Economic analysis of some emerging infectious diseases for the Dutch livestock sector - A pilot study

Minor Thesis Business Economics

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Preface

Ever since my BSc thesis on the symptoms of a Bluetongue infection in Dutch dairy cattle and sheep, emerging infectious diseases have had my interest. The level of uncertainty connected to such outbreaks has always intrigued me. Will it arrive here? If so, when? What will the clinical effects be in Dutch animals? The impact on the Dutch livestock sector? What measures should be taken? To answer these questions coordinated research efforts on prevention and consequences are required.

This Minor thesis in Business Economics has given me the opportunity to do something with these questions, and to run into the problems associated with them. It has given me a greater understanding of the knowledge gaps that need to be addressed, and I hope that this goes for all who read this document.

My thanks goes out to Helmut Saatkamp in the first place, for his patience, motivational feedback and for telling me when enough really is enough. I would furthermore like to thank Aline de Koeijer and Piet van Rijn (Central Veterinary Institute) and Susanne Waelen (Ministry of Economic Affairs, Agriculture and Innovation) for their input.
Last but not least, I would like to thank my parents and family, the DVDM and other friends for being there for me, for the advice and the occasional night out. Matthieu, merci pour tout, je n’aurai pas pu le faire sans toi.

Dominique Noome

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Summary

Due to global warming and increased international trade the distribution of emerging infectious diseases (EIDs) around the world is changing. This is also linked to a changing vector distribution. A recent example was the outbreak of Bluetongue virus in Europe. For regions such as the Netherlands, with a high livestock production and a high livestock density, these diseases present a future and current risk.

Outbreaks of EIDs can have huge negative impacts on the livestock sector, thereby disproportionally affecting certain stakeholder groups. The Dutch government has the use of multiple veterinary measures to prevent or control such outbreaks. However, not much is known about these EIDs. This study aims at providing a comparison of the total costs between EIDs at farm level.

Four EIDs were chosen, based on characteristics such as zoonotic, infected ruminants are all vector borne. These were Epizootic hemorrhagic disease, Lumpy skin disease, Rift valley fever and Vesicular stomatitis. In an excel model epidemiological and economic input per EID was analyzed, followed by a sensitivity analysis. Epizootic Hemorrhagic Disease, one of the four, was used for two outbreak scenarios based on bluetongue epidemiological data.

From the analysis it appeared that Rift valley fever caused by far the highest costs per farm, due to mortality. Vesicular stomatitis also caused reasonably high costs. Due to their zoonotic nature and complicated transmission these two should have priority for further research. The best and worst scenarios with EHD have effectively proven that even with a relatively harmless disease as Epizootic Hemorrhagic Disease the costs can go up into tens of millions of euros.

This pilot study has given more insight into what information is needed to be better prepared for such an event. Further research recommendations include the risk of introduction, vector habitat and competence as well as clinical symptoms in Dutch livestock.

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List of Abbreviations

BTV	Bluetongue Virus
CFSPH	Center for Food Security and Public Health
CVI	Central Veterinary Institute
EHD	Epizootic Hemorrhagic Disease
EID	Emerging Infectious Disease
FMD	Foot and Mouth Disease
LSD	Lumpy Skin Disease
MRZ	Movement restriction zone
RVF	Rift Valley Fever
VS	Vesicular Stomatitis
VWA	Voedsel en Waren Autoriteit (Food and Consumer Product Safety Authority)

1. Introduction

A difference in climatic conditions has often served as a safety barrier against livestock diseases. Due to global warming, the distribution of disease pathogens or, most importantly, their vectors, is changing. Recent examples are the outbreaks of Bluetongue virus in Europe, 800 km further north than usual (Martini *et al.*, 2008) and the emergence of West Nile Fever in France in 2000 (Dufour *et al.*, 2008). For regions in temperate climates that have a high livestock production and a high livestock density, such as in certain parts of Northwestern Europe, these so-called emerging infectious diseases (EIDs) present a future and current risk.

Outbreaks of exotic diseases such as Foot- and- mouth disease and Classical swine fever can have huge negative economic impacts on the livestock sector (Huirne, 2002). Certain stakeholder groups within this sector are often disproportionately affected.

In case of outbreaks of EIDs in the Netherlands, the Dutch Ministry of Agriculture can decide to implement various control measures, depending on the type of disease and the size of the outbreak. Although general plans are available in case of such an outbreak, more information is needed for EID specific contingency plans. A lack of previous experience with these EIDs causes uncertainty about transmission, pathology and economic impact in the Dutch situation.

This pilot study aims at providing a preliminary insight into the economic effects of some EIDs in the Dutch livestock sector. Particular focus will be on (1) a comparison of total costs per farm between EIDs, (2) the economic impact for various stakeholder groups.

2. Materials and methods

2.1 Overview

An outline of the research approach is presented in figure 1.

First, an inventory of EIDs potentially relevant for the Netherlands was made (Appendix I and Appendix II) Information was collected by means of a literature study and expert information.

Subsequently, a limited number of EIDs was selected for further study. This had to be a manageable number of EIDs (4 to 6) with comparable characteristics such as animal type affected, zoonosis, vector borne and risk of introduction.

Various combinations were made, but in the end four EIDs were chosen. These are Epizootic hemorrhagic disease (EHD), Lumpy Skin Disease (LSD), Rift Valley Fever (RVF) and Vesicular Stomatitis (VS). This will be explained in more detail in chapter 2.2.2.

The selected EIDs were subject to a Quick scan displaying current veterinary measures most likely to be implemented following introduction of a specific EID in the Netherlands. Examples of such measures are the isolation of farms, zoning with transport restrictions, vaccination and export restrictions.

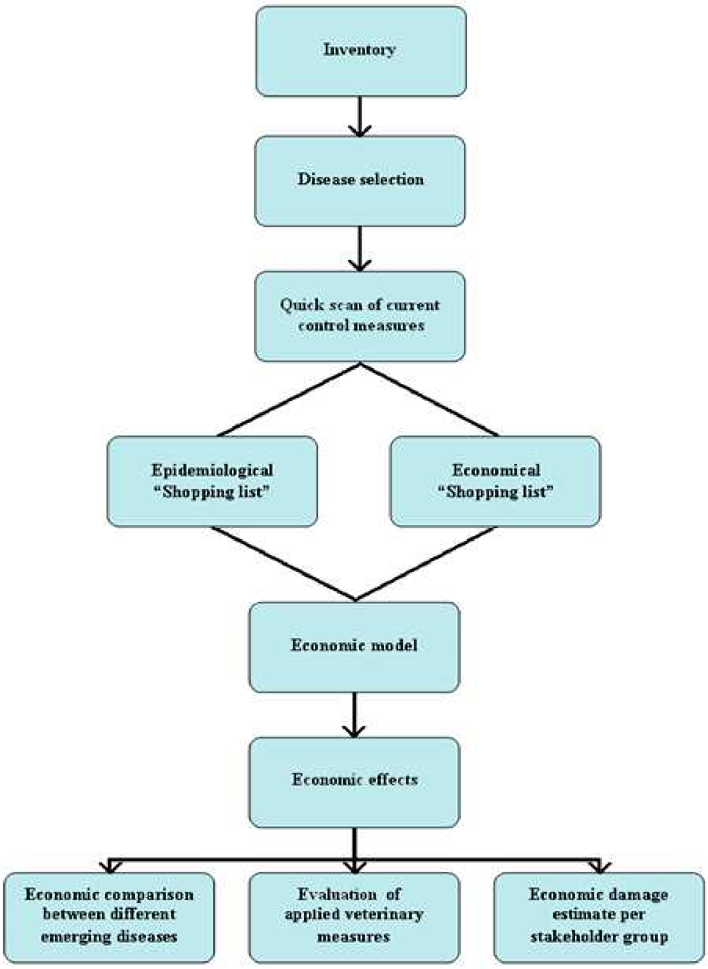

Figure 1. Outline of research approach

After selection of the EIDs the epidemiological and economic "shopping lists" were composed. These included information such as the number of animals on an average farm, the percentage of animals with milk production loss, or the slaughter price.

Originally, it was the intention to create nationwide outbreak scenarios. However, there was too little data and knowledge available, making a prediction of the course of an outbreak in the Dutch situation mere guesswork, even for experts. Due to this problem, the following changes were made:

The scenarios were no longer used, instead the focus shifted to the single farm level. In this way the differences between EIDs could still be made visible. The emphasis was moved to the zoonosis versus non zoonosis (eradication versus coping) veterinary measures.

Subsequently, an economic model was developed in Excel. Economic input was derived from experts and literature. Examples of input parameters are production loss per animal, culling, costs of a transport ban and veterinary expenses.

Obtaining the results allowed for a first comparison between EIDs, including a differentiation of economic impact for various stakeholder groups. The economic impact of veterinary measures was analyzed per EID and per outbreak type and subjected to a sensitivity analysis.

2.2 Delimitation and assumptions

This study is a pilot study within the framework of a thesis, meaning time and budget restrictions. Below an overview of the study limits that were chosen are discussed.

2.2.1 Economic context

The economic context is limited to stakeholders that have direct or indirect consequential costs from an outbreak. This has been limited to farms only, not including hobby farmers. Only the most common farm types were chosen.

Cattle

Based on information from CBS (2010) and from Saatkamp *et al*. (2005) the choice was made for dairy and veal farms, because they are the most numerous in the Netherlands. See Table 1 for an overview of farm numbers per animal type.

Table 1. Number of farms with different categories of cattle in the Netherlands in 2009 (CBS, 2010)

Category	Sub category	Number of farms
Cattle, total	Cattle, total	33,268
Dairy- and breeding animals	Dairy and breeding animals, total	26,038
Dairy- and breeding animals	Calves, < 1 yr, female	22,269
Dairy- and breeding animals	Calves, < 1 yr, male	11,472
Dairy- and breeding animals	Yearlings, 1-2 yr, female	22,239
Dairy- and breeding animals	Yearlings, 1-2 yr, male	7,144
Dairy- and breeding animals	Heifers, >= 2 yr	14,936
Dairy- and breeding animals	Melk- and calf cows(>= 2 yr)	20,268
Dairy- and breeding animals	Meat- and pasture cows (>= 2 yr)	5,524
Dairy- and breeding animals	Breeding bulls (>= 2 yr)	5,064
Meat- en feeder cattle	Meat- en feeder cattle, total	12,647
Meat- en feeder cattle	Veal calves for white meat (< 1 yr)	1,023
Meat- en feeder cattle	Veal calves for rosé meat (< 1 yr)	1,109
Meat- en feeder cattle	Calves, < 1 yr, female	5,960
Meat- en feeder cattle	Calves, < 1 yr, male	5,478
Meat- en feeder cattle	Yearlings, 1-2 yr, female	5,985
Meat- en feeder cattle	Yearlings, 1-2 yr, male	4,012
Meat- en feeder cattle	Feeders, >= 2 yr, female	3,431
Meat- en feeder cattle	Suckler cows (>= 2 yr)	7,583
Meat- en feeder cattle	Bulls for meat production (>= 2 yr)	2,346

Dairy cattle

See Table 2 for the number of animals on a dairy farm.

Dairy cattle have an assumed average milk production of 8542 kg in 305 days with 4.30 fat and 3.47 protein (KWIN, 2010).The average calving interval is 423 days (KWIN, 2010).

Table 2. Number of animals on average dairy farm

Animal type	**# Animals**
Dairy cow	79.6
Heifer 1-2 yrs	30.8
Calf 0-1 yrs	31.6

Veal calves

In the Dutch veal sector there are two types of veal production; rosé and white. Because the white veal makes up the largest part of the Dutch veal sector this has been taken as the standard. An average veal calf farm has 564 animals (Bont *et al*., 2008). An all-in, all out system is assumed.

Sheep

Although there are many people that keep sheep in the Netherlands, there are not many farmers that keep sheep exclusively. This study is limited to dairy and meat sheep farms.

Table 3. Number of farms with sheep categories in the Netherlands in 2009. (CBS, 2010)

Category	Number of farms
Sheep, total	12833
Ewes	12710
Lambs	9913
Rams	6003

Dairy sheep

An average dairy sheep farm has 200 sheep and 400 lambs (Ipema *et al*., 2002).

If we assume that the outbreak will occur between May and November (7 months), average sheep can only be pregnant in the last two months. This is about 28.5% of the time. However, sheep won't all become pregnant on the first of October so the assumption is made that (28.5 * 50% =) 14.25% of the sheep is pregnant at the time of the outbreak.

Meat sheep

A meat sheep farm is assumed to have 144 ewes and 274 lambs (Bont *et al.,* 2008).

In the Netherlands there are two main breeding types, the traditional one (lambing once a year) and year round production (lambing three times in two years). Because the number of sheep farmers that uses year round production is very low, this has been left out of the model and 14.25% is assumed to be pregnant.

Goat

Most of the goat farms in the Netherlands are located in Noord Brabant or Gelderland.

Table 4. Number of farms with goat categories in the Netherlands in 2009 (CBS, 2010)

Category	Number of farms
Goats, total	3,916
Dairy goats, younger than 1 year	246
Dairy goats, 1 year or older	610
Other goats, Younger than 1 year	1,206
Other goats, 1 year or older	3,565

Dairy goat

One dairy goat farm is assumed to hold 375 goats and 619 kids (Ipema *et al.,* 2002).

Again, we assume that the outbreak will occur between May and November (7 months). Some goats will start their mating season as early as August, but the largest part will occur in October and November

(Praktijkonderzoek rundvee, schapen en paarden, 2000). Therefore the assumption in made that only in the last two and a half months of the outbreak goats can be pregnant. This is about 35.7 % of the time. However, the goats will not all be pregnant halfway in September, so (35.7 * 50% =) 17.9% is assumed to be pregnant at the time of the outbreak.

The male kids and a part of the female ones aren't needed for replacement. They are sold to meat goat farms in the Netherlands, or exported alive to the South of Europe (KNAW Onderzoek Informatie, 2011).

One buck is present for about every 33 goats (Winkelmolen, 2008), but these are not taken into account in the model.

Meat goat
A typical meat goat farm will have 1086 kids on the farm. At the age of about 8 to 10 weeks they are slaughtered.

2.2.2 EIDs

Out of a list of 18 EIDs, four were selected. This was done by creating various lists of EIDs that shared certain characteristics, such as target species, vector borne, zoonosis and current location. Finally a choice was made for the four EIDs that affect ruminants, are on the OIE list and depend completely or partially on transmission by vectors. See Table 5 for a quick overview.

Table 5. Overview of main characteristic for the four EIDs

	EHD[1]	LSD[1]	RVF[1]	VS[1]
Transmission	Vector borne	Direct contact and mechanical vector	Vector borne	Direct contact and mechanical vector
Zoonosis	No	No	Yes	Yes
Target species[2]	C, S	C	C, S, G	C, S, G

[1] EHD=Epizootic Hemorrhagic Disease, LSD= Lumpy Skin Disease, RVF=Rift Valley fever, VS=Vesicular Stomatitis
[2] C=Cattle, S=Sheep, G=Goat

Epizootic Hemorrhagic Disease

The Epizootic Hemorrhagic Disease (EHD) virus is of the genus *Orbivirus* in the family of the Reoviridae. Transmission takes places by *Culicoides sp.* and possibly other hematophagus insects (CFSPH, 2008).

Although originally known as a disease of white-tailed deer, EHD first appeared in cattle in Japan, where it was given the name Ibaraki disease and later recognized as a strain of EHD virus serotype 2 (Yadin *et al.*, 2008).

There is no detectable viraemia in goats (Gibbs and Lawman, 1977) Although there is a low level in sheep, no clinical signs have been documented.

In cattle clinical signs include a loss of appetite, a drop in milk production, fever and anorexia. In a further stage animals develop redness of the muzzle, ocular and nasal discharge, respiratory distress and swelling of the eyelids. Some animals develop a stiff gait (Yadin *et al.,* 2008; Temizel *et al.*, 2009) EHD does not give clinical signs very often in cattle (Nol *et al.,* 2010). Infected calves do not display clinical signs (Aradaib *et al.*, 1994; Abdy *et al.,* 1999)

There is no vaccine for EHD (COGEM Commission, 2010).

Lumpy Skin Disease

Lumpy Skin Disease (LSD) is caused by a virus of the genus *Capripoxvirus* in the Poxviridae family. The virus is closely related to sheep and goat pox viruses, and cannot be differentiated with routine diagnostic tests (CFSPH, 2008).

Transmission takes place primarily through biting insects. This is only a mechanical transmission however, as virus replication does not take place within the insect. LSD is also transmitted by direct contact between animals.

Bos Taurus is more subsceptible to LSD than *Bos Indicus* breeds. Morbidity is dependent of insect vector (mechanical transmission)(United States Animal Health Association, 2008). Mortality is low, most animals recover although very slowly, taking 1 to 3 months and occasionally up to six (Davies, 1991).

The first stage of LSD is a fever, in combination with drooling, lachrymation, anorexia and a drop in milk production. This is followed within a few days by characteristic nodules on the skin and mucous membranes. These nodules develop a typical necrotic center, and are prone to secondary bacterial infections and ulceration. The nodules are found mainly on the head, neck, genitalia, udder and legs, but can also occur in the lungs or gastro-intestinal tract. Less common are rhinitis and ocular infections as well as inflammation or necrosis of tendons. Edema in the legs is also seen. A low percentage of abortions and infertility are possible in cattle (CVI, 2011).

Secondary infections can play a large role in causing permanent damage to the animal, in particular the tendons, teats, joints and mammary glands (CFSPH, 2008). Severely infected animals may become emaciated. This is an important reason for premature culling.

There are no vaccines for LSD available in the Netherlands.

Rift Valley Fever

Rift Valley Fever is a *Phlebovirus* from the family of Bunyaviridae. It is a vector borne disease, transmitted by different kinds of mosquito, although mainly the *Aedes* species. An *in utero* transmission from mother to fetus has also been reported.

It affects many ruminant species, whereby sheep are more susceptible than cattle. As a zoonosis, humans can get RVF mainly through infected vetors or by exposure to the infected blood or tissue of an animal. It is therefore most often seen in slaughterhouse personnel. There is some evidence that humans may get infected by ingesting raw milk (WHO, 2010). Although a zoonosis, it is important to note that not every epizootic becomes an epidemic (Favier *et al*., 2006).

In ruminants, the incubation period following infection ranges from a few hours to a few days and is dependent on multiple factors, including: the inoculation dose, the virus strain, the route of inoculation, the age of each animal and the animal species. Although disease symptoms are quite mild, RVF is severe in very young animals, and lambs can die within 36 hours. Main symptoms in adults are the “abortion storms”, abortion regardless of state of pregnancy (Pepin *et al.*, 2010).

Modified live attenuated vaccines as well as inactivated virus vaccines are ready (WHO, 2010). Live vaccine only needs 1 dose, but can lead to abortions. Inactivated virus vaccine needs multiple doses. A transport standstill is thought effective. No effective test exists yet (Van der Giessen *et al.*, 2010)

Vesicular Stomatitis

VS is a zoonotic disease caused by a *Vesiculovirus* from the family of Rhabdoviridae.

The transmission of VS is not yet understood. It seems to be a combination of insect vector, mechanical transmission and direct contact (Mead et al, 2004). There is also some speculation that VS could be found in pastures, infecting grazing animals (CFSPH, 2008). VS does not appear to be found in milk.

Humans can be infected by contact with the lesions and infected fluids of the animal, or by an infected vector.

The incubation period is around 3-5 days. Symptoms are similar to Foot and Mouth Disease (FMD). Mortality is low, morbidity can be up to 90% in a herd (Min EL&I, 2002) Cattle start salivating excessively and develop vesicles in and around the mouth. Lesions may appear on the udder and feet. Recovery is in about two weeks but complications such as mastitis and a major loss of production are common. High rate of culling due to secondary mastitis (lesions on teats) (Alderink, 1984).

At present there is no vaccine available.

2.2.3 Prevention and control strategies

The Dutch government has various prevention and control strategies available in case of an outbreak. These include zoning (into protected area and surveillance zone), vaccination and vector control measures such as the use of insecticides or confinement. Below an overview is given of the possibilities per EID.

Epizootic Hemorrhagic Disease

If animals are discovered infected with EHD in a free zone, they may be culled to prevent further spread. Once it is discovered that the infection is widespread, the vector infection will make culling animals no longer useful.

A transport standstill is expected. In the protected area animals are in principle not allowed to leave the farm except for slaughter. The surveillance zone size will be comparable to the one for BTV, 150km, as they have a similar transmission. Export from the surveillance zone to EHD free areas is expected to be possible after serological testing.

Vector control measures are assumed in the form of insecticides and confinement of animals. The maximum incubation period is considered 40 days (Annex I of 92/119/EEC).

Lumpy Skin Disease

If animals in a free zone are discovered infected with LSD, they will be culled. Because LSD can spread via direct contact as well as via a mechanical vector, it is probable that the whole herd will be culled as prevention.

For LSD a transport standstill is expected for cattle only. This will probably be quite long, due to the vesicles, which take a long time to heal. The maximum incubation period is 28 days (Annex I of 92/119/EEC).

Vector control measures will concentrate on making sure the vectors such as flies do not come into contact with the vesicles of the infected animals.

Rift Valley Fever

A RVF infection is expected to be treated with culling of the infected animals as well as preventative culling. Because it is a vector borne disease this will not be as effective at a later stage. Vaccination may then be used.

A transport standstill and a large surveillance zone will be used, similar to the one during the BTV8 outbreak, due to the vector. Export is only allowed after testing.

It is important that people do not come into contact with infected tissue, so an awareness campaign for everybody that works with livestock will be implemented, as well as vaccination for high risk groups such as slaughterhouse personnel (Adewale *et al.*, 2011). Infected or suspicious animals may not be slaughtered or used for consumption, because handling the meat is a possible source of infection for humans.

The maximum incubation period is 30 days (Annex I of 92/119/EEC).

Vesicular Stomatitis

For VS a transport standstill is assumed. Because direct contact is one of the methods of transmission, animals of infected farms will be culled. A large surveillance zone will also be put into effect to prevent transmission by flying insects.

Confinement will be used, not only for limiting the number of infected vectors, but also to prevent new cases by infected pastures. With this in mind a thorough disinfection of the housing and equipment should be executed. Humans risk infection when handling infected animals.

VS is expected to have a long transport restriction, because animals can only be moved 21 days after last lesions have healed (USDA, 2007) (Annex I of 92/119/EEC).

2.3 Modeling approach

This chapter gives an overview of the epidemiological input per EID, as used in the model. It is then followed by the direct, direct herd and direct consequential costs.

2.3.1 Epidemiological input

Epizootic Hemorrhagic Disease

For EHD the only epidemiological input collected was for adult dairy cows. Cattle of other ages and sheep did not display clinical signs (Aradaib *et al.*, 1994), and goats are not susceptible to EHD at all.

In Table 6 the epidemiological input used for EHD is given.

Table 6. Epidemiological input for EHD

Animal type	Clinical signs	Input (%)	Duration in days
Dairy cows	Morbidity	8[1,2]	17[1]
	Mortality	10	9[2]
	Abortions	0[3]	9
	Lame	50	9
	Animals delayed conception	5	9
	Milk production loss	50	9
	Altered feed conversion	50	9
	Premature disposal	5	-

[1] Yadin *et al.*, 2008, [2] Bréard *et al.*, 2004, [3] Gibbs and Lawman, 1977,

Lumpy Skin Disease

The animal types affected by LSD are cattle of all ages. Sheep and goat are not susceptible. For a full overview of LSD input, see Appendix III.

Rift Valley Fever

RVF infects cattle, sheep as well as goat. See Appendix IV for the complete epidemiological input.

Vesicular Stomatitis

Cattle are the most severely affected, sheep and goat occasionally. Other input is found in Appendix V.

2.3.2 Direct costs animal level

Production effects

Death

The mortality cost for an animal is the sum of the retention pay off, the slaughter value and costs of removal (€ 35.82) and destruction by Rendac (Rendac, 2011). The assumption is made that removal costs are incurred for every dead animal.

Table 7. Destruction costs per animal type in € (Rendac, 2011). Lamb and kid prices are assumptions.

	Dairy cow	Heifer	Calf	Sheep	Lamb	Goat	Kid
Destruction cost	9.35	1.31	0.75	0.75	*0.39*	0.39	*0.39*

Changed animal value - PM

Animal value can change during outbreaks due to various factors. The most straightforward reason can be that although recovered, the infected animal still has consequences from the disease. An example is a cow with LSD, of which the skin is covered with scars. Because these costs are not directly noticeable for the farmer and difficult to predict and quantify they have not been included in the model.

Altered feed conversion

Sick animals do not eat as much as healthy animals. Especially with diseases such as EHD and VS, that can cause lesions in the mouth. Apart from a drop in feed intake, this will also affect feed conversion. Feed nutrients will be spent on fighting disease and main body functions instead of growth or milk production. The full potential of the animal as well as the feed is therefore not reached and it will take an animal longer to reach the right weight.

In the model the assumption is made that heifers need 1 month extra to mature, at € 40 per animal (Drie, van, 2004). For calves this is € 20 and for lambs and kids € 10.

Lower production

Disease will normally cause a drop in milk production. VS and LSD in particular cause this effect, although it has also been reported for RVF and EHD, such as Yadin *et al.* (2008) who reported a 10 to 20% reduction in milk production for EHD.

The economic impact of a drop in milk production depends on the quotum situation. The outbreak is assumed to take place between May and November, which is far enough ahead for a farmer to make management changes in order to fill his quotum. However, these changes usually bring extra costs, which have been estimated at € 0.06 per kg of milk (Velthuis *et al.,* 2008) for dairy farms. The impact of milk production loss in dairy cattle has therefore been calculated as the production loss per animal in kg times € 0.06. This is then multiplied by the number of days that the production loss occurs and the number of affected animals.

For sheep and goat dairy farms, there is no quotum, with the effect that every kg of lost milk is equal to the milk prices found in Velthuis *et al.* (2008) and De Haan and Vermeij (2010) (Table 8). The production loss per animal times the milk price, multiplied by the number of days and the number of animals give the impact for the farm.

The milk production drop in kg is a value found for an infection with Bluetongue (Velthuis *et al*., 2008), and is applied for all four EIDs. Although Bluetongue may not be representative of all four EIDs, this percentage is assumed due to a lack of data for the EIDs in this study. The duration of this milk drop has been assumed at 9 days for EHD and RVF, 21 for LSD and 14 for VS, based on respective recovery times.

Table 8. Milk prices and production loss

	Dairy cow	**Sheep**	**Goat**
Milk price (€/kg)	0.31	1.13	0.41
Variable costs milk production (€/kg)	0.06	-	-
Daily production (kg/day)	28	1.88	2.48
Milk drop (%)	20	20	80

Reduced fertility

Fertility issues can be divided into two main components, abortion and a delayed conception.

For dairy animals the cost of an abortion is composed from the cost of a longer between calving interval, the loss of a calf and an extra insemination. The abortion has been assumed to take place in the 5th month of gestation, after which the cow will only need 1 insemination. The cost of a longer calf interval of 5 months is € 101.90 (Velthuis *et al*., 2008). One insemination is priced at € 11.75 and the average value of a calf is € 85 (KWIN, 2010).

Sheep or goat that abort will be culled, so the replacement value is used, which is € 12 for a ewe, and € 60 for a goat (Velthuis *et al.,* 2008). This is summed up with the value of their offspring at a few days old which is € 17.15 for 1.9 lambs (Praktijkonderzoek veehouderij, 2002) and € 3.60 for 1.8 goat kids (Winkelmolen, 2008).

The delayed conception will cost one extra insemination of € 11.75 and will cost € 7 per cow for one extra cycle (Hogeveen *et al.,* 2005). The cost of a cycle for sheep and goat has also been assumed at € 7, with the addition of a drop in lamb price for meat sheep of € 4 per lamb (Velthuis *et al.,* 2008).

Premature disposal

During or after an outbreak it may be necessary to cull animals for humane reasons or because the animal is still not at an optimal production level. LSD is a good example, because cows may need 6 months to recover. In Table 9 the RPO of an average third parity dairy cow is given. For heifers, sheep and goat this is the value of the animal minus that of a replacing calf, lamb or kid (Velthuis *et al*., 2008). For calves this is the average value of a calf.

Table 9. RPO for dairy cow and replacement value for other animal types (Velthuis et al., 2008; Livestock Research, 2010)

	Dairy cow	Heifer	Calf	Sheep	Goat
RPO or replacement value(€)	785	490	335	12	60

Susceptability for secondery infections

LSD in particular but VS is also mentioned as an EID that may lead to secondary infections. Although this is known, it is very difficult to predict and quantify, and has therefore not been included in the model.

Veterinary treatment and drugs

Veterinary treatment is based on the average amount of time that a vet spends with a sick animal, here assumed to be about 4 minutes. A vet charges € 116.17 per hour and a call fee of € 20.58. Because the vet will probably come for a few animals at a time, the call fee is only charged per five animals.

Specific treatment does not exist for any of the four EIDs. However, supportive treatment is often provided.

Table 10. Drug prices per EID

Medication type	EHD	LSD	RVF	VS
Antibiotics (per animal)	75	150	75	75
Blue spray (1 can/3 animals)	-	-	-	7.35
Iodine solution (500ml/5 animals)	12.75	-	-	12.75

For VS and EHD there is no treatment except to rinse the lesions with a mild antiseptic such as Betadine to avoid secondary bacterial infections, as well as giving antibiotics (CFSPH, 2008; Merck & Co. Inc., 2008). The antibiotics have been set at € 15 for 5 days for 50% of the infected cattle or 15% of sheep and goat. Cattle with LSD require administration of sulfonamides (antibiotics) to prevent further infections (Davies, 1991; Merck and Co. Inc., 2008).
Blue spray is used for disinfection of vesicles of feet (€ 7.35 per 150 ml)(CIDRAP, 2011).
It is also advised to give soft feed and fresh water, notably for VS and LSD, but this is not included in the model.

Labour

An outbreak of an infectious disease will create more work on a farm. This includes treatment and extra care of animals, application of insecticides. However, labour opportunity costs are set at € 0 in the model and are therefore not taken into account.

2.3.3 Direct costs herd level

Herd composition change

A farm that has had an outbreak will have a herd composition change. Animals that were meant for reproduction may have been culled and there are less possibilities for genetic selection. Maybe a lot of the older animals were culled and have been replaced by new heifers, thereby creating a much younger herd. These types of changes will have an effect in the long run and quantification is difficult, so is not taken into account in the model.

Quotum issues

Dairy farms may also have extra costs depending on the quotum situation. If an outbreak occurs near the end of the quotum period the farmer will need to take extra measures to ensure he reaches his quotum, such as buying new cows. Because all four EIDs depend partly or fully on transmission by insect vectors the assumption is that an outbreak will occur between May and November. This is far enough ahead that the farmer can make management decisions to fill his quotum by the end of March. Because dairy sheep and goat do not have a quotum this is not applicable.

Diagnosis

When an animal is sick, the farmer will contact his vet, who will come to investigate and run some tests. When there is a suspicion of a notifiable disease, the Food and Consumer Product Safety Authority (VWA) is contacted. The VWA will send their own veterinarian assess the animal and take samples for a reference laboratory. The Animal Health Fund for the Control of Contagious Diseases or the Ministry of EL&I will pay for the VWA vet and test (Veterinary Service, 2002). Only the cost of the own veterinarian for half an hour including call fee is taken into account in the model.

2.3.4 Direct consequential costs

Transport restrictions

As a result of transport restrictions animals might not be sold at the best time or to the usual parties. If the average dairy farm sells 42 calves per year (LEI Binternet, 2009), on average they will sell 1 calf every 8.7 days, or 0.12 calves a day. For example at the shortest possible standstill of 21 days this means about 2.5 calves. For these calves a lower price may be given, but this depends on many different factors and is therefore not taken into account in the model.

Veal calves are slaughtered at the age of about 30 weeks or older, so stay on the farm for at least 28 weeks. This means around 1.85 rounds per year for an all in-all out system. The timing and length of a transport standstill then becomes a very important factor to determine the cost of these measures. The cost of extra feed is multiplied with the number of animals and the extra days. However, the price drop, if there even is one, cannot be predicted within the framework of this thesis and is therefore not taken into account in the model.

On sheep and goat dairy farms the lambs and kids will most likely already be sold if an outbreak occurs between May and November. However, this is not the case for the meat farms. Transport restrictions may have an effect on the slaughter price received for lambs or kids, but it is not included in the model. The extra costs for bedding and feed are taken into account.

Vector control measures
One way to prevent spread of disease as much as possible is by stopping the vector. This includes treatment of animals and buildings with insecticides. Treatment of the buildings is calculated according to building size: Dairy cattle and veal calf farms calculated for 500m2 (€ 139.95), dairy sheep and goat at 250 m2 (€ 69.98), the meat kids and lambs at 50m2 (€ 14) as seen in Velthuis *et al*. (2008).

Confinement
Animals that are kept outside are now kept inside instead, meaning extra costs for bedding, water, feed and removal of manure. On average 50% of dairy cows go out to pasture during the day and remain in the barn at night. The costs of confinement have therefore only been calculated for 50%.

All other farm types are considered to keep the animals inside anyway, so do not have extra costs for confinement.

Idle production factors
In case of a transport standstill three zones will be formed, according to article 10 in European Council directive 92/119/EEC. This will be the protection area, with a radius of at least 3 km around the infected farm, the surveillance zone with a radius of at least 10 km, and a free zone.

Because the chosen EIDs all have transmission that takes place fully or partly through vectors, it is assumed that the protection area will be set at 20km around an infected farm, like at the time of the BTV outbreak.

Vaccination
Vaccination costs are assumed for the farmer. There is a possibility that the Animal Health Fund will pay for this. Vaccine costs are only included for RVF and consist of vaccine costs and veterinary expenses.

Price fluctuations
These are not taken into account in the model and are therefore set at 0.

2.4 Sensitivity Analysis

A lot of the percentages assumed in this study are subject to uncertainty. Many of them were difficult to find, which of course is normal when dealing with EIDs that have not been seen in the Netherlands before. Apart from that, the literature is not able to give very decisive answers to questions as for example mortality rates, which were reported for example as being 40 -100%.

For this reason a sensitivity analysis is done on the four EIDs for morbidity, mortality and the next greatest cost.

2.5 Scenarios

It was not possible to make outbreak scenarios for the four EIDs chosen, due to uncertainty regarding transmission, vector competence and severity of clinical symptoms. However, to be able to provide some insight into the possible economic impact of one of these EIDs, data from the 2006 and 2007 BTV outbreak was used.

Bluetongue is a vector borne *Orbivirus* from the family of Reoviridae*,* and is closely related to EHD virus. Furthermore, *Culicoides spp.* serve as a vector for both EIDs. In August of 2006 BTV serotype 8 emerged in the Netherlands. This remained a relatively small outbreak, infecting a total of 460 farms. In 2007 however, the outbreak returned and was much larger. The exact numbers are mentioned in Table 11.

Table 11. Number of infected farms during 2006 and 2007 BTV outbreak in the Netherlands (Velthuis et al., 2010)

	Cattle		Sheep		Goats	
Year	**2006**	**2007**	**2006**	**2007**	**2006**	**2007**
# infected farms	200	30,417	270	45,021	0	35,277

Because of the method of transmission that BTV and EHD have in common, the number of infected farms as mentioned in Table 11 is used as a blueprint for two EHD outbreak scenarios, a best and worst case. However, goats are not susceptible to EHD infection, so the number of infected goat farms was set to zero.

Based on the number of farms per farm type as seen in Velthuis *et al*. (2010), the percentage of veal farms is about 9% of the total number of farms, and dairy is 63.4%. The number of infected cattle farms given in Table 11 was adjusted accordingly when calculating total cost.

The percentage of sheep dairy farms is about 0.05% of the total number, and meat sheep farms are 3.1%. A very large part of the sheep sector consists of hobby sheep farms (about 81%).

Dairy goat farms are 0.5% of the goat sector, and meat farms 0.1%. The rest of the goat sector are hobby animals.

3. Results

3.1 Default

3.1.1 EHD

The results for EHD can be found in Table 12. The first observation is that the direct herd and direct consequential costs for the infected farms and farms in the movement restriction zone (MRZ) are the same. At a closer look, these costs consist of diagnosis, transport restrictions, vector control measures and confinement which explains why they are applicable for both farm types.

The results for EHD show that only adult dairy cattle are affected, and have direct costs. The direct costs for an infected dairy farm are € 1,266, of which almost 67% is formed by the death of dairy cows. Something else that immediately draws attention are the direct consequential costs for veal calves at € 4,753. This amount is mainly due to transport restrictions.

Table 12. Direct and direct consequential costs of an Epizootic hemorrhagic disease outbreak on farm level

Farm type		Cost type	Infected (€)	MRZ (€)
Cattle	**Dairy**	direct	1,266	-
		direct herd	62	62
		direct consequential	1,294	1,294
		Total dairy cattle	**2,622**	**1,356**
	Veal	direct	0	-
		direct herd	62	62
		direct consequential	4,753	4,753
		Total veal	**4,816**	**4,816**
Sheep	**Dairy**	direct	0	-
		direct herd	62	62
		direct consequential	831	831
		Total dairy sheep	**893**	**893**
	Meat	direct	0	-
		direct herd	62	62
		direct consequential	542	542
		Total meat sheep	**604**	**604**

3.1.2 LSD

In Table 13 LSD results are displayed for cattle, as sheep and goat are not susceptible to LSD. The direct costs for dairy farms is € 13,120, where the majority of the costs comes from death, premature culling and drugs in dairy cattle. These directs costs form a major difference between infected farms and those in the movement restriction zone

In the case of veal calves this effect is even stronger, with € 21,099 direct costs. Again this is caused by death, stunted growth, veterinary treatment and drugs. The nature of these costs already reveals that LSD is a disease with a long and difficult road to recovery.

Table 13. Direct and direct consequential costs of a Lumpy skin disease outbreak on farm level

Farm type		Cost type	Infected	MRZ
Cattle	**Dairy**	direct	13,120	-
		direct herd	62	62
		direct consequential	1,294	1,294
		Total dairy cattle	**14,476**	**1,356**
	Veal	direct	21,099	-
		direct herd	62	62
		direct consequential	3,738	3,738
		Total veal	**24,900**	**3,800**

3.1.3 RVF

The first noticeable thing on the RVF result is € 65,073 direct costs for veal calf farms (Table 14). 93% Of this amount can be attributed to calf mortality. In line with these results, the direct costs of other farm types are also very high, notably in the meat goat sector with around € 30,000. Here as well mortality plays a major role as well as veterinary treatment. When compared to other EIDs, the high morbidity combined with high mortality of RVF is clearly visible in these results.

These direct costs form a great contrast with the impact on a MRZ farm, the costs for infected farms are at least 10 times higher.

Table 14. Direct and direct consequential costs of a Rift valley fever outbreak on farm level

Farm type		Cost type	Infected	MRZ
Cattle	**Dairy**	direct	16,495	-
		direct herd	62	62
		direct consequential	1,547	1,547
		Total dairy cattle	**18,105**	**1,610**
	Veal	direct	65,073	-
		direct herd	62	62
		direct consequential	4,674	4,674
		Total veal	**69,809**	**4,736**
Sheep	**Dairy**	direct	14,188	-
		direct herd	62	62
		direct consequential	815	815
		Total dairy sheep	**15,065**	**877**
	Meat	direct	14,521	-
		direct herd	62	62
		direct consequential	848	848
		Total meat sheep	**15,431**	**910**
Goat	**Dairy**	direct	24,831	-
		direct herd	62	62
		direct consequential	1,861	1,861
		Total dairy goat	**26,754**	**1,923**
	Meat	direct	30,170	-
		direct herd	62	62
		direct consequential	2,016	2,016
		Total meat goat	**32,248**	**2,078**

3.1.4 VS

In Table 15. Direct and direct consequential costs of a Vesicular stomatitis outbreak on farm levelTable 15 the most distinct cost is the direct cost for dairy cattle, at € 7,170. For VS all direct costs are somewhere between € 1,000 and €4,500, except for dairy cattle. More than half of this € 7,170 direct cost comes from premature culling. This is due to the clinical symptoms of VS, lesions can occur on the teats making these cows no longer suitable for milking. The same effect occurs in dairy goats and sheep, although the effect is less pronounced.

Table 15. Direct and direct consequential costs of a Vesicular stomatitis outbreak on farm level

Farm type		Cost type	Infected	MRZ
Cattle	**Dairy**	direct	7,170	-
		direct herd	62	62
		direct consequential	1,293	1,293
		Total dairy cattle	**8,526**	**1,356**
	Veal	direct	1,468	-
		direct herd	62	62
		direct consequential	3,146	3,146
		Total veal	**4,676**	**3,208**
Sheep	**Dairy**	direct	2,708	-
		direct herd	62	62
		direct consequential	800	800
		Total dairy sheep	**3,571**	**862**
	Meat	direct	1,822	-
		direct herd	62	62
		direct consequential	522	522
		Total meat sheep	**2,406**	**584**
Goat	**Dairy**	direct	4,328	-
		direct herd	62	62
		direct consequential	1,846	1,846
		Total dairy goat	**6,236**	**1,908**
	Meat	direct	3,668	-
		direct herd	62	62
		direct consequential	1,983	1,983
		Total meat goat	**5,712**	**2,045**

When comparing the results of the four EIDs it is clear that in terms of economic impact per farm, RVF has the highest direct costs per farm. In addition it can affect cattle, sheep and goat whereas for EHD and LSD no direct costs are generated for sheep and goats. VS and LSD have a somewhat lower impact, followed by EHD.

The veal calf sector is particularly vulnerable to RVF as well as LSD, showing the largest amounts in both tables. The goat sector as a whole also seems more vulnerable to EIDs.

3.2 Sensitivity Analysis

The sensitivity analyses were set to plus and minus 20% of the original percentage in the epidemiological model. This percentage was chosen because biological limits were not always available. For example, when default morbidity was 8%, it was set to 6.4 and 9.6%.

In Table 16 the sensitivity analysis for EHD is given. Because EHD only affects dairy cattle all other animal and farm types are disregarded. As expected, morbidity had the largest effect on the total direct costs of a dairy farm and at 12.7% change the direct costs are quite sensitive to changes in mortality. Premature culling did not make a large difference in the direct costs.

Table 16. Sensitivity analysis for Epizootic hemorrhagic disease

Farm type		Default (%)	Default Direct costs (€)	-20% (€)	+20% (€)	Difference %
Dairy cattle	Morbidity	8	1,266	1,013	1,519	20.0
	Mortality	10	1,266	1,105	1,427	12.7
	Premature culling	10	1,266	1,245	1,287	1.7

For LSD in Table 17 the effects were restricted to bovines, which is why sheep and goat farms are not displayed. The most important effects were mortality and premature disposal for dairy farms and mortality and drugs for veal calves. Drug costs for were € 150 and were raised and lowered with 20%.

Table 17. Sensitivity analysis for Lumpy Skin Disease

Farm type		Default (%/€)	Default Direct costs (€)	-20% (€)	+20% (€)	Difference %
Dairy cattle	Morbidity	45	13,120	10,496	15,744	20.0
	Premature culling	20	13,120	12,470	13,770	5.0
	Drugs	150	13,120	12,351	13,890	5.9
Veal	Morbidity	45	21,099	16,879	25,319	20.0
	Drugs	150	21,099	19,291	22,908	8.6
	Mortality	5	21,099	19,912	22,286	5.6

In Table 18 the sensitivity analysis for RVF is displayed. In this table it can be seen that the sensitivity for mortality in veal calves is very high, 17.1 %. Other farm types that are sensitive for changes in mortality are dairy cattle and meat sheep. Sensitivity for veterinary treatment lies around 4 percent except for meat sheep (2.7%) and veal calves (0.7%).

Table 18. Sensitivity analysis for Rift valley fever

Farm type		Default (%)	Default Direct costs (€)	-20% (€)	+20% (€)	Difference %
Dairy cattle	Morbidity	50	16,495	13,196	19,794	20.0
	Mortality	10 a[1], 40 c[2]	16,495	14,735	18,238	10.6
	Abortions	40	16,495	16,012	16,978	2.9
Veal	Morbidity	50	65,073	52,058	78,087	20.0
	Mortality	40	65,073	53,919	76,226	17.1
	Veterinary treatment	7	65,073	64,614	65,531	0.7
Dairy sheep	Morbidity	18 s[3], 80 l[4]	14,188	11,351	17,026	20.0
	Mortality	25 s[3], 42 l[4]	14,188	13,185	15,191	7.1
	Veterinary treatment	7	14,188	13,609	14,768	4.1
Meat sheep	Morbidity	18 s[3], 80 l[4]	14,521	11,616	17,425	20.0
	Mortality	25 s[3], 42 l[4]	14,521	12,796	16,273	12.1
	Veterinary treatment	7	14,521	14,122	14,920	2.7
Dairy goat	Morbidity	30 g[5], 80 k[6]	24,831	19,865	29,797	20.0
	Mortality	10 g[5], 42 k[6]	24,831	22,735	26,927	8.4
	Veterinary treatment	7	24,831	23,844	25,818	4.0
Meat goat	Morbidity	80	30,170	24,136	36,204	20.0
	Mortality	40	30,170	27,420	32,919	9.1
	Veterinary treatment	7	30,170	28,757	31,583	4.7

[1] adult, [2] calf, [3] sheep, [4] lamb, [5] goat, [6] kid

In the sensitivity analysis of VS (Table 19) there is only premature culling in dairy cattle that displays a sensitivity of higher than 10%. The next findings are drugs in veal calves and veterinary treatment in goats, with a 7.6 and a 7.2 percent change, respectively.

Table 19. Sensitivity analysis of Vesicular stomatitis

Farm type		Default	Default Direct costs (€)	-20%(€)	+20%(€)	Difference %
Dairy cattle	Morbidity	60% co, 5% ca[1]	7,170	5,736	8,604	20.0
	Premature culling	20%	7,170	6,446	7,894	10.1
	Drugs	€ 80	7,170	6,776	7,564	5.5
Veal	Morbidity	5%	1,468	1,174	1,761	20.0
	Drugs	€ 80	1,468	1,356	1,580	7.6
	Stunted growth	75%	1,468	1,384	1,552	5.7
Dairy sheep	Morbidity	15%	2,708	2,167	3,250	20.0
	Veterinary treatment	7%	2,708	2,562	2,855	5.4
	Fetility issues	20%	2,708	2,623	2,794	3.2
Meat sheep	Morbidity	15%	1,822	1,458	2,187	20.0
	Veterinary treatment	7%	1,822	1,720	1,924	5.6
	Drugs	€ 80	1,822	1,738	1,906	4.6
Dairy goat	Morbidity	15%	4,328	3,463	5,194	20.0
	Veterinary treatment	7%	4,328	4,086	4,571	5.6
	drugs	€ 80	4,328	4,121	4,535	4.8
Meat goat	Morbidity	15%	3,668	2,934	4,401	20.0
	Veterinary treatment	7%	3,668	3,403	3,933	7.2
	Stunted growth	50%	3,668	3,506	3,829	4.4

3.3 Scenarios

The best and worst case scenarios derived from the BTV outbreak in the Netherlands in 2006 and 2007 were used for EHD. Table 20 displays the total cost per farm type for cattle and sheep.

The interesting thing about this table is the enormous difference in total cost between the best and worst case scenario. What is important is that it reflects the type of uncertainty that exists around these type of EIDs. One year the cost could be minimal while an entirely different scenario is seen in the year after it.

The cost for sheep farms in the worst case is also notable, because although EHD can infect sheep, it does not give any clinical signs. These farms are therefore subject to transport restrictions and confinement to prevent spread of disease, but do not create any direct costs at animal level.

Table 20. Cost for EHD per BTV outbreak scenario and per farm type

		Best case (2006)		Worst case (2007)	
		# infected farms	Total (€)	# infected farms	Total (€)
Cattle	Dairy	127	332,490	19,284	50,566,756
	Veal	18	86,682	2,738	13,183,055
	Total	**145**	**419,172**	**22,022**	**63,749,811**
Sheep	Dairy	1	1,206	225	201,015
	Meat	8	5,058	1,396	843,371
	Total	**10**	**6,263**	**1,621**	**1,044,386**

4. Discussion

In this report, some insight has been given into the costs of an EID outbreak and subsequent veterinary measures on farm level. The results are discussed in this chapter.

For EHD the direct costs per farm were quite low, consisting mainly of death in adult dairy cattle. Furthermore on all farm types the direct consequential costs had the highest impact, notably the vector control measures. The sensitivity analysis did not show a large amount of variation in total direct costs.
In case of an outbreak of LSD, the direct costs per animal were by far the largest problem for a farm. Veal farms were especially vulnerable. Because LSD has such a long recovery time the main costs were death, a milk drop, premature culling and drugs. The sensitivity analysis showed that LSD total costs did not change much, 5.5 to 8.6 percent when the costs of drugs changed 20%.
For RVF, the direct costs per animal were much higher than for the other EID, up to € 65,073 for veal calves. This was mainly the result of mortality of young animals and abortions, which was reflected in the sensitivity analysis. A 20% change in mortality caused a 17.1% change in the total direct cost. A point to keep in mind is that RVF is a zoonosis, so the costs of an outbreak may not be limited to the livestock sector.
VS results per farm are somewhat in between the other EID. The main costs were premature culling and drugs, also indicating that although the clinical signs are not life threatening, they take a long time to recover or do not recover at all. Veterinary treatment is therefore important when dealing with this EID. The sensitivity analysis shows that although total direct costs change when the duration of veterinary treatment is changed with 20%, this is only around 5%.

However, the question remains whether the costs that result from the model are realistic. Morbidity and mortality were difficult to find for these diseases and clinical signs hard to predict. An example of this can be found in the BTV8 outbreak, where based on literature mainly subclinical infections were predicted in cattle. As it turned out, the Dutch cattle did develop clinical signs from BTV (Elbers et al., 2008).
Although the sensitivity analysis was conducted to investigate to what extent costs would vary when assumptions changed, this will only go so far. The epidemiological and economic model were built on certain assumptions that were not always backed up by literature. An example is the percentage of infected animals that suffers from lameness. The USAHA (2008) claims that lameness is “common” in infected cattle, and the assumption was therefore made that 50% of infected cows were lame. This may lead to considerable over or underestimation. Furthermore, there is considerable variation in levels of susceptibility for EIDs between breeds, from inapparent infections to death. For example, European breeds are considered highly susceptible to RVF (Davies and Martin, 2003).
Another important assumption is not only that the outbreak takes place between May and November, but also that it’s the first year of an outbreak. Acquired immunity and possible vaccination would create a different situation in the second or later year where this model is no longer applicable.

The 2006 and 2007 BTV scenarios that were taken and used for EHD show a massive difference between the best and worst case scenario, with for example costs for dairy cattle farms ranging between € 419 thousand and € 63 million. The most important thing about these scenarios is that they have happened recently, in the Netherlands, with a disease very similar to EHD. The conclusion that can be drawn from this particular table is that anything can happen.
As the EIDs in this study are all partly or fully vector borne diseases, some thought must be given to the transmission by a vector, notably vector competence which will vary for different virus strains.
Another factor to keep in mind is the geographic spread of farms. An outbreak in an area with many farms with the same target species will increase the risk of transmission between these farms. This has been completely disregarded in this study due to the focus on farm level.

When determining the relative importance of these EID, RVF quickly comes to mind. The costs per farm are many times higher than for other EID. Only, it is not that simple.
First, these costs are calculated per farm. As a purely vector-borne disease it is possible that the transmission may not be very effective and that in the end relatively few farms were infected. However, for an EID like VS, of which we are not even sure how the transmission works exactly, transmission may be much faster, eventually infecting more farms.
Second, the example of the two EHD scenarios makes it painfully clear that even with a relatively mild EID such as EHD, which only causes clinical signs in cattle, the cost of an outbreak can run into tens of millions. Add this to the level of uncertainty engrained in the model and it is difficult to prioritize any EID of these four.
However, RVF as well as VS are zoonoses, and have the power to infect and create clinical symptoms in cattle, sheep as well as goats. Not only does this bring a risk of disease in humans, but it can also influence the transmission speed and range. Coupled with the relatively high costs per farm and the lack of an available vaccine for VS these two belong at the top of the priority list.

In this pilot study the importance is not in the exact amounts per EID, but in the differences between the four and the questions that were raised to get there. Based on the results and assumptions that needed to be made, here are some recommended areas for further study:

- Vector studies (habitat, vector competence)
- Risk of introduction
- Clinical signs in Dutch animals
- VS transmission

5. Conclusions

Several conclusions can be reached from this pilot study:

- The costs per farm are quite variable per EID, depending mostly on morbidity, mortality and veterinary treatment.
- Of the four EIDs, RVF caused the highest costs per farm, which were mainly caused by mortality of young animals and abortions.
- Even for EHD, a relatively mild disease, the economic impact on the whole livestock sector can go to several millions of euros.
- RVF and VS are the most important EIDs of these four, due to their costs per farm, zoonotic nature and target species. Furthermore the transmission of VS is not yet understood, which is an important knowledge gap in case of an outbreak.
- The lack of data for these four EIDs is a crucial point in prevention and possible eradication. Future research should be aimed at the consequences of an infection for Dutch livestock. People do not know what to expect, making it difficult for policy makers to anticipate and prioritize.

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Appendix

Appendix I

List of EIDs relevant for the Netherlands (Source: S. Waelen, Min LNV)

Obligatory control:

- African Horse Sickness
- African Swine Fever
- Epizootic Hemorrhagic Disease
- Lumpy Skin Disease
- Peste des Petits Ruminants
- Rift Valley Fever
- Rinderpest
- Sheep pox and goat pox
- Vesicular stomatitis

Notifiable:

- Equine viral encephalomyelitis:
    - Eastern
    - Western
    - Venezuelan
- Equine Infectious Anemia

Not notifiable:

- Borna Disease
- Hendra: Acute Equine Respiratory Syndrome
- West Nile fever
- Crimean Congo Hemorrhagic fever
- Nipah virus encephalitis: Porcine Respiratory and Encephalitis Syndrome (PRES)
- Porcine reproductive and respiratory syndrome -Vietnam strain (PRRS)

Appendix II

Quick scan

Emerging Infectious Diseases	Species affected*						Vector borne**							
	P	C	E	S	G	O	Yes/No	Vector	Zoonosis**	Vaccine	Where present***	Mortality	Morbidity	Source
Obligatory control:														
African Horse Sickness			X				Y	C	N	YN	AF, EU, ME	50-95%		Mellor, 2004; OIE; Hunter, 1994
African Swine Fever	X						B	T	N	N	RU, EU, AF	0-100%		Merck; OIE; Hunter, 1994
Epizootic Hemorrhagic Disease		X		X		X	Y	C	N	N	NA	<10%	5%	OIE; CFSPH, 2010
Lumpy skin disease		X		X	X	X	B	B, M	N	Y	AF, ME	<10%	5-50%	Merck; OIE; Hunter, 1994
Peste des petits ruminants	X	X		X	X	X	N	-	N	Y	AF, ME	50-100%	90-100%	Merck; OIE; Hunter, 1994
Rift Valley fever		X		X	X		Y	M	Y	Y	AF, ME	S: 20-70% C&G: <10%	S: 5-100% C: <10%	WHO; Merck; OIE; Hunter, 1994
Rinderpest	X	X		X	X	X	N	-	N	Y	-	10%-90%	100%	Merck; OIE; Hunter, 1994
Sheep pox and goat pox				X	X		N	-	N	Y	AF, ME, AS, EU	5-100%	70-90%	Merck; OIE; Hunter, 1994
Vesicular stomatitis	X	X	X	X	X		Y	B, M	N	N	NA, SA	"rare"	5-70%	Merck; OIE
Notifiable:														
Equine viral encephalomyelitis:														
Eastern			X			X	Y	M	Y	Y	NA, SA	50-90%		Merck; Hunter, 1994
Western			X			X	Y	M	Y	Y	NA, SA	20-50%		Merck; Hunter, 1994
Venezuelan			X			X	Y	H	Y	Y	SA	50-75%	10-40%, 50-100%	Merck; OIE; Hunter, 1994
Equine Infectious Anemia			X				Y	H	N	N	EU	<70%		Merck, Hunter, 1994
Not notifiable:														
Borna Disease		X	X	X	X	X	N	-	Y		EU	E: >80% S: 50%		Dauphin, 2002
Hendra: Acute Equine Respiratory Syndrome			X			X	N	-	Y	N	AU	>60-70%		Merck
West Nile fever			X			X	Y	M	Y	Y	NA, EU, AF, IN	30-40%		Merck; Hunter, 1994
Crimean Congo Hemorrhagic fever		X		X	X	X	Y	T	Y	Y	AF, EU, AS	rare	13-36%	WHO; CFSPH, 2010
Nipah virus encephalitis: Porcine Respiratory and Encephalitis Syndrome (PRES)	X		X		X	X	N	-	Y	N	AS	<5% ("low")	~100%	Merck
Porcine reproductive and respiratory syndrome -Vietnam strain (PRRS)	X					X	N	-	N		AS	20-100%	50-100%	Tong, 2007

* E= Equids, P=Pigs, C=Cattle, S=Sheep, G=Goat, O=Other ** Y=yes, N=no, B=both; C=Culicoides, T=ticks, B=Biring flies, M=mosquitoes, H=Heamatophagus insects

*** AF=Africa, EU=Europe, NA=North America, SA= South america, ME= Middle East, AS=Asia, SA=South America, IN=India, Ru=Russia, AU=Australia

Appendix III

Epidemiological input for LSD

Input		**Epid. Input CATTLE Dairy**	**%**	duration (days)
#animals/farm	Dairy Cattle	%infected animals/farm	0.45	14
		% dead animals/farm	0.05	
		% animals abortion	0.2	14
		% animals lame	0.2	14
		% animals delayed conception	0.05	21
		% animals milk production loss	0.8	21
		% animals altered feed conversion	0.5	21
		% animals premature disposal	0.2	14
	Heifers 1 - 2 yrs	%infected animals/farm	0.45	14
		% dead animals/farm	0.05	
		% animals abortion	0.2	14
		% animals lame	0.2	14
		% animals delayed conception	0.2	21
		% animals altered feed conversion	0.5	21
		% animals premature disposal	0.2	14
	Calves 0 - 1 yrs	%infected animals/farm	0.45	14
		% dead animals/farm	0.05	
		% animals lame	0.2	14
		% animals lower birth weight	0.05	21
		% animals altered feed conversion	0.5	21
		% animals premature disposal	0.2	14

	Epid. Input CATTLE Veal	**%**	**duration (days)**
Calves	%infected animals/farm	0.45	14
	% dead animals/farm	0.05	
	% animals lame	0.2	14
	% animals altered feed conversion	0.5	14
	% animals premature disposal	0.2	14

Appendix IV

Epidemiological input for RVF

Input		Epid. Input CATTLE Dairy	%	duration (days)
#animals/farm	Dairy Cattle	%infected animals/farm	0.5	15
		% dead animals/farm	0.1	3
		% animals abortion	0.4	3
		% animals lame	0	15
		% animals delayed conception	0.05	3
		% animals milk production loss	0.8	9
		% animals altered feed conversion	0.8	3
		% animals premature disposal	0.05	3
	Heifers 1 - 2 yrs	%infected animals/farm	0.5	15
		% dead animals/farm	0.1	3
		% animals abortion	0.4	3
		% animals lame	0	15
		% animals delayed conception	0.2	3
		% animals altered feed conversion	0.8	3
		% animals premature disposal	0.05	3
	Calves 0 - 1 yrs	%infected animals/farm	0.5	15
		% dead animals/farm	0.4	5
		% animals lame	0	15
		% animals lower birth weight	0.05	3
		% animals altered feed conversion	0.8	3
		% animals premature disposal	0.05	3

	Epid. Input CATTLE Veal	**%**	**duration (days)**
Calves	%infected animals/farm	0.5	15
	% dead animals/farm	0.4	2 to 8 days
	% animals lame	0	10
	% animals altered feed conversion	0.1	3
	% animals premature disposal	0.05	3

	Epid. Input SHEEP Dairy	**%**	duration (days)
Dairy Sheep	%infected animals/farm	0.181	3
	% dead animals/farm	0.25	3
	% animals abortion	0.8	3
	% animals lame	0	3
	% animals milk production loss	0.2	3
	% animals fertility issues	0.2	3
	% animals premature disposal	0.05	3
Lambs	%infected animals/farm	0.8	3
	% dead animals/farm	0.417	max 96 hours
	% animals lame	0	3
	% animals delayed conception	0.2	3
	% animals altered feed conversion	0.2	3
	% animals premature disposal	0.05	3

	Epid. Input SHEEP meat	**%**	**duration (days)**
Ewes	%infected animals/farm	0.181	3
	% dead animals/farm	0.25	
	% animals abortion	0.8	3
	% animals lame	0	3
	% animals milk production loss	0.2	3
	% animals fertility issues	0.2	3
	% animals premature disposal	0.05	3
Lambs	%infected animals/farm	0.8	3
	% dead animals/farm	0.417	max 96 hours
	% animals lame	0	3
	% animals altered feed conversion	0.2	3
	% animals premature disposal	0.05	3

	Epid. Input GOAT Dairy	**%**	duration (days)
Dairy Goats	%infected animals/farm	0.298	3
	% dead animals/farm	0.1	
	% animals abortion	0.8	3
	% animals lame	0	3
	% animals milk production loss	0.2	3
	% animals fertility issues	0.2	3
	% animals premature disposal	0.05	3
Kids	%infected animals/farm	0.8	3
	% dead animals/farm	0.417	max 96 hours
	% animals lame	0	3
	% animals delayed conception	0.1	3
	% animals altered feed conversion	0.2	3
	% animals premature disposal	0.05	3

	Epid. Input GOAT meat	**%**	**duration (days)**
Lambs	%infected animals/farm	0.8	3
	% dead animals/farm	0.4	max 96 hours
	% animals lame	0	3
	% animals altered feed conversion	0.2	3
	% animals premature disposal	0.05	3

Appendix V

Epidemiological input for VS

Input		**Epid. Input CATTLE Dairy**	**%**	duration (days)
#animals/farm	Dairy Cattle	%infected animals/farm	0.6	14
		% dead animals/farm	0.01	
		% animals abortion	0	14
		% animals lame	0.5	14
		% animals delayed conception	0.05	14
		% animals milk production loss	0.75	14
		% animals altered feed conversion	0.75	14
		% animals premature disposal	0.2	14
	Heifers 1 - 2 yrs	%infected animals/farm	0.05	14
		% dead animals/farm	0.01	
		% animals abortion	0	14
		% animals lame	0.5	14
		% animals delayed conception	0.5	14
		% animals altered feed conversion	0.75	14
		% animals premature disposal	0.2	14
	Calves 0 - 1 yrs	%infected animals/farm	0.05	14
		% dead animals/farm	0.01	
		% animals lame	0.3	14
		% animals lower birth weight	0.5	14
		% animals altered feed conversion	0.75	14
		% animals premature disposal	0.2	14

	Epid. Input CATTLE Veal	**%**	**duration (days)**
Calves	%infected animals/farm	0.05	14
	% dead animals/farm	0.01	
	% animals lame	0.3	14
	% animals altered feed conversion	0.75	14
	% animals premature disposal	0.05	14

	Epid. Input SHEEP Dairy	%	duration (days)
Dairy Sheep	%infected animals/farm	0.15	14
	% dead animals/farm	0.01	
	% animals abortion	0	14
	% animals lame	0.2	14
	% animals milk production loss	0.5	14
	% animals fertility issues	0.5	14
	% animals premature disposal	0.05	14
Lambs	%infected animals/farm	0.15	14
	% dead animals/farm	0.01	
	% animals lame	0.2	14
	% animals delayed conception	0.2	14
	% animals altered feed conversion	0.5	14
	% animals premature disposal	0.05	14

	Epid. Input SHEEP meat	%	duration (days)
Ewes	%infected animals/farm	0.15	14
	% dead animals/farm	0.01	
	% animals abortion	0	14
	% animals lame	0.2	14
	% animals milk production loss	0.5	14
	% animals fertility issues	0.5	14
	% animals premature disposal	0.05	14
Lambs	%infected animals/farm	0.15	14
	% dead animals/farm	0.01	
	% animals lame	0.2	14
	% animals altered feed conversion	0.5	14
	% animals premature disposal	0.05	14

	Epid. Input GOAT Dairy	**%**	duration (days)
Dairy Goats	%infected animals/farm	0.15	14
	% dead animals/farm	0.01	
	% animals abortion	0	14
	% animals lame	0.2	14
	% animals milk production loss	0.5	14
	% animals fertility issues	0.5	14
	% animals premature disposal	0.05	14
Kids	%infected animals/farm	0.15	14
	% dead animals/farm	0.01	
	% animals lame	0.2	14
	% animals delayed conception	0.2	14
	% animals altered feed conversion	0.5	14
	% animals premature disposal	0.05	14

	Epid. Input GOAT meat	**%**	**duration (days)**
Lambs	%infected animals/farm	0.15	14
	% dead animals/farm	0.01	
	% animals lame	0.2	14
	% animals altered feed conversion	0.5	14
	% animals premature disposal	0.05	14