 2006; OIE, 2015).

Considering the diversity and volumes of products/by-products exported, the endemic FMD situation of the countries of origin, and the suggestion that ineffective risk mitigation processes are applied to these products, the risk of having contaminated products/by-products is High (Step I). Some products are traded in extensive amounts, which increases the likelihood of having a contaminated goods selected for exportation. However, given the existent measures in official trading routes the risk is considered

moderate (Step II). Once selected the product will likely enter SEA given the lack of active surveillance in testing these products for FMDV (Step III and IV).

With all of this in mind the risk of disease introduction through this route is considered moderate. Malaysia and Thailand are the main importers of these products from India (A/Asia/G-VII and Asia 1) and China, and are therefore more exposed to this risk pathway. As with the legal animal trade, the data extracted from FAO stats is not up-to-date (FAO, 2013) which introduces additional uncertainty. Additionally, there was no data available for some key countries such as Myanmar regarding this topic. **The level of uncertainty is therefore moderate.**

Informal import of animal products and/or by-products

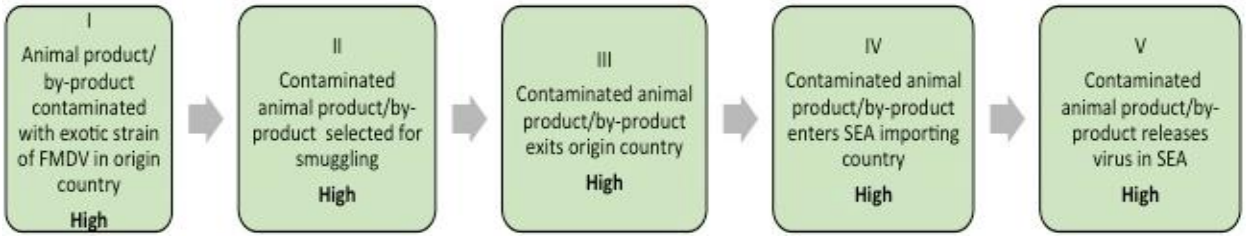


Figure 7. Risk pathway for the release of FMDV into SEA through the informal import of animal products and/or by-products (bold text refers to likelihood)

As with live animals, little data is available on the imports of animal products and/or by-products into SEA (origin, volumes, etc). Data supplied by the Department of Livestock Development of Thailand indicate that carcasses (frozen and unfrozen) and offal from buffalo, cattle and pig were informally imported to the country between 2014 and 2017 but the country of origin is not specified. Information collected during the fieldtrip mission suggested that animal products (beef and offal) from India are being exported to Malaysia wrongly labelled (as maritime products), even though Malaysian authorities forbid the importation of Indian animal products (except for deboned meat).

The high demand for these products in SE Asian countries motivates the informal import of animal products and by-products. Given the endemic FMDV status of some exporting countries the risk of having a contaminated product selected for smuggling to SEA is high (Step I and II). While being smuggled the procedures in place to control the trade of these products are often bypassed. Additionally, human traveling across the region can be responsible for the undetected transport of animal products. A report from EFSA on the risk of introduction of FMD into Europe considered the constant flow of animal products by travellers a high risk (EFSA, 2006). Although human movement seems to be more intense within SEA than between SEA and neighbouring countries (Sorichetta et al., 2016) one cannot disregard this risk factor.

Although there is a **high level of uncertainty**, given the lack of data, **the risk of disease introduction into SEA by this risk pathway is considered high.**

Wildlife

Figure 8. Risk pathway for the release of FMDV into SEA through infected wildlife (bold text refers to likelihood).

In Southern Africa scientific evidences suggest that, although not fully understood, wildlife plays a role in the epidemiology of FMD. The African buffalo (*Sincerus caffer*) has been particularly studied in this respect (Sinkala et al., 2014). However, there is extensive lack of knowledge as to the role in disease transmission (if any) of other wild animal species (Weaver et al., 2013). Some stakeholders from the public sector expressed concern about wild boar, and associated their presence with FMD outbreaks, particularly during the dry season when animals gather near scarce water sources/puddles. However, there was also agreement as to the lack of data to support this connection.

Despite the uncertainty about the importance of wildlife and livestock interactions in the epidemiology of FMD, the presence of wild animal species in South and Central Asia susceptible to FMD (wild boar, deer, gaur, yak, etc) may represent a risk of disease introduction and/or spread to SEA, particularly given that most FMD reports in South Asian wildlife are from India (Weaver et al., 2013). Wild boar, which likely represent the species of most concern, are also widely spread across the region (Ramos-Onsins, Burgos-Paz, Manunza, & Amills, 2014) (Step I), and the difficult-to-control borders with neighbouring countries would allow for cross-border movement of wildlife. (Step II). Wild boars are not however known for their migratory behaviour, and their role in disease transmission is more likely restricted to smaller spatial scales. The probability of having infectious wild animals entering SEA from outside the region is therefore considered low (Step III).

The likelihood of an infected wild animal entering SEA and releasing the virus is considered low, with a high uncertainty level.

Communal grazing

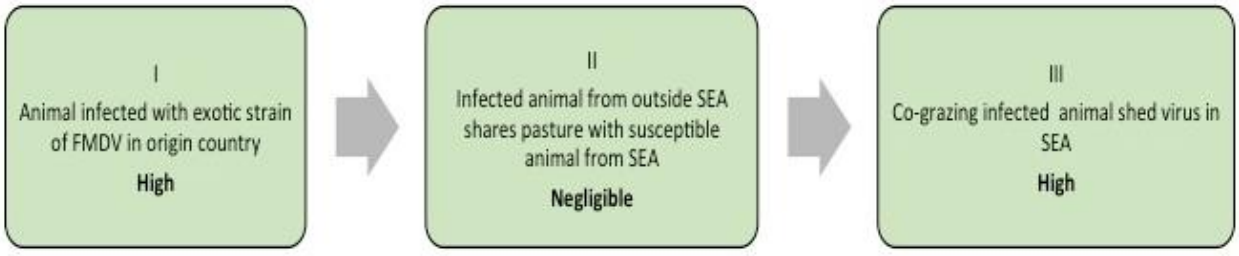


Figure 9. Risk pathway for the release of FMDV into SEA through cross-border communal grazing (bold text refers to likelihood).

This risk pathway depicts the probability of an infected animal from a country outside SEA infecting a

susceptible animal from SEA through the shared use of pasture that may be bridging national borders or that may lie within one of the SEA countries and where an infected animal has been taken to.

As discussed previously the likelihood of having an infected animal with FMDV from a country that shares its borders with SEA is high (step I), as most of them are endemic for FMD.

Given the declared lack of control over animal moments an animal would move between borders fairly easy (data from fieldtrip mission). However, while communal grazing is commonly practiced in the traditional/familial animal production systems that typify the main livestock sector for South, Central and South-East Asian countries, there is no evidence that farmers will share pastures with neighbouring countries. Data collected in stakeholder interviews during in-country visits indicated that communal grazing occurs within village domains and surrounding land, and does not involve the sharing of land by livestock from different countries (Step II).

As direct contact is the main transmission route between animals the risk of FMDV transmission to susceptible animals is considered high (Step III) (EFSA, 2006). Taking into consideration the infectious period and often large size of co-grazing animal groups the risk of viral shedding of FMDV is high (Step IV).

In summary, and although it would be likely for an infected animal to move freely, there is no evidence that communal grazing is practiced between countries and so **the likelihood of this pathway is considered negligible**. However little geospatial data is available for mapping the distribution of the regional livestock population, which would help to identify areas where there would be a higher risk of disease introduction through communal grazing based on proximity of production units from different countries. **The uncertainty level regarding the estimate is thus high.**

Human

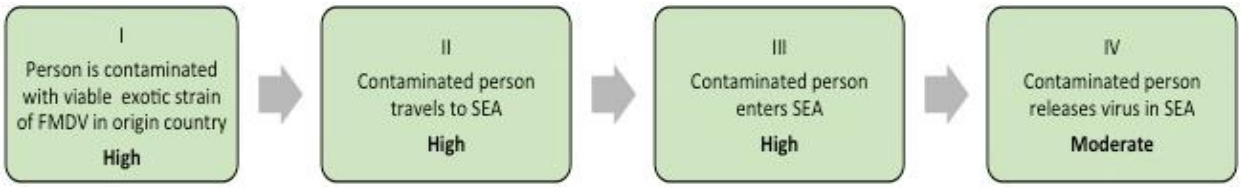


Figure 10. Risk pathway for the release of FMDV into SEA through cross-border human movement (bold text refers to likelihood).

This risk pathway of viral release into SEA requires people to be contaminated with virus in their country of origin. The people posing this risk are therefore those traveling from FMD-endemic countries. In these settings there is little tourism. The human movement risk is linked to people who are likely to be in regular contact with animals – farmers, traders, "walkers" (people that move cattle for trading purposes on foot), workers, market workers, veterinarians, animal health technicians etc.

From table 17 below we can see that in general a high proportion of the population from the South and Central Asian countries work in agriculture. As previously stated traditional smallholder farms are dominant in these regions, meaning that farmers will own a small piece of land for crops and some animals for labour (data collected during fieldtrip mission). There will therefore be a high proportion of people in contact with animals in countries that are endemic to FMD (Table 9) (Step I).

Table 17. Proportion of countries' labour force working in agriculture

Country	% of labour force in agriculture
Afghanistan	78,6
Bangladesh	47,0
Bhutan	57,0
China	33,6
India	49,0
North Korea	37,0
South Korea	5,707
Nepal	69,0
Pakistan	43,7
Sri Lanka	28,4

Source: www.CIA.org accessed on 25th April 2017

For the virus to be released into SEA the contaminated person needs to travel to SEA. Even though human movements into SEA seem to be less intense than within SEA (Sorichetta et al., 2016) there is still a high probability of human movement along the border, especially if we take into consideration the people involved in animal trade (Steps II and III).

Virus also needs to survive the trip so that it reaches the destination in a viable condition. This would relate to the different types of material (clothes, shoes, skin, etc.) and presence of organic matter (that fosters viral survival). It is unlikely that people coming from such humble conditions will take expensive means of transportation like an airplane. They would most likely travel by road and/or boat. Although people are not likely to be submitted to control measures to mitigate disease spread (eg. disinfection), the virus would need to survive the length of the trip and endure environmental conditions that are unlikely to favour virus survival given its sensitivity to heat and desiccation (EFSA, 2006). An EFSA report highlights the relation of environmental conditions with the natural elimination of the virus (EFSA, 2006). However, the wet season would favour virus survival and thus the probability of it entering SEA viable is considered moderate (Step IV).

In summary, there is a chance for viable virus to be spread via contaminated people. **The risk of introduction of FMD into SEA through this pathway is thus considered moderate.** However, as it is based on several assumptions and little data **the uncertainty level is high.**

Feed/Fodder

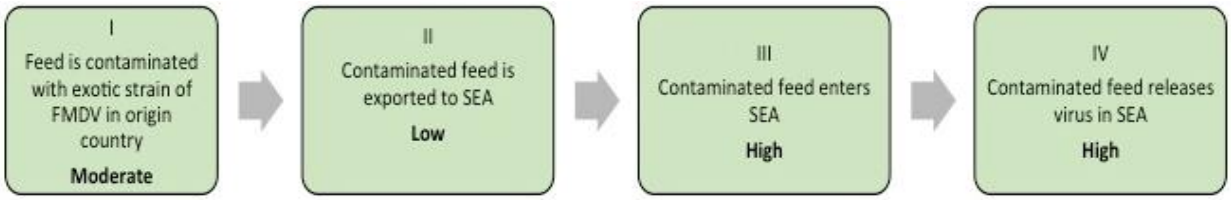


Figure 11. Risk pathway for the release of FMDV into SEA through importation of feed/fodder (bold text refers to likelihood).

After consulting the FAO Stats platform, Malaysia seemed to be the sole importer of forage products to SEA (3 tonnes in 2013) from a source that could represent a risk of disease introduction (FAO, 2013) – China. However, one does not know to what extent the information regarding the trade of feed with SEA is complete and it is hard to draw reliable conclusions.

Nevertheless feed/fodder could pose a risk of introduction of FMDV into SEA if imported from an FMD-endemic country. Given the intense agricultural activity in the region and neighbouring countries, and the trading relation presented in previous risk pathways, there is a possibility that feed is being imported to SEA (Step I and II). If imported the product would most likely enter SEA (Step III). Depending on the level of moisture? in the feed, the virus would have different chances of survival. However, studies have indicated that the virus can survive up to 15 weeks and thus the probability of the virus reaching SEA viable is considered high (Davies, 2002) (Step IV).

Even though there is a high probability of viable virus being present in contaminated feed there is little chance that feed is imported to SEA. **This pathway is considered low risk with a high uncertainty level** (no data on the imports of feed/fodder and little studies on the risk posed by this sort of product).

Vehicle

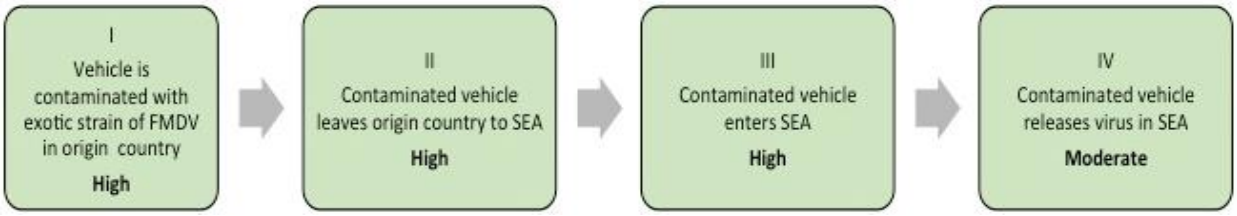


Figure 12. Risk pathway for the release of FMDV into SEA through vehicle movement across the border (bold text refers to likelihood).

This pathway follows the same reasoning as the human risk pathway, in that vehicles are required to be in close contact with animals/animal farms from FMD-endemic countries. With this pathway, we have considered equipment (use in animal production (shovel, wheel barrow, tools)) included as these are carried on often with vehicles by those involved in animal production. Assuming that traditional smallholdertraditional smallholder farmers have no means of motorized transport it is unlikely that virus will be introduced to SEA via farm vehicle movements. However other social actors need to be considered as they could also be moving across the border into SEA to perform activities related to their work, particularly people involved in the high intensity animal trade (Steps I and II).

In the event that a contaminated vehicle enters SEA there are little to no control measures in place to prevent the disease from spreading (disinfection of vehicles) (Step III). Data collected during fieldtrips suggests that vehicles carrying animals are sometimes washed and roughly disinfected, but routine disinfection of vehicles does not occur. The EFSA document on the risk of FMD introduction into Europe stresses that there have been no reports on the introduction of the virus via contaminated vehicles and suggests two explanations for this: i). the control measures at the border (disinfection) and ii). environmental conditions. In this case the reduction of risk would only derive from the latter, and there

would be an increased chance of virus survival, and thus introduction into SEA, during the wet season (Step IV).

For the probability of virus survival, the risk for this pathway is considered moderate with a high uncertainty level (based on assumption and perceptions of interviewed stakeholders).

Genetic material

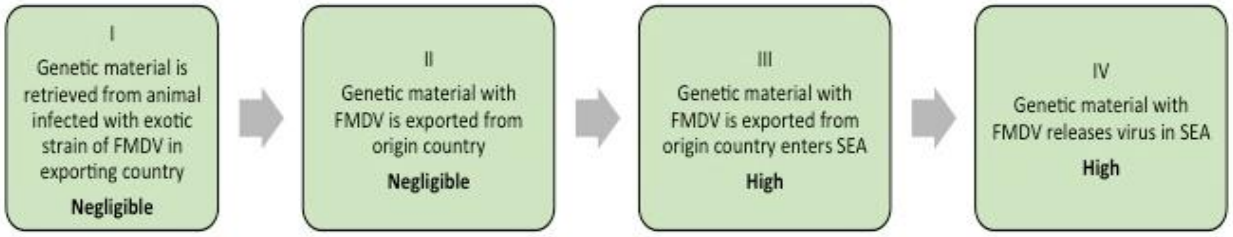


Figure 13. Risk pathway for the release of FMDV into SEA through the import of genetic material (bold text refers to likelihood)

Virus can be detected in semen collected from an infected animal with viraemia, which then constitutes a risk of disease introduction should a SE Asian country import semen from a FMD-endemic country, particularly because semen's preservation methods favour the survival of the virus (Callis, 1996; EFSA, 2006). From the field data collected during in-country visits we conclude that semen is being imported only from free-from-FMD countries (Australia and New Zealand), which means that the likelihood of having contaminated semen imported to SEA is negligible, as the animal health services of these countries are very capable (Steps I and II).

Thus, and even though the control measures in the importing countries would be effective to prevent the entry of contaminated semen (step III), the probability of having such material from Australia and/or New Zealand is practically nil, and the **risk for this pathway is considered negligible.** There seems to be consensus on this theme and thus **the level of uncertainty is considered low**.

Annex 3: Exposure pathways

For the exposure assessment six (6) pathways have been considered as described below:

- Animal contact – trade (both legal and informal)
- Trade of animal products and/or by-products (both legal and informal)
- Wildlife
- Human
- Feed/fodder
- Vehicle

Direct Animal Contact - Trade

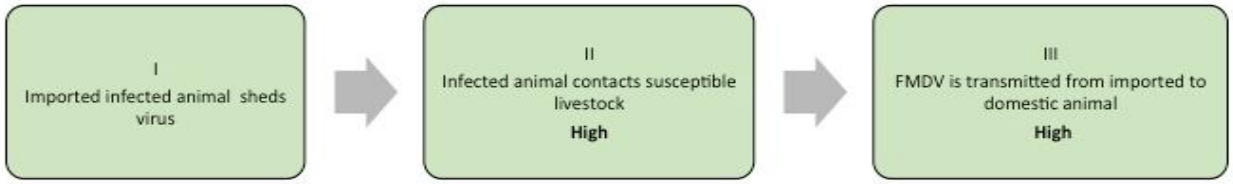


Figure 14. Risk pathway for the exposure of FMDV in SEA through animal contact as a results of trade (bold text refers to likelihood)

Before reaching their final destination, animals are moved along trading routes from market to market, where intense animal grouping occurs without any biosecurity measure (Smith et al., 2015) and (from field data). According to data collected during fieldwork trips these animals are unlikely to be vaccinated (Step II). Direct contact between infectious and susceptible animals is the most import transmission route for FMD (Di Nardo et al., 2011; EFSA, 2006) (Step III).

Animals are being legally and informally traded from countries with an endemic status for FMD. Little animal movement control allows them to reach markets easily where the probability of virus transmission is high. **The risk of exposure through this pathway is thus considered high**. Although there is some data around the informal trade, and a shared agreement that animal movement is the main source of introduction and spread of FMDV in the region, there is still a lot of information missing. **Thus, there is high uncertainty around this evaluation.**

Exposure to animal products and/or by-products (both legally and informally imported)

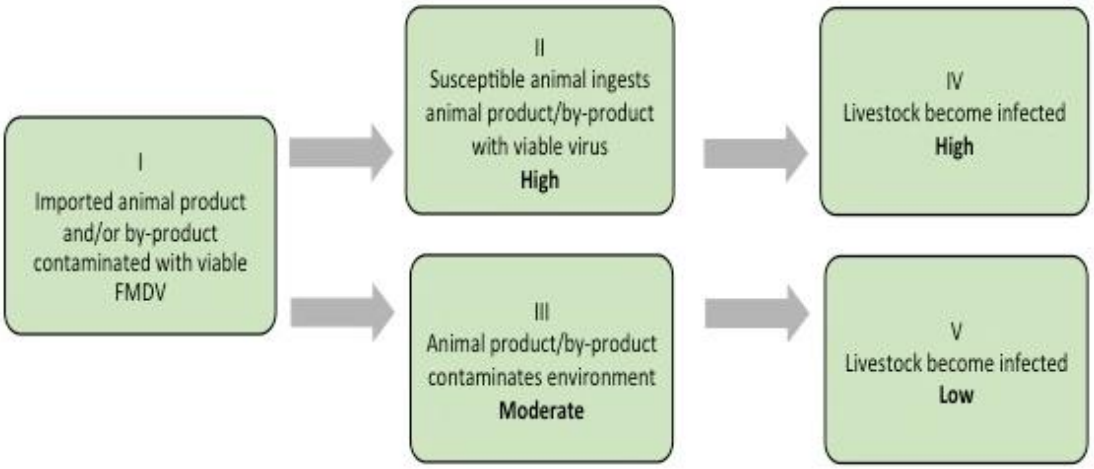


Figure 15. Risk pathway for the exposure of FMDV in SEA through trade of animal products and/or by-products (bold text refers to likelihood))

Please note that this risk pathway considers food wastes and swill feeding practices.

Information is lacking about the source, destination and volumes of the products entering SEA, particularly regarding the informal trade. However, previous risk assessments from other settings have identified the plausible routes by which livestock might be exposed to contaminated animal products as i) swill feeding, ii) landfill waste from restaurants (carried by scavengers) and iii) littering (inappropriate waste disposal).

According to EFSA, feeding contaminated food waste to pigs is the most efficient way of establishing disease. Pigs are easily infected by the gastro-intestinal route (Step IV) and, once infected, will excrete large viral loads into the environment, highly increasing the probability of spread (EFSA, 2006).

Given the origin of animal products and associated volume of trade there is a good chance that FMDV-contaminated food wastes are being given to pigs. Data collected during the mission to Myanmar and Vietnam suggested that farmers are giving food waste (restaurants and household) to pigs. Under the assumption that the livestock sector is similar across the region there is good chance that swill feeding is being practiced in SEA - swill feeding has been blamed for FMD outbreaks (EFSA, 2006; Scudamore, 2002; Wooldridge, Hartnett, Cox, & Seaman, 2006) (Step II).

Additionally, there are some other products, such as offal that are washed and cleaned before being cooked which pose a risk of environmental contamination (Step III). Given this indirect route of transmission the likelihood of a susceptible animal becoming infected is considered low (V).

The likelihood of a susceptible animal becoming infected with an exotic strain of FMDV through this pathway is considered high. **There is a high level of uncertainty** due to lack of knowledge on the precise nature of these products and their destination.

Wildlife

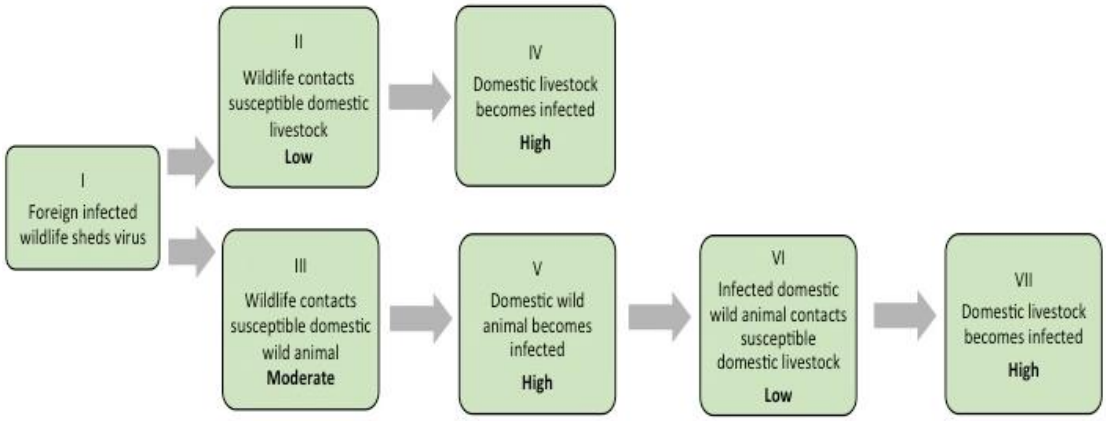


Figure 16. Risk pathway for the exposure of FMDV in SEA through wildlife (bold text refers to likelihood)

Some stakeholders from the public sector interviewed during the fieldwork trip commented that there is occasional contact between wild boar and domestic livestock during the dry season, when the water scarcity forces animals to congregate around the available water sources. However this was not a common observation and most people interviewed did not mention it (Step II and VI). Contact between wildlife would be more likely (Step II). Although there is little scientific evidence on the role of wildlife in the transmission of the FMD (except for the African buffalo) (Weaver et al., 2013) this situation could pose a risk for the transmission of disease from wild animals to domestic livestock, as direct contact between animals is the major FMD transmission route (Steps IV, V and VII). One possible explanation for the outbreak in Bulgaria in 2011 was roaming wild boars (Alexandrov et al., 2013).

According to the data collected the risks associated with this pathway would be higher during the dry season. Provided that the reported wildlife contact with livestock occurs infrequently, **the risk of exposure by this pathway is Low**, **with a high uncertainty level** considering the lack of studies on incidence of FMD in wildlife, their role in the epidemiology of the disease and its geographical distribution.

Human

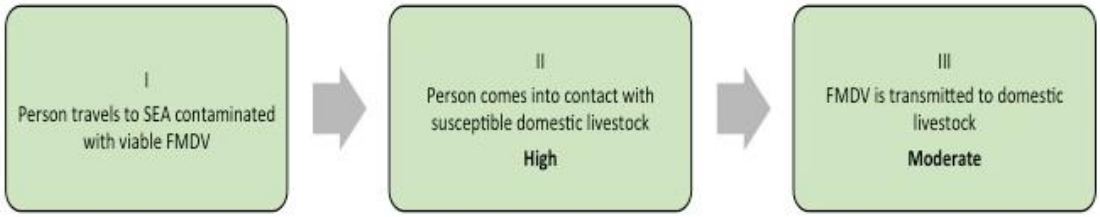


Figure 17. Risk pathway for the exposure of FMDV in SEA through human movement (bold text refers to likelihood)

Given the high proportion of people that work in agriculture (table 17) and intense animal trade it is likely that travellers will at some point come into contact with domestic livestock (Step II) – be it for working purposes (traders and "walkers") or for visiting relatives. The likelihood of the virus transmission will depend on the route of infection, contamination load and species (EFSA, 2006). However being an indirect route the probability of an animal becoming infected is lower than the one assumed for the direct contact (Step III).

Even though travellers could probably be in contact with susceptible livestock, given the indirect transmission route **the risk of exposure of FMDV through human movement is considered moderate. There is a high level of uncertainty** around this estimate due to lack of data.

Feed/Fodder

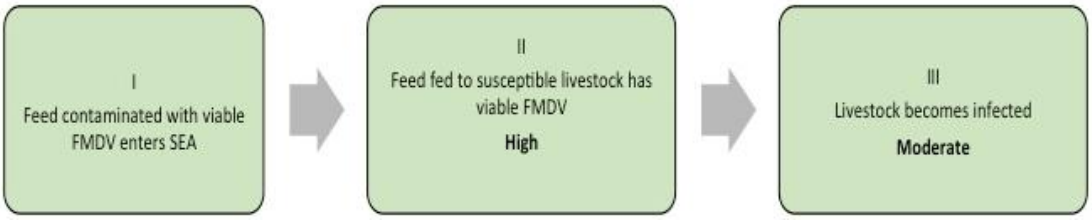


Figure 18. Risk pathway for the exposure of FMDV in SEA through feed/fodder (bold text refers to likelihood)

As seen previously the virus can survive up to 15 weeks in feed (Davies, 2002). In the event that the feed reaches SEA it would most likely end up being fed to animals (Step II). Depending on the species and contamination load the likelihood of an animal getting infected would vary. However this sort of product will most likely be used to feed ruminants, which are more susceptible to infection by the respiratory tract. Thus it is assumed that the likelihood of viral transmission by the ingestion of feed/fodder is moderate (Step III).

The exposure through this risk pathway is considered moderate. There is however high uncertainty around this estimate (no data on the purpose of these products and studies on the actual risk they pose with regards to FMD).

Vehicle

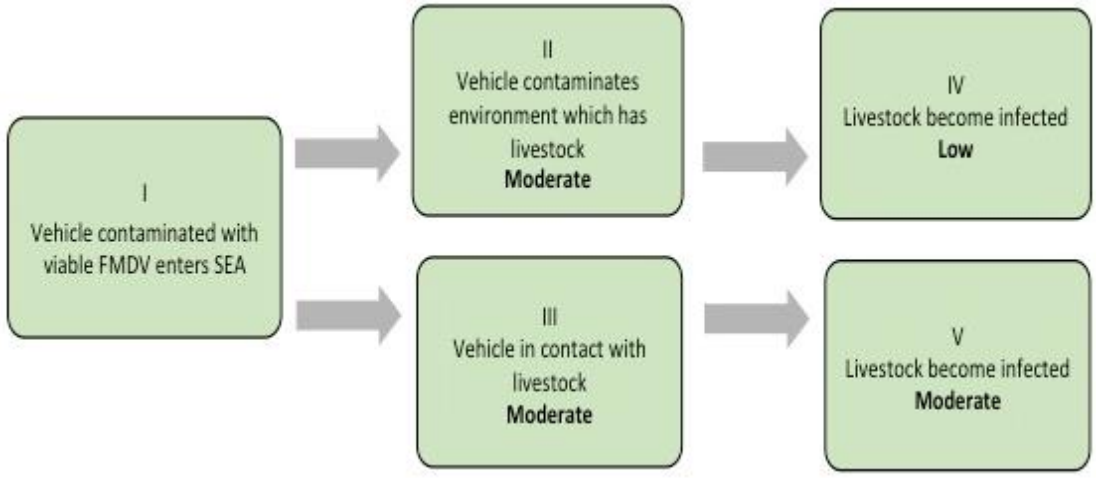


Figure 19. Risk pathway for the exposure of FMDV in SEA through vehicles (bold text refers to likelihood)

Once in SEA, and being a farm vehicle, there would be a chance of it contacting animals or grounds where

animals usually are as few biosecurity measures are in place (data collected during fieldwork trip) (steps II and III).

The infection of susceptible animals through indirect routes is less likely to occur (EFSA, 2006). Animals would be at higher risk of infection if in direct contact with the vehicle as it would probably have materials that pose higher risk (eg. manure). The likelihood of an animal becoming infected is taking this into account (Step IV and V).

The likelihood an animal becoming infected through this exposure pathway is moderate with a high level of uncertainty as a result of the unavailable data and assumptions made.

Annex 4: Assessment of the performace of veterinary services in South-East Asia

For the consequence assessment, we used the information available on the performance of the Veterinary Services as assessed by the OIE PVS evaluation and gap analysis as a proxy of the capacity for early detection and response to an incursion of exotic FMD virus. Of the 47 critical competencies assessed in the PVS 13 were selected to represent the assessment of surveillance and response (Table 18, next page).

Information about the performance of the veterinary services is available for countries that have been evaluated through the OIE-PVS evaluation and gap analysis. Such PVS missions have been conducted for most of the South-East Asian countries except for Brunei Darussalam, Malaysia and Singapore (OIE SRR-SEA based on Report, 2014). With regard to early detection and rapid response to an incursion of exotic FMD virus, the critical competencies outlined in Table 19 are particularly relevant.

When compiling this assessment on critical competencies in relation to early detection and rapid response, countries are roughly divided into three categories: poor (9-13), moderate (5-8) and good (0-4) capacity of the veterinary services (Table 19). No information is available for Brunei Darussalam, Malaysia and Singapore. It was deemed appropriate to categorize Brunei Darussalam and Malaysia in the 'Moderate' and Singapore in the 'Good' category.

Table 189. Assessed performance of veterinary services using the PVS evaluation reports.

Country	Issues with regard to critical competencies	Category	Intra-regional trading (livestock and animal products)
Brunei Darussalam	.	Unknown	Limited
Cambodia	12	Poor	Extensive
Indonesia	10	Poor	Limited
Lao PDR	11	Poor	Extensive
Myanmar	9	Poor	Extensive
Malaysia	.	Moderate	Extensive
Philippines	4	Good	Limited
Singapore	.	Good	Limited
Thailand	1	Good	Extensive
Timor Leste	6	Moderate	Limited
Vietnam	9	Poor	Extensive

Table 19. Overview of critical competencies assessed during PVS evaluation missions that were considered relevant for the early detection and response to an incursion of FMD virus into SEA.

Critical competency		Assessment for SEA - 2014	CA	ID	LA	MM
			PH	TH	TL	VN
I-5	Stability of structures and sustainability of policies	Lack of legal authority of VS	x	x		
		Introduction of a decentralization/autonomy policy with negative impact on chain of command (ID)				
I-6A	Internal coordination (chain of command)	Lack of direct chain of command with provincial/district level, with potential negative impact on disease surveillance and control	x	x	x	
					x	x
I-8	Operational funding	Routine activities depending on project due to limited operating funds	x	x	x	x
			x		x	x
II-1AZ QQ	Access to laboratory diagnosis	In general there is a good infrastructure for laboratory diagnosis, thanks to technical assistance from donor agencies				
		Main weaknesses are the lack of national budget, insufficient staff and the incompatibility between databases between laboratory and the VS				
II-3	Risk analysis	There is lack of formal or documented risk assessment	x	x	x	x
		And lack of data to inform risk assessment	x		x	
II-4	Quarantine and border security	Variety of issues, from lack of resources to enforce control at borders, improper inspection procedures, uncontrolled cross-border movements of animal and animal products to lack of a data management system	X	x	x	x
			X		x	X
II-5A	Passive surveillance	Gaps in reporting system, shortcomings in outbreak investigation, insufficient supervision of paraprofessionals and community animal health workers to limited active surveillance programmes and often dependent on external funding and lack of electronic data management system	X		x	x
II-5B	Active surveillance		x		x	X
II-6	Early detection and emergency response	Delays in reporting from field level	x	x	x	
		Contingency plans limited to certain diseases and lack of simulation exercises				
		Inadequate funding for contingency				
		Weak authority and capability of VS				
II-7	Disease prevention, control and eradication	Insufficient measures employed such as active surveillance, movement control, biosecurity, preventive vaccination, etc.	x		x	x
		Lack of mid- and long-term strategy for disease control, and related lack of funds				x
II-11	Emerging issues	Lack of pro-active monitoring	x	x	x	X
		Activities mostly related to emerging issues mainly driven by donor projects or regional meetings		x		x
II-13A	Animal identification and movement control	No national animal identification systems, thus lack of traceability of live animals, while there are extensive unregulated movement of animals	x	x	x	X
						x
III-2	Consultation with stakeholders	Lack of consultation with livestock smallholders	x	x	x	X
		Consultative mechanisms are not regulated nor formalized			x	X
III-4	Accreditation/authorization/delegation	Lack of legislative framework and authority to delegate official tasks to private sector	x	x	x	X
		Insufficient supervision of paraprofessionals and CAHWs				x

CA = Cambodia, ID = Indonesia, LA = Lao PDR, MM = Myanmar, PH = Philippines, TH = Thailand, TL = East Timor, VN = Viet Nam

Annex 5: Risk-assessment workshop, 5 April 2017, Bangkok, Thailand

The Regional Workshop to wrap-up and review the field investigation findings was conducted on 5 April 2017. The workshop was an avenue to discuss the objectives of the study and to further gather/validate information on risk pathways.

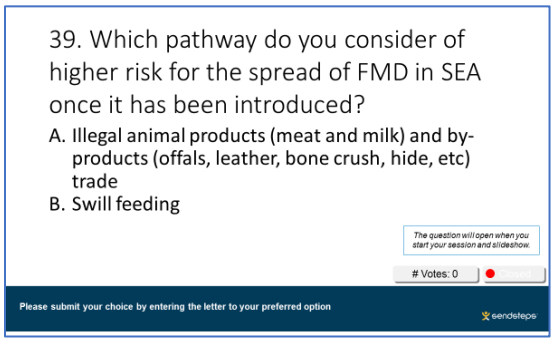
Participants were key persons in national veterinary services working on FMD surveillance/control or animal international trade/quarantine. Participants were present from Cambodia, China, Lao PDR, Vietnam and Thailand, with notification from Myanmar and Malaysia that the time was too short to attain Ministerial approval to attend.

The workshop's objectives were to:

1. Update participants on the current regional FMD situation as well as challenges posed by exotic FMDV strains
2. Review and validate information of risk pathways collected from field investigations
3. Discuss and make recommendations on risk mitigation measures
4. Exchange experiences and lessons learned from FMD surveillance and control.

The approach taken during the workshop was one of consultative sessions by use of an audience response system. For each of the three components of risk-assessment (Release, Exposure and Consequence), the putative risk-pathways were pair-wise ranked by the participants. For a total of 77 questions participants had to vote which of the two pathways displayed they considered the higher risk in the risk-assessment of FMD incursion into the region of SEACFMD.

This approach minimised the risk that a person's collected opinion would be unduly influenced by someone else's. After each pairwise ranking (each question), the results of the workshop participants were displayed as a means to provide immediate feedback.



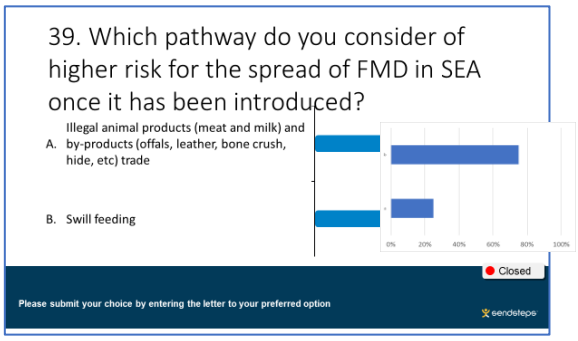


Figure 20 - Left. Example of question 39, with two risk pathways for spread (exposure) of FMD. Figure 21 - Right. Results were shown in the graph (the percentages here are given as an example and are not related to the output of the workshop).

Results of pairwise ranking

Release pathways

With regard to Release risk pathways, the workshop participants regarded the informal live animal movement the highest risk pathway for release of exotic FMD viruses into SEA (Risk score 107). When

appearing in a pair-wise comparison, this option was often anonymously selected as the highest risk of the two presented.
Second (risk score 87) came informal import of animal products such as meat, milk but also hides, bone-crush, leather etc). Interestingly, when participants had to choose between informal animal products and legal live animal movement, 7 out of 19 selected live animal movement as a higher risk.
Legal live animal movement was ranked third, closely followed by 'fomites', while the other risk pathways (human movement, legal animal products, wildlife) were ranked lowest.

Risk score	Release risk pathways	Human	*question*	Fomites	*question*	Illegal livestock	*question*	illegal animal products	*question*	legal livestock	*question*	legal animal products	*question*	wildlife
			1	15	*7*	19	*8*	19	*9*	11	*10*	7	*11*	7
35	human movement (immigration, tourism)			3		0		0		8		12		12
					2	18	*3*	15	*4*	11	*5*	4	*6*	7
55	fomites (materials, equipment, vehicles)					1		4		8		15		12
							12	4	*#*	0	*14*	1	*15*	0
107	illegal live animal movement							15		18		18		19
									#	7	*17*	1	*18*	0
87	illegal animal products (meat and milk) and byproducts (off-all, leather, bone crush, hide, etc)									12		18		19
											19	1	*20*	4
62	legal live animal movement											18		15
													21	5
28	legal animal products (meat and milk) and byproducts (off-all, leather, bone crush, hide, etc)													14
23	domestic animal in contact with wildlife													

Figure 22. Results of pairwise ranking of release risk pathways

Exposure pathways

For risk pathways related to Exposure or Spread within SEA, informal live animal movements were again considered the highest risk (risk score 134) and the participants were unanimous about this being the highest risk. Second came informal animal products (risk score 107).

The next level of risks were considered 'fomites', 'legal live animal movements' and 'communal grazing', all three related to livestock movements within SEA. These movements of livestock may be local as well are across longer distances within a country or between countries.

The lowest level of risk was attributed to 'legal animal products', 'contact with wildlife' and 'swill feeding'.

Risk score	Exposure risk pathways	Fomites	question	illegal animal movement	question	illegal animal products	question	legal animal movement	question	legal animal products	question	wildlife	question	swill feeding	question	communal grazing
			22	19	23	16	24	9	25	5	26	3	27	4	28	7
71	fomites (materials, equipment, vehicles) and human movement			0		3		10		14		16		16		12
					29	1	31	1	30	0	32	1	34	0	33	1
134	illegal live animal movement					19		19		20		19		20		18
							35	4	36	0	37	2	39	1	38	2
107	illegal animal products (meat and milk) and byproducts (off-all, leather, bone crush, hide, etc)							16		20		18		19		17
									40	1	41	5	43	5	42	10
73	legal live animal movement									19		15		15		10
											44	6	46	8	45	13
39	legal animal products (meat and milk) and byproducts (off-all, leather, bone crush, hide, etc)											14		12		7
													48	8	49	18
31	domestic animal in contact with wildlife													12		2
															47	18
28	Practice of swill feeding															2
69	communal grazing															

Figure 23. Results of pairwise ranking of exposure risk pathways

Improving early detection and rapid response

In the third consultative session, participants were asked to reflect on where to improve the capacity for early detection and rapid response. The options provided were components of surveillance (farmer awareness, notification and reporting, outbreak investigation, laboratory diagnostics, epidemiologic analysis) and contingency (general preparedness, emergency vaccination, animal movement restrictions).

The results clearly showed that participants considered enforcement of animal movement restrictions and general preparedness as the most important areas for improvement. These issues typically relate to national and international coordination.

Second came elements of the surveillance 'Raising awareness with farmers', 'strengthening notification and reporting', 'local outbreak investigation' and the capacity to implement emergency vaccination.

Third came the need to improve diagnostic and epidemiologic capacity.

Other than with the Release and Exposure risk pathways, there were fewer pair-wise comparisons that brought about unanimous responses.

Score	Where to improve to strengthen early detection and rapid response	Awareness	question	notification and reporting	question	local investigation	question	lab diagnostics	question	Epi capacity	question	Prepared ness	question	Emerg vaccination	question	Animal movement restrictions
			50	6	51	7	52	7	54	5	55	15	56	11	57	17
65	Raising awareness on risks of FMD with farmers and other stakeholders			13		12		12		14		4		8		2
					77	12	70	9	53	2	67	12	69	12	68	13
60	Strengthening the notification and reporting within the veterinary services					7		10		17		7		7		6
							59	7	58	5	66	15	64	9	65	15
63	Improving the capacity to conduct outbreak investigation (local level)							12		14		4		10		4
									60	9	73	15	71	13	72	18
44	Improving the diagnostic capacity of the central laboratory									10		4		6		1
											61	16	75	9	74	14
39	Strengthen the epidemiologic capacity to analyse, interpret and report the FMD situation											3		10		5
													62	6	76	10
95	Improving the general preparedness for a FMD outbreak (contingency plan, roels and responsibilities, vaccine bank, etc)													13		9
															63	13
66	Implementing a quick response by emergency vaccination (men on the ground, cold chain, etc)															6
100	Enforcing the implementation of animal movement restrictions when there is a FMD outbreak confirmed															

Figure 24. Results of pairwise ranking of strengthening early detection and rapid response.

As a summary, the results of the workshop can be depicted as follows:

Risk pathway	Release	Exposure	Where to improve early detection and rapid response	
Illegal livestock	107	134	Animal movement restrictions	100
Illegal animal products	86	107	Preparedness	95
Legal livestock	62	73	Emergency capacity	66
Fomites*	56	71	Awareness	65
Communal grazing		69	Local investigation	63
			Notification and reporting	60
Human movements	35			
Legal animal products	28	39	Laboratory diagnostics	44
Contact with wildlife	23	31	Epidemiology capacity	39

Figure 25. Overall results of pairwise ranking for release and exposure pathways, and strengthening early detection and rapid response.

**for the Exposure, the risk pathway of fomites included human movements where human movement was asked separately for Release*