THESIS

RISK ANALYSIS OF THE POTENTIAL INTRODUCTION OF
AFRICAN SWINE FEVER VIRUS INTO THAILAND
BY PIG PRODUCTS FROM ITALY, 2015 (QUALITATIVE RISK ASSESSMENT)

Submitted by

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ABSTRACT

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African swine fever (ASF) is a serious contagious pig disease that produces a wide range of clinical signs and lesions. ASF virus (ASFV), the causative agent for ASF, can spread very rapidly. Fortunately, ASF has never been reported in Thailand. The National Institute for Animal Health (NIAH), Department of Livestock Development (DLD) has done an ASF survey and reported zero sero-prevalence. Thailand, however, has imported live pigs and pig products from many countries; most notably in 2015 approximately 4 million kilograms were imported from Italy where ASF outbreaks occurred on the island of Sardinia, Italy during the same year. Since ASF is exotic to Thailand and likely to be introduced into the country, risk analysis can be a tool for estimating the likelihood of an introduction and consequences of the disease, and for revealing any gaps and preparing preventive measures. This study is divided into three sub-studies: assessing risk of ASFV introduction into Thailand by importing pig products from Italy in 2015 – development of an approach, estimation of risks of ASFV introduction into Thailand by importing pig products from Italy, 2015, and qualitative risk assessment of ASFV introduction into Thailand by importing pig products from an endemic country based on different hypothetical scenarios. Also, risk analysis of ASFV of this study should be considered as a model for DLD to improve strategy and policy for preventing new emerging and reemerging diseases.

The first step in the process was the development of the conceptual framework of risk analysis composed by generating a general risk pathway and risk question, identifying a hazard, developing a physical pathway and scenario trees, assessing the risk, mitigating the risk, and communicating the risk based on OIE risk analysis for imports. Also, eight possible routes of ASFV introduction were generated by utilizing information from DLD and from scientific publications. Using these routes and the OIE animal disease reporting system and DLD trading database, the specific risk question was generated: “What is the risk of introducing ASFV into Thailand by importing pig products from Italy in 2015?”

The second step in the process was analysis of risks according to the risk question and specific pathway based on DLD official documents, the OIE WAHIS database, EU commission decision, EU legislation, EU council directive, exportation and importation requirements and government guidelines, scientific literature, and expert opinions. The potential introduction of ASFV by importing pig products from Italy in 2015 was identified as a hazard to Thailand in the hazard identification step. However, the risk of introduction was deemed “Negligible” by qualitative risk assessment. Risk mitigation giving recommendations to minimize the risk based on weak points identified for the high or moderate likelihood of introduction and significant consequences, and also effective means of communicating the risk, was provided.

The third step in the process was qualitative risk assessment in different hypothetical risk mitigation scenarios whereby four scenarios were developed to show how the mitigations would change the risk based on the assumption that the virus was in the products. The first scenario was a worst-case scenario, the second was reducing risk at release assessment, the third was reducing risk at exposure assessment and the fourth was reducing risk at consequence assessment. Based on initial information from the qualitative risk assessment and the descriptive partial budget, the second scenario would provide the most efficiencies risk mitigation.

Even though there are limitations, this study is a good fundamental project to reveal gaps to the country and stakeholders. Therefore, the lesson learned from this project is that DLD should improve laboratory technique to screen the disease in the products at border, collaboration among stakeholders in government, promote an increase in the sizes of farm and develop surveillance system of emerging diseases. All are critically necessary to decrease a risk to achieve the best way to prevent the introduction of ASFV and other emerging/reemerging diseases into Thailand. Moreover, improving the approaches of DLD officers in risk analysis and integrating and performing risk analysis to support DLD's strategy and missions would work best for regional and international certification in risk analysis.

ACKNOWLEDGEMENTS

This thesis was developed to provide initial information to identify gaps and provide recommendations to minimize the risk of introduction of African swine fever virus by importing pig products into Thailand. The project was supported financially by the Royal Thai Government Scholarship.

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AUTOBIOGRAPHY

Dr. Tosapol Dejyong is a veterinary officer in the Bureau of Disease Control and Veterinary Services and Department of Livestock Development (DLD), Thailand. He was graduated Doctor of Veterinary Medicine (DVM) with First Class Honors from Kasetsart University, Bangkok, Thailand. While he was a student, he was a president of the Veterinary Student Club of Kasetsart University in 2011 and a president's advisor of that same in 2012. Also, he was a subcommittee member of the Kasetsart University Veterinary Alumni Association in 2011.

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Tosapol Dejyong, DVM

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER I.
INTRODUCTION

African swine fever (ASF) is a highly contagious disease that can infect swine species such as *Sus domestica* (permanently captive and farmed free-range pigs), European wild boars, American wild pigs and African wild pigs etc. [1]. African swine fever virus (ASFV) is an enveloped DNA virus in family Asfarviridae and genus Asfivirus. There is only one serotype of ASFV. However, there are 16 genotypes and different strains. ASFV is highly resistant to the environment especially in blood, excretions, pork and pork products such as sausage, ham, salami etc. ASFV is durable at low temperature for 3-6 months. It can be transmitted by direct contact with infected animals, indirect contact with fomites, and tick vectors and infected animals can become carriers for ASF [2]. As per the World Animal Health Organization (OIE) report, ASF outbreaks have occurred in Benin, Burkina Faso, Guinea-Bissau, Italy, Lithuania, Nigeria, Poland, Russia, Togo, Ukraine, and Zambia during January-August 2015 [3].

Pig production in Thailand is very important to the economy of the country, not only for consumption inside the country, but also for exporting to other countries such as Russia and countries neighboring Thailand. In 2014, the numbers of pigs produced in Thailand were 5,876,562 fattening pigs, 3,054,758 breeder pigs and 580,069 other pigs. Thailand spent about 88,205,100 bahts (Approx. US$ 2,500,000) on importing pigs and pig products in 2014 [4].

Major swine diseases that are frequently reported in Thailand are Classical Swine Fever and Porcine Reproductive and Respiratory Syndrome. ASF has not been reported in Thailand. Thailand, however, has imported breeder pigs and pig products from many countries including genetic materials and livers imported from Germany, South Korea, Brazil, and Denmark; skin and other visceral organs from Italy, the Netherlands, Germany, and Spain. [5]. Illegal imported pig products for personal consumption are an important factor as well. ASF can have considerable socioeconomic impact owing to easy transmission and the highly contagious nature of the disease, and the potential scope of these effects on the pig industry in Thailand has not been studied. Risk analysis is the key to assess the likelihood of introduction of ASF into Thailand, improving the confidence of trading partners, and improving the export performance of the country. Furthermore, the risk analysis can be used to enhance control programs and surveillance systems of swine diseases in Thailand.

1.1. An overview of risk analysis in animal health international trading

1.1.1. Introduction of risk analysis

In business, engineering, or other endeavors, there are times when a decision must be made even when the information is incomplete or the situation is uncertain. The best decision has to come from a rational process with certain supportive information to reduce the likelihood that a negative outcome will occur in the future. When there is uncertainty, risk analysis is a way to support and/or facilitate a decision with the use of logical steps to identify the best solution.

According to the OIE terrestrial animal health code 2011, a risk is the chance of facing a loss or a harmful or damaging event. The high risk provide less possibility of success or earn less profit; conversely, low risk provides high possibility for success or to earn a high profit [6]. The analysis is an interpretation by a rational process or logical thinking. So, by definition, risk analysis is the logical way to estimate risks to minimize them. Risk analysis is mostly applied in business, however, there are a variety of other fields and disciplines where it can be very useful. Government scientists, for instance, can apply this approach when they launch projects which have a high impact on public and/or economic conditions.

1.1.2. Risk analysis for imports of animals and animal products

Risk analysis has been used in animal trading since the 1990s when the implementation of the World Trade Organization (WTO) Agreement on the Application of Sanitation and Phytosanitary Measures (the SPS agreement) occurred [7]. The SPS agreement is the compound of WTO for food safety in both animal health and plant health to protect the health of humans, plants, and animals among WTO members and avoid unfair or unnecessary impacts to trade. In the SPS agreement all analysis and measurement is to be based on science. Also, according to the SPS agreement scientific justification article 3&5, the measurement of international trade must be based on international standards or risk assessment [8]. Since SPS agreement requires scientific basis for assessing the risk, risk analysis has been used to support information for making the best decisions.

In addition, the WTO SPS agreement is concerned that international trading should consider animal health because trading live animals and animal products are highly risky activities in terms of spreading diseases between various parts of the world. Live animals, semen, embryos, and biological products can carry pathogens, so trade can be a way to transport pathogens from an endemic area to vulnerable areas. So, to minimize the risk of disease spreading, risk analysis has been used to assess the risk of introducing specific diseases as well as the consequences of disease introduction.

According to the World Organization for Animal Health (OIE) Terrestrial Animal Health Code and Aquatic Animal Health Code, risk analysis for imports of Animals and Animal products is the preferred method to manage the disease risks associated with the importation of live animals and animal products for human consumption, agriculture, industrial use, animal feeding, or medical reasons. There are two components of risk: likelihood and consequence.

Likelihood is the probability of an event or situation happening by chance. In animal trade, likelihood is the probability of a disease entering, establishing or spreading in the importing country. Consequence is a strong and often bad effect on something or someone. In the trade of animals and animal products, consequence/impact is the effect on animal or human health, the environment, public welfare and the economy [7].

For animal health issues, we can assess risks in animals by using likelihood and consequence based on the OIE handbook on Risk Analysis for imports of Animals and Animal products. Figure 1.1 shows risk analysis composed of four components: hazard identification, risk assessment, risk management and risk communication. These are explained more thoroughly in the next section.

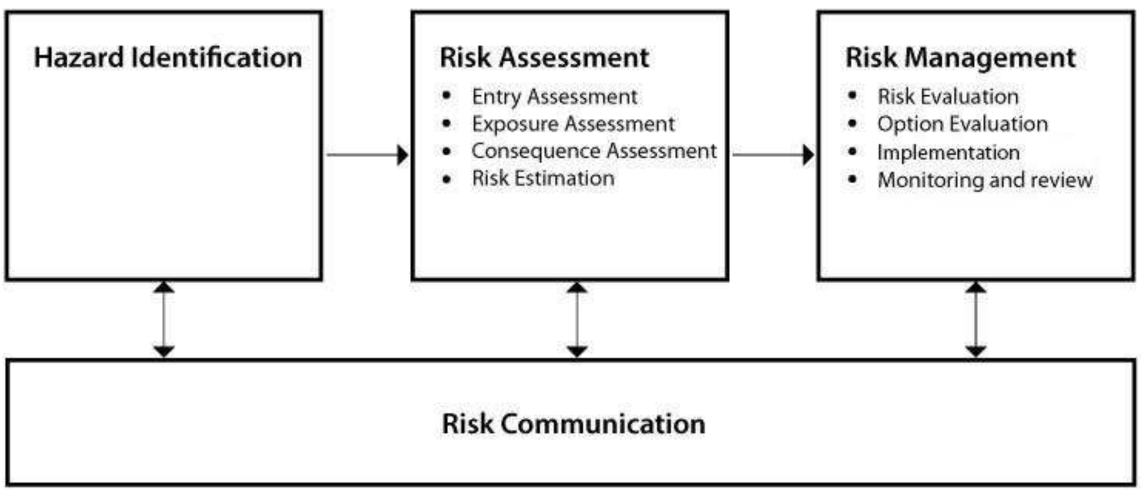

Figure 1.1. The structure of the OIE risk analysis process, [7].

1.1.3. Hazard identification

Hazard identification is the first step of risk analysis. The purpose of this step is to identify all the hazards, risks, or harm which could enter into the importing country. The OIE code defines a hazard as a biological agent, chemical agent, or physical agent. For trade of animals and animal products, hazards are identified by the OIE Terrestrial Animal Health Code and Aquatic Animal Health Code as a list of pathogens that are of concern. However, hazard identification is not just the list of diseases, but also takes into account scientific literature regarding the nature of the commodity or the degree of processing such as infectivity, pathogenicity, and modes of transmission. For instance, some gastrointestinal parasites are prohibited for trading, but the exportation of semen or embryos of specific hosts for these parasites is allowed since semen or embryos cannot transfer the parasites [7]. Another example is a pathogen that is not able to live in cooked meat is not considered a hazard for exportation of cooked products such as poultry meat for human consumption.

Scientific evidences are needed to identify a hazard such as,

1. Is the agent a hazard? If a disease is not classified as a potential hazard and is not in the OIE list of diseases of concerned for international trade, then no further steps in risk analysis are taken.

2. Is that merchandise able to carry the pathogenic agent? If the importation of embryos into the country is being considered, should you be concerned that gastrointestinal parasites, for example, are a hazard? The answer might be NO because embryos are not a merchandise or commodity that carries gastrointestinal parasites.

3. Is the disease present in either the exporting or importing country or both? Evidence from the authorities in the importing country such as surveillance information, surveys or OIE clarification, is needed.

1.1.4. Risk assessment

Once the disease of interest is identified as a potential hazard, the next step of risk analysis is risk assessment. Risk assessment is the process of evaluating the risks resulting from hazards, the likelihood of entry, and the biological, environmental and economic consequences which may occur in the importing country if the disease enters and spreads. Risk assessment can be done using qualitative and quantitative data depending on available information, time, budget, events etc. [7].

Qualitative risk assessment

Qualitative risk assessment is often used to quantify risks when the data may not be enough to make reliable calculations. The output for this assessment process is not numbers, but in terms that reflect probability. The likelihood/probability of the outcome or the magnitude of the consequences/impact are presented in qualitative terms such as “high”, “medium”, “low” or “negligible”. Qualitative risk assessment has the advantage of being faster to complete than the quantitative method. In addition, it can be applied in a wide array of circumstances. However, the disadvantages of qualitative assessment are that it is subjective, the conclusions are less profound, it does not provide a numerical probability of occurrence for an adverse event, and it results in less precise decision making [7, 9].

Quantitative risk assessment

Quantitative risk assessment of hazards expresses outputs in numeric form. The advantages of quantitative risk assessment are that the conclusions are more profound, and are better for making informed decisions. However, the disadvantages are that it requires more time and good quality data, and it cannot be applied in all circumstances, and quantitative outcomes are considered objective [7, 9].

Before moving to components of risk assessment, the physical pathway and/or the scenario tree (also called the biological pathway) should be compiled. The physical pathway is the graphical representation of commodity movement and is used to effectively communicate the process and to show the framework of the risk assessment. The physical pathway should be developed before creating the scenario tree. A scenario tree is similar as it is the graphical representation of biological pathways by which a hazard may be introduced into the country. It effectively communicates the framework of the risk assessment, and is more focused in the analysis as the likelihood of risk is estimated for each station of movement (node) [10].

Import risk assessment of OIE is composed of four steps which are release assessment, exposure assessment, consequence assessment and risk estimation.

Release assessment

This step evaluates the likelihood that the hazards can be introduced into the importing country. Each disease has different epidemiological characteristics so the biological or physical pathway must be described in order to identify the infecting or contaminating commodities [7].

Exposure assessment

This step evaluates how likely a susceptible host will be exposed to the hazard. Exposure describes the movement of the hazard after passing the border until domestic animals are exposed. Exposure assessment then describes the biological pathway to exposure of animals and humans in the importing country, estimates the likelihood of the exposure, and estimates the contagiousness of the hazard for the exposed animal or human [7].

Likelihood and uncertainty categories

Once the physical pathway and biological pathway or scenario tree have been developed and all possible nodes are estimated, the next step is to estimate the level of likelihood for each node in both release assessment and exposure assessment.

Table 1.1. Qualitative likelihood scale categories (Modified from USDA, 2013, [11].)

Category	Descriptor
High	The event has more than an even chance that the event will occur.
Moderate/Medium	The event does occur but is unlikely to.
Low	The event is very unlikely to occur.
Very low	The event is very rare to occur, but cannot be excluded
Negligible	The likelihood that the event will occur is insignificant: not worth considering

For qualitative assessment, the table above can be used to categorize the likelihood of risk (Table 1.1.). All supportive information for each node would be considered in order to estimate the likelihood of the event. For example, if laboratory testing for BSE at the farm level has a very high sensitivity so it is less likely to have a false negative, then we can infer that we are almost always able to detect non-infected animals, it is nearly impossible that BSE would be on the farm. Therefore, based on Table 1.1. the likelihood of risk is low.

Table 1.2. Uncertainty scale categories (Kasemsuwan, 2009, [12])

Levels	***Characteristic of evidences***
Low	Solid and complete data available; Strong evidence provided in multiple references; authors report similar conclusions.
Medium	Some but no complete data available; evidence provided in small number of references; authors report conclusions that vary from one another.
High	Scarce or no data available; evidence not provided in references but rather in unpublished reports or based on observations, or personal communication; authors report conclusion that are uncertain and that vary considerably.

Not only does the level of likelihood have to be identified, but also the level of uncertainty of the supportive information. In risk assessment, many different sources of data may be used to best identify likelihood for each node. Some nodes might have strong evidences such as scientific articles, government documents or databases, but some might be only from expert opinions. So when we tell someone the level of likelihood that risk would occur, we should also be able to say how confident we are by giving the level of uncertainty of the supportive information. Table 1.2. shows a good example of how we can estimate a level of uncertainty using uncertainty scale categories.

<u>Consequence assessment</u>

Consequence assessment is mostly about how pathogenic agents can successfully infect a susceptible host in the importing country and the impact of that hazard. However, consequences are not only to animals but also to people, the environment and the economy. The level of consequence will be estimated by related factors such as the dose of the pathogenic agent, host health status, establishment and spread of disease, control policies and assumed exposure of susceptible animals [7].

<u>The consequence assessment should be done by rational approach such as:</u>

- Estimating the likelihood of an animal becoming infected.
- Identifying the biological, environmental and economic consequences related to the entry and spread of the hazard.
- Estimating the likelihood that these consequences occur.

Consequence assessment is divided into direct and indirect consequences which can be estimated for many levels such as national, regional, province, village and farm.

Direct consequences

Outcomes for domestic animals include biological (morbidity, mortality, latent infection, etc.), production losses, public health consequences (zoonosis) and environmental consequences (loss of genetic diversity) [13].

Indirect consequences

Economic effects including control, prevention and eradication costs; veterinary service and surveillance costs; trade losses; compensation costs, etc. Social effects include reduced tourism, public amenity, etc.

<u>Risk matrix and risk estimation</u>

Once the level of likelihood has been estimated for each node then all the nodes must be combined to assess "the likelihood of risk of release". Similarly, we should be able to identify "the likelihood of risk of exposure". In order to do this, we need a matrix for combining the nodes.

Table 1.3. A matrix of rule for combining descriptive likelihoods (Modified from Guidelines for Import Risk Analysis, Biosecurity Australia, 2001, [14])

A matrix of "rules" for combining descriptive likelihoods					
	High	**Moderate**	**Low**	**Very low**	**Negligible**
High	High	Moderate	Low	Very low	Negligible
Moderate		Low	Low	Very low	Negligible
Low			Very low	Very low	Negligible
Very low				Negligible	Negligible
Negligible					Negligible

(See table 1.1. for the definitions of high-negligible)

As an example, if 5 nodes have been evaluated using release assessment and the likelihoods of risk are moderate for node 1, and low for node 2, 3, 4 and 5, then based on Table

1.3. the overall likelihood for the release assessment is very low. Finally, we can combine the two likelihoods (from release and exposure assessments) to get the likelihood of introduction of the hazard. However, to get an overall risk, the likelihood of introduction and the level of consequence would be combined by using risk estimation.

Risk estimation is the process of integrating release, exposure and consequence assessment to produce an overall measure of hazard. The results of risk estimation are described to the magnitude of the consequence of importing animals or animal products. Risk estimation's results also depend on the level of uncertainty and variability. In addition, the risk estimation process should be conducted together with scientific literature reviews [13].

Table 1.4. The table of risk estimation (Modified from Guidelines for Import Risk Analysis, Biosecurity Australia, 2001, [14])

Risk estimation matrix						
Likelihood of entry and	High likelihood	Negligible	Very low	Low	Moderate	High
	Moderate	Negligible	Very low	Low	Moderate	High
	Low	Negligible	Negligible	Very low	Low	Moderate
	Very low	Negligible	Negligible	Negligible	Very low	Low
	Negligible	Negligible	Negligible	Negligible	Negligible	Negligible
		Negligible	Very low	Low	Moderate	High Impact
	Consequence of entry and exposure					

Risk estimation is all about "likelihood" and "consequence". For example, introduction of a hazard may have a very low likelihood but it may carry high consequences if it is introduced. For instance, imported animals or animal products can carry BSE especially in the brain, bone marrow, or related nervous tissue. Importing only meat might have a very low likelihood that it will introduce BSE into the importing country. However, because BSE is a high impact disease the consequences of introduction, should it occur, have to be considered very seriously. The meat should be tested to prove that the product is not contaminated with nervous tissue.

As the table above (Table 1.4.) illustrates that the risk estimation matrix is used to integrate likelihood and consequence to estimate whether each factor is a negligible factor or not. The risk estimation can be converted to scores that help the assessor understand the results more clearly.

1.1.5. Risk management

The main aim of the entire risk analysis process is to manage and reduce the risk. Risk management uses the findings from hazard identification and risk assessment to help decision makers choose the most appropriate options for mitigating the risk as much as possible. The risk management options can be classified into several groups outlined below [15]. The term risk mitigation is also used. The goal of risk mitigation is to reduce the risk of each node. According to the OIE, [7], import risk management is the process of determining and implementing measures to change the risk to an "acceptable risk".

1. Acceptance: Do nothing. This option is used for low-likelihood low-impact scenarios. However, the decision maker should still consider risk mitigation or avoidance options.

2. Increase: Spending more necessary resources in order to minimize the risk.

3. Get more information: The risk analysis process can describe the uncertainty, so if some uncertainty is due to the lack of information, then collecting better input data is important for conducting future analyses.

4. Avoidance (Elimination): This option is used for high-likelihood high impact hazards. It would be necessary for the importing country to reject the commodity.

5. Reduction (Mitigation): This option reduces the risk by training personnel, using new technology.

1.1.6. Risk communication

Risk communication is primarily for communicating risk to all stakeholders. This step should start at the time risk analysis begins. In order to support risk analysis successfully, all stakeholders should understand and agree to the same point of view. Participants in risk communication for import risk analysis include veterinary administrations, international organizations, importers, exporters, producers, famers, consumers, academic institutions, and social media [7].

The goals of risk communication are:

- To exchange information between all stakeholders (two-way communication) especially stakeholders outside the risk analysis team.
- To provide information from each step of the risk analysis to specific stakeholders.
- To promote consistency and transparency in implementing risk management.
- To maximize the effectiveness and efficiency of the risk analysis.
- To increase the relationship among stakeholders.
- To improve public awareness about importing commodities.

1.2. Comprehensive review of African swine fever

1.2.1. Introduction of African swine fever

African swine fever (ASF) is a highly contagious disease that can infect all swine species. ASF is mainly reported in Africa and Europe; and it causes significant problems for the pig industry due to the high case-fatality rate which can be close to 100%. Natural reservoir hosts could be wild pigs and *Ornithodoros* sp. ticks. ASF spreads among pig populations via direct contact such as with secretions and tissues of an infected pig, and also the oral-nasal route. Indirect transmission can also occur via fomites and vectors such as *Ornithodoros* sp. ticks. The ASFV can survive in pH 3.6-11.5. This virus is inactivated at 56 degrees Celsius for 70 minutes or 60 degrees Celsius for 20 minutes. ASFV can live a few days to a few months in uncooked pork, pork products, blood, feces and tissues [16].

1.2.2. History of the disease

African swine fever was first identified by R. Eustace Montgomery in 1910 (Published in 1921). At that time, Montgomery described epidemiological characteristics of ASF in East Africa, summarized as follows: ASF associates with wild pigs, and this disease is not related to fomites or movement of pigs. Also, ASF can be transmitted via *Suidae* species or perhaps by vectors (which were unknown at that time). Clinical signs of ASFV infection are pyrexia and an infected pig develops viremia. Later was observed that this infection can be directly transmitted between wild and domestic pigs. Montgomery could identify the difference in the clinical and pathological characteristics of ASF from Classical swine fever (CSF). After Montgomery discovered ASFV, W.A. Malmquist who was working in Kenya in 1950, discovered haemadsorption (Had) and cytopathic effects of ASF and successfully cultured ASFV. These findings stimulated study of diagnostic techniques, serology, pathogenesis, immunology, epidemiology and molecular biology, and much more [17].

The first reported outbreaks of ASF were in Kenya in 1914, and since then a link between wild pigs and domestic pigs in the transmission of ASF has been verified. In addition, since 1960 ASF has spread to many countries in Africa and Europe. The first outbreak in Europe occurred in Portugal in 1957 and second was in the Iberian Peninsula in 1960 [18]. Today ASF outbreaks still occur among wild and domestic pigs in both African and European countries. Because ASF is a highly contagious disease that can cause huge problems across the globe, the World Animal Health Organization (OIE) has added ASF to the territorial animal health code for control, prevention, and international trade. The OIE is responsible for minimizing any epidemic of ASFV [1].

1.2.3. Etiology and ecology

African swine fever virus (ASFV) causes African swine fever (ASF) and is a double-stranded deoxyribonucleic acid (dsDNA) virus in genus *Asfivirus*, family *Asfarviridae* (ASFV had previously been in the *Iridoviridae* family). ASFV is the only DNA virus that is arthropod-borne (arbovirus) [16]. ASFV is large, about 200 nm, and is a lipoprotein-enveloped, icosahedral, double-stranded DNA whose genome encodes 160 – 175 genes [16]. In addition, restriction enzyme has been used to identify viral genotypes of ASF; this is important because clinical signs and virulence vary depending upon the genotype [2].

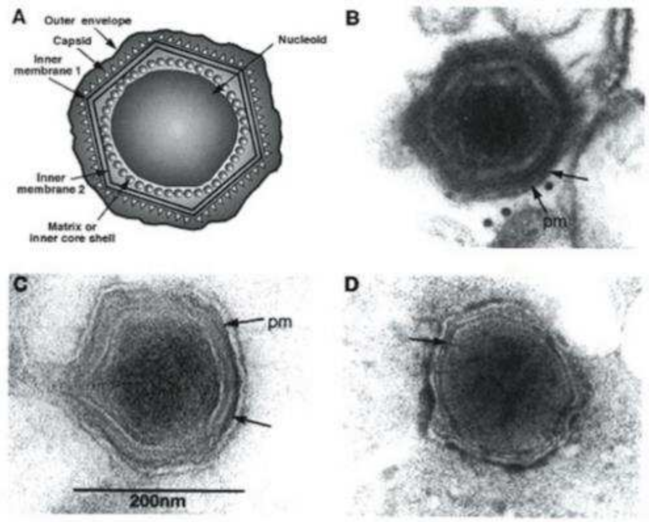

Figure 1.2. ***Asfarviridae*****, Afican swine fever virus, picture from ICTVdB, 2002**

There are different names for ASF that depend on the region of the outbreak, such as Pesti Porcine Africaine, Peste Porcina Africana, Pestis Africana Suum, Maladie de Montgomery, Warthog Disease, Afrikaanse Varkpes, and Afrikanische Schweinepest [16].

Species susceptible to ASFV include all those in the *Suidae* family such as domestic pigs, wild boars, warthogs (*Phacochoerus africanus*), bush pigs (*Potamochoerus porucs*), and giant forest hogs (*Hylochoerus spp*.). Reservoir hosts and carriers are mainly wild pigs, warthogs and *Ornithodoros* sp. ticks. Virus titers in pigs is low, however, infected ticks have high virus titers. As a result, some scientists believe that *Suidae* are accidental hosts of ASFV [16].

1.2.4. Current situation of disease distribution

As per the OIE report, during January-December 2015 ASF outbreaks occurred in Benin, Burkina Faso, Guinea-Bissau, Italy, Lithuania, Nigeria, Poland, Russia, Togo, Ukraine and Zambia (Figure 1.3., disease distribution map; Figure 1.4., disease outbreak map, OIE, WAHID). Most of the outbreaks in western Africa are different than in other zones as the free-ranging pigs spread the disease in that area. In contrast, on Sardinia island, Italy, the outbreak occurred in the wild pig population [3].

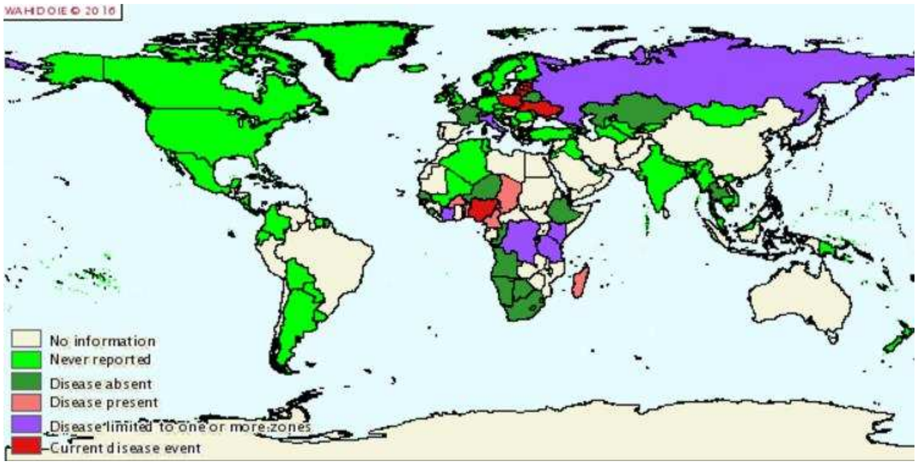

Figure 1.3. ASF distribution January – December 2015, (OIE, WAHID)

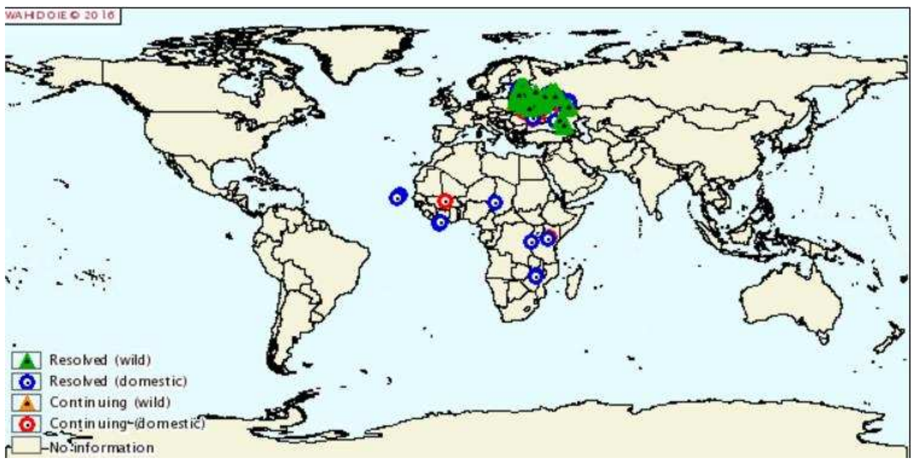

Figure 1.4. ASF outbreaks January – December 2015, (OIE, WAHID)

1.2.5. Transmission of ASF

ASF can be transmitted by direct contact, indirect contact, and also vectors. Direct contact mostly occurs via the oral-nasal route, especially when naïve pigs are near to infected pigs. ASFV can be found in all parts of the host's body including fluids, tissues, and particularly in blood. As a result, ASFV can be spread easily when pigs live in high-density environments with an infected pig. Indirect contact with ASFV can occur via fomites such as clothes, equipment, vehicles, and animal feed, also. ASFV can also spread to other areas in uncooked pig products. ASFV is highly resistant in environment [2]. According to scientific opinion on

African swine fever by the European food safety authority [19], ASFV can live in the domestic pig about 3-6 days, in wild pigs about 1-9 days (most infected pigs die), and in ticks for more than a year to about 5 years. In pig products, ASFV can live in meat and pork fat stored at 22-27 °C (salted) about 16 days, chilled meat about 100-150 days, in frozen meat and organs several years, in feces from 60-160 days, etc. ASFV can also be transmitted via the bite of infected *Ornithodoros* spp. soft ticks. Other bloodsucking insects are also able to spread the virus. For example, Stable flies (*Stomoxys calcitrans*) and mosquitos can carry high levels of the virus for 2 days [2].

1.2.6. Incubation period

The incubation period of ASF is dependent upon the route of transmission. Naïve pigs show clinical signs ASFV infection about 5 to 19 days after direct contact and less than 5 days after a bite from an infected tick [2].

1.2.7. Resistance of ASFV

African swine fever virus can survive in very low temperatures; About 56° degrees Celsius for 70 minutes, or 60° Celsius for 20 minutes is needed to destroy the virus. The virus cannot survive in pH <3.9 or >11.5; however, the virus can live in pH 13.4 in serum. Many chemicals and disinfectant can be used to destroy the virus such as, ether, chloroform, 8/1000 sodium hydroxide, hypochlorites, 2.3% chlorine, 3/1000 formalin, 3% ortho-phenylphenol and iodine compounds [16].

1.2.8. Clinical signs

There are four clinical forms of ASF, per-acute, acute, sub-acute and chronic depending on the virulence of the virus with which pigs are infected [20]. Less virulent ASFV can cause milder signs which might be confused with other disease. The per-acute from occurs with a highly virulent virus and the pigs immediately die or are moribund after a high fever (death before seroconversion). The acute form is characterized by high fever (40.5°C–41.5°C), abortion, leucopenia, anorexia, bloody diarrhea, thrombocytopenia, and erythemic skin or cyanosis. The morbidity rate is about 100%, and the case fatality rate is close to 100%; recovered pigs can be carriers of the ASF virus. Also, because of the high virulence of the acute form, most infected pigs die before developing seroconversion. The sub-acute form is caused by a moderate to low virulence virus. Pigs show less intense clinical signs, a slight fever, and the mortality rate is 30-70% (high in young pigs, low in older pigs) and survivors can become carriers. Infection with low virulence virus causes the chronic form of ASF which has no specific clinical signs or lesions. Pigs might develop a mild fever, pregnant sows may abort, there may be necrotic skin lesions. Even with the subacute form of ASF, surviving animals can become carriers [2, 16].

1.2.9. Post mortem Lesions

Gross lesions depend on the virulence of virus and can be variable and confused with other diseases. With the per-acute and acute forms most pigs do not develop any specific lesions because they die within a few days. However, in acute form they might develop bluish-purple discoloration or hemorrhages in the skin and signs of bloody diarrhea or internal hemorrhages. Internal organ hemorrhages may be found in the spleen, lymph nodes, kidneys, and heart because of viremia. If the animal is infected with a high number of virus, its spleen could be very large and dark red to black, which is a significant sign to differentiate this infection from CSF. The lymph nodes are also swollen, especially the gastro-hepatic and renal nodes. Heart lesions can include hydro pericardium with hemorrhagic fluid. Other organs such as lung, urinary bladder, and stomach can also develop hemorrhages, both petechial and ecchymosis lesions [2].

Infections with the moderate form can show lesions such as a slightly enlarged and hemorrhagic spleen (1.5 times normal size) and hemorrhages in the lymph nodes and kidneys [2].

Gross lesions with the chronic form of ASF include fibrinous pleuritis, pleural adhesions, hyperplastic lymphoreticular tissues, an emaciated carcass, skin necrosis, and skin ulcers [2, 16].

1.2.10. Pathogenesis

After naïve pigs are infected with ASFV the virus enters the body via the tonsils and lymph nodes and then it spreads throughout the body via the blood stream through viremia. Thereafter, the virus is able to be detected in all tissues, especially the spleen and lymph nodes, because ASFV infects the mononuclear phagocyte system (reticuloendothelial cellular elements) which occur in high numbers in the spleen and lymph nodes. The virus invades target cells (monocytes, macrophages) via endocytosis and then replicate in the cells causing lymphoid depletion. Hemorrhagic lesions are not caused by direct endothelial cell damage, but rather by ASVF replication in monocytes and macrophages so that endothelial cells are stimulated to produce cytokines. The cytokines combined with thrombocytopenia are the main factors causing hemorrhages in organs [21].

1.2.11. Differential diagnosis

Clinical signs and lesions of ASF are typical of other viremic diseases; there are no signs that specifically identify the disease. There are several diseases which might show similar clinical signs and lesions in infected pigs [22], such as Classical Swine Fever (hog cholera), Acute Porcine Respiratory and Reproductive Syndrome (PRRS), Porcine dermatitis and nephropathy syndrome, Erysipelas, Salmonellosis, Eperythrozoonosis, Actinobacillosis, Glasser's disease, Aujeszky's disease (Pseudorabies), Thrombocytopenic purpura, Warfarin poisoning and heavy metal toxicity.

1.2.12. Diagnosis

To diagnose ASF the best is to identify the ASFV by laboratory examination and to observe the pattern of the disease outbreak, morbidity, and mortality with clinical signs and post mortem lesions.

Identification of the agent

When ASF is suspected, the blood of affected animals should be kept in an anticoagulant (EDTA), and internal organs such as the spleen, lymph nodes, tonsils, and kidneys should be kept in a cold environment without freezing. The laboratory samples should be stored at -70° Celsius. There are many different tests for identifying ASFV. For example, the Haemadsorption (HAD) test, antigen detection by fluorescent antibody test (FAT), and detection of virus genome by polymerase chain reaction (PCR) [22].

Serological tests

Infected animals develop antibodies against the virus, and those antibodies are produced for long periods after infection. The antibodies can be used to detect or diagnose ASF. The most common technique for detecting ASF is ELISA which is suitable with different samples such as serum, body fluids, or tissues. Detecting antibodies is better than detecting antigen when pigs are infected with the low virulence form of ASF which can cause chronic disease. In endemic areas ELISA should be used with an alternative serological test (IFA) or an antigen detection test to increase sensitivity and specificity of the tests. Enzyme-linked immunosorbent assay (ELISA) (the prescribed test for international trade), Indirect fluorescent antibody test (IFA) and Immunoblotting test can all be used to verify ASF infection [22].

1.2.13. Potential risk factors of African swine fever

ASF has occurred in Africa and Europe, and there is some research in outbreak areas which has identified potential risk factors of the disease. Risk factors differ between farm levels and also between the regional/international levels. In order to stop ASF outbreaks, it is important to know specific risk factors so that suitable control and prevention measures can be established.

<u>Farm level</u>

In south-west and central Kenya, the risk factors for spreading ASF are free-grazing pigs, replacement pigs, and the distance from a national park. Free-grazing pigs may easily contact wild boars which are the main reservoir host of ASFV. Free-grazing pigs are also a factor for spreading the disease to neighboring farms. This is mainly a problem for small farms. Large farms typically have good biosecurity. However, large farms in areas close to a national park that has wild boars have a high possibility for infection with ASF. Moreover, animal loans for breeding or replacement pigs are factors contributing to transmission of the virus between farms. Thus to screen for ASF before trading is an important step for stopping an outbreak [23].

In Nigeria the risk factors contributing ASF infection at the farm-level include abattoir/slaughter slabs within pig communes (Odds ratio: 20.85, CI: 7.80, 55.75), infected neighborhoods (Odds ratio: 8.52, CI: 3.81, 19.05), wild birds entering pig pens (Odds ratio: 3.57, CI: 1.64, 7.76), and rats having access to feed stores and pig pens (Odds ratio: 4.77, CI: 2.07, 10.97). These findings support that ASFV can be transferred by direct contact and indirect contact with wild birds and rats [24].

Risk factors of spreading ASFV are pest animals, birds, pig farming characteristics and management, and farm location. So biosecurity and the management of pig farms are the main factors to stop the spread of the virus. Good biosecurity can protect a farm from other animals or pests; this is important because ASFV can live a long time in the environment and attach to any surface easily. Good biosecurity is about how to build a border between the inside and outside of pig farms, and this can be done by regularly using disinfectants to clean the farm, keeping animals within a closed environment, cleaning and restricting movement of humans, vehicles, and equipment. Not only good biosecurity but also good farm management is important; for example, an all in - all out farming practice is the best way to clear out carriers of the disease, and screening for the disease in breeding pigs can stop the introduction ASFV.

Regional/International level

Outbreaks of ASF may arise from sources which vary depending on the outbreak area. For example, recent outbreaks of ASFV in endemic areas such as Georgia and Armenia have risen from the environment or wild animals. Outbreaks are difficult to control in these countries because there is no effective long-term response in place. In contrast, in Ukraine and Belarus ASFV may have been introduced by ticks and indirect contact in the environment. Both countries share borders with Russia, so there is also the possibility of transboundary spread from infected wild boar and human movement. Infected pigs were moved without any control measures in place; this was one of the most important risk factors that led to undetected spread of ASFV. Moreover, contaminated pork is also a source of infection of ASFV in Russia. Experts of EFSA showed that ASFV can be carried to domestic pigs and cause an outbreak by the different ways listed in the table below [19]. These experts also showed that ASFV can live in a variety of environmental conditions. Table 1.5 helps define what are the important risk factors of ASF.

Table 1.5. Ranked ability of ASFV to spread via different carriers. (Based on expert elicitation) (EFSA, 2014), [19]

Rank	Matrix
Very high	Frozen meat
High	Chilled meat
	Wild boar (transported)
	Domestic pigs (transported)
	Skin fat
	Vehicles for animal transport-contaminated inside
Moderate	Naturally smoked meat
	Salted, fermented, dried (+/- spiced) meat (e.g. pepperoni, salami,…)
	Salted, dried meat (e.g., salted and dried hams, shoulders, loins…)
	Any vehicles-contaminated outside
	People involved with pig-keeping
	Slurry
	Animal feed
	Litter
	Fomites
Low	People not involved with pig-keeping
	Ticks
Very low	Vegetables
	Crops
	Pests (rodents)
	Pets
	Hay and straw
	Bloodsucking insects
Negligible	Meat cooked for 70 °C for 30 min

ASFV was introduced into Europe via movement of live animals along the border of Europe with other regions, and that non-detectable infected animals can spread the disease to free regions within a country or to disease-free countries. All countries should follow OIE international trading guidelines and conduct quantitative import risk assessments [25].

To control outbreaks at the regional and international levels it is critical to improve the animal health surveillance system, increase laboratory capacity for detecting ASFV, improve performance of veterinary services, control the tick population, and follow the OIE international trading guideline. Moreover, as the table above shows, high to very high risks for ASF are associated with live pigs and pig products. Importantly, some countries are more concerned about the movement of live pigs than pig products, and have many procedures in place for screening and controlling the spread of disease via live pigs. Live pigs are a high risk and of concern, but pig products should be carefully considered because ASFV can live a very long time in frozen or chilled pork which is the main form by which pig products are traded. Thailand is an example of a country in which live pigs are taken much more into account than pig products, and this is a significant gap in the strategy for preventing the introduction of ASFV.

1.2.14. Control and prevention strategy for ASF

There currently is no vaccine for ASFV, however, there is ongoing research in several labs to develop one. As a result, in order to control outbreaks and prevent the spread of ASF a diligent surveillance system, outbreak investigation, and quarantine measures should be used.

Eradication and control of ASF can be accomplished by [18, 26]

- Increasing the efficiency of an early detection/surveillance system for ASF. If ASF is detected as fast as possible, then control and prevention measures will be implemented early, increasing the possibility of success.
- International organizations and federal government supporting local capacity development in areas such as laboratory facilities, research activities, risk assessment etc. to prepare local officers for controlling outbreaks.
- Developing a high-capacity diagnostic laboratory screening test that is cheap, and has a high sensitivity and specificity to be used in the field.
- Restricting contact between wild and domestic pigs; this can stop transmission of the disease.
- Increasing disease awareness of animal health officers in both the endemic country and the free country to make sure that ASF is added to any eradication policy.

- Investigating increases in wildlife reservoirs and having a wildlife disease surveillance system in place.
- Investigating the distribution of *Ornithodoros sp*. ticks, and making available information about these ticks.
- Establishing ASF-free zones in endemic countries to increase trading capacity, and then use them as examples for being a free country.
- Following the international standard as outlined by the World Organization for Animal Health (OIE) for movement of livestock and livestock products between countries.
- Developing risk assessment especially in disease-free countries to identify which introduction pathways are most important and to identify gaps or weak points in the control policy. Endemic countries should also do risk assessment to identify mechanisms of spreading the disease in their pig population.
- Developing targeted or risk-based surveillance strategies in free countries.
- Educating officers, meat inspectors, and farmers about ASF. At least they should know how important ASF is and what clinical signs may be seen with the disease.
- Establishing standards for pig slaughtering facilities and the transport of pigs.

CHAPTER II.

ASSESSING RISK OF ASFV INTRODUCTION INTO THAILAND BY IMPORTING PIG PRODUCTS FROM ITALY IN 2015. – DEVELOPMENT OF AN APPROACH

2.1. Summary

African swine fever (ASF) is an infectious disease that affects swine population. The Department of Livestock Development (DLD), Thailand, considers ASF as an exotic disease likely to be introduced into the country. To estimate the risk of introduction ASF into Thailand, risk analysis is a tool that can support information and identify gaps in the preventive measures being prepared in the country. This study will demonstrate a conceptual framework of risk analysis modified from import risk analysis introduced by OIE, generate a general risk pathway by utilizing information from the Department of Livestock Development (DLD) and published literature, illustrate how to choose a potential risk pathway topic and risk question by utilizing the OIE animal disease reporting system and DLD trading database. The framework is composed of generating general risk pathway and risk question, identifying a hazard, developing physical pathway and scenario trees, assessing the risk, mitigating the risk and communicating the risk. The general risk pathway shows eight possible routes for introducing ASF into Thailand. Moreover, based on the OIE animal disease reporting system and DLD trading database, the introduction of ASF into domestic pigs in Thailand might be risked by importing pig products from Italy. Therefore, the risk question is "What was the risk of introducing ASFV by importing pig products from Italy to Thailand in 2015?". The strategy developed during the study will be beneficial in assessing the risk of ASF introduction into Thailand.

2.2. Introduction

African swine fever (ASF) is a severe contagious disease among pig populations. Thailand considers ASF an important exotic disease that can greatly affect the pig industry and international trading and is likely to be introduced into the country. ASF is currently in the Animal Epidemics Act 2015 [26]. In addition, the Department of Livestock Development (DLD) in Thailand is now developing the project for self-declaration and official recognition as an ASF-free country by the OIE. Historically, Thailand has been importing pigs and pig products from many countries, so in order to prevent an ASF outbreak in Thailand, risk analysis of ASFV should be conducted to identify gaps and weak points in the prevention strategy for the country.

Thailand has never conducted risk analysis for ASF. As a result, there is no good baseline information about this disease in Thailand. Qualitative risk assessment is often used to create baseline for identifying the gaps and to develop quantitative risk assessment in the future. The risk analysis by the OIE was divided into four steps: hazard identification, risk assessment, risk management and risk communication [7]. However, because of limitations of time and resources, this assessment is needed to narrow down the topic to choose the most important potential route of introduction of the disease, specifically importing pigs or pig products from an exporting country that is likely to have the disease. Also, the project would be useful as an easy model for beginners for analyzing risk. Then modification on the OIE risk analysis is necessary to minimize some steps as well as put more detail mainly focusing on how to develop the risk analysis. This chapter mainly focuses on how to approach a risk analysis process by developing a conceptual framework of risk analysis, and choosing a risk question for the topic “analyzing the risk of ASFV introduction into Thailand from imported pig products from Italy in 2015.”

2.3. Material and Methods

Developing the conceptual framework of risk analysis of introducing ASFV

The OIE risk analysis guideline has been used and accepted among its members, and including Thailand, so the conceptual framework of risk analysis of introducing ASFV to Thailand was developed based on that guideline. The OIE risk analysis was integrated with USDA risk analysis resources and DLD officers' opinions. Mainly the focus was on what would be the steps to develop risk analysis through risk communication without having a risk question or a topic of interest at the beginning plus making four scenarios to demonstrate how risk mitigation will change a risk. The main objective for the conceptual framework is to make the risk analysis process clear and easily understood and followed.

Generating the general physical risk pathway

Before choosing a particular pathway for analyzing risk of introduction of ASFV into Thailand, the general risk pathway had to be developed. This described all possible routes of introduction of ASFV into Thailand. Scientific literature, Thai livestock trading information, and expert opinions and information were used to identify what routes and commodities could possibly introduce ASF into Thailand. Moreover, the movement of each commodity had to be identified to provide the initial information to briefly analyze the risk before choosing a particular pathway.

Generating a risk question and how to choose the particular topic and pathway.

To choose particular topic and pathway and generate a risk question, we needed to consider the most likely situation at risk by analyzing fundamental information from the general risk pathway. The OIE animal diseases epidemic database need to be researched with the DLD live pigs and products trading databases. Based on all supportive evidences with expert opinions, especially the acceptance from DLD officers who are the main stakeholders, the topic and a risk question were developed. This topic is the most likely the situation at risk to introduce ASF into Thailand.

2.4. Results

Developing conceptual framework of risk analysis of introducing ASFV

Before following the steps in the conceptual framework, ASFV was identified as a general hazard by using the DLD policy, which states ASF as one of the diseases that is important to Thailand. Also, trading of live animals/animal products is the critical point for the introduction of exotic diseases from other countries.

Based on figure 2.1, the conceptual framework is composed of eight steps., The first step is development of a general risk pathway. A detail of the general risk pathway of the introduction of ASFV into Thailand is described in the subtopic: “Generating the general risk pathway.”

The second step is generating a risk question. Before working on risk analysis, a risk question is extremely important because it defines the research objective which is to answer that question. The details of how to generate a risk question are discussed in the topic: “Generating a risk question and the approach for analyzing the risk of ASFV introduction into Thailand by importing pig products from Italy in 2015.”

This chapter mainly focuses on steps 1 and 2 which involve the development of an approach for analyzing the risk of ASFV introduction into Thailand by importing pig products from Italy, 2015. Once the topic is chosen and a specific risk question is formed, and the risk analysis process can begin. The details of the third to the seventh steps of the process are presented in the next chapter.

The third step is to “identify a hazard” as discussed in Chapter 1.

The fourth step is developing a physical pathway and the scenario trees. After identifying a hazard, an assessor should develop a physical pathway which shows how the hazard moves from the point of origin to the destination (population at risk) and identifies every possible node between those two points. For example, the movement of pig products from Italy to Thailand should begin with domestic pig farms in Italy and progress to domestic pig farms in Thailand. Between those two nodes the slaughterhouse, processing plant and quarantine station should appear in the physical pathway. Scenario trees are developed by modifying a physical pathway; it just changes the meaning of movement of the commodity to be able to get the level of likelihood and uncertainty whether the hazard would pass the node.

The fifth step is risk assessment. This is the heart of risk analysis and is about how to identify the level of likelihood of risk for each node as well as the uncertainty of the supportive data. It starts with release assessment, exposure assessment, and consequence assessment and then combining them via risk estimation and matrix. The assessment finally generates the level of likelihood and uncertainty that the hazard can pass each node, the overall likelihood of introducing the hazard, the level of consequence if the hazard already exists at the destination, and the overall risk (combination of likelihood and consequence).

The sixth step involves risk mitigation and provides recommendations to stakeholders. Risk mitigation focuses primarily on the nodes that have a high or moderate level of likelihood, uncertainty and consequence. The recommendations should be based on how to decrease the likelihood of introduction and consequence of hazard, and to increase the certainty of evidence. Moreover, risk mitigation needs to be feasible in a real situation and in accordance with policy.

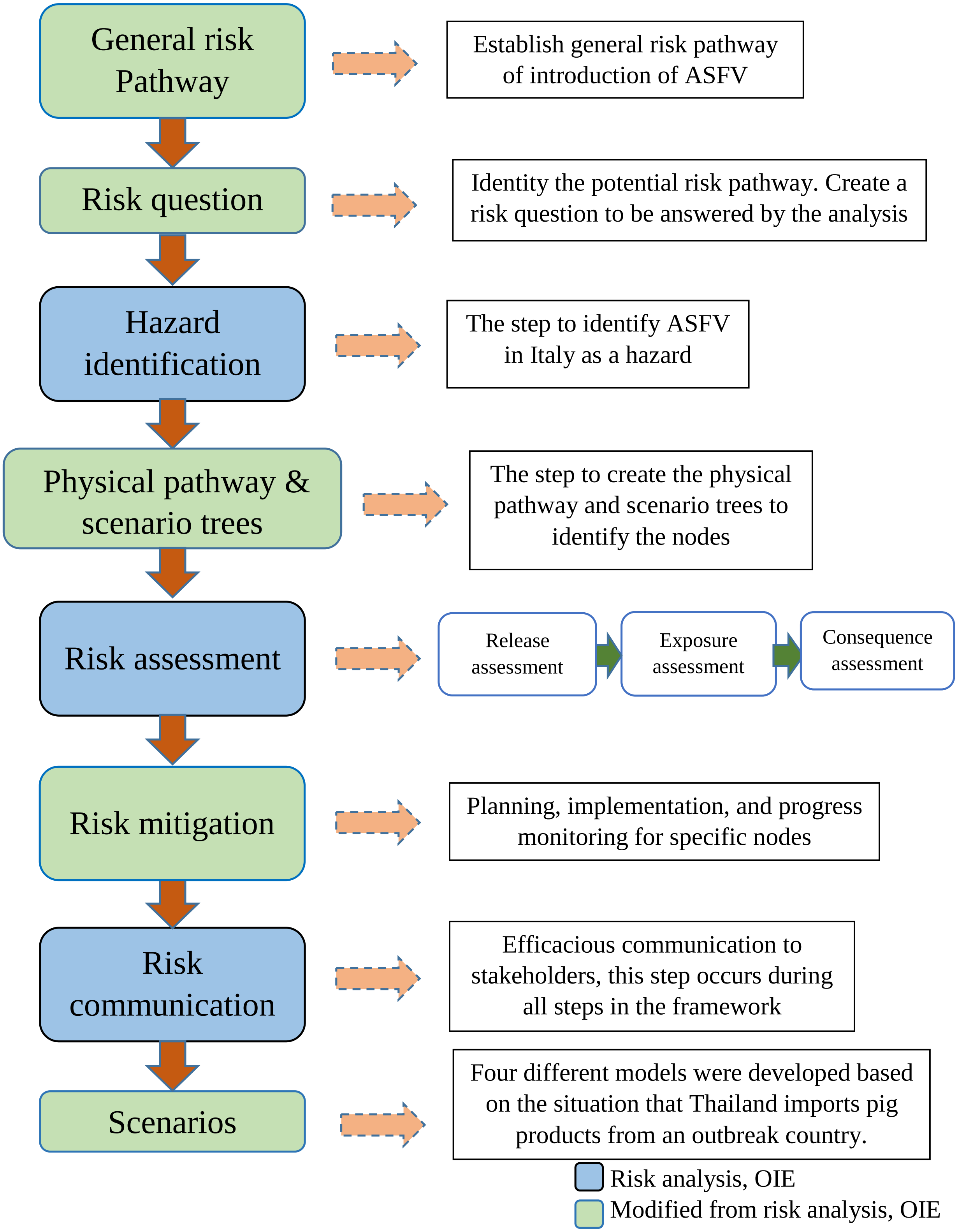

Figure 2.1. Conceptual framework of risk analysis of introduction of African swine fever to Thailand.

The seventh step is risk communication. From the first step to the last, the researchers need to communicate with all stakeholders, exchange data with them, and report the results of the project to them. The project topic should have the acceptance of all stakeholders, and they also should be able to understand all the steps for analyzing the risk. If they have not been kept informed since the project started, they would likely ignore the results, making the research unsuccessful. Effective communication of the risk to all stakeholders is critical because the hazard might cause unnecessary panic for people. The focus of risk communication is how to deliver truthful information to maximize awareness while minimizing as much as possible any fears.

The last step is this study will be the chapter IV which is how the risk of a such introduction will be changed if DLD has imported pig products from an outbreak country. Four scenarios have been developed based on different implementations. This step is just an example how risk mitigation will be used to reduce a risk.

Generating the general risk pathway

The general risk pathway is the representative diagram of the movements of the commodities that are able to carry ASFV into Thailand. Based on experts' opinions and DLD trading documents, there are eight possible routes of introduction: live pigs, pig products, pig semen and embryos, wild boars, wild boar meat, biological products, potbellied pigs, and personal items. This pathway includes legal as well as illegal (potbellied pig and personal items) imports. The pathway is also divided into three areas: the exporting countries, the border of Thailand, and inside Thailand. Exporting countries and the border of Thailand are in the release assessment pathway, and inside Thailand is in the exposures assessment pathway.

As shown in Figure 2.2., the first pathway is the movement of live pigs (purple line). Live pigs have to be exported from an ASF-free country and pass the DLD certification system before entering Thailand. The requirement for importation into the Kingdom of Thailand includes health certification, pedigree certification and a quarantine period of at least 30 days (in the exporting country) [27]. After approval, live pigs needed to be at the quarantine station of DLD, Thailand at least 30 days as well [28]. Then those pigs can be moved to domestic pig farms and sent to a slaughter house to enter the food chain. At the farm level, ASF should be monitored by the farmers and a veterinarian at the farms, and at the slaughter house ASF inspection is done by veterinarians.

The second pathway is the movement of pork or pig products (green line). The requirements for importing those products into Thailand includes health certification, exporting from an ASF-free country, ASF-free farms, testing for food microorganisms etc. [28]. After passing the requirements, the products have to be screened for diseases at the DLD quarantine station. Once the product is approved to move, it can be transported directly to consumers.

The third pathway is the movement of pig semen and embryos (black line). The semen and embryos essentially have the same requirements as for pork and products, the difference being that after passing DLD diagnostic testing at the quarantine station they are sent to the DLD artificial insemination center or a company for future use in domestic pig farms.

The fourth pathway is the movement of wild boars (blue line). Those pigs have to be exported from an ASF-free country and pass DLD certification; the requirements and quarantine period are same as the live pigs, [28]. Export of wild boars has to meet the requirements of the Department of National Parks, Wildlife and Plant Conservation (DNP). Once approved those pigs can move to farms and be sent to slaughter for consumption the same as domestic live pigs.

The fifth general risk pathway is the movement of wild boar meat (brown line). The requirements for importing that product into the Kingdom of Thailand are almost the same as for importing pork and pork products such as requiring a health certification, export from an ASF-free country, ASF-free farms, tested for food microorganisms etc. [28]. Also, the meat must pass the DNP requirements for CITES as well. After passing all requirements, it can be transported directly to consumers.

The sixth pathway is the movement of biological products such as pig vaccines, cell cultures (pig kidney cells). These biological products are outside the control of the DLD. The Thai Food and Drug Administration (Thai FDA) has the responsibility to screen and approve the importation of these products. After receiving Thai FDA approval, the products can be used for humans, laboratory animals, pig farms, and AI centers.

The seventh and eight routes are importing potbellied pigs and personal items. These do not have good supportive information to create diagrams because it is illegal for them to be imported into Thailand.

To sum up, the general risk pathway (Figure 2.2.) shows the possible routes of introducing ASFV into Thailand. This step was established by using DLD trading information and expert opinions. This pathway helped the researchers have a better understanding of how the ASFV may be able to enter Thailand.

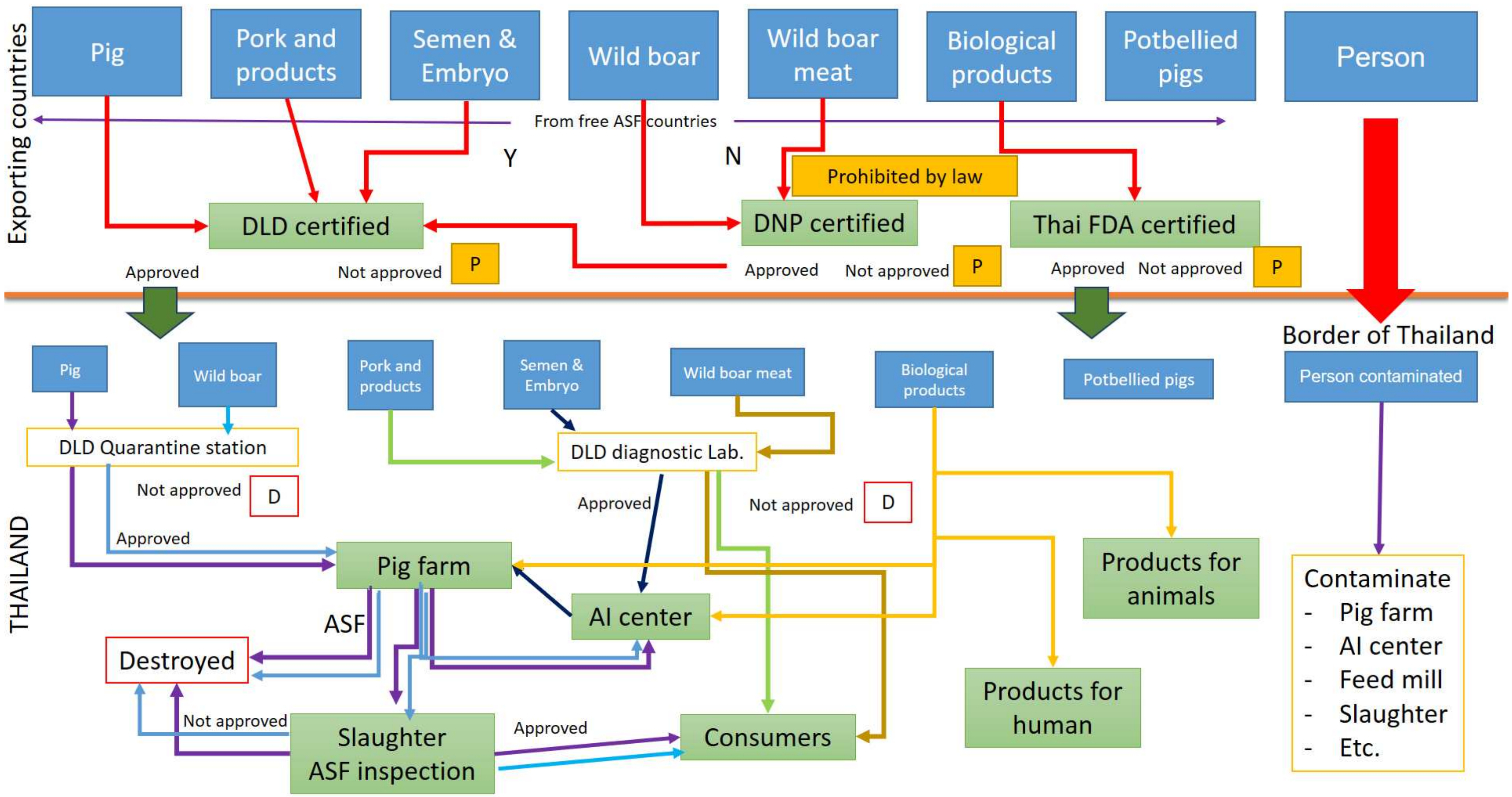

Figure 2.2. General risk pathway of introducing ASFV into Thailand.

Generating a risk question and how to choose the particular topic or pathway.

After identifying the possible routes of introducing ASFV into Thailand, the researcher need to select the topic, keeping in mind the limited time and resources. According to the DLD trading database. In 2015, live pigs were imported from two countries, Denmark and the United State of America, and pig products were imported from Greece, Canada, Japan, Denmark, Netherlands, Brazil, Belgium, France, Spain, Sweden, German, United States of America, United Kingdom, South Korea, China, Italy, and Albania. Interestingly, ASF outbreaks were detected in one of the exporting countries, namely Italy (Sardinia Island), in both wild boar (January to June 2015) and domestic pigs (July to December 2015) [3]. Thailand imported approximately 4 million kilograms of pig products from Italy in 2015 (Table 2.1.) (Source: DLD trading database). Pig products are significantly important to the spread of ASF globally and be vehicles for the virus. [19].

Table 2.1. Number and type of pig products imported from Italy in 2015 (DLD trading databases, 2015).

Type of pork products	Kilograms	Value (baht)
Dry salt curing pork	20,180	6,319,258
Frozen internal organs	371,106	11,490,840
Frozen intestine	226,035	6,012,065
Frozen pork skin	3,556,309	72,638,832
Salt chilled pork	36,794	12,574,267
Total	4,210,425	109,035,264 (3 million dollars)

Considering all the supportive evidence and DLD acceptance, the suitable topic for this analysis is "**Analyzing the risk of ASFV introduction into Thailand by imported pig products from Italy, 2015**" In addition, the risk question is **"What is the risk of introducing African swine fever virus into Thailand by importing pig products from Italy in 2015?"**

2.5. Conclusion and discussion

The conceptual framework of risk analysis was developed based on the OIE guidelines for import risk analysis. The original OIE risk analysis is divided into four main steps which are hazard identification, risk assessment, risk management and risk communication. The framework here followed those four steps, but included four additional steps: the process of generating a general risk pathway, forming a risk question, separate development of a physical pathway and scenario trees from risk assessment, adding risk mitigation instead of doing risk management and demonstrate the impact of risk mitigation by making four different scenarios. The reasons why these modifications are necessary are outlined as follows:

First, because the assessor needed to know all possible routes by which ASF could be introduced to Thailand, generating a general risk pathway was the way to get the big picture of product movement before zeroing in on a particular route. This step could be ignored if the assessor already has a risk question or topic from policy makers or one of their own interest. Second, typically the risk question is identified by a policy maker or is a topic of interest at the time. Since this study would be an example of the whole process of developing risk analysis, a step for generating a risk question would show the process for how to choose a topic that meets the objective of a study. Third, development of a risk pathway and scenario trees usually occurs at the very beginning of risk assessment, but in this study the assessor intended to focus on how to develop a physical risk pathway and scenario trees. This is very useful for a novice because a physical risk pathway and scenario trees can be used for expensing, narrowing or modifying a study. Forth, a whole process for managing the risk needs a lot of information and agreement among related stakeholders, the risk management must be composed of acceptable measures having a low likelihood or impact, more necessary resources must be spent in order to minimize the risk, and more information must be gathered for an uncertain information, and mitigation to reduce the risk [15]. So, given the limited resources and time, this project focused on risk mitigation or how to minimize the risk, which uses most of the information from the results of the risk assessment, and briefly give recommendations to stakeholders. The four scenarios of different risk mitigation will be showed in the chapter IV.

According to the general risk pathway (Figure 2.2.), there are eight possible routes of introduction of ASF from another country to Thailand. These routes have been identified from the literature, DLD information and experts' opinions. These eight movement pathways are not complete since some movement pathways especially inside Thailand lack supportive information such as the movement of potbellied pigs and personal items. Also, there might be other potential routes in addition to these eights routes. However, these eights pathways are enough to provide an initial idea of how to choose the pathway that is most likely to bring the virus into Thailand. Moreover, with limited available resources from other departments such as the DNP and Thai FDA, for some pathways (wild boars, wild boar meat, biological products) there was some difficulties to verify the routes such as all possible movements. Other pathways, however, full details were obtained since required information was available from DLD. Finally, this general approach to estimate the pathways should not be used for other kinds of commodities and hazards and/or for other diseases, different animals, and different countries.

Choosing the particular topic or pathway overlaps with the hazard identification process. However, because this study was not developed based on any policy, the assessor needed a trusted method to choose a pathway and a risk question when there is a variance of data. Risk communication also had to be started at this step, leading to a pathway and risk question that all stakeholders could agree upon to make sure the results of this project will be useful and handled in a trustworthy manner.

Since this chapter has shown how to develop a risk analysis work at the beginning, the following chapters will be done based on this conceptual framework of risk analysis and the particular topic which is analyzing the risk of ASFV introduction into Thailand by imported pig products from Italy, 2015.

CHAPTER III.

ESTIMATION OF RISKS OF INTRODUCTION OF ASFV TO THAILAND BY IMPORTING PIG PRODUCTS FROM ITALY, 2015 (QUALITATIVE ASSESSMENT)

3.1. Summary

African swine fever (ASF) is a highly contagious disease which infects swine species and highly impacts the pig industry. Thailand imported approximately four million kilograms of pig products from Italy in 2015 during time when an ASF outbreak was occurring on Sardinia island in Italy, thereby posing a potential risk of introduction of ASF to Thailand. To prove whether or not importing pig products from Italy is a risk for Thailand and to identify gaps in the country, risk analysis should be done. The objective of this study was to estimate the risk of introduction of ASF virus by importing pig products from Italy into Thailand in 2015 utilizing qualitative risk assessment approaches with an aim to define specific control and preventive measures. The framework to analyze the risk in this study was composed of hazard identification, qualitative risk assessment, risk mitigation and risk communication. The qualitative risk assessment revealed that the likelihood of introduction of the ASFv into Thailand was negligible, contrastingly, the level of consequence of the virus was high. The overall risk was "negligible". Recommendations were framed based on risk mitigation to minimize the risk. Suggestions were made on how to communicate the risk effectively and how the results would be accepted and used by the stakeholders. In addition, this study provided baseline qualitative risk of ASFv introduction and systematic approach to a qualitative risk analysis.

3.2. Introduction

African swine fever (ASF) is an infectious disease that affects swine populations. It is caused by African Swine Fever virus (ASFv). ASFv is a double-stranded deoxyribonucleic acid virus in the genus *Asfivirus*, family *Asfarviridae* [2, 3] that affects suidae family family such as domestic pigs and wild boars. The current outbreak areas are mainly located in Africa and some countries in Europe, however, ASF is a disease for which OIE members need to develop a strategy to monitor, control, prevent and eliminate it, especially focusing on the trade of live pigs and pig products [1]. ASFv can be transmitted by direct contact and indirect contact. It is, also vector-borne, *Ornithodoros* sp. ticks being the main vector contributing the spread of disease [16]. Therefore, ASFv is easily spread within a susceptible population. ASFv can also be spread via commodities such as pig products because ASFv is highly resistant to the environment [2]. Clinical signs of ASF are high fever, abortion, leucopenia, anorexia, bloody diarrhea, thrombocytopenia, and erythemic skin or cyanosis. The mortality rate is about 30-70%, while the case-fertility rate could be 100% depending on the virulence of the virus [16].

To minimize the likelihood of introduction of the virus via international trading, a risk analysis has been the recommended approach to develop a risk management or mitigation plan. The World Trade Organization (WTO) has developed the Agreement on the Application of Sanitation and Phytosanitary Measures (the SPS agreement), which is mainly to protect the right of WTO members to provide a level of food safety, animal health, or plant health [7]. Accordingly, OIE has launched a risk analysis for imports for supporting animal health, and this is composed of hazard identification, risk assessment, risk management and risk communication.

Thailand has a large pig industry which is reflected by the number of pig produced and exported. In 2014, Thailand produced 5,876,562 fattening pigs and 3,054,758 breeder pigs

(Department of Livestock Development (DLD), 2014). In 2013, Thailand also exported 23,952 breeders, 89,260 nursery pigs, 136,933 fatteners, 1,001 tons of frozen and chilled pork, and 16,987 tons of cooked products, which converts to approximately 130 million US dollars [5]. Fortunately, Thailand has never had ASFV as confirmed by zero sero-prevalence during a survey by the National Institute for Animal Health. (NIAH, 2015). Since Thailand is a member of OIE and needs to prevent ASF from being imported with live pigs and pig products, risk analysis is important for determining gaps in the country.

The highest likelihood for bringing the ASF virus into Thailand is considered to be from port and pig products (opinions of DLD officers) because the preventive methods at quarantine stations are generally more focused on screening imported live pigs are less on pig products. According to the DLD trading database and the WAHIS OIE database, ASF outbreaks were detected on Sardinia island, Italy in both wild boars (January to June 2015) and domestic pigs (July to December 2015), During 2015, and Thailand imported approximately four million kilograms of pig products from Italy during the same time as the outbreaks. Considering all the supportive evidence, Thailand might be at risk of introducing ASFV. Risk analysis would provide initial information for estimating the risk of ASFV introduction into Thailand by importing pig products from Italy in 2015, and provide recommendations for decreasing risk of introduction and spread of the virus in Thailand. It could also show the gaps in the country. This study is the first research to estimate the risk of ASF introduction and spread in Thailand. The risk question for this study is “What was the risk of introducing ASFV from pig products from Italy into Thailand in 2015?”

3.3. Materials and Methods

Steps of Risk Analysis

Hazard identification, physical pathways and scenario trees, risk assessment, risk mitigation and risk communication were generated. Qualitative risk assessment was performed with "release assessment", beginning at Sardinia island through the border of Thailand, and "exposure assessment" from the DLD quarantine station to the domestic pig farms. Also, "node" is the subject to identify the likelihood of risk is estimated for each station of movement. At each node a level of likelihood of risk was identified based on supportive evidence. A risk matrix was used to estimate the likelihood of each "release" and "exposure" assessment and to combine them to get the overall "likelihood of introduction". In addition, "consequence" assessment provided the level of impact if the hazard entered Thailand in terms of negative and positive consequence. In order to obtain the "overall risk" and thus answer "risk question", the level of likelihood of introduction was combined with the level of consequence by using risk estimation. In addition, risk mitigation plan was developed by listing recommendations for minimizing the nodes with high likelihood and uncertainty. A risk communication plan was also developed to explain how to effectively communicate the risk to stakeholders.

Data collection

For this study official trading documents from Italy and Thailand and information about ASF outbreaks in Italy during 2015 were the main sources of data for analyzing risk; trade and ASF control and prevention documents included the EU commission decision, EU legislation, EU council directive, export and import requirements and government guidelines. Scientific literature validate the data collected from these documents in addition to expert opinions when published literature was not available. The expert opinion information was collected using four questionnaires for Italian veterinary officers and DLD veterinary officers in three different divisions were created and delivered to collect their opinions and information.

The level of consequence was estimated based on Performance of Veterinary Services (PVS) gap analysis by OIE, characteristics of pig farms, veterinary legislation, DLD background information, DLD control measures for preventing and controlling ASF, DLD laboratory and human capacity, expert opinions and information, scientific literature, exportation data of pigs and products and basic economic concepts.

Table of likelihood and uncertainty categories

Once risk pathway and scenario trees were developed, the likelihood of occurrence and uncertainty of supportive evidence were estimated based on available data and multiple risk factors. The level of likelihood that ASFV would be able to pass each node was categorized by using the definitions outlined in Table 3.1.

Table 3.1. Qualitative likelihood scale categories (Modified from USDA, 2013 [11])

Category	Descriptor
High	The event has more than an even chance that the event will occur.
Moderate/Medium	The event does occur but is unlikely to.
Low	The event is very unlikely to occur.
Very low	The event is very rare to occur, but cannot be excluded
Negligible	The likelihood that the event will occur is insignificant: not worth considering

The level of uncertainty for each node was categorized based on the definitions in Table 3.2. Uncertainty levels have to be estimated to prevent misinterpretation and overconfidence.

Table 3.2. Uncertainty scale categories (Modified from Kasemsuwan, 2009 [12])

Levels	*Characteristic of evidences*
Low	Solid and complete data available; Strong evidence provided in multiple references; authors report similar conclusions.
Medium	Some but no complete data available; evidence provided in small number of references; authors report conclusions that vary from one another.
High	Scarce or no data available; evidence not provided in references but rather in unpublished reports or based on observations, or personal communication; authors report conclusion that are uncertain and that vary considerably.

Combination risk matrix and risk estimation

After determining the level of likelihood of risk for each node, risk matrix was used to combine each level of likelihood to obtain the level of the likelihood for release assessment and exposure assessment, then combine both to get the likelihood of introduction of ASFV. The risk matrix is shown in Table 3.3.

Table 3.3. A matrix of rules for combining descriptive likelihoods (Modified from Guidelines for Import Risk Analysis, Biosecurity Australia, 2001 [14]).

A matrix of "rules" for combining descriptive likelihoods					
	High	**Moderate**	**Low**	**Very low**	**Negligible**
High	High	Moderate	Low	Very low	Negligible
Moderate		Low	Low	Very low	Negligible
Low			Very low	Very low	Negligible
Very low				Negligible	Negligible
Negligible					Negligible

(See table 3.1. for the definitions of high-negligible)

After determining the likelihood of introduction and level of the consequence of the risk, Table 3.4. was used to combine those to describe the overall risk of ASFV entering Thailand.

Table 3.4. The table of risk estimation (Modified from Guidelines for Import Risk Analysis, Biosecurity Australia, 2001 [14])

Risk estimation matrix						
Likelihood of entry and exposure	High likelihood	Negligible	Very low	Low	Moderate	High
	Moderate	Negligible	Very low	Low	Moderate	High
	Low	Negligible	Negligible	Very low	Low	Moderate
	Very low	Negligible	Negligible	Negligible	Very low	Low
	Negligible	Negligible	Negligible	Negligible	Negligible	Negligible
		Negligible	Very low	Low	Moderate	High Impact
	Consequence of entry and exposure					

Finally, recommendations were developed for risk mitigation based on the weak nodes which are likely to allow the virus to pass. Moreover, suggestions of how to communicate the risk to all stakeholders were developed.

3.4. Results

Hazard identification

The major goal of this step was to identify whether or not ASFV in importing pig products from Italy would be a risk for Thailand. According to World Animal Health Information System (WAHIS) by the OIE, ASF is an endemic disease on Sardinia Island, Italy with two outbreaks in 2015. Therefore, the first supportive reason is that Italy had ASFV. The second supportive reason is that Thailand has never reported ASF with a zero sero-prevalence was shown in a survey by the National Institute of Animal Health (NIAH), DLD in 2015. ASFV is therefore absolutely an exotic virus to Thailand. The third reason is that in 2015 Thailand imported 4,210,425 kilograms of pig products from Italy. Fourthly, those imported pork products are able to carry the virus or can be the vehicle for the virus [19]. In conclusion, when all the supportive reasons were considered ASFV in the importation of pig products from Italy was identified as a hazard for Thailand.

Physical risk pathway and scenario trees

Movement of hazard (ASFV) originated from Sardinia Island in Italy to domestic pig farms in Thailand is described in Figure 3.1. Since the virus could possibly move from the island to the mainland, infection in the exporting pig farms, passing through the slaughtering and processing step, meeting the DLD requirements and EU requirements, and passing the DLD quarantine station to enter into Thailand were all included in the release assessment pathway.

After passing the DLD quarantine station, the hazard would possibly move to the importing company and storage facility where it would then be placed for sale at markets and restaurants. Since passing the DLD quarantine station was categorized as an exposure assessment, it was divided into two scenarios to demonstrate how animals would expose to the hazard. In the first scenario, pig farmers were able to buy the products from markets or restaurants and those products could contaminate the pig farms at the household level. In the second scenario, waste products from the importing company and storage facility as well as from markets and restaurants could contaminate water and other parts of the environment which might be used at domestic pig farms. Consequence assessment would then assess the impact of an ASF outbreak at the domestic pig farm level. The scenario trees provided the movement of the hazard in the sense of how to estimate the level of likelihood of the virus to pass each node (see detail in Figure 3.1).

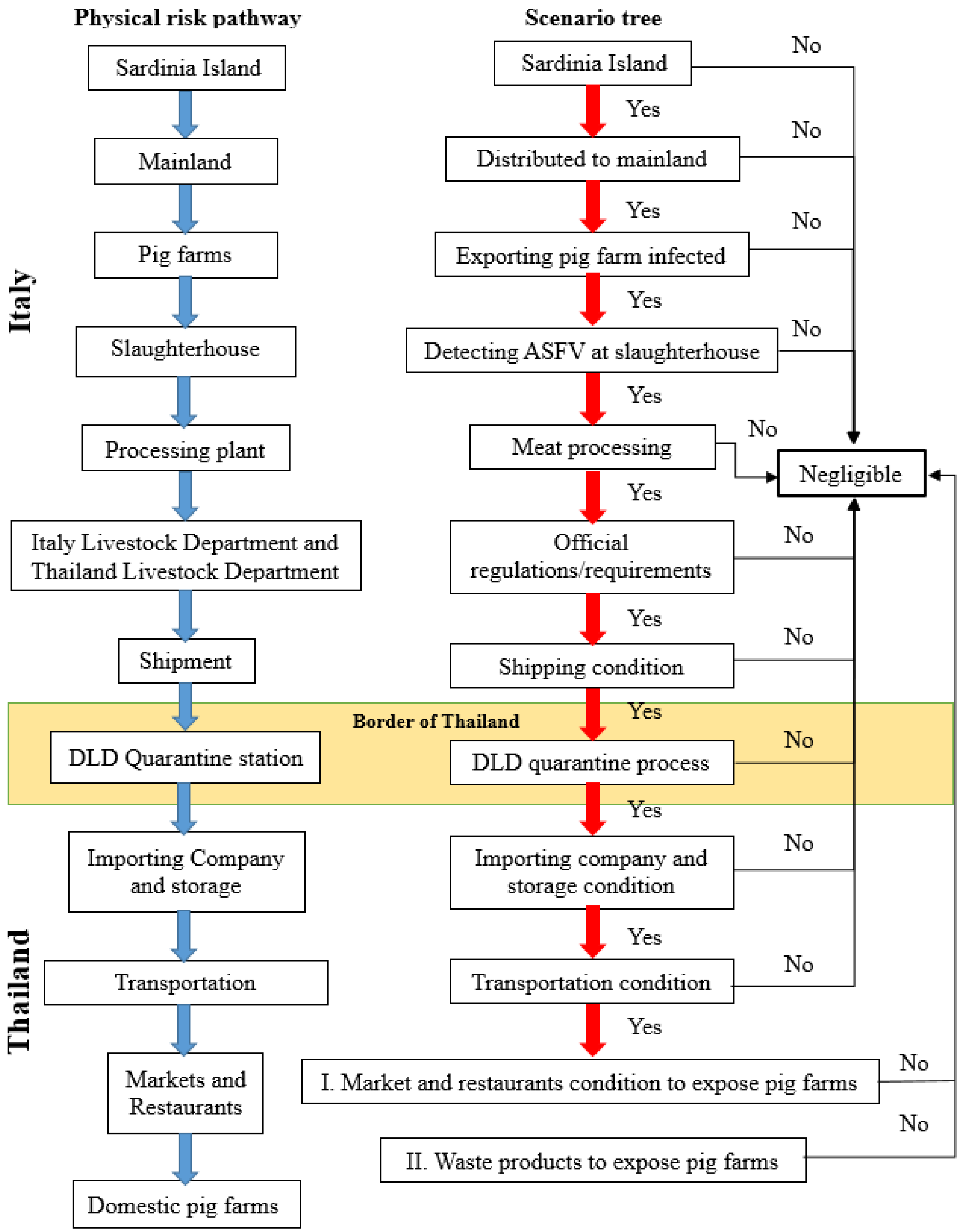

Figure 3.1. Physical risk pathway and scenario tree for introduction of ASFV into Thailand by importing pig products from Italy.

Risk assessment

The levels of likelihood that the virus could pass each node and levels of uncertainty are shown in Table 3.5. To estimate the levels of likelihood and uncertainty, the supportive information is shown in detail in Appendix 2, briefly, in Italy veterinary services, ASF control measures on the island and the mainland are very good and reflect the EU commission decision, EU legislation and EU council directive. Also, based on the EU Regulation and EU council directive, biosecurity and management of exporting pig farms and slaughtering plants are good. In Thailand, DLD importation requirements are strong, so the levels of the likelihood for the virus to pass these nodes are very low or low with low or medium uncertainty. On the other hand, there are no specific quarantine measures to detect ASFV. As the pork products are processed, shipped, stored and transported, they are always kept either chilled or frozen. Evidence shows the virus is able to survive in chilled and frozen meat for a long time [19]. Moreover, because of weak biosecurity and management in small-scale pig farming, the virus could easily expose domestic pigs. Therefore, these nodes were identified with high or moderate likelihoods with high or medium uncertainty.

Table 3.5. Summary of levels of likelihood and uncertainty of each node

Nodes	*Likelihood*	*Uncertainty*
1. Sardinia Island & Mainland	Very low	Low
2. Italian pig farms	Very low	Low
3. Italian slaughter house	Low	Low
4. Italian processing plant	Moderate	Moderate
5. Italian livestock department & DLD quarantine station	Very low	Low
6. Shipment	High	High
7. DLD quarantine station	High	Low
8. Importing company & storage	High	Moderate
9.Transportation	High	High
10.1. Market/Restaurant to pig farms	Moderate	High
10.2. Waste products to domestic pig farms	Moderate	High

The negative biological consequence could be explained as domestic pigs do not have ASF antibody and about 90% of pig farms in Thailand are small scale, and these farms often do not have good management or biosecurity measures [5]. So, ASF will likely become endemic, spread fast, and over a widespread area because ASFV is tolerant in the environment and infected animals could be carriers and monitor/surveillance system for ASF is not good. Another negative consequence at the farm level could be factors affecting costs, for example, less live weight sold, increased incidence of other diseases, increased labor costs, and increased veterinary costs and medicines. Moreover, negative consequences at the country level would be of high impact since all pig product exportation would be banned (130 million dollars) if Thailand had ASFV [5]. Also, the DLD would need to greatly increase their budget for controlling ASF, and when ASF affects the farms the supply of pork would decrease, causing the market price of pork to increase and affect the whole society. On the other hand, based on PVS GAP analysis by OIE, Thailand has very strong veterinary services, an international animal health policy, and the relationship between the DLD and stakeholders (industries, vet schools) and the animal movement controls seem to be doing well, and ASF is currently in the Act of Animal Epidemic 2015 which means the DLD is able to effectively restrict an outbreak. In conclusion, even if Thailand veterinary services are good and ASF control is supported by legislation, the impact of the disease in terms of biological and socio-economic consequences are still pretty high, therefore the level of consequence assessment is high with medium uncertainty.

Table 3.6. Levels of likelihood of release assessment, exposure assessment, introduction, consequence assessment and overall risk.

Pathway	Likelihood
Release assessment	Negligible
Exposure assessment	Moderate
Likelihood of introduction	Negligible
Consequence assessment	High
Overall risk	**Negligible**

Table 3.6 shows the results of the combination of levels of likelihood of all nodes for release assessment, exposure assessment. The likelihood of introduction resulting from a combination of both release and exposure assessments by using the risk matrix are shown in the same table. The results showed that the level of likelihood for release assessment is negligible and moderate for exposure assessment so the likelihood of introduction is negligible. Also, since the level of consequence is high then the overall risk of introduction ASFV into Thailand by importing pig products from Italy in 2015 is “Negligible” by combining the likelihood of introduction and consequence by risk estimation.

Risk mitigation and Risk communication

The first recommendation was for Italian processing plants (Moderate likelihood). Because there is no way to destroy the virus in production, products should be irradiated as this can destroy the virus and also keep the product longer in production. Since the DLD does not have a specific method to detect ASFV in pork products at its quarantine stations, a screening laboratory should be in place to detect ASFV and reduce the likelihood of introduction. Real time PCR technique by using kits such as the QIAamp® Viral DNA Mini Kit (QIAGEN) for real-time PCR [29] have been used for screening live pigs in Thailand and can be used for pork products as well (NIAH, DLD).

The next recommendation is based on the conflict of interest between the government organizations. There is no regulation to control or screen for the disease after passing the quarantine station, so the DLD should implement procedures such as a laboratory survey of meat at markets and restaurants to detect the virus. Also, the DLD should collaborate with other stakeholders such as the Thai FDA, local administrations and other public health organizations to develop regulations or waste water management procedures to destroy the virus and prevent it from contaminating the environment. Finally, the DLD should improve fundamental knowledge of ASF, disinfectants and basic biosecurity procedures for the farmers. In long term the DLD should try to promote an increase in the sizes of small-scale farms and have a certification system that is required to operate farm. To reduce the consequence of the ASF, the DLD could benefit from a control and prevention strategy specific to the disease such as monitoring for it globally, improving the knowledge of DLD officers especially, researching or modelling ASF in Thailand.

In addition, the assessor needed to communicate the data, steps to analysis, and results to all stakeholders because they needed to know, agree, comment, and exchange information (two-way communication). Risk mitigations will be sent to DLD officers to stopper the gaps and show how risk mitigation would change the model and reduce the risk. As a result, DLD officers need to communicate well with the farmers to clarify their understanding of the disease, improve their confidence in the government control policy, and build awareness so the farmers stop illegal trading of infected pigs or carcasses. The DLD should take advantage of the disease in terms of promoting small-scale farms to medium or large-scale farming, improving veterinary services in the country, and collaborating with Thai and international organizations.

3.5. Discussion

Although the risk of introduction of the virus by importing pig products from Italy into Thailand in 2015 was negligible, is negligible acceptable? OIE members use the term acceptable to reflect a balance of the country's wishes and what it achieves. The acceptable level is different among countries. [7]. According to the Table 3.1, negligible means the likelihood that the event will occur is significant is not worth considering. Generally, a decision maker needs to ensure the risk is mitigated to an acceptable level, and the negligible level is often lower than acceptable level [15]. Therefore, negligible is often acceptable. Risk analysis, however, could be used as gap analysis as the results showed that there are high levels of likelihood of risk in some nodes and high consequences of the disease. To improve performance and also as a precaution, the DLD should implement risk mitigations which would be applicable to preventing other animal health risks as well.

In addition, since there was limited time and resources, the quantitative risk assessment was difficult to be apply to this study. Nevertheless, a semi-quantitative risk assessment could have been considered to evaluate the risk. Instead of categorizing the risk by textual evaluation such as low or high, semi-quantitative uses probability ranges such as low equals 10^{-3} to 10^{-4} or high equals 10^{-1} to 10^{-2} [30]. However, semi-quantitative risk assessment would provide a probability value which might not be easy for officers to interpret in the field. For example, what if the risk of introduction was 10^{-2}; this number might not seem high in the human understanding, but actually it means the risk is high.

The determination of the level of the consequence of the disease by the assessor in this study is subjective as the supportive evidence is all descriptive information and collected necessary data. To better estimate a biological consequence, disease spread models and habitat suitability models should be developed to show how and where the virus may spread over a susceptible population and the resulting biological impacts [31]. Similarly, to evaluate economic consequences, risk-based benefits and costs or cost-benefit analysis is preferable to identify the acceptable levels of risk, and tools in economics such as life cycle cost analysis, farm level analysis, partial budgeting, time value of money and basic microeconomic ideas should be applied to achieve better results [32, 33].

Next, the risk analysis in this study used the term “risk mitigation” instead of “risk management”. Risk management is composed of acceptance (do nothing), increase, get more information, avoidance (elimination) and reduction (mitigation) [15]. To choose what of these management procedures would be suitable for this study, the economic, disease modeling and intensive communication with stakeholders needs to be taken into account. So risk mitigation, which primarily identifies gaps and provides information on how to reduce the level of risk based on each gap [10] is more suitable within the limitations of this study.

The limitations of this study were critically important in terms of designing an assessment and a topic, choosing methods to get data and to correct the results. Limitations faced in this study were time, resources, distance communication, government limitations, lack of previous research and character of the assessment.

Limited time influences how reliable the supportive information is, and also the assessment. Input data for this study were limited since the assessor had to communicate to stakeholders online whether it was to send questionnaires or emails. As a result, misunderstandings, untrue or missing data might have occurred. In addition, qualitative risk assessment requires less time and fewer resources than quantitative risk assessment and semi-quantitative assessment, so normally qualitative risk assessment is chosen as the first step provide an initial idea or information. Since Thailand has never found ASF within its borders, and there has been no risk analysis of ASF in Thailand before, then qualitative risk analysis was the most suitable for this study.

This study has provided the baseline of doing risk analysis for the future, and this research should be continued by improving the quality of data in order to get numerical data, including economic data, to develop a quantitative risk assessment. Moreover, with the same model, stakeholders should consider changing scenarios based on risk mitigations to estimate how each mitigation affects the overall risk and what mitigation is the most effective to be adapted for preventing the disease in the future.

3.6. Conclusion

African swine fever is a hazard to Thailand because of the potential presence of virus in pig products imported from Italy. The risk analysis revealed that the likelihood of release of hazard into Thailand was negligible, while the likelihood of exposing the domestic pigs to the hazard was moderate. The likelihoods of introduction of the ASFv resulted to be negligible. In addition, the level of consequence of the virus in Thailand was high compiled through estimating negative biological consequence, negative economic consequence, and positive consequence. The overall risk of ASF from importing pig products from Italy to Thailand in 2015 was "negligible".

The DLD and importers should mitigate the risk by implementing new protective measures. For example, radiating the imported products or keep them longer than the virus surviving time, enforce and practice existing laws, developing a screening laboratory to reduce the probability of risk, collaborating with the Thai FDA and local administrations to develop regulations to control and screen for the disease, and improving biosecurity and management of small-scale pig farms. Moreover, the DLD should continue this study while minimizing the limitations to maximize accuracy of the results.

CHAPTER IV.

QUALITATIVE RISK ASSESSMENT OF ASFV INTRODUCTION INTO THAILAND BY IMPORTING PIG PRODUCTS FROM AN ENDEMIC COUNTRY BASED ON DIFFERENT RISK MITIGATION SCENARIOS

4.1. Summary

Pork production is an important part of the livestock industry and the economy of Thailand. ASF is exotic to Thailand and would cause a huge impact if it successfully entered the country. The OIE has been recommended developing risk analysis for preventing the introduction of animal infectious diseases, especially, exotic diseases. The estimation of risk of introduction ASF by importing pig products from Italy into Thailand in 2015 has been done and showed “Negligible” risk. The objective of this study was to show the effect of risk mitigations, and if the DLD in Thailand would implement new mitigations, how the risks would be change and what is the best mitigation plan. All four scenarios developed were based on assuming that the ASF virus was in the products. The first is a worst-case scenario, the second targets reducing the risk at release assessment, the third targets reducing the risk at exposure assessment, and the fourth targets reducing the risk at consequence assessment. These scenarios were developed and analyzed based on the initial pathway and supportive evidence from the previous chapter. The results showed moderate risk for a worst-case scenario, negligible risk for the second scenario, low risk for the third scenario, and low risk for the last scenario. Also, the second scenario which mitigated the risk at release assessment would have the most efficiency by using a descriptive partial budget. However, because of limitations of this study and other economic tools, the DLD

should continue this study by creating other scenarios concerning DLD policy and budget and increasing the accuracy of the results by improving the quality of supportive evidence.

4.2. Introduction

Livestock production has been an important factor for developing the country since the beginning of Thailand's history. In the past, Thailand produced livestock for domestic consumption, but currently Thailand shares a large portion of its livestock products with the world, such as cooked chicken and cooked pork. Also, Thailand is the member of the World Trade Organization (WTO) and World Organization for Animal Health (OIE). To protect the rights of WTO members by enforcing a level of food safety, animal health, or plant health, WTO developed the Agreement on the Application of Sanitary and Phytosanitary Measures (SPS Agreement), and OIE developed the International Animal Health Code for supporting livestock production standards that cover safety from livestock farm to exportation process. In addition, in Thailand, the Department of Livestock Development (DLD) is the main government organization that is responsible for developing or supporting livestock in the country and collaborating with OIE, especially for eliminating, controlling and preventing animal diseases.

According to the SPS agreement, OIE has taken responsibility for developing tools for controlling animal diseases, and risk analysis is a tool that OIE has been recommended for its members. OIE suggested members consider using risk analysis to support international trade, for transparency, and also for equivalency. Moreover, risk analysis requires scientific evidence or expert opinions, thus providing better support for making decisions. Veterinary services of the country and the animal health situation could also be analyzed by risk analysis to reveal gaps that could allow import and spread of disease, and risk analysis would improve risk management by giving recommendations to manage or reduce the risks [7].

The pig industry of Thailand is a very important driver of the economy of the country. The number of domestic pigs in Thailand is approximately 5,876,562 fattening pigs, 3,054,758 breeder pigs, and 580,069 domestic pigs (DLD) Information Center, 2014), and approximately 130 million dollars in pork products was exported in 2013 [5]. Therefore, pig diseases are enemies of the pig industry, especially exotic contagious diseases which can have a huge impact on Thailand's naive domestic pig population. For example, the Thai DLD has been monitoring African swine fever (ASF) which would make the pig industry get in trouble if the disease entered the country.

ASF is caused by African swine fever virus (ASFV) which is in the genus *Asfivirus*, family *Asfarviridae*. ASFV is a double-stranded deoxyribonucleic acid (dsDNA) virus [16]. ASF is one of the most serious diseases of domestic pigs in Africa and some countries in Europe, and there is no effective vaccine [34]. Wild boar is the main reservoir for local spread of the virus, but for international trade movement of live pigs and pork products are the most important factors. ASFV can be effectively transmitted by a variety of ways such as direct contact when naïve pigs are close to infected pigs, and indirect contact including contact with fomites and vector-borne. The *Ornithodoros* tick spp. is the vector which can spread the virus from pig to pig via biting (Iowa State University, 2010). Subclinical cases infected with low virulence virus causes a chronic form of ASF and there are no specific clinical signs or lesions. An infected pig might develop mild fever, abortion, and necrotic skin lesions, and infected animals can become carriers if they survive the disease [2, 16].

Potential risk factors of ASF are divided into local spread at the farm level, district level, and at the regional or international level. In southwest and central Kenya and Nigeria, for example, the risk factors for local spread are free-grazing pigs, replacement pigs, distance from the national park, abattoir/slaughter slabs within pig communes, infected neighborhoods, and wild birds and rodents enter pig pens [23, 24]. For the regional or international levels, the important risk factors are possible transboundary spread via infected wild boar or human movement, the undetected spread of ASFV, movement of infected pigs without any control measures, and movement of contaminated pig products [19]. To eradicate and control ASF, one of the recommendations especially for an ASF-free country is to develop a risk assessment, to estimate which introduction pathways are important, the risk of the disease, the consequence, and to identify gaps or weak points of introduction [18, 35].

The study discussed in the previous chapter showed “Negligible” risk, however since risk analysis could be used as gap analysis. Therefore, to minimize the gaps by mitigating risk is critical argument for improving the performance and capacity of the DLD. This chapter is continuing the development of chapter III in asking what different control and protective measures should be implemented by the DLD if ASFV is in imported pig products. The objectives of this study are to show the impact on or change in risk if the DLD implemented different approaches for preventing the disease. Because this chapter focuses on different mitigation scenarios, a brief descriptive partial budget analysis is included which is about how to choose the best alternative based on added income, reduced costs, added costs and reduced income [36]. Partial budget analysis has been used to support making the best and most efficient decision.

The four scenarios were developed to identify the overall risks. The scenarios are as follows:

- The first case scenario: What if DLD, Thailand would do nothing different from the current regulations or practices (a worst-case scenario).

- The second scenario: What if DLD, Thailand would improve the sensitivity of import regulations and establish a screening laboratory at quarantine stations to minimize the likelihood of introducing the virus at release assessment.
- The third scenario: What if DLD, Thailand would implement collaboration, regulations to detect the virus at markets and restaurants, treatment of water before it contaminates the environment, and improve biosecurity and management of small-scale pig farms to minimize the likelihood of introducing the virus at exposure assessment.
- The fourth scenario: What if DLD, Thailand would improve effective control and prevention measures to minimize the level of the consequence of the disease.

4.3. Materials and Methods

Model development and scenario trees

Four different models were developed based on the situation that Thailand imports pig products from an outbreak country that does not have good veterinary services and is unable to control ASF outbreaks or detect ASFV in exported products. These models assumed that the virus was in the products once past the responsibility of the export country. Risk assessment is divided into release assessment, exposure assessment, and consequence assessment, therefore three possible risk mitigations were implemented based on each assessment and the performance and capacity of, Thailand, in terms of human resources, financial resources and policies. These were used to develop a worst-case scenario and three scenarios in which implementations were used differently to minimize risk at release assessment, exposure assessment, and consequence assessment. The scenario trees were created from a possible movement pathway of pig products once past the responsibility of the export country to domestic pigs in Thailand. The movement pathway of ASFV was developed from expert opinions and literature to identify the nodes.

Data collection

The scenarios were developed using to trade documents of Thailand, importation requirements and government guidelines, scientific literature and expert opinions and information gathered via four questionnaires.

The consequence of the disease for a real situation was estimated based on the different scenarios and the possible magnitude and impact of an ASF outbreak if ASFV were introduced into Thailand. The Performance of Veterinary Services (PVS) GAP analysis, pig farm management and characteristics, veterinary legislation, DLD background information, DLD policy to control and prevent ASF, DLD laboratory and human capacity, expert opinions and information, scientific literature, and export data for pigs and pork products were used to estimate the level of consequence. For the fourth scenario, the consequence scenario was generated based on the best-case scenario.

Qualitative risk assessment, category tables and basic economic analysis

To estimate the risk of each scenario, the likelihood of introduction for the risk and the level of the consequence of the risk were identified. The level of likelihood of each node in release assessment and exposure assessment was categorized by using the qualitative likelihood scale categories (Table 4.1).

Table 4.1. Qualitative likelihood scale categories (Modified from USDA, 2013 [11])

Category	Descriptor
High	The event has more than an even chance that the event will occur.
Moderate/Medium	The event does occur but is unlikely to.
Low	The event is very unlikely to occur.
Very low	The event is very rare to occur, but cannot be excluded
Negligible	The likelihood that the event will occur is insignificant: not worth considering

The risk matrix (table 4.2) was used to combine the likelihoods of each assessment to get the level of likelihood of releasing risk, exposing risk and combine likelihoods of both assessments to get a likelihood of introduction of the AFSV.

Table 4.2. A matrix of rule for combining descriptive likelihoods (Modified from Guidelines for Import Risk Analysis, Biosecurity Australia, 2001 [14])

A matrix of "rules" for combining descriptive likelihoods					
	High	**Moderate**	**Low**	**Very low**	**Negligible**
High	High	Moderate	Low	Very low	Negligible
Moderate		Low	Low	Very low	Negligible
Low			Very low	Very low	Negligible
Very low				Negligible	Negligible
Negligible					Negligible

(See table 4.1. for the definitions of high-negligible)

In addition, risk estimation (Table 4.3) was developed to combine both levels of likelihood of introduction and level of the consequence of the risk to know the overall risk of ASFV introduction from importing pig products into Thailand from an outbreak country.

Table 4.3. The table of risk estimation (Modified from Guidelines for Import Risk Analysis, Biosecurity Australia, 2001 [14])

Risk estimation matrix						
Likelihood of entry and	High likelihood	Negligible	Very low	Low	Moderate	High
	Moderate	Negligible	Very low	Low	Moderate	High
	Low	Negligible	Negligible	Very low	Low	Moderate
	Very low	Negligible	Negligible	Negligible	Very low	Low
	Negligible	Negligible	Negligible	Negligible	Negligible	Negligible
		Negligible	Very low	Low	Moderate	High Impact
	Consequence of entry and exposure					

Basic economic analysis

Descriptive partial budgeting was used to compare positive and negative changes in economic consequences for the second, third and fourth scenarios. It showed what scenario would be the most effective for minimizing the risk. The first scenario was ignored because the worst-case scenario did not add new risk mitigations.

4.4. Results

Models and scenario trees

Four scenarios have been developed as shown in Figure 4.1. The first scenario is a worst-case scenario where the virus was already in the products and the DLD has not developed any new policy to reduce the risk, based on current control and prevention measures. In the second scenario the risk was mitigated at release assessment step where the DLD added or improved implementations which increased the sensitivity of the import regulations and established a screening laboratory for detecting ASFV at the quarantine station to reduce the risk. For the third scenario, the risk was mitigated at exposure assessment where the DLD developed regulations to detect ASFV at markets and restaurants, destroy the virus in wastewater from the company, markets, and restaurants before contaminating the environment, and improve biosecurity of small-scale farms. The last scenario was if the DLD developed an effective control and prevention policy to reduce the consequence of the risk such as enforcing the law to stamp out all infected and suspected animals and developing a surveillance system specific to ASF. Finally, all scenarios would be analyzed to know the overall risks in order to estimate the most effective DLD implementation policy for ASF.

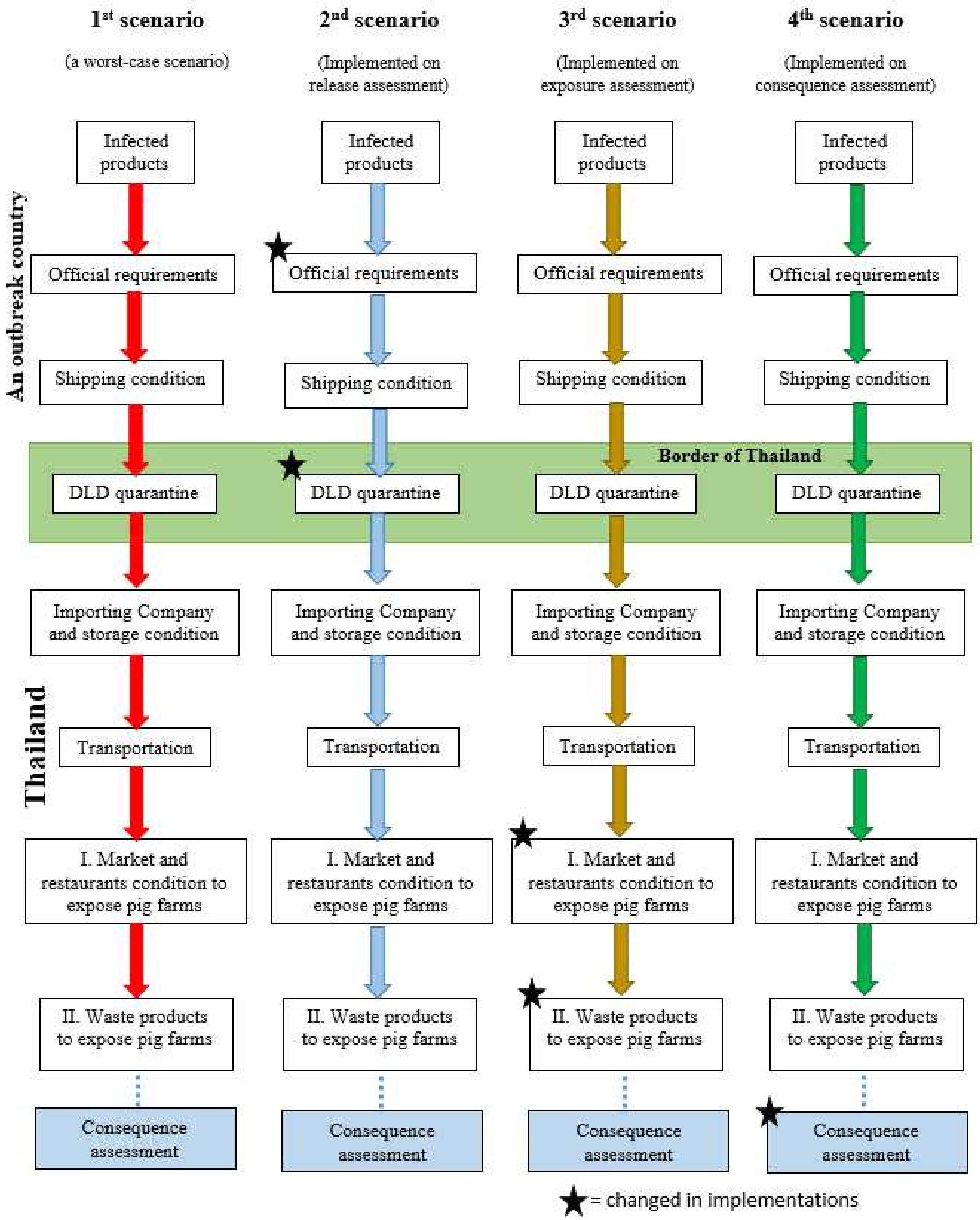

Figure 4.1. The four scenarios conducted differently in implementations

Qualitative risk assessment

Baseline supportive evidence to estimate the likelihood of introducing the risk are in Appendix 2 and identical to the last chapter. However, since different scenarios were developed based on what-if situations, the level of likelihood for each node in each step would be different, as shown in Table 4.4.

The first scenario, the worst-case scenario, assumes that an export country has an ASF outbreak, has no good control and prevention measures, and that everything outside the control of the DLD, Thailand is terrible. Current DLD policy and strategy could reduce the likelihood of risk by the 2006 DLD importation regulations [28] which restricted the import of live pigs and pig products to only from ASF-free countries and requiring health certification (more detail in Appendix 2). These measures show a low likelihood of risk. However, the conditions at shipment and in the DLD quarantine station, in the importing company and transportation could not reduce the number of virus since the imported products are raw (chilled, frozen and salted dry pork). Also, small-scale pig farms have weak biosecurity and management systems, the virus may be spread to domestic pigs via the market, restaurants, waste water and transportation, so these nodes were identified with high or moderate likelihoods.

In the second scenario everything is same as the first scenario, except what if the DLD improved the sensitivity of importation regulations. For instance, the current policy restricts import of products from an ASF outbreak country, however during ASF outbreaks in Italy (Sardinia Island) Thailand still imported tons of pig products from them. Even if Italy and the EU has a very good way to control or restrict outbreaks on the island, importing pig products from them is still wrong based on current regulations. so the DLD has to improve/develop the definition of an ASF-free country, and include all parts of a country. Also, DLD may request laboratory testing for ASFV before exporting pig products from an export country. With these improvements, the level of likelihood would change from low to negligible. In addition, the DLD would need to implement laboratory testing to screen the products at the quarantine stations. The DLD has been using Real time PCP (the QIAamp® Viral DNA Mini Kit (QIAGEN)) for real-time PCR [29] for detecting the virus in live pigs, however it could be adapted for screening pig products by using water from meats. These new implementations can change the level of likelihood from high to very low.

The third scenario considered if the DLD would improve biosecurity and management of small-scale pig farms by enforcing the law or certifying the farms. As of now the DLD does not have responsibility over the products at markets and restaurants; that is handled by the Thai FDA and local administrations However, the Thai FDA and local administrations do not have a high level of concern about non-zoonotic animal diseases in the products. The DLD could collaborate with them to take responsibility to detect ASFV. For waste water treatment, under current policy the DLD oversees hygiene regulations and enforcement at the company level, and for transportation, storage, and in a slaughterhouse to prevent animal disease outbreaks, but this is just for producing and consuming inside the country. So, if the DLD could establish the same regulations for the import side of each of these areas, the level of likelihood would change from moderate to low at these nodes.

Table 4.4. Summary of levels of likelihood and uncertainty of each node

NODES	LEVEL OF LIKELIHOOD / CONSEQUENCE			
Release assessment	**Scenario 1**	**Scenario 2**	**Scenario 3**	**Scenario 4**
1. An export country	High	High	High	High
2. DLD importation regulations	Low	Negligible	Low	Low
3. Shipment	High	High	High	High
4. DLD quarantine station	High	Vere low	High	High
Exposure assessment				
5. Importing company & storage	High	High	High	High
6.Transportation	High	High	High	High
7.1. Market/Restaurant to domestic pig farms	Moderate	Moderate	Low	Moderate
7.2. Waste products to domestic pig farms	Moderate	Moderate	Low	Moderate
Consequence assessment	High	High	High	Moderate

The forth scenario was a change in consequence assessment. If the DLD improved the biosecurity of small-scale farms as in the third scenario, it would not only just prevent the exposure from ASF-infected products to domestic animals, but also easily eliminate the virus if there is an outbreak in Thailand, resulting in a smaller outbreak. Because ASF is very easily transmitted and is highly contagious, immediate investigation, detection, and stamping out is the best way to control the disease. Even if current policy allowed that farmers might confuse ASF with CSF and illegal movement, especially movement of carcasses would likely occur. The DLD should therefore prepare control implementations. For example, a program to educate farmers to be concerned and aware, and to differentiate ASF from CSF; to use control measures modeling to estimate an outbreak and find the best way to control it; and to establish an ASF-free zone to reduce the impact of banned pig exportation. ASF could cause a huge impact to society and the economy of Thailand especially if all pig product exportation is banned (4,508 million bahts or 130 million dollars) [5]. Also, the DLD would need to spend a huge budget for controlling ASF, and when ASF affects the farms the supply of pork will decrease and the market price of pork will increase. In addition, farmers would spend more money because of increased veterinary costs and medicines, increased labor costs, increased overhead costs, and increased feed costs. They would also incur a loss of profit, less live weight sold and increased incidence of other diseases. Therefore, because of all the reasons above the consequence of the disease would change from high to moderate.

According to the new levels of likelihood and consequence in each scenario, the risk would be different as shown in Table 4.5; these results were estimated by using the risk matrix and the risk estimation.

Table 4.5. The levels of likelihood of release assessment, exposure assessment, introduction, consequence assessment and overall risk for each scenario

Pathway	Likelihood			
	Scenario 1	**Scenario 2**	**Scenario 3**	**Scenario 4**
Release assessment	Low	Negligible	Low	Low
Exposure assessment	Moderate	Moderate	Low	Moderate
Likelihood of introduction	Low	Negligible	Very low	Low
Consequence assessment	High	High	High	Moderate
Overall risk	**Moderate**	**Negligible**	**Low**	**Low**

As seen in Table 4.5, the overall risk is less in the second scenario which is negligible, low for the third and fourth scenarios, and moderate for the first scenario.

Basic partial budget analysis

For describing the basic economic analysis, it is assumed that collaboration, negotiation and law enforcement do not have costs. Based on Table 4.6 the positive change specific to minimizing the risk of introduction ASF by imported pig products into Thailand would be the best with the second scenario. The three steps reduction is significant when there are just five steps of levels of risk in this study. However, to be able to reduce the risk the costs include a screening test which is about $20 per a sample (QIAGEN), information from NIAH, DLD, Thailand, and to run the test there are costs for equipment, labor, and management. In the third scenario the risk reduced just one step (from moderate to low), and to reduce the risk the DLD would also need to implement the screening test for products at markets or restaurants, and there would be costs for improving the biosecurity of small-scale pig farming. Collaboration with other agencies, law enforcement and improvement of farm biosecurity at the exposure level would reduce other risks to animal health as well. In the last scenario the risk reduced one step even if the implementations benefitted pig farming and livestock in general, as there are costs for better control measures such as compensation money for efficiently stamping out an outbreak, as well as costs for developing better biosecurity in small-scale farming.

Table 4.6. The descriptive partial budgeting table

Scenario 2 (Negligible risk)	Positive	• From moderate to negligible risk (save costs for controlling the disease) • The laboratory testing could be adapted for other importations such as live pigs or personal items. (Specific to ASF)
	Negative	• To screen the products at quarantine station, costs of screening test; real time PCR by QIAGEN, approximately $20 per a sample (including a sample extraction price) (NIAH, DLD) • Opportunity costs for equipment, labor and management
Scenario 3 (Very low risk)	Positive	• From moderate to low risk (save costs for controlling the disease) • These mitigations would help to protect from other risks and improve collaboration which supports pig farming, livestock and public health in general. (Broader to other risks)
	Negative	• To screen the products at market and restaurant, costs of screening test; real time PCR by QIAGEN, approximately $20 per a sample (including a sample extraction price) (NIAH, DLD) • Opportunity costs for equipment, labor and management • Cost to improve small-scale farm biosecurity and management
Scenario 4 (Low risk)	Positive	• From moderate to low risk (save costs for controlling the disease) • These mitigations would help to protect from other risks and improve collaboration which supports pig farming, livestock and public health in general (Broader to other risks) • Save costs for controlling the disease to both famers and the government
	Negative	• Opportunity costs for labor and management • Cost to improve small-scale farm biosecurity and management • Cost for stamping out and other control measures

4.5. Discussion

Based on this study, the second scenario is the best one the DLD should consider, allowing the importation of radiated pig products or products stored longer than the virus survival time. Also, the DLD should update importation regulations to describe more precisely a definition of an ASF-free country, whether to keep not import from ASF free country or modify to ASF free zone or compartment definition. Laboratory tests should be considered to screen products before they enter Thailand. The QIAamp® Viral DNA Mini Kit (QIAGEN) for real-time PCR is suitable for this because the results are available within two hours [29], and this fits within the required short quarantine period. This technique has recommended by the OIE to detect the virus in blood from infected animals [22]. The DLD by NIAH has tested for the virus by this technique in a survey project. This kit can test the washing water from products at the quarantine station which contain blood from infected animals, however the sampling technique and sample size depends on the sensitivity of the test and the number, packaging or containers for the products. Also, according to partial budgeting, even though, there is no number of costs or incomes to make a comparison because of the nature of the data in this study, however, partial budget shows that the second scenario is also the best efficient way to minimize the risk, since three steps reduced and the costs are not much different from another scenario. However, to estimate the efficiency of an implementation, should consider other economic tools such as life cycle cost analysis, farm level analysis, time value of money and basic microeconomic ideas [32, 33].

The scenarios developed here targeted a worst-case scenario for release assessment, exposure assessment, and consequence. Other scenarios such as a change in nodes or the movement pattern of the products, as well as different techniques or implementations should be further analyzed to better understand how risk assessment would be useful when faced with different options. Also, this chapter is mainly for showing how different implementations would affect the risk of ASF. The DLD should consider the results with other factors that were not included in this study, for instance DLD policy, DLD budget, DLD limitations and human capacity, as well as relationships between other countries and stakeholders.

The limitations of this study were time, resources, and character of the assessment. Limited time requires qualitative risk assessment instead of quantitative or semi-quantitative risk assessment because both of those techniques need time to obtain fine data such as the number of products, sensitivity, and specificity of tests to know the probability the virus would pass each node. Moreover, to estimate the levels of likelihood and levels of consequence the assessor used supportive evidence and a category table; this is subjective, and other assessments might come to different conclusions.

4.6. Conclusion

The four scenarios had the different results. For the first (worst case) scenario where the DLD never changed current implementations even though the virus was in the products, the overall risk is moderate. The second scenario, what if the DLD restricted the importation regulations and developed a screening laboratory to detect the virus, resulted in negligible risk. This scenario showed the best results to mitigate the risk. The third scenario, what if the DLD collaborated with the Thai FDA and local administrations to prevent the virus in markets, transportation, and restaurants and forced them to treat waste water, as well as improved biosecurity in small-scale pig farms, resulted in low risk. For the last scenario the overall risk was low, and it included the DLD developing control and preventive measures to reduce the consequence such as educating farmers, improving biosecurity, enforcing the law to stamp out infected animals, modeling a disease outbreak and establishing an ASF-free zone. Since the overall risks of each scenario are different, the second scenario would be best in terms of minimizing the risk and having the best efficiency for implementation. However, with the limitations of the study the DLD needs to conduct more research to include policy, budget and limitations to make suitable decisions.

CHAPTER V.

CONCLUSION AND LESSON LEARNED FROM THIS STUDY TO IMPROVE DLD POLICY AND STRATEGY

Department of Livestock Development (DLD) is the main government organization which is responsible for developing livestock production in the country. The strategy plan was developed by the DLD during 2013-2017. One of the strategies is to improve productivity and performance to meet the international animal health standards to promote safe trade in livestock and livestock products [37]. So, to meet the standards, DLD may consider to improve a policy and strategy of livestock production system to be able to control, prevent and eliminate animal diseases, especially diseases which highly impact socioeconomic conditions. Control and prevention of animal diseases by DLD has been successful in the past. Thailand controlled a Highly pathogenic avian influenza (HPAI) and officially because free from Rinderpest and African horse sickness [38]. However, currently, there are several diseases that affects the improvement of livestock production in Thailand such as Foot and mouth disease (FMD), Classical swine fever (CSF), and Brucellosis. Moreover, there are a lot of factors that would distribute or introduce the emerging and reemerging diseases such as, poor biosecurity of small-scale farming and knowledge and attitude of the farmers. Hence, DLD in Thailand has to research, develop or revise tool, policy and strategy to be ready for preventing introduction of new diseases.

Risk analysis is a tool that could be used for improving animal health system of the country. There are new risk factors in animal health which have come into existence in the society, because of climate change, human behavior, microorganism adaptation, and transportation. So, to develop the suitable implementation which used to prevent the introduction of new risks, OIE suggested members to consider using risk analysis to support international trading, for transparency and equivalency. Also, veterinary services of the country and animal health situation could be analyzed by risk analysis to be able to know the risk of importation and spreading of disease, as well as risk analysis would give recommendations to manage or reduce risks [7]. Since this project demonstrated how to estimate the potential risk of introduction of ASFV into Thailand by importing pig products from Italy, 2015, ASF could be used as a model to improve the DLD practices and strategies in assessing the risk of introduction or spread of animal diseases. The questions are what DLD has learned and what DLD needs to improve through this project.

As per chapter III, the level of the risk of ASFV introduction into Thailand is "Negligible". However, the detailed calculations indicated that the level of overall risk is negligible because the level of likelihood of introduction at release assessment is negligible. While, the level of likelihood of introduction at exposure assessment is moderate and the level of consequence is high. Both exposure and consequence assessment steps are in the responsibility of the DLD. It seems that DLD's measurements for importing animal products are not good enough to prevent introducing and spreading of animal diseases. Even though DLD has developed the importation requirement which includes not to import animals and products detected of diseases listed by OIE [28], what would happen if some country intends not to report the real situation as well as bias or error of veterinary service in their county. The best way is that DLD should improve laboratory techniques (specific to particular disease of any species) to screen products for each lot of importation as if a product comes from an outbreak country.

Moreover, consequence assessment showed that DLD is not ready for preventing the spreading of emerging diseases. There are a lot of small-scale farming, conflict of interest among government organizations, and DLD does not have a specific surveillance system for emerging diseases. So, improving collaboration among stakeholders in government, promoting an increase in the sizes of farm and developing surveillance system of emerging diseases are critically necessary to disease a risk. All recommendations are showed in chapter IV, four scenarios were developed to show how overall risk would change if DLD did better implementations.

What have been found additionally when developed this project, but not related to the project is the limitation of DLD data collecting system, and DLD veterinary officers. Risk analysis requires plenty of information, better input will product better output. Another funding of this project is that DLD has a good system to collect data, but it is difficult to get data from different bureau or division in DLD because there is no common system to share information. Also, most of DLD veterinary officer are not aware of what risk analysis is and how it is useful for improving livestock production. In addition, risk analysis currently is not considered important in DLD structure, strategy or policy. Since DLD does not have a particular division responsible for developing risk analysis, it is extremely difficult to attain the data. Sharing process of a database of the bureau or division is not well established to perform risk analysis routinely. Moreover, risk analysis knowledge is quite new in ASEAN countries. Fortunately, DLD, Thailand, has a high capacity to lead others in risk analysis. So, it would be helpful if DLD could consider importance of risk analysis as a lead of ASEAN countries and being accepted or certified in international area.

Recommendations

1. Integrating and conducting risk analysis to support DLD's strategy and missions

1.1. Develop collaborating, and strategy process for risk analysis which accords to DLD structure and missions to be the fundamental development of risk analysis structure in the DLD in the future. This may require establishment of an administrative unit with this specific mandate.

1.2. Implement risk analysis in important animal health issue such as zoonosis, emerging and reemerging diseases, and using risk management in all decisions to make an efficiency policy

1.3. Implement risk analysis for live animal and animal products trading as the recommendation of World Trade Organization and World Organization for Animal Health

2. Driving the risk analysis of DLD to be certified for regional and international

2.1. Improve DLD officers in risk analysis by short course training or continued learning

2.2. Risk analysis of DLD to be certified

2.2.1. At the country level by Field Epidemiology Training Program for Veterinary (FETP-V)

2.2.2. At the regional level by ASEAN Veterinary Epidemiology Group

2.2.3. At the international level by supporting DLD to be the FAO Collaborating Centre and OIE Reference Centre for Veterinary Epidemiology and Risk Assessment by twinning program

Finally, Thailand is one of the leading country in agricultural exportation, risk analysis might be the tool to support Thailand to be certified in the regional as well as supported DLD to be the FAO and OIE reference center for veterinary epidemiology, and international risk analysis center for the region. Then, Thailand could be the kitchen of the world genuinely.

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APPENDIX 1

Institutional review board (IRB) Colorado State University approval

Colorado State University

Research Integrity & Compliance Review Office
Office of Vice President for Research
Fort Collins, CO 80523-2011
(970) 491-1553
FAX (970) 491-2293

Date: May 6, 2016

To: Rao Sangeeta, PhD
Assistant Professor, Clinical Sciences

Tosapol Dejyong
Master's Student, Clinical Sciences

From: Evelyn Swiss, CIP, IRB Coordinator Evelyn Swiss

Re: Analysis of risks of African swine fever (ASF) introduction into Thailand by Pig Products from Italy, 2015

After review of information regarding the survey data to be collected for this project, it was determined that this activity does not meet the requirements of the federal definition of *human subject* research. "Human subject means a living individual **about whom** an investigator conducting research obtains data through intervention or interaction with the individual, or identifiable private information" 45CFR46.102(f).

Living individual – Y
About Whom – N (Pigs)
Intervention/Interaction – Y
Identifiable Private Information – Y

Thank you for submitting this information. If you have more projects that are similar, please contact us prior to submission. The IRB must determine whether a project needs to have IRB approval.

Figure 5.1. the letter of approval by institutional review board Colorado State University

APPENDIX 2

Supportive evidences/information to estimate the levels of likelihood

Node 1. Sardinia Island & Mainland of Italy

According to the world animal health information database (WAHID), there were two outbreaks during 2015 in Italy; one outbreak occurred in the feral swine population, another one occurred in the domestic pig population. Moreover, both outbreaks were on Sardinia Island which is the part of Italy [3]. ASF has been on the island since 1978 and is an endemic disease. The main risk factors contributing the disease are small-scale farming or household farming which is about 90% of all pig farms on the island. Small-scale farms do not have good biosecurity which makes it easy for the virus to spread within the pig population. Although the local government has implemented the standard farm, there are still some illegal farms or free-range farms. There is also illegal trading of live pigs and products within the island [25].

Even there are many risk factors for spreading the disease, Italy seems to have a very good plan to minimize spread to the mainland:

First, according to the European commission (2011/852/EU) live pigs, products and materials are prohibited by law from moving to the mainland [39].

Second, according to EU legislation on ASF (2013 Food and Veterinary Office (FVO) report), the new 2015-2017 eradication program established a task force or policy strategy to create a clear chain of command. It also proposed strong actions against illegal free-ranging pigs such as information and training for farmers and depopulation of illegal pigs. Pig owners will only get financial support if they comply with the minimum EU law requirements as well as holding certification for farming for ASF-infected farms [40].

Third, there is a new tool for controlling the disease which is an antibody screening technique with 99% specificity and 100% sensitivity [25].

Forth, according to the EU Commission Decision, if there is an outbreak, the local veterinary officers must do an outbreak investigation. If ASF is officially confirmed, a stamping out policy needs to be considered at the farm level or zone, carcasses destroyed, and all equipment and vehicles must be cleaned. In addition, there is an establishment of a protective zone and surveillance zone to control the disease [41].

Fifth, in about two decades ASFV has never crossed over to the mainland [42]. That shows the success of the Italy and EU policy.

Expert opinions/information

- A comprehensive surveillance is active in Sardinia Island. This activity is based on a continued passive surveillance and an active plan during the annual hunting season. A wide infected area is estimated every year where all dead and shot wild boar are investigated by serological and virological laboratory tests.

- It is permitted to export pork products from Sardinia Island if the meat is derived from swine not bred on the island. Any live pig or fresh pork meat or pork products deriving from pigs bred on Sardinia Island must be consumed or destroyed there.

- The prevalence was assumed by the national informative system for notifiable diseases. To declare an outbreak, laboratory confirmation is necessary. Four laboratories on Sardinia Island are accredited to perform the laboratory tests following the rules described in the diagnostic manual for ASF (2003/422/CE). The NRL located in Perugia is responsible for the standardization of the methods.

Node 1: Conclusion and decision
Based on the supportive evidences ASF is endemic on Sardinia island, but there are strong control and prevention measures in place to minimize the disease as well as policies prohibiting the movement of live animals and animal products from the island to the mainland. However, there is no information about illegal transportation by human movement or personal items. There are many government documents and literature available. So, the level of likelihood that the virus could spread to the mainland is **“Very Low”** with **“Low Uncertainty”.**

Node 2. Exporting pig farms

To estimate the level of likelihood that ASFV could infect the exporting pig farms if there is ASFV in mainland, information about veterinary services and the control and prevention program of Italy are needs to be considered.

- According to the EU Council Directive 2002/60/EC [41], the veterinary services of Italy have a very strong action plan to control the disease if there is ASFV on the mainland. The control measures include,
- The ASF is a notifiable disease and must be reported to the national surveillance system.
- There is a passive surveillance system available for ASF.
- There is identification and registration of animals.

- If there is an ASF outbreak, immediate investigation has to be done with establishment of a surveillance zone and a protective zone (radius 10 km.). Also, no pigs, carcasses or products may leave the holding area, and movement of people, and vehicles needs authorization. Cleansing, disinfection and treatment with insecticides must be considered. In addition, in cases where ASF is suspected or confirmed in feral pigs there should be a plan for eradication (Immediate killing of all pigs (culling) in the outbreak area—Stamping out policy).
- Italy has *Ornithodoros (Alectorobius) coniceps* ticks that can be a vector for the disease [43].

Expert opinions/information

- The wide territory of Italy, excluding the Sardinia Region, should be considered as free from ASF infection.
- Exporting farms have a very good biosecurity system especially in the north of Italy which have exported pig products to Thailand.

Node 2: Conclusion and decision
Based on the supportive evidence, if ASFV entered the mainland, there are a lot of control and prevention measures in place to minimize the disease. Moreover, exporting farms normally have very good biosecurity systems and standards, so, it is very difficult for the virus to spread among exporting pig farms. However, Italy has an effective vector for the virus. There are government documents and literature available. So if there the virus does reach the mainland, the level of likelihood and uncertainty that exporting pig farms would be infected with ASFV is **"Very Low"** with **"Low Uncertainty".**

Node 3. Italian slaughter house

Ante-mortem and post-mortem examinations during the slaughtering process can detect pathogenic microorganisms by observing the clinical signs or lesions of the ASF. Regulations for screening live pigs before slaughter is a critically important step to certify that those animals are free from the disease. To estimate the level of likelihood the ASFV is able to pass the slaughtering process, information is needed about how live pigs are screened before going to slaughter as well as how well meat inspectors and veterinarians are able to detect the abnormal signs or lesions.

According to EU Council Directive 2002/99/EC, the general health requirements for slaughtering animals prevent the disease from passing this step [44].

The general health requirements include: First, the animal origin must fulfill the animal health conditions set by community legislation, the animals do not come from a holding/restriction area where the disease could be present, and any suspected infected/ill animals will not be slaughtered and enter the food chain. Second, the transportation from the farm to the slaughtering plant must be approved by the competed authority. Also, veterinary authorization is needed to allow the slaughter of animals.

According to EU Regulation (EC) 854/2004 for ante-mortem inspection, the slaughtering plant must have a visual inspection since animals are in a vehicle until they are quarantined in stalls. For the post-mortem inspection the procedures are divided into carcass inspection, organ inspection and tissue inspection [45]. However, of 100 ASF-infected pigs sent for slaughter, it is estimated that 90 of them would be detected and 10 would not. Of the 90 detectable cases, 55 % were estimated to present as typical cases and 45 % as non-typical cases based on expert opinions [46].

Based on the DLD inspection report that was developed for inspecting Italian pig products in 2011, veterinarians checked the pigs before slaughter, and the slaughterhouses had a very good system to prevent the disease from the outside such as keeping records for human movement, and screening sick pigs.

Expert opinions/information

- All swine are submitted to a veterinary check, even for family consumption, prior to slaughter.

- The most important clinical test is the check of body temperature, as well as skin lesions and reproduction rate. The laboratory is accredited to perform the PCR test, direct Immunofluorescence as a virological test at the time of slaughter.

Node 3: Conclusion and decision

Based on the supportive evidence there are many steps in place which are able to detect ASF such as the general health requirements, and ASF is on the list of diseases that need to pass ante-mortem and post-mortem steps. However, since an infected pig could be a carrier of the disease, it is possible that there no clinical signs or lesions would be observed. Under those conditions the virus that could pass the slaughtering process. There are government documents and literature available. So if the virus in the exporting pig farms, the level of likelihood and uncertainty of undetectable virus is **“Low”** with **“Low Uncertainty”.**

Node 4. Italian processing plant

There are five different kinds of pig products exported to Thailand each year: dry salt curing pork, frozen internal organs, frozen pork skin and salt chilled pork. ASFV can survive in chilled meat 84 – 155 days, in frozen meat and organs 103 – 1000 days, and in salted (cured) and dried meat about 140 days [19].

Table 5.1 The condition of process [19, 45, 46]

Type of pork products	Process	Time of ASFV detection (days)
Dry salt curing pork	Adding salt, nitrates, nitrites and sugar. Dry curing can take months, even years. Stored at temperatures between 32° to 40°F.	140
Frozen internal organs	Often stored at or near −18 C.	103 – 1000
Frozen intestine	Often stored at or near −18 C.	103 – 1000
Frozen pork skin	Often stored at or near −18 C.	103 – 1000
Salt chilled pork	Salt + Often stored at or near −1.5 - 8 C.	84 – 155

According to the Table 5.1, salt, nitrates, nitrites and sugar are used to process dry salt curing pork and it take months or even years of storing at temperatures between 32° to 40°F to complete the process. Compared with the time that ASFV can survive in dry salt curing pork, it seems the virus can survive if exported products have been stored fewer than 140 days. Similarity, frozen meat and organs are stored at -18 Celsius, and the virus can survive in that condition 103 – 1000 days. Also, salt chilled pork, is stored at -1.5 to -8 Celsius, and the ASFV can survive for 84 – 155 days [19, 47, 48]. In addition, based on the DLD inspection report that was developed for inspecting Italian pig products in 2011, to make dry salt curing pork or salt chilled pork required about a year with pH 5.7, a_w 0.90 conditions, but this varied depending on the size of the products.

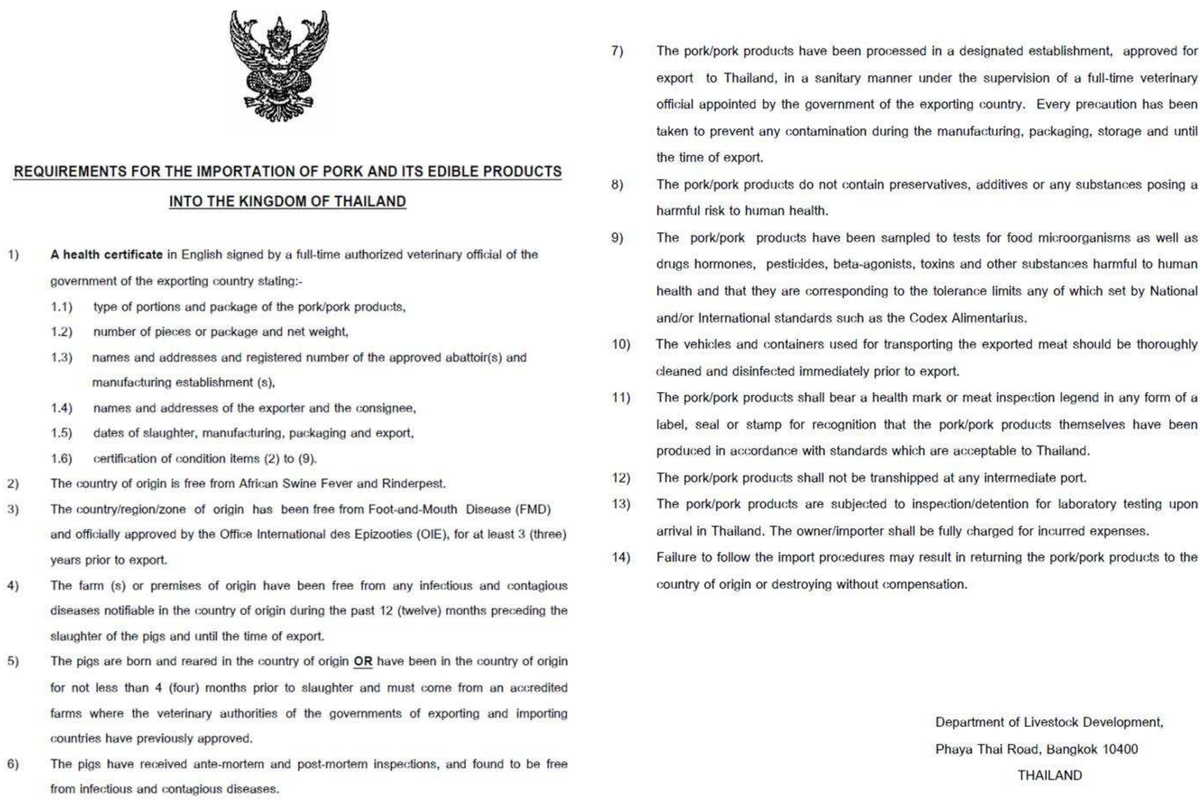
So, in all these processing conditions the virus can survive in the products after processing. Therefore, time must be the prime factor to consider since neither heat, radiation nor any other way will destroy the virus. To sum up, the processing plants do not have methods to minimize the number of the virus. However, the supportive evidence is not from real data from the exporting plants in Italy that export to Thailand, so variability of the process has to be considered.

Node 4: Conclusion and decision
Based on the supportive evidences, the process at processing plant could not destroy or minimize the number of the virus. So even if the pig products pass a processing plant the virus can still survive. There is supportive literature available but a lack of real data from real exporting plants in this situation. If the virus is in the meat before processing, the level of likelihood and uncertainty of risk that the virus could survive is **"Medium"** with **"Medium Uncertainty".**

Node 5. Italian livestock department & Department of Livestock Development of Thailand

The Italian Livestock Department by EU regulations and DLD requirements are the steps to prevent the ASFV introduction. The pig products have to meet the requirements of both countries in terms of exporting requirements and importing requirements to make sure that there is no disease which would spread to another country.

The EU requirements for exporting include an official veterinary export health certificate to confirm that the exporting products do not have any diseases. Similarly, the DLD requirements include a health certificate, and the products have to come from an ASF-free country and originate from ASF-free farms. Also, the products need to pass ante-mortem and post-mortem exams, and exportation has to be under the supervision of a veterinarian. The details of the DLD requirements are shown below:



REQUIREMENTS FOR THE IMPORTATION OF PORK AND ITS EDIBLE PRODUCTS INTO THE KINGDOM OF THAILAND

1) **A health certificate** in English signed by a full-time authorized veterinary official of the government of the exporting country stating:-
   1.1) type of portions and package of the pork/pork products,
   1.2) number of pieces or package and net weight,
   1.3) names and addresses and registered number of the approved abattoir(s) and manufacturing establishment (s),
   1.4) names and addresses of the exporter and the consignee,
   1.5) dates of slaughter, manufacturing, packaging and export,
   1.6) certification of condition items (2) to (9).
2) The country of origin is free from African Swine Fever and Rinderpest.
3) The country/region/zone of origin has been free from Foot-and-Mouth Disease (FMD) and officially approved by the Office International des Epizooties (OIE), for at least 3 (three) years prior to export.
4) The farm (s) or premises of origin have been free from any infectious and contagious diseases notifiable in the country of origin during the past 12 (twelve) months preceding the slaughter of the pigs and until the time of export.
5) The pigs are born and reared in the country of origin **OR** have been in the country of origin for not less than 4 (four) months prior to slaughter and must come from an accredited farms where the veterinary authorities of the governments of exporting and importing countries have previously approved.
6) The pigs have received ante-mortem and post-mortem inspections, and found to be free from infectious and contagious diseases.
7) The pork/pork products have been processed in a designated establishment, approved for export to Thailand, in a sanitary manner under the supervision of a full-time veterinary official appointed by the government of the exporting country. Every precaution has been taken to prevent any contamination during the manufacturing, packaging, storage and until the time of export.
8) The pork/pork products do not contain preservatives, additives or any substances posing a harmful risk to human health.
9) The pork/pork products have been sampled to tests for food microorganisms as well as drugs hormones, pesticides, beta-agonists, toxins and other substances harmful to human health and that they are corresponding to the tolerance limits any of which set by National and/or International standards such as the Codex Alimentarius.
10) The vehicles and containers used for transporting the exported meat should be thoroughly cleaned and disinfected immediately prior to export.
11) The pork/pork products shall bear a health mark or meat inspection legend in any form of a label, seal or stamp for recognition that the pork/pork products themselves have been produced in accordance with standards which are acceptable to Thailand.
12) The pork/pork products shall not be transhipped at any intermediate port.
13) The pork/pork products are subjected to inspection/detention for laboratory testing upon arrival in Thailand. The owner/importer shall be fully charged for incurred expenses.
14) Failure to follow the import procedures may result in returning the pork/pork products to the country of origin or destroying without compensation.

Department of Livestock Development,
Phaya Thai Road, Bangkok 10400
THAILAND

Figure 5.2. Requirements for the importation of pork and its edible products into the Kingdom of Thailand, DLD, 2006 [28].

Node 5: Conclusion and decision

Based on government documents, Thailand has excellent requirements to be best able to prevent the disease from other countries as well as Italy. Italy also has excellent requirements. However, the actual practice is more important than the documents. Since infected products are difficult to export to Thailand, the level of likelihood of risk for ASFV passing the requirements of both countries is **"Low"** with **"Low Uncertainty".**

Node 6. Shipment

In 2015, pig products imported from Italy to Thailand arrived mainly by ship and some of them were imported by airplane. In 2015 there were four routes of importation of pig products from Italy. The Suvarnabhumi Airport DLD quarantine station has the responsibility for imported products arriving by air shipment. The Bangkok DLD quarantine station, the Ladkrabang DLD quarantine station and Chonburi DLD quarantine station are responsible for products arriving by ship (DLD quarantine documents).

Expert opinions/information

- Chilled products are shipped in 0 Celsius.
- Frozen products are shipped in -20 Celsius.
- The time for air shipment is about 2 days.
- The time for ship shipment is about 30 – 45 days.
- The packages and containers are always in good condition during shipping.

This information came from experts; there are no official documents that prove the real conditions of shipment specific to the imported products. In comparing the information of time of ASFV detection from node 5 with shipment information, it seems that ASFV can also survive in those condition.

Node 6: Conclusion and decision
Based on the supportive evidences, it is possible for ASFV to survive during shipping. However, this information is mainly from experts. So, the level of likelihood of risk for ASFV passing the shipping condition is **"High"** with **"High Uncertainty".**

Node 7. DLD Quarantine station

According to the DLD importation procedures, importers must submit the importation requirement to the Division of Veterinary Inspector and Quarantine, DLD. After that the DLD would check the disease status of an exporting country and send the import regulations to that country. When products arrive, DLD veterinarians check the health certificate and whether the products meet the requirements or not.

Expert opinions/information

- For importing pig products, a quarantine station takes samples to screen only for Salmonella spp. There are no other measures in place to screen for other diseases including ASF.
- Veterinarians check whether or not the products meet the regulations including coming from an ASF-free country, slaughter at an approved abattoir, and having veterinary authority for export purposes.

Node 7: Conclusion and decision
Based on the supportive evidences, at the quarantine station ASF would not be screened. All processes are to check the official importation documents. It is possible for ASFV to survive and pass the quarantine station if ASFV is in the products. The information is from official documents and experts. So the level of likelihood of risk for ASFV passing the quarantine station is **“High”** with **“Low Uncertainty”.**

Node 8. Importing company & storage

The storage condition at the importing company can show whether the virus can survive or not. According to DLD quarantine documents and the DLD information center, imported pig products from Italy were stored in provinces which have a high density domestic pig population such as Nakornpathom (240,091 head), Chachoengsao (306,666 head), and Nakhon Sawan (104,269 head) provinces. The companies that imported pig products from Italy to Thailand in 2015 included Global Food Products Co., Ltd., King Well Advance Import Co., Ltd., Greenfresh-Innovation Co., Ltd., Big-C Supercenter Co., Ltd. and Jagota Food Ingredients Co., Ltd.

The DLD regulations for certifying places for storing animal products focus on structure and management. For example, isolation from the public, no other products in the same storage area, pest control, and records of human and vehicle movement.

Expert opinions/information

- The importing company and storage area has to be certified for good conditions such as having suitable temperature for storing dried, chilled or frozen meat, structure of the container or building in good condition and is clean, and having personal protection for good hygiene.

- There is no information which shows that any animal diseases have been transmitted by animal products from a company, market, or restaurant to farm or slaughter.
- By the Act of Food and Act of Animal Epidemics, the Bureau of Livestock Standards and Certification does not have any ability to enforce or check the imported products after the products have passed the DLD quarantine station.
- The importing company might be possible to re-packaging the products.

Node 8: Conclusion and decision
Based on evidence and expert opinions, the regulations mainly focus on preventing diseases transmitted between inside and outside storage facilities. Without any specific method for minimizing the virus it is possible for ASFV to survive in the storage condition. The information mainly from experts. So the level of likelihood of risk for ASFV passing the storage condition is **"High"** with **"Moderate Uncertainty".**

Node 9. Transportation

Expert opinions/information

- The Division of Veterinary Inspector and Quarantine, DLD, has animal quarantine stations in almost every province. To transport the products, a transporter has to submit transportation requirements to the DLD. The DLD will approve based on the condition of the products. They will check the origin of the products and might have some disease screening, but not for ASF.
- After getting the certification for transport, the DLD quarantine stations will check whether or not the products match the certification along the way to the destination.

- The DLD is approving the use of GPS (Global Position System) to track the movement of livestock and products.

Node 9: Conclusion and decision
Based on expert opinions and information, the regulations mainly focus on documents. If there was the virus in the product, the virus would possibly survive in the transportation condition and never be detected. The information mainly from experts. So the level of likelihood of risk for ASFV passing transportation is **"High"** with **"High Uncertainty".**

Node 10.1. Market/Restaurant to domestic pig farms

Similar to the shipment and storage, temperature, time and conditions for storing or selling the products could be used to estimate the likelihood ASFV will survive. According to the Guideline for Food Sanitation in Markets (Bangkok Metropolitan Administration, 2012), the temperature for keeping meat must be less than 5 Celsius and must be sold within 2 days for chilled meat. The temperature for keeping frozen meat must be less than -18 Celsius (no time period). Also, those products have to always be in good packaging and there are also restrictions for the quantity of the products in the chilled/frozen fridge. However, there are no suggestions for keeping dry salt curing pork.

According to a guide for food businesses (at a restaurant), the temperature for storing meat could vary, but the recommendation is keeping chilled meat at between 0-5 Celsius and frozen meat at less than -18 Celsius [49].

Small-scale pig farms are also a risk because they do not have good biosecurity and management; for example, only using a disinfectant basin in front of the farm, no record of visitors, housing areas open to the environment [50].

Figure 5.3. Small-scale pig farming in Thailand (picture from DLD)

Expert opinions/information

- There is no information which shows any animal diseases have been transmitted by animal products from the company, market, or restaurant to a farm or slaughter plant.
- By Act of Food and Act of Animal Epidemics the Bureau of Livestock Standards and Certification does not have any ability to enforce or check the imported products after the products pass the DLD quarantine station.
- On small-scale farms the biosecurity is not good enough to prevent contamination from the household.
- At the household level, it is possible that waste products from the human tables would feed the pigs, but pig products from Italy are too expansive for famers so they are less likely to feed then to an animal.

Node 10.1: Conclusion and decision
Based on the supportive evidences and expert opinions/information, it is possible for ASFV to survive in the storage condition at a market or restaurant. Moreover, the biosecurity system of small-scale pig farming is weak, so, it is possible the infected products would survive in the market and restaurant and expose to domestic pig farms at the household level. Also, the DLD does not have any ability to enforce or check the imported products after they pass the DLD quarantine station. However, those pig products are less likely to be bought by farmers and fed to animals. So the level of likelihood of risk for ASFV passing the storage condition at a market or restaurant and exposing domestic pig farms is **"Medium"** with **"High Uncertainty".**

Node 10.2. Waste products to domestic pig farms

According to information about the location of importing companies, they are in high density area of domestic pig population from node 8 and have characteristics of small-scale pig farms in node 10.1. That information shows that the waste products from importing companies, markets and restaurants are possible avenues for exposing domestic pig farms to ASFV. Moreover, the DLD can control the waste water treatment of slaughter plants and companies inside the country that are consuming/producing the products, but not treatment of water from the importing company.

Expert opinions/information

- If the company does re-packaging, it is possible that they have waste water. And ASFV is able to contaminate the public via waste water.

- Also, it is possible the waste products from the company & restaurant will be used for feeding animals in small farms.
- Thailand has a lot of environmental conditions which are not good for the ASFV to live for long such as heat, acid in rain as well as in water.

Node 10.2: Conclusion and decision
Based on the supportive evidences and expert opinions/information, it is possible for ASFV to survive in waste products. Moreover, the biosecurity of small-scale pig farming is weak, so, it is possible for infected waste products to expose domestic pig farms. Also, the DLD does not have any ability to enforcement or control waste water treatment and waste products which are likely used for feeding animals. However, Thailand climate and environment is not suitable for the virus to live for long. So the level of likelihood of risk that ASFV could contaminate the environment and expose a domestic pig farm is **“Medium”** with **“High Uncertainty”.**

APPENDIX 3

Expert selection criteria

Italian subject-matter experts have to match *at least 2* of below criteria in addition to criterion #1.

1. Have an experience in working with the livestock department in Italy.
2. Have a veterinary degree
3. Have an experience in working with ASF outbreak in Italy.
4. Have an experience in working with pig products exportation in Italy.

Subject –matter experts from DLD quarantine stations have to match *at least 2* of below criteria in addition to criterion #1.

1. Have an experience in working at quarantine station at least 1 year.
2. Have a veterinary degree
3. Being engage in importation of livestock products.
4. Have an experience in working with ASF.

Experts from bureau of disease control and veterinary services of DLD have to match *at least 2* of below criteria.

1. Have an experience in working in BDCVS at least 1 year.
2. Have an experience in the field of epidemiology.
3. Have an experience in the field of swine disease.
4. Responsible for disease surveillance system.
5. Have high scholarly qualifications. (MS., Ph.D.)

Experts from bureau of livestock standards and certification of DLD have to match *at least 2* of below criteria.

1. Have an experience in working in BLSC at least 1 year.
2. Have an experience in the field of disease in pig products
3. Responsible for certifying livestock products
4. Have high scholarly qualifications. (MS., Ph.D.)

APPENDIX 4

The list of experts

Italian veterinary officer

Francesco Feliziani, DVM, PhD, Head of national reference laboratory for swine fevers

Division of Veterinary Inspection and Quarantine, DLD

Lamai Nammongkol, DVM, Veterinary Medical Officer, Professional level
Wanida Chaengprachak, DVM, MSc, Veterinary Medical Officer, Professional level
Arden Ratcharee, DVM, MSc, Veterinary Medical Officer, Practitioner level
Panyarat Orkoonsawat, DVM, Veterinary Medical Officer, Practitioner level
Yotsaran Chalaardisai, DVM, Veterinary Medical Officer, Practitioner level

Bureau of Disease Control and Veterinary Services, DLD

Sangchai Thitichankamol, DVM, Veterinary Medical Officer, Senior level
Sith Premashthira, DVM, MSc, PhD, Veterinary Medical Officer, Senior level
Weerapong Thanapongtharm, DVM, MSc, PhD, Veterinary Medical Officer, Senior level
Kitipat Sujit, DVM, M.Ag, Veterinary Medical Officer, Senior level
Chayanee Jenpanich, DVM, MSc, Veterinary Medical Officer, Professional level
Khemmapat Boonyo, DVM, MSc, Veterinary Medical Officer, Professional level
Soontaree Weeragidpanit, DVM, MSc, Veterinary Medical Officer, Practitioner level
Natthawut Jira, DVM, Veterinary Medical Officer, Practitioner level

Bureau of Livestock Standards and Certification, DLD

Atchabun Sangsiriruk, DVM, Veterinary Medical Officer, Professional level
Pramot Phuangchomphoo, DVM, Veterinary Medical Officer, Practitioner level

National Institute of Animal Health, DLD

Tapanut Songkasupa, DVM, Veterinary Medical Officer, Practitioner level

Chulalongkorn University

Sonthaya Tiawsirisup, DVM, MSc, PhD, Associate Professor

APPENDIX 5

Questionnaires

Questionnaire for Italian veterinary officers

The project: Analysis of risks of African swine fever (ASF) introduction into Thailand by pig products from Italy, 2015

This questionnaire is designed to collect data about the 2015 ASF outbreak in Sardegna Island, Italy. Our intent is to analyze control measures for ASF in Italy, and the risk associated with exporting porcine/pig products to Thailand. Answers will be used to assess levels of risk, and the uncertainty of data sources in risk assessment. This project is a part of Dr. Tosapol Dejyong's master degree at Colorado State University, USA. If you have any questions, please contact Dr. Dejyong via e-mail at tosapol.dejyong@colostate.edu

Note: Some questions ask for your own opinions. Please answer all questions and identify whether the answers are your opinion. Please send any supporting documents/evidence for your answers to the e-mail.

Respondent information

First Name: Family name:

Gender: ☐ Male ☐ Female Current position:

Education: ☐ Bachelor degree ☐ Master degree ☐ Doctoral degree ☐ Other………

How many years have you worked in current position:

How many total years of professional experience do you have:

What are the names of the previous organizations you worked in (please list all)

Questions

(Questions 1-10 ask about confirming an outbreak of ASF, definitions of ASF free zone/compartment, current ASF control measures in Italy, and existing policies to prevent ASF spread from Italy to other countries.)

1. Was the ASF pathogen identified in Italy in 2015?
   ☐ Yes ☐ No ☐ Do not know

2. Do you know the definition of ASF free zone/compartment?
   ☐ Yes ☐ No ☐ Do not know

3. If yes to Q2, what is the definition of ASF free zone/compartment?

4. Does Italy have an ASF free zone/compartment?
   ☐ Yes ☐ No ☐ Do not know

5. If yes to Q4, where is the ASF free zone/compartment in Italy? (City, or Region)

6. What are the control measures of ASF in Italy? (check all that apply)
   - ☐ Notifiable disease ☐ Precautions at the borders ☐ Monitoring
   - ☐ Screening ☐ General Surveillance ☐ Targeted Surveillance
   - ☐ Movement control inside the country ☐ Stamping out
   - ☐ Stamping out (Modified) ☐ Zoning ☐ Treatment
   - ☐ Control of wildlife reservoirs ☐ Control of vectors
   - ☐ Other……………………….
7. Do current exportation policies require all porcine/pig products to be certified ASF-free?
   ☐ Yes ☐ No ☐ Do not know

8. If 'yes' to Q7, what type of activities/policies are in place?

9. What is the prevalence of ASF in Italy in domestic animal?

10. According to Q9, please describe how the ASF prevalence is calculated, what laboratory testing is used, and what is the sensitivity and specificity of the test.

(Questions 11-17 ask about the possibility of the ASF outbreak spreading to the mainland and other countries through pig or pig product movement.)

11. Is the outbreak (in Wild boar, in Sardegna, Jan 2015) likely to spread to the main land?
    ☐ Yes ☐ No ☐ Do not know
    Please give reasons, and documentary evidences, if relevant:

12. If the response is 'No' to Q8, what type of measures, if any, are taken to stop such spread?
13. Dose Italy has Ornithodoros ticks spp.?
    ☐ Yes ☐ No ☐ Do not know

14. If the response is "Yes" to Q 13, how does Italy control distribution of ASFV via Ornithodoros ticks spp spreading?

15. Has ASFV has been detected in pig farms before sending animals to slaughter?
    ☐ Yes ☐ No ☐ Do not know
    Please give reasons, and documentary evidences, if relevant:

16. If so, what clinical signs/laboratory testing is used to detect ASFV on pig farms? What are the sensitivity and specificity of these tests?
17. Is there any pig/pig product movement between Sardegna and main land?
    ☐ Yes ☐ No ☐ Do not know
    Please give reasons, and documentary evidences, if relevant:

18. Have those source pigs of pig products been subjected to ante-mortem inspections and found free of any sign suggestive of ASF.

    ☐ Yes ☐ No ☐ Do not know

    Please give details about the ante-mortem inspection process. What is the sensitivity and specificity?

19. Have those source pigs of pig products been subjected to post-mortem inspections and found free of any sign suggestive of ASF.

    ☐ Yes No ☐ Do not know

    Please give details about the post-mortem inspection process. What is the sensitivity and specificity?

(Questions 18-23 asks about the possible risk of spreading ASF from the outbreak to Thailand)

20. Are pig farms that serve as the source of pig products exported to Thailand possibly infected with ASF?

    ☐ Yes ☐ No ☐ Do not know

    Please give reasons, and documentary evidences, if relevant:

21. Are pig products able to carry the pathogenic agent of ASF, how?

22. Does Italy have an ASF surveillance system and/or any specific ASF control programs for exporting the pig products to Thailand?

    ☐ Yes ☐ No ☐ Do not know

    Please give reasons, and documentary evidences, if relevant:

23. Does Italy have traceability program or system for exported pig products that allows for product to be traced back to the original pig farm or slaughter plant?

24. For this question, please feel free to put all information to describe any precautionary measures being taken by Italy to control the spread of virus to other countries via Italy's exportation of pig products.

Questionnaire for DLD veterinary officers at quarantine station

The project: Analysis of risks of African swine fever (ASF) introduction into Thailand, by pig products from Italy, 2015

This questionnaire has made for collecting data mainly about knowledge of ASF, ASF preventive measures at boarder, and capacity of Thailand to prevent ASFV from imported pig product. All of the answers would be used to assess level of risks, and uncertainty of data sources in risk assessment. This project is a part of Dr.Tosapol Dejyong's master degree at Colorado State University, USA. If you have any questions, please contact Dr. Dejyong via e-mail at tosapol.dejyong@colostate.edu

Note: Some questions ask for your own opinions. Please answer all questions and identify whether the answers are your opinion. Please send any supporting documents/evidence for your answers to the e-mail.

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Questions

(Questions 1-7 asks about trading standards of Thailand)

1. Do imported pig products from Italy, 2015 come with international veterinary certificates?
   ☐ Yes ☐ No ☐ Do not know

2. Do you know if pig products from Italy are from pigs that have been kept in an ASF free country, zone or compartment since birth or for at least the past 40 days?
   ☐ Yes ☐ No ☐ Do not know

3. Do pig products from Italy come from pigs that were slaughtered in an approved abattoir?
   ☐ Yes ☐ No ☐ Do not know

4. Have those source pigs of pig products been subjected to ante-mortem inspections and found free of any sign suggestive of ASF.
   ☐ Yes ☐ No ☐ Do not know

5. Have those source pigs of pig products been subjected to post-mortem inspections and found free of any sign suggestive of ASF.
   ☐ Yes ☐ No ☐ Do not know

6. Have those pig products been approved by the Veterinary Authority for export purposes?
   ☐ Yes ☐ No ☐ Do not know

7. Has a sample been collected from every animal killed and been tested for ASF through viral isolation, detection assays, and/or serology, with negative results. (in Italy)
   ☐ Yes ☐ No ☐ Do not know

(Questions 8-18 asks about ASF awareness, control measures, officer knowledge and possibility of introduced ASF)

8. Is the DLD quarantine station concerned about ASFV in meat/pig products?
   ☐ Yes ☐ No ☐ Do not know
   Please give detail, and documentary evidences, if relevant:

9. What are specific methods does the DLD use to screen ASFV in meat/pig products? (Please give detail/documentary evidences, if relevant)

10. What is the average length of time it takes for pig products to be transported from Italy to Thailand?

11. Under what conditions are pig products transported from Italy to Thailand? Ex. Temperature, Package etc.
    (Please list top 3 conditions)

12. How are you sure/not sure those pig products are free from ASFV after passing through the DLD quarantine station? Please explain

13. What if Italy had an ASF outbreak, and Thailand imported pig products from them? Do you think Thailand would be at risk for ASF?
    ☐ Yes ☐ No ☐ Do not know
    Please give reasons, and documentary evidences, if relevant:

14. Regarding import companies that imported pig products in 2015, how did they store the products? (Ex. temp. /time…)
    Please give reasons, and documentary evidence, if relevant:

15. Regarding the same companies in Q 19, do those companies re-package the products?
    ☐ Yes ☐ No ☐ Do not know
    Please give reasons, and documentary evidences, if relevant:

16. Is it possible that trucks used to transport imported pig products would also be used to transport items for pig farms such as feed, pigs, equipment etc?
    ☐ Yes ☐ No ☐ Do not know
    Please give reasons, and documentary evidences, if relevant:

17. According to 16, if yes, how are the trucks sanitized? It is possible for imported pig products to contaminate pig farms via this pathway? How?
    Please give reasons, and documentary evidences, if relevant:

18. For this question, please feel free to put other information that shows Thailand has a good way to prevent ASFV via exporting pig products or other important information.

Questionnaire for veterinary officers at bureau of disease control and veterinary services

The project: Analysis of risks of African swine fever (ASF) introduction into Thailand, by pig products from Italy, 2015

This questionnaire has made for collecting data mainly about ASF situation in Thailand, capacity of Thailand to prevent ASFV introduction into Thailand, spreading ASFV from imported pig product to domestic animals. All of the answers would be used to assess level of risks, and uncertainty of data sources in risk assessment. This project is a part of Dr.Tosapol Dejyong's master degree at Colorado State University, USA. If you have any questions, please contact Dr. Dejyong via e-mail at tosapol.dejyong@colostate.edu

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(Questions 1-10 ask about ASF situation in Thailand, possibility of ASF spreading Thailand via import pig products)

1. Does the Bureau consider ASFV exotic to Thailand?
   ☐ Yes ☐ No ☐ Do not know

2. Is ASFV notifiable in Thailand?
   ☐ Yes ☐ No ☐ Do not know

3. Is ASFV controlled by an official control program in Thailand?
   ☐ Yes ☐ No ☐ Do not know
   Please list all activities

4. Are there free zones of ASFV in Thailand?
   ☐ Yes ☐ No ☐ Do not know
   Please give details, and documentary evidences, if relevant:

5. Are there low prevalence areas of ASFV in Thailand?
   ☐ Yes ☐ No ☐ Do not know
   Please give details, and documentary evidences, if relevant:

6. Do you think DLD has ever imported pig products from outbreak country?
   ☐ Yes ☐ No ☐ Do not know
   Please give reasons, and documentary evidences, if relevant:

7. If Thailand has imported pig products from an outbreak country, is that possible to introduce ASFV into Thailand? (Passed quarantine process)
   ☐ Yes ☐ No ☐ Do not know
   Please give reasons, and documentary evidences, if relevant:

8. If there is an evidence that imported pig products carry ASFV from outside Thailand, is there a chance to infect domestic pigs. (from company, market, restaurant to pig farms)
   ☐ Yes ☐ No ☐ Do not know
   Please give reasons, and documentary evidences, if relevant:

9. If domestic pigs in Thailand were infected with ASFV, what would the magnitude of the ASF outbreak? (Please give reasons, and documentary evidences, if relevant)

10. If there was an ASF outbreak among domestic pigs in Thailand, what control and preventive measures would be instituted to prevent further spread and/or stop the outbreak?

11. If there were an ASF outbreak among domestic pigs in Thailand, what socio-economic impact would this have on the pig industry?

12. Is there information which shows that any diseases of animals have been transmitted by animal products from company, market, restaurant to farm or slaughter?
    ☐ Yes ☐ No ☐ Do not know
    Please give detail, and documentary evidences, if relevant:

13. For this question, please feel free to put other information to show how likely that Thailand has imported pig products from an outbreak country, how likely that infected pig products can or cannot pass quarantine station, and how likely that infected pig product can or cannot spread the virus to domestic animal after passed quarantine station, and other important information.

Questionnaire for veterinary officers at bureau of livestock standards and certification
The project: Analysis of risks of African swine fever (ASF) introduction into Thailand, by pig products from Italy, 2015

This questionnaire has made for collecting data mainly about knowledge of ASF, ASF preventive measures in importing pig products, and capacity of Thailand to prevent spreading ASFV from imported pig product to domestic animals. All of the answers would be used to assess level of risks, and uncertainty of data sources in risk assessment. This project is a part of Dr.Tosapol Dejyong's master degree at Colorado State University, USA. If you have any questions, please contact Dr. Dejyong via e-mail at tosapol.dejyong@colostate.edu **Note: Some questions ask for your own opinions. Please answers all questions and identify whether the answers are your opinion. Please send any supporting documents/evidence for your answers to the e-mail.**

Respondent information
First Name: Family name:
Gender: ☐ Male ☐ Female Current position:
Education: ☐ Bachelor degree ☐ Master degree ☐ Doctoral degree ☐ Other………
How many years have you worked in current position:
How many total years of professional experience do you have:
What are the names of the previous organizations you worked in (please list all)

Questions
(Questions 1-8 ask about the possible route of spreading of the disease inside Thailand, and the potential level of detecting it)
With your experience, if there is an ASF infected pig product introduction into Thailand, are they transported directly to company, market, and restaurant?

1. Is it possible that importing pig products can contact domestic pig farms?
   ☐ Yes ☐ No ☐ Do not know
   Please give reasons, and documentary evidences, if relevant:

2. Does bureau of livestock standards and certification have any measure to detect ASFV from pig products after passing through quarantine station (company, market, restaurant)
   ☐ Yes ☐ No ☐ Do not know
   Please give reasons, and documentary evidences, if relevant:

3. Is there information which shows that any diseases of animals have been transmitted by animal products from company, market, restaurant to farm or slaughter?
   ☐ Yes ☐ No ☐ Do not know
   Please give reasons, and documentary evidences, if relevant:

4. If pig products from Italy were contaminated with ASFV and passed through a quarantine station, Is it possible ASFV would be in waste products/water from an **importing company**? (Do they have good sanitation or water treatment?)
   ☐ Yes ☐ No ☐ Do not know
   Please give reasons, and documentary evidences, if relevant:

5. If pig products from Italy were contaminated with and passed through a quarantine station, is it possible ASFV would be in waste products/water from **a market and restaurant?**

☐ Yes ☐ No ☐ Do not know

Please give reasons, and documentary evidences, if relevant:

6. From Q4, Q5 if ASFV can pass through waste products/water, is it possible pig farms could be infected by the contaminated waste water?

☐ Yes ☐ No ☐ Do not know

Please give reasons, and documentary evidences, if relevant:

7. If there were an ASF outbreak among domestic pigs in Thailand, what socio-economic impact would this have on the pig industry?

8. For this question, please feel free to put other information to show how infected pig products can or cannot spread the virus to domestic animal after passing through quarantine station, and other important information.