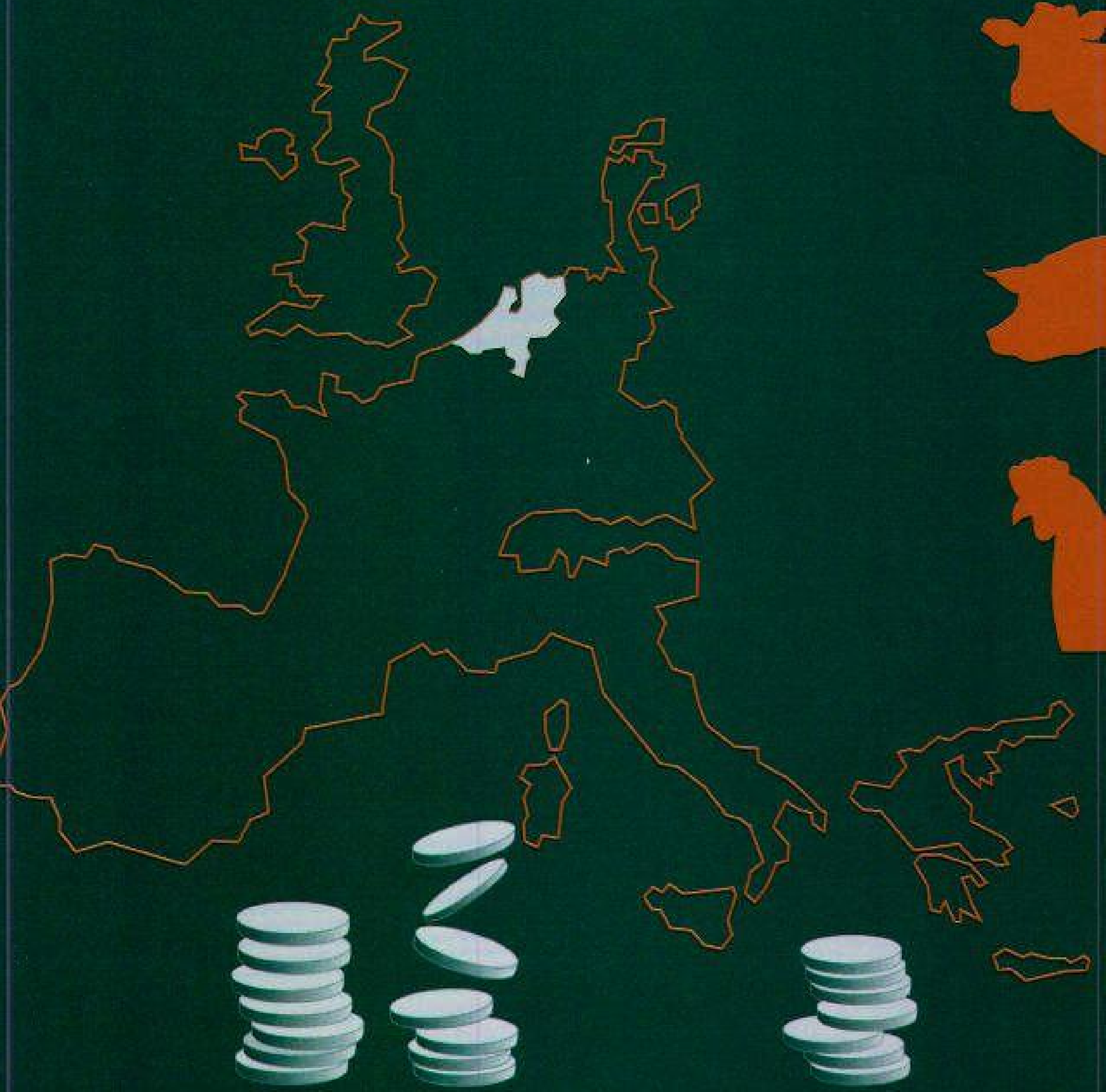
Risk and economic consequences of contagious animal disease introduction

H.S. Horst



Stellingen

1. Het combineren van modellen die respectievelijk de kans op insleep, verspreiding en economische gevolgen van besmettelijke dierziekten beschrijven, resulteert in een bruikbare aanpak voor de evaluatie van preventiestrategieën.
   Dit proefschrift

2. Expertkennis vormt, mits op zorgvuldige wijze gekwantificeerd en geïnterpreteerd, een waardevolle aanvulling op de vaak schaars aanwezige informatie over insleep en verspreiding van besmettelijke dierziekten.
   Dit proefschrift

3. Voor èxport-georiënteerde landen zoals Nederland is het investeren in monitoring- en bestrijdingsprogramma's van landen met een lagere diergezondheidsstatus een mogelijk kosten-effectieve maatregel om de eigen diergezondheid te beschermen.
   Dit proefschrift

4. In het algehele streven naar een betere diergezondheidsstatus in de Europese Unie is geen plaats voor protectie van gegevens en ervaringen die opgedaan zijn bij het bestrijden van epidemieën.

5. Gedifferentieerde heffingen zijn een goed instrument om het risicogedrag van veehouders te beïnvloeden en leiden tot een meer rechtvaardige verdeling van de kosten voor politionele diergezondheidszorg, mits de differentiatie een direct verband heeft met de risico's op insleep en verspreiding van ziekten.

6. Virussen zijn al verder met de Europese eenwording dan de meeste Europeanen.

7. Het tegelijkertijd bereiken van de deels conflicterende milieu-, welzijns- en gezondheidsdoelen in de Nederlandse varkenssector zou wel eens net zo moeilijk kunnen zijn als het verkrijgen van een fraudebestendig en klantvriendelijk paspoort.

8. Parapenten draagt bij tot het ontwikkelen van helicopterview. Het verdient derhalve een vaste plaats in het onderricht van jonge onderzoekers (en hun begeleiders).

9. Zolang informeren naar de kleur van het kalfsvlees bij veel restaurants nog een glazige blik oplevert, is niet te verwachten dat diervriendelijk geproduceerd kalfsvlees een belangrijk marktaandeel zal innemen.

10. Zonder risico geen geluk.

Proefschrift van H.S. Horst
Risk and economic consequences of contagious animal disease introduction
Wageningen, 7 januari 1998

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Proefschrift
ter verkrijging van de graad van doctor
op gezag van de rector magnificus
van de Landbouwuniversiteit Wageningen,
dr C.M. Karssen,
in het openbaar te verdedigen
op woensdag 7 januari 1998
des namiddags te vier uur in de Aula

Omslag: Ernst van Cleef
Druk: Grafisch Bedrijf Ponsen & Looijen B.V., Wageningen

ISBN 90-5485-784-6

The research described in this thesis was funded by the Central Office for Insurance on Animals for Slaughtering (CBS) in Utrecht, and the Dutch Ministry of Agriculture, Nature Management and Fisheries.

Abstract

Risk and economic consequences of contagious animal disease introduction
Risico op en economische gevolgen van insleep van besmettelijke dierziekten
Horst, H.S., 1997

The research described in this thesis focused on risks and economic consequences of the introduction of contagious animal diseases into the Netherlands, in particular of Classical Swine Fever (CSF) and Foot-and-Mouth Disease (FMD). Special emphasis was placed on the development of a virus introduction model. Using an integrated approach, this model was then combined with an existing model describing virus spread and an economic model focusing on quantification of losses due to epidemics. As objective quantitative information on underlying aspects of virus introduction was only scarcely available, additional information to base the proposed simulation model on was required and therefore obtained from experts. In order to elicit this information in an objective and quantitative way, various questionnaire techniques were evaluated and combined within a computerized design. In particular the questionnaire techniques Conjoint Analysis and ELI, which had not or only scarcely been used in the area of animal health economics thus far, proved to be useful methods to elicit expert knowledge. These techniques were used to elicit the relative importance of risk factors related to virus introduction (Conjoint Analysis) and probability density functions on the duration of the interval first infection-first detection (ELI). The expert knowledge thus obtained formed, combined with quantitative data obtained from databases and experiments described in the literature, the input on which the virus introduction model was based. This Monte Carlo simulation model, called VIRiS (Virus Introduction Risk Simulation), simulates the introduction of virus into the Netherlands. The results show that important causes of outbreaks are the import of live animals and trucks used for export and re-entering the country. These two factors together are expected to account for more than 70% of the primary outbreaks of CSF and FMD in the Netherlands. Insights and results obtained by VIRiS were combined with outcomes of models describing spread and economic consequences of epidemics. In this way alternative prevention strategies were evaluated as to their ability to reduce annual losses due to outbreaks. For example, the complete elimination of risks related to the risk factor 'returning trucks' reduces the expected annual losses due to FMD and CSF epidemics together by approximately US$ 9 million. The approach presented in this thesis is general and may be used for other diseases and countries as well.

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Voorwoord

Begin 1994 begon ik aan de vliegtocht die promotie-onderzoek heet. Nu, bijna 4 jaar later, lijkt met de afronding van het proefschrift de vlucht op een doellanding uit te lopen. Dat ik heb leren vliegen (en niet ben neergestort of doelloos blijven zweven) is aan een groot aantal mensen te danken, waarvan ik er hier een paar met name wil noemen. In de eerste plaats prof. dr ir A.A. Dijkhuizen en dr ir R.B.M. Huirne, mijn promotor en co-promotor. Aalt en Ruud, ik ben blij dat jullie mij ervan hebben weten te overtuigen dat onderzoek misschien toch wel iets voor mij was. Jullie positieve en stimulerende begeleiding heb ik altijd zeer kunnen waarderen. Aan ideeën nooit gebrek! De laatste loodjes waren af en toe best zwaar maar mijn eindconclusie luidt toch: Onderzoek op een dergelijk praktisch en toegepast onderwerp is gewoon leuk!

Stimulerend waren ook de bijeenkomsten met de Klankbordgroep. In het bijzonder wil ik hier de heren Van Norel, De Veer en De Leeuw noemen; zonder hun initiatief was het project nooit van de grond gekomen. Heren bedankt! Dat de laatstgenoemde mijn co-promotor heeft willen worden, beschouw ik als een blijk van vertrouwen en een groot compliment.

Dit proefschrift had niet tot stand kunnen komen zonder de welwillende medewerking van een groot aantal deskundigen op het gebied van de besmettelijke dierziekten. Workshopdeelnemers, het waren interessante en leerzame avonden die mij een schat aan informatie hebben opgeleverd!

Mijn vlucht werd zeer veraangenaamd door de plezierige sfeer op de vakgroep en de collegialiteit onder de 'jonge onderzoekers' c.q. 'tijdelijken'. Altijd in voor een praatje of een geintje maar ook altijd de interesse en bereidheid om mee te denken als ik daar behoefte aan had.

Miranda en Saskia, ik ben blij dat jullie mij bij de promotie als paranimfen terzijde willen staan. Zie het als een blijk van dank mijnerzijds voor de bijdrage die jullie elk op eigen wijze hebben geleverd aan dit proefschrift (en Miranda, ik heb er alle vertrouwen in dat jij me binnen no time volgt).

Na uren computeren, denken en overleggen was het voor mij altijd een verademing om lekker aan de gang te kunnen gaan met de paarden van de familie van Laar. Johan en Hennie (en niet te vergeten de kids), jullie hebben een belangrijke bijdrage geleverd aan de totstandkoming van dit proefschrift!

Ook het thuisfront heeft zich gedurende de afgelopen jaren niet onbetuigd gelaten. Ouders en broers, zowel de bemoedigende woorden als de (soms felle) discussies kon ik zeer waarderen. En mams, laten we vooral blijven streven naar de ideale combinatie van 'economisch haalbaar' en 'respect voor het dier'!

Tot slot een speciaal woord van dank voor Maarten. Positief kritisch en beslist niet alleen vanaf de zijlijn heb jij mijn vorderingen gevolgd. Jouw steun en vertrouwen waren en zijn voor mij heel waardevol.

Suzan Horst
Wageningen, november 1997

Contents

Chapter 1

GENERAL INTRODUCTION

1.1 INTRODUCTION

The further integration within the European Union (EU) towards one single market has major consequences for contagious animal disease control. In order to maintain trade relations with partners inside and outside the EU, countries increasingly require a disease-free status to be obtained and maintained, without applying preventive vaccination programs. Important diseases in this respect are the so-called 'List A diseases', defined by the Office International des Epizooties (OIE) as 'communicable diseases which have the potential for very serious and rapid spread, irrespective of national borders, which are of serious socio-economic or public health consequences and which are of major importance in the international trade in livestock and livestock products' (FAO/OIE/WHO, 1992). Examples of important List A diseases are Classical Swine Fever (CSF) and Foot-and-Mouth Disease (FMD). EU regulations demand strict adherence to a prescribed set of actions for the eradication of outbreaks of these diseases: measures include the establishment of surveillance zones with complete standstill of all animals, stamping-out of infected herds, etcetera. In some cases export bans on live animals are imposed. The recent CSF epidemic in the Netherlands has shown the great economic impact when an epidemic occurs in a region with a high density of animals and farms, and an export-oriented production.

Clearly, the best way to minimize losses from epidemics is to prevent introduction of the virus into the country. Preventive measures are very costly and may affect all stages of the production chain. Such measures should be based on the best information available. More insight into the factors related to virus introduction may support policymakers in the development of a (cost-)effective disease prevention program. In order to make sound economic decisions and to simplify and standardize the evaluation of existing and new prevention programs, integration of epidemiologically based risk analysis and economics is essential. Real-life experiments on virus introduction are too risky, too time-consuming, and too costly, and therefore not a realistic option. In addition to evaluating past epidemics, simulation modelling is a worthwhile alternative to provide information and insights.

Joint action by the Dutch government and private industry has resulted in a research project aimed at gaining more insight into the risk and economic consequences of virus introduction into the Netherlands. More precisely, insight into the following issues was to be obtained:

1. the factors that influence the losses due to epidemics of contagious animal diseases such as CSF and FMD;
2. the economic benefits, in terms of reduction in expected losses, of alternative prevention strategies.

Considerable research has already been done on various aspects of introduction and spread of contagious animal diseases. Literature on this subject having been published so far tends to focus only on the consequences resulting from a primary outbreak, i.e., the situation after the initial outbreak. These studies generally do not deal with the risk of occurrence of such an outbreak. Furthermore, most researchers focus on particular aspects only; an integration of risks and economic consequences is usually lacking.

Therefore the research goal of this study was the development of an approach which integrates risk and economic consequences of disease introduction. Inherent to such an approach is the combination of models of disease introduction, further spread, and economic consequences of epidemics. As suitable models describing the spread of epidemics within a country were already available for major diseases such as FMD and CSF (Jalvingh et al., 1996; Saatkamp, 1996), most attention was given to the development of a model describing the introduction of virus into the Netherlands, and subsequently to the combination of all available information in the integrated approach mentioned above.

1.2 OUTLINE OF THE STUDY

The project involved the following steps:

1. *Design of a suitable approach*

   Chapter 2 provides a general overview of the problem under study and combines existing knowledge and techniques in a proposal for an integrated modelling approach.

2. *Qualitative and quantitative elicitation of aspects involved in virus introduction*

   Epidemics of contagious animal diseases such as CSF and FMD occur irregularly over time, place and magnitude, which makes it very difficult to derive general properties and predictive values for modelling purposes. Furthermore, circumstances may change (for example, new trading partners, better disease prevention and eradication programs) which makes the value of historical information for predictive purposes questionable.

Therefore, besides 'objective' information originating from databases and experiments, also 'subjective' expert knowledge was used to provide model input. The major issue when using expert knowledge is how to derive quantitative data that mirror the knowledge of the experts involved as closely as possible. Chapters 3 to 5 address this topic. Chapter 3 describes a pilot experiment with the questionnaire technique 'Conjoint Analysis'. This technique is well known and widely used in consumer and marketing studies but was also expected to be useful for the elicitation of expert knowledge on the relative importance of risk factors related to virus introduction. Chapter 4 describes the results of the final Conjoint Analysis experiment and discusses the usefulness of the technique for elicitation of expert knowledge. Chapter 5 gives a description of an extensive workshop experiment which provided the expert data needed to complete the data for the computer model.

3. *Modelling virus introduction*

   Based on the information derived from 'objective' (databases, experiments described in the literature) and 'subjective' (experts) information sources, a simulation model was developed which describes the introduction of virus into the Netherlands. The model, called VIRiS (Virus Introduction Risk Simulation), is a Monte Carlo simulation model. The Monte Carlo approach uses random drawings from specified input distributions which enables a realistic representation of the variation and uncertainty involved in the input information and the system to be modelled. The VIRiS-results provide the distribution of the number of primary outbreaks in a 5-year period, their regional location, and the country and risk factor that causes them. Chapter 6 gives a description of the VIRiS model and its properties.

4. *The integrated approach*

   In Chapter 7 all elements of the preceding chapters come together. The various models describing introduction, spread and economic consequences are combined and used to evaluate prevention strategies on their ability to reduce the expected annual losses due to primary outbreaks of CSF and FMD. The results provide insight into the economic window which is available for implementation of such strategies.

5. *General discussion*

   In the general discussion (Chapter 8) an evaluation of the entire project is given in which the techniques used and the results obtained are discussed and recommendations for further research are given.

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Chapter 2

OUTLINE FOR AN INTEGRATED MODELLING APPROACH CONCERNING RISKS AND ECONOMIC CONSEQUENCES OF CONTAGIOUS ANIMAL DISEASES[1]

ABSTRACT

Outbreaks of contagious animal diseases pose a major threat to livestock production. Especially outbreaks of diseases that are on list A of the OIE are feared because these outbreaks will often result in serious economic losses, especially for major exporting countries such as The Netherlands. Management decisions in this area may have a large impact, but are usually based on scarce and unreliable information. Extensive research has been done on contagious animal diseases but an integrated model which combines the various aspects of outbreaks and risks with economic consequences is still missing. A flexible model with the possibility of evaluating the consequences of various strategies can be an important tool to aid in policy and decision making. In this paper a modelling approach is proposed which should lead to such an integrated model. In the paper the approach (a general framework) is outlined and several techniques to be applied are discussed. Subjective mathematical probability seems to be an appropriate technique as a basis for the model. In developing the model, special emphasis should be given to gathering the input data, which could include the use of expert panels. Promising techniques to deal with expert panels mainly originate from the area of marketing and consumer science and include conjoint analysis and the elicitation of subjective probability distributions.

2.1 INTRODUCTION

In 1994, Belgium and Germany were badly hit by outbreaks of Classical Swine Fever (CSF). More than 7.4 million pigs were killed and destroyed, the total costs of this operation estimated at almost 75 million ECU (Vanthemsche, 1995). However, these are only the direct costs (operational costs, market support, sanitary actions). Indirect costs,

[1] paper by Horst, H.S., Dijkhuizen, A.A. and Huirne R.B.M.
published in *Netherlands Journal of Agricultural Science 44 (1996): 89-102*

resulting from market disruption due to export restrictions, are often much higher and account for the major part of the total economic losses due to outbreaks of CSF and other 'list A' diseases (Berentsen et al., 1992; Dijkhuizen, 1988).

List A diseases are defined by the FAO/OIE/WHO Animal Health Yearbook (FAO/OIE/WHO, 1992) as 'communicable diseases which have the potential for very serious and rapid spread, irrespective of national borders, which are of serious socio-economic or public health consequences and which are of major importance in the international trade in livestock and livestock products'. Besides CSF, some other well-feared (because of their economic impact) viral diseases on this list are: African Swine Fever (ASF), Foot-and-Mouth Disease (FMD), Swine Vesicular Disease (SVD), Newcastle Disease (ND) and Avian Influenza (AI). Outbreaks have to be reported to the OIE (Office International des Epizooties) and eradication has to take place according to EC regulations, laid down in so-called 'Council Directives'. For instance, with respect to CSF, the following measures are required (CEC, 1980): rapid detection, confirmation and subsequent stamping-out of infected herds, tracing of risky herds (i.e. possibly infected herds), establishment of protection (3 km) and surveillance (10 km) zones around infected herds with complete movement standstill of all animals, and a continuous epidemiological surveillance within these zones.

Because of the great economic impact of outbreaks, adequate disease prevention and eradication is of major importance. Improvements may be made in various areas, for example the tracing of contact herds (by improvement of I&R systems, Saatkamp, 1996) or the operational management of outbreaks (by using programs such as EpiMAN, Sanson, 1993). A simulation model which is flexible enough to analyse the effects of different strategies (such as the two described above) could be a useful tool to support policy makers in this area. Therefore this paper proposes a modelling approach which (1) integrates the risk and economic consequences of outbreaks, (2) starts after an outbreak occurs in a 'foreign' country that could lead to the introduction of the disease into one's 'home' country, and (3) follows the disease/infection through all the various levels of the production-marketing chain. The structure of the paper is as follows: Firstly a brief overview of related research is presented (with no intention to be complete, only to present the reader with some background information). Then a basic idea of the system is introduced, followed by a discussion concerning the various phases of introduction of virus into one's 'home' country. Next, the general outline of an integrated model is discussed, with emphasis on modelling uncertainty and gathering input information. The paper concludes with further discussion of the issues and concluding remarks.

2.2 BACKGROUND

Extensive research has been done on contagious animal diseases, roughly to be divided into the following areas of interest: (1) the agent that causes the disease, (2) the mechanism of disease transmission, (3) economic consequences of outbreaks, and (4) prevention and eradication programs. Several studies focus on only one of these areas. Studies on vaccines (Terpstra and Wensvoort, 1988) belong to area 1, while studies by, for example, De Jong (1994) primarily focus on the second area: the transmission of the disease. Sanson et al. (1994) used stochastic simulation to model the transmission of FMD virus. The resulting spatial simulation model, called InterSpread, was included in a decision support system, called EpiMAN, developed for use in FMD control in New Zealand (Sanson, 1993).

There is a large number of studies that show overlap in certain areas. Especially studies from a veterinary point of view often combine areas 1 and 2. Examples are laboratory studies to gain insight into the influence of vaccination regime on immune response (Corthier, 1978), or studies in which the influence of various levels of virulence on symptoms and detection of infected animals is evaluated (Wensvoort and Terpstra, 1985). Although areas 1 and 2 are still important, the existence of dense populations of livestock in certain countries (within the European Union (EU) e.g. The Netherlands, Belgium, Germany and Italy), the increasing importance of international trade of livestock and livestock products, and the fact that countries are allowed to implement trade bans by only the slightest suspect of outbreaks (to protect their own animal health status, or as some might say, protect their national livestock production), induced the interest in economic consequences in combination with prevention and eradication programs (areas 3 and 4). Studies in these areas include, among others, Berentsen et al. (1992), Caporale et al. (1981), and Davies (1993). Berentsen et al. (1992) used a simulation approach to determine the economic consequences of alternative strategies to prevent and control FMD in The Netherlands. In this study, also the influence of outbreaks on export was taken into account. This aspect becomes increasingly important, especially for countries that suffer from outbreaks on a more or less regular basis and for countries that are historically free of certain diseases and wish to maintain that status. The latter concerns for example countries blessed with physical isolation, such as Australia and New Zealand. Risk assessment studies, concerning import of livestock products, are becoming of major importance. General outlines for developing a quantitative risk assessment study when international trade is involved are given by Miller et al. (1993) and MacDiarmid (1993). Other studies in this area include Heng and Wilson (1993) and Wilson and Banks (1993).

It can be concluded that many researchers have explored the area of contagious animal diseases and their control. Many attempts have been made to construct models which could support decision makers in a useful way (among others Berentsen et al. (1992); Sanson (1993)). Although these attempts have led to a number of useful models, an integrated model which includes the various aspects of outbreaks of contagious diseases and which combines risks with economic consequences is still not available. In the remaining part of this paper, an attempt will be made to describe a modelling approach which does integrate these aspects.

2.3 SCOPE AND DEFINITIONS

To structure the ideas on modelling risk and economic consequences of contagious diseases, a system, a 'geographic world', is assumed which contains small units (the small blocks), surrounded by a 'border' (Figure 2.1). The part enclosed by the border might be seen as a population. The border divides the world into an endogenous part (the population) and an exogenous part. The exogenous world is regarded as being uncontrollable and unpredictable. There are all kinds of contacts possible between the endogenous and the exogenous world; animals, human beings and commodities, all pass the border on a frequent base. Also between the small units within the borders all kinds of connections are possible. Some connections (but not all) are presented in the diagram by arrows. If somewhere in the exogenous world an outbreak of a contagious animal disease occurs, there is a probability that the pathogen will spread into the endogenous world (the population) and cause outbreaks in the small units.

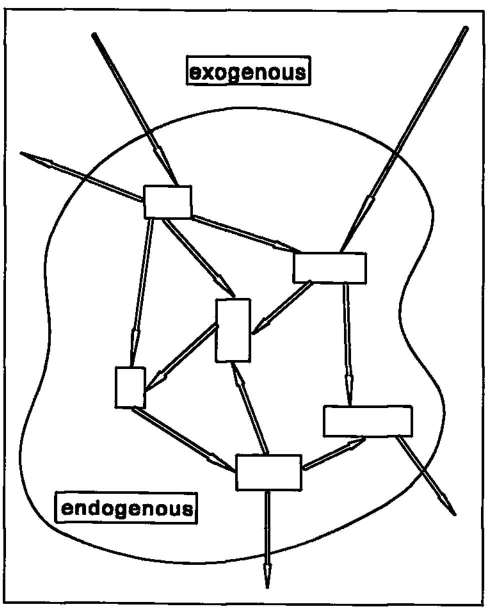

Figure 2.1
Schematic outline of a geographic system containing an exogenous and an endogenous part.

To cause such an outbreak, susceptible animals should be available and the pathogen has to be transported in one way or another. Risk factors are factors which can be responsible for this transport. The definition of risk factors as used in this paper is rather broad and includes all factors that can be responsible for the pathogen transport. Using this definition, also vectors (defined by Ahl et al. (1993) as 'organisms which can carry and transmit disease') and commodity factors (defined by the same authors as 'parameters specific to an animal or animal product which affect the likelihood that the unit, if contaminated, will carry, maintain and transmit an agent after arrival in the country of destination) can be seen as risk factors. From the literature it becomes clear that most diseases of list A of the OIE have many risk factors in common. Risk factors can be roughly divided into four groups: livestock (including livestock products), human beings, materials and air. The relative importance of these groups differ per disease, e.g. 'air' is an important factor for FMD (Mann and Sellers, 1989), while feeding of swill (organic waste, belonging to the group 'livestock products') is said to be the major cause of several outbreaks of ASF (Becker, 1987).

The first outbreak occurring within the population (the endogenous world) is commonly defined as the primary outbreak. After this outbreak, the pathogen can spread to other units (also endogenous) via the risk factors, and cause secondary outbreaks. As indicated by the arrows in Figure 2.1, there are contacts between the block units within the endogenous world. That means that the status of one unit may influence the status of a neighbouring one. For example, if the units represent individual farms, a farm with a poor hygienic status and regular import of animals may increase the risk of infection for a neighbouring farm.

Using the diagram in Figure 2.1, it is possible to modify the scope of the problem under consideration by adjusting the border line (thus adjusting what is considered to be a 'population'). When considering a primary farm, the border will be the fence around the farm and the small block units the different stables. Expanding the scope, the blocks could present farms and the border could be one of a province, or a country. Expanding even further, the population could be the EU, with the member states as small blocks.

Concerning the approach described in this paper, the endogenous area covers not only the 'home' country, but also several other countries, indicated as contact regions. A contact region is defined as a (part of a) country which has a direct or indirect contact with the home country which, when the region suffers from an outbreak, can lead to the introduction of a virus (due to risk factors) into the home country. The problem of how the virus has entered these contact regions and caused an outbreak has not been incorporated because this is part of the exogenous world.

2.4 TOWARDS AN INTEGRATED APPROACH

Most studies concerning risk and economic aspects of contagious animal diseases are meant to be useful in risk management. Risk management has been defined by Ahl et al. (1993) as 'the pragmatic decision-making process concerned with regulating risk'. A somewhat similar definition has been given by MacDiarmid (1993). Both definitions regard the process of identifying the sources of risk and assessing the risk as separate activities. However, risk management is based on the results of these activities and cannot be seen separately. Therefore, a good risk management plan includes all these activities and consists of five basic steps:
1) risk identification;
2) risk assessment;
3) assessing risk attitude;
4) developing alternative risk management strategies;
5) analysing and evaluating strategies.
The approach proposed in this paper aims at incorporating these five steps into one generally applicable model. During the developmental phase, steps 1, 2 and 3 will be taken. With the resulting model it should be possible to take steps 4 and 5.

The flowchart in Figure 2.2 indicates the several phases which are considered in the approach suggested. The model starts with an outbreak in a contact region. Spread of the pathogen followed by an introduction into the home country can cause a primary outbreak. Due to transport of pathogen by risk factors, secondary outbreaks are likely to follow. To model these phases it is necessary to perform steps 1 and 2, i.e. identify the sources of risk (contact regions and risk factors) and assess the risks involved.

Following Figure 2.2, outbreaks will activate an eradication program containing slaughtering of animals in affected regions, export bans etc. These actions have economic consequences. Evaluation of the consequences can lead to new policies (or strategies), developed by the people responsible for the risk management (step 4: developing alternative risk management strategies). Choosing a new strategy will, however, depend among other things on the evaluation of the expected costs and benefits of this strategy; costs not only for developing the strategy (e.g. costs for establishing and maintaining prevention measures), but also for bearing the (negative) consequences of the possible risks connected to that policy (e.g. losses due to eradication when an outbreak occurs).

Typical for the type of diseases under consideration (viral diseases of list A, as mentioned in the introduction) is that the probability of introduction of a virus in a certain country is low. However, if the virus has been introduced and causes outbreaks, the

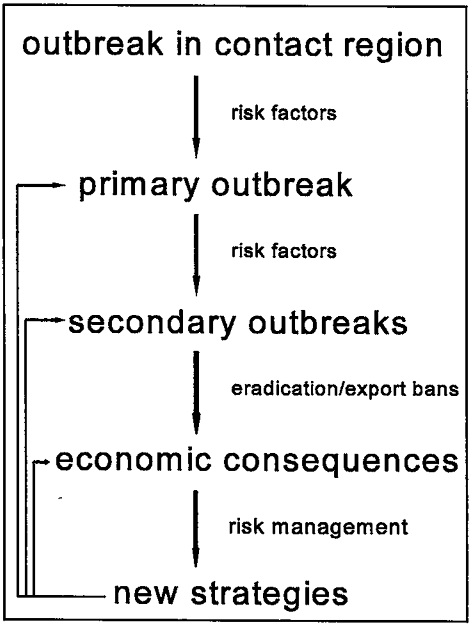

Figure 2.2
Various steps of the integrated outbreak model.

consequences are generally huge. But while these losses are expected to be large, they might vary to a large extent between outbreaks. Berentsen et al. (1992) estimated total losses from FMD at between US$ 45 million and 5 billion, depending on region (animal density) and eradication strategy. Determining the optimal strategy to deal with such uncertain situations requires knowledge of the decision maker's risk attitude. The decision maker has to find the optimal trade-off between expected monetary consequences of strategies and the risks involved (step 3 of the risk management plan). This is important in order to enable decision makers to use the insight gained by model results (number of outbreaks, magnitude of the economic consequences) to develop alternative strategies (step 4) and analyse and evaluate these strategies (step 5). The model should be flexible enough to perform all kinds of scenario studies and sensitivity analyses as to enable step 5, i.e. analysis and evaluation of new strategies.

New strategies (for example better I&R systems, see Saatkamp (1996)) can lead to better eradication programs which will affect the number of secondary outbreaks and the economic consequences. New preventive programs could affect the number of primary outbreaks. This is symbolized in Figure 2.2 with the arrows going from 'new strategies' towards the other phases (there is no arrow from 'new strategies' towards 'outbreak in contact region', because outbreaks in contact regions are considered to be part of the exogenous world). In this way the approach integrates the various phases of disease outbreaks and management planning.

2.5 OUTLINE OF THE MODEL

2.5.1 Properties

As shown in Figure 2.2, the problem of outbreaks of contagious diseases can be divided into several subproblems, which can all form a separate module of an integrated modelling approach. A model consisting of modules is easier to build, to adapt to new situations and to maintain and will also enhance the flexibility of the model. According to Kleijnen (1995), modular programming will also ease the verification of the model.

Various types of models are available and applied in the field of Animal Health Economics (Dijkhuizen, 1988). A choice has to be made on three fundamental properties of the model: static or dynamic, stochastic or deterministic, and optimization or simulation. The nature of the problem, as shown in the flowchart in Figure 2.2, is a sequence of events, e.g. a primary outbreak comes before a secondary one. Thus, a dynamic approach which contains time as an explicit variable is needed to describe the problem. A deterministic approach means that the outcome of an event can be derived assuming certainty about input values and relationships. Although historical data are not widely available, as stated before, it will be clear that an outbreak can vary in its duration, in the number of secondary outbreaks after a primary outbreak, etc. Monte Carlo simulation (i.e. stochastic modelling) will provide the user not only with the expected value but also with the expected variation of the results. Variance is an important piece of information for decision makers (risk management), who can use it to adapt strategies according to their risk attitude. Risk averse decision makers will especially be interested in the negative side of the outcome distribution (what happens if it comes to the worst) while others may put more emphasis on the reverse side.

An optimization model determines the optimum solution given the objective function and restrictions (Dijkhuizen, 1988). Simulation calculates the effects of pre-defined sets of input variables (scenarios, strategies) and is therefore attractive for exploring strategies that have not been applied yet. Sensitivity analysis, i.e. using different sets of input variables, and comparing the results will give insight into the importance of the various input values. In this way it is possible to discover which input values are most important and need extra attention (additional research).

Thus, to describe the problem realistically and provide the decision maker with the most useful information, the model should be dynamic and stochastic, and results should be obtained by using the simulation technique.

The performance of a model is largely determined by the degree to which its structure mirrors reality. Therefore, the last step in the developmental process should be the verification and validation of the system. Good elaborations on this topic are given by, amongst others, Harrison (1991), Law and Kelton (1991), and Kleijnen (1993). To simplify one might say that verification is aimed at building the system right (building the structure exactly as intended, without any errors in the programming code) where validation refers to building the right system (a right presentation of the real system), which depends on the goal of the model (level of accuracy needed etc.). Without an abundant availability of real-world data (well-documented outbreaks are scarce), validation of the system described in this paper might be a problem, but some possible solutions are given in literature (such as what-if analysis (Kleijnen, 1993)).

2.5.2 Modelling uncertainty

The reality of outbreaks of contagious animal diseases contains many aspects about which knowledge is uncertain (e.g. number of outbreaks per year, probability of transporting virus via certain risk factors, etc.). To model this type of uncertainty, several approaches are available. The approaches that have been most widely used and discussed in literature are the use of certainty factors (confirmation theory, Shortliffe and Buchanan, 1975), subjective Bayesian probability theory (Duda et al., 1976), the Dempster-Shafer theory of belief functions (Dempster, 1967; Voorbraak, 1990) and the theory of fuzzy sets (Zadeh, 1988). These techniques were developed mainly to be used in rule-based expert systems, where knowledge is typically expressed in the form of IF-THEN rules (i.e. IF A THEN B), where there is a rule premise (A) and a rule conclusion (B). In general, all techniques try to give the experts consulted a method to express their feelings about the two types of uncertainty that must be addressed in a rule-based expert system, namely rule uncertainty ('does A always lead to B?') and evidence uncertainty ('how likely is A to happen?'). Good descriptions and comparisons of these methods are given by Gold et al. (1990), Heatwole and Zhang (1990), and Van der Gaag (1989). Van der Gaag states in her critical review that the models are intuitively attractive but present some theoretical difficulties, especially when multiple evidence has to be combined.

When looking for scientific correctness, the basic concept of mathematical probability is still appealing. This concept has long been the primary approach for dealing with uncertainty. Probability is rooted in the concept that the likelihood of an event can be determined, based on past history of occurrences or based on a good causal model of the system. According to Heatwole and Zhang (1990), mathematical probability is a good approach for dealing with uncertainty when the necessary data, which can be statistical data or objective assessments, are available. They also state that if it is not possible to obtain that type of data, alternative approaches, such as the use of certainty factors (described above), are required. This opinion is not shared by Anderson et al. (1977) who state that 'objectivity in science is a myth, in life an impossibility, and in decision making an irrelevance'. According to these authors, subjective probability is the only available concept for decision making. Strong emphasis must be placed, however, on the elicitation of the probabilities in order to get as near as possible to the three basic axioms of probability calculus. These axioms are (1) probabilities cannot lie outside the range of zero to one, (2) the probability that two or more mutually exclusive events will occur is the sum of their respective probabilities, and (3) the probability of the exhaustive (universal) set of events is one.

2.5.3 Input

As outlined in the second section of this chapter, literature concerning epidemiology and economic consequences of outbreaks is available (although not abundant). Therefore the most crucial 'unknowns' needed for the model suggested are the risk factors which might be responsible for the introduction of pathogen in a country. The concept of risk factors is well-known. Interviewing experts, organizing brainstorm sessions, for instance, will certainly result in a qualitative list of potential risk factors. Quantifying this information, i.e. assigning probabilities to the risk factors (probability that the risk factor will transport pathogen), is a more complicated task. Anderson et al. (1977) emphasize that subjective probability should be consistent with the probability calculus (as described above) and with the decision makers' true beliefs. Several techniques are available to deal with this problem. Depth interviews may seem a logical choice only when a qualitative insight is required. However, according to Selvidge (1975) it is also possible to arrive at a numerical expression of uncertain knowledge during such interviews. Her procedure is especially aimed at cases where the assessors have little or no personal experience with the event being considered and/or have difficulty in distinguishing among very small probability values. Major emphasis is put on splitting the original problem into small parts which should make it easier for the expert to understand what is asked and to assign probabilities. In this way, parts of the procedure could also be useful as an introduction prior to other methods.

A technique already applied in the area of risk factors of contagious animal diseases, is the Delphi method. This method was used in New Zealand to determine the risks involved in FMD (Forbes, 1992) and in the US in a study concerning pseudo rabies (Miller et al., 1994). According to Sackman (1975), Delphi is an attempt to elicit expert opinion in a systematic manner for useful results. Martino (1983) states that the Delphi procedure is a feasible and effective method of obtaining the benefits of group participation in the preparation of a forecast while at the same time minimizing or eliminating most of the problems of committee action. It usually involves iterative questionnaires (several rounds) administered to individual experts (by mail) in a manner guaranteeing the anonymity of their responses. Besides anonymity also controlled feedback is an important characteristic of the Delphi procedure. In each round, group results of the preceding round are provided and the experts are given the opportunity to revise their opinion and/or bring in arguments for or against the group opinion. Sometimes, the questionnaire rounds (by mail) are followed by a group discussion (Forbes, 1992). After this discussion, experts are again given the opportunity to revise their opinion. The aim of the procedure is to reach a certain convergence in opinion about the problem or forecast being considered.

If the risk factors are known, a procedure to rank them might be the method of conjoint analysis. Conjoint analysis was developed in the sixties (Krantz, 1964; Luce and Tukey, 1964; Krantz and Tversky, 1971) and rooted in traditional experimentation. Conjoint analysis developed from a need to analyse the effect of predictor variables that are often qualitatively specified or weakly measured (Hair et al., 1987). The method is widely used in market research to measure consumer preferences in order to develop new products. According to Fishbein (1963), a product or an event can be seen as a composition of attributes. In conjoint analysis, respondents are asked to rank profiles, where a profile represents a product or an event formed by a specific combination of attributes. Attributes are characteristics of a product, e.g. when selecting a car, attributes can be: colour, make, price etc. In the case of contagious animal diseases, the risk factors are the attributes, related to the event 'introduction of virus'. Using regression analysis, the relative importance of the various attributes can be calculated. In this way, the method does not only provide the user with an ordering of the attributes but also gives insight into the distances between them. A major advantage of the method is that it is possible to check up on the consistency of the respondents.

The methods described above all try to help respondents to express their preferences and ideas. Although the methods acknowledge that respondents may feel uncertain about their knowledge, this uncertainty is not expressed in the outcomes of the procedures. A way of expressing uncertainty could be the assessment of Subjective Probability Distributions (SPDs). The mathematical modus of an SPD reflects the best guess of a respondent, the dispersion of the distribution corresponds with the uncertainty about this best guess.

Assessing SPDs appears to be a difficult task and several techniques have been developed that support assessors during the specification of their SPDs. These elicitation techniques can be either direct or indirect (characteristics of the SPDs are inferred from the responses of the assessor). Research in this area has been done by, among others, Spetzler and Staël von Holstein (1975). A relatively new method for the elicitation of SPDs has been developed by Van Lenthe (1993). In this method (called ELI) scoring rules have been used to enhance the accuracy of the estimates (SPDs) of the respondents. Van Lenthe's research has resulted in a graphically oriented interactive computer program, called ELI, with a built-in scoring rule. According to its inventor, ELI appears to be a practical and useful method that contributes to relatively reliable and valid SPDs.

The techniques described all contain interesting elements. A combination of several of these methods may be used to quantify the input necessary for the described model.

2.6 DISCUSSION AND CONCLUSION

Contagious animal diseases formed an interesting topic for researchers from the past, and still do for the present and probably also future, not least because of the considerable economic consequences connected with outbreaks of these diseases. Although many useful studies have been accomplished, there is still need for an integrated model that includes the various aspects of outbreaks and integrates risk components and economic consequences.

Literature shows that various techniques are available that can be used in the development of such a model, none of them being perfect, however. The most appealing technique to base the structure of the model on is mathematical probability, because of its scientific correctness and clear concept. In that case, special emphasis should be given to gathering of input data, which will include the use of expert panels. One of the techniques that can be used when trying to elicit expert knowledge, is the Delphi-method, already used in the area of animal diseases (Forbes, 1992; Miller et al., 1994). However, a good Delphi approach is very time-consuming (several rounds of questionnaires have to be performed) and it is difficult to involve a large number of experts in such a method (Miller used only 8 experts), and keep them involved in each questionnaire round (Forbes started with 28 experts, only 15 of whom completed the second round). Delphi solves the problem of how to reach a kind of an agreement (one answer) when asking different people the same question, minimizing the influence they might have on one another. It does not, however, give any clues about how the question has to be framed.

Promising techniques which give more grip concerning framing of questions are conjoint analysis and eliciting Subjective Probability Distributions (SPDs). Conjoint analysis has proved itself in the area of marketing research. Cattin and Wittink (1982) stated that around 1,000 commercial applications were carried out between 1971 and 1981. An important advantage of the technique over other methods is the possibility of checking up on consistency and reliability of respondents. Elicitation of SPDs is interesting because it allows respondents to express uncertainty about an answer. So far, both conjoint analysis and eliciting SPDs have been used mainly in the area of marketing research. However, in studying their possibilities and limitations, there seem to be no constraints for the use in other fields as well.

It can be concluded that several promising techniques for eliciting expert knowledge are already available. The best method might be an eclectic approach. More research is needed to adapt the methods to the use in the field of animal diseases and to develop the best combination. However, absolute values for the probabilities concerned with the potential transport of pathogen by risk factors will be hard to estimate, because these probabilities are expected to be very small. Moreover, according to Davis and Olson (1985), lack of understanding statistical analysis can heavily bias direct questions on probabilities. Therefore the elicitation of relative values might result in more reliable values, which implies that the resulting model will have its use mainly in comparing situations (i.e. in ranking strategies).

The use of expert panels will provide estimates for input variables for which no historical or experimental data are available. It will be hard (if not impossible) to judge if these estimates are close to the 'real' values. However, until historical data and/or experimental research are able to provide better results, estimates based on expert knowledge will be the best information there is. In all cases, sensitivity analysis should be an important feature of the proposed model. Not only to enable the users (decision makers) to evaluate consequences of various strategies but also to evaluate the impact of uncertain input variables, which will help to guide efficient planning of further research efforts. It must be emphasized that a model will never be a perfect representation of reality, especially not if part of the input is based on estimated values. Therefore, models will never be more than a (hopefully useful) tool to aid decision makers. The final decision will always be the responsibility of the decision makers themselves.

To conclude, because of specialization and increasing international trade of livestock and livestock products, prevention and eradication of contagious animal diseases have become a matter of national and international importance. Decision makers are operating at 'high' levels and often lack information to foresee all consequences of their decisions for all parts of the production chain. An integrated approach, as suggested in this chapter, will enable a better insight and thus be beneficial to the decision making process.

Several elements of the approach suggested have already been subject of extensive research. Now it is time to combine these elements into one model. Research is under way to develop and test such a model (and will be described in the next chapters).

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Chapter 3

ELICITING THE RELATIVE IMPORTANCE OF RISK FACTORS CONCERNING CONTAGIOUS ANIMAL DISEASES USING CONJOINT ANALYSIS: A PRELIMINARY SURVEY REPORT[1]

ABSTRACT

Conjoint Analysis is a technique well known in marketing research to elicit consumer preferences and opinions. This paper describes the results of an experiment which explores the potential application of Conjoint Analysis in the field of veterinary epidemiology and economics. In this experiment, the method of Conjoint Analysis was used to elicit the opinion of experts about the relative importance of risk factors concerning contagious animal diseases. Diseases studied were: African Swine Fever (ASF), Classical Swine Fever (CSF), Foot-and-Mouth Disease (FMD), Swine Vesicular Disease (SVD), Newcastle Disease (NCD) and Avian Influenza (AI). Risk factors included were import of livestock, import of animal products, feeding of swill, tourists, returning livestock trucks and air. The Conjoint Analysis technique was used to draw up a questionnaire which was handed out during the 7th ISVEE held at Nairobi, Kenya, from 15 to 19 August 1994. According to the experts approached, the factors 'import of livestock' and 'import of animal products' were the major sources of risk for all diseases. For ASF, CSF and FMD, the risk factor 'swill feeding' ranked third. For FMD and the two poultry diseases NCD and AI, only the risk factor 'air' was important. Overall conclusion was that Conjoint Analysis could be a useful method for eliciting the opinion of experts about risk factors concerning contagious animal diseases. In further research, special attention should be given to the selection of experts and the presentation of the conjoint questions.

3.1 INTRODUCTION

Outbreaks of epidemic contagious animal diseases pose a major threat to livestock industries worldwide. Outbreaks of diseases that are on list 'A' of the Office International des Epizooties (OIE) are greatly feared. List-A diseases are defined by the Animal Health

[1] paper by Horst, H.S., Huirne, R.B.M., and Dijkhuizen, A.A.
published in *Preventive Veterinary Medicine 27 (1996): 183-195.*

Yearbook (1992) of the Food and Agricultural Organization (FAO), OIE, and the World Health Organizations (WHO) as, 'communicable diseases which have the potential for very serious and rapid spread, irrespective of national borders, which are of serious socio-economic or public health consequences and which are of major importance in the international trade in livestock and livestock products'. Outbreaks of these diseases often result in major economic losses, especially for exporting countries.

Extensive research has been done on contagious animal diseases, roughly to be divided into the following areas of interest: (1) the agents that cause the diseases, (2) the mechanisms of disease transmission, (3) economic consequences of outbreaks, and (4) prevention and eradication programs. Several studies focus on only one of these areas. Studies by, Anderson and May (1979) and Diekmann et al. (1990), for example, focus primarily on transmission of the disease, using a mathematical approach (i.e. differential equations). Numerous studies have been done on the topic of disease agents, mainly based on laboratory research. It is obvious that there could be a large number of studies that show overlap in certain areas, especially areas 3 and 4 (e.g. the study by Ghilhardi et al. (1981), concerning the economic evaluation of control campaigns in Italy). Such studies are usually based on historical data, if available and applicable. In some studies historical data were used as input for a computer simulation model (Berentsen et al., 1992). When historical and laboratory data are insufficient, additional information is provided for such models based on estimates and assumptions.

The reliability of this additional information is difficult to judge. Important decisions that have to be made on eradication and prevention programs and which often have a strong impact on the livestock industry, must be made regardless, and hence considerable effort must be made to obtain reliable estimates and assumptions.

If researchers consider their own knowledge insufficient, it is necessary to consult experts. The general issue then is how to obtain as much reliable and quantitative information as possible from these experts, which suits model evaluations and decision making. If there is no 'gold standard' available to judge the reliability, the researcher should at least aim for consistent quantitative information which mirrors the opinions of the experts as closely as possible.

There are several techniques available to deal with this situation, ranging from very open in-depth interviews to strictly organized computer experiments. In this paper a study involving a questionnaire is described. The questionnaire focused on the risk factors that are involved in the introduction of an epidemic animal disease into a country. The six diseases considered were (all on list A of the OIE): African Swine Fever (ASF), Classical Swine Fever (CSF), Foot-and-Mouth Disease (FMD), Swine Vesicular Disease (SVD), Newcastle Disease (NCD) and Avian Influenza (AI). The key issue of the questionnaire was the use of the method of Conjoint Analysis. Conjoint Analysis has been used extensively in marketing research to estimate the impact of selected product characteristics on customer preferences for products (Cattin and Wittink, 1982). The major objective of this study was to explore the potential application of this method to the field of veterinary epidemiology and economics. This study focused on the use of the conjoint technique for the elicitation of the opinion from international experts, concerning the relative importance of risk factors.

This paper is organized as follows: Firstly the use of the method of Conjoint Analysis is explained in general (briefly) and with respect to the questionnaire experiment under consideration. Next the results are shown. These results and their importance to further research are discussed thereafter. The last part of the paper includes some final remarks.

3.2 MATERIALS AND METHODS

3.2.1 Conjoint Analysis

A product or an event can be evaluated as a composition of attributes or characteristics (Fishbein, 1963). The importance of each attribute is determined by the person who examines the object. For example when selecting a car, important attributes in deciding whether to buy it are: color, price, make, maximum speed, size etc. The process by which consumers (a) compare different cars on the basis of sets of attributes, (b) form final choice sets, and (c) finally make choices is complex. Conjoint Analysis is a technique that enables the quantification of the relative importance of the attributes of a product or event in relation to the final choice. It was developed in the 1960s (Krantz, 1964; Luce and Tukey, 1964; Krantz and Tversky, 1971) and was rooted in traditional experimentation techniques.

Conjoint Analysis is a so-called 'de-compositional method'. Respondents are asked to give a rank or a score for each profile, where a profile stands for a specific combination of attributes (or attribute levels). The car-selecting problem provides a good example for a typical conjoint experiment. In this case, respondents will be shown a number of small cards, each presenting a different car. A car is described using attributes like make, speed, color, price (a profile). The respondents are asked to give a score or a rank for each card. Using statistical analysis, the importance of each attribute (or attribute level) can be estimated. These 'importances' are termed 'part-worth scores' and indicate the influence of each attribute on the respondent's preference for a particular profile (in this case, a particular car). A car company could use this information about part-worth scores, for example to predict the 'likelihood of buying' when a new car is developed. The method of Conjoint Analysis is developed from a need to analyze the effect of predictor variables (attributes) that are often qualitatively specified or weakly measured (Hair et al., 1990).

Basic assumptions of Conjoint Analysis are: (1) a product can be described according to levels of a set of attributes and (2) the consumer's overall judgement with respect to that product is based on these attribute levels (Steenkamp, 1987).

Conjoint Analysis may look like a rather complicated and indirect method to reveal systematic components that underly people's evaluations of objects. On first sight, a compositional method, such as direct questioning, may be a more attractive option. Compositional methods ask respondents to assess values for attribute levels, and use these values to build up preferences for attribute bundles or profiles (Huber, 1974). The compositional method is also referred to as a self-explicated method and has speed and simplicity as main advantages. Because of these properties, the method can be used, even when the number of attributes is large. However, it has several problems, the major one being lack of realism. It is difficult for respondents to provide a non-biased score for an attribute, holding everything else equal. Heavy biases may result from direct questioning on the importance of socially sensitive factors (Green and Srinivasan, 1990). The de-compositional conjoint method provides a more realistic situation to the respondent because attributes are evaluated as combinations (as is the case in the 'real world'. Moreover, many researchers have compared the predictive performance of the conjoint method with the self-explicated approach and in most studies the conjoint techniques outperform the latter one (Huber et al., 1993, Green et al., 1983). Green and Srinivasan (1990) argue that the above described method of Conjoint Analysis (also referred to as full profile Conjoint Analysis) works very well when there are only a few (about six) attributes. Larger numbers of attributes could place a severe information overload on the respondents. In these cases the self-explicated approach, or a combination of the self-explicated and the conjoint method (which is called 'hybrid conjoint modelling') should be considered. For more details about the technical aspects of the conjoint method and comparisons with the self-explicated and combined approach, the reader is referred to Green and Srinivasan (1978), Huber et al., (1993), Krantz and Tversky, (1971), and Luce and Tukey, (1964).

The adoption of the, relatively new, technique of conjoint modelling has grown quickly and nowadays its area of application ranges from the development of new products (Green et al., 1981) to student university choice process (Hooley and Lynch, 1981). Conjoint Analysis has been more extensively used in consumer and marketing research of products. However in general it is possible to use the method in cases where an object or event and its related attributes can be determined and where one's aim of study is the elicitation of the respondents' feelings towards these attributes. The method provides a handy tool to quantify feelings or subjective knowledge about attributes. Den Ouden et al. (1994), for instance, used the method for eliciting respondent's ideas about weights on animal welfare issues that were to be included in a multiple-goal programming model for production marketing chains in swine.

3.2.2 The experiment

In the case of contagious animal diseases, risk factors can be seen as attributes related to the event 'disease outbreak'. Because literature (Liess, 1981; Becker, 1987 and Mann and Sellers, 1989) and in-depth interviews with a limited number of experts provided six major risk factors, this situation was considered to be interesting to elicit the subjective knowledge of experts on these attributes with the use of the conjoint method. Because there is no 'gold standard' for these risk factors, the term 'knowledge' should not be taken too literally. But it is this knowledge that is also used by the experts to make decisions in real situations.

The following six risk factors were selected to be examined within the conjoint method:

(1) import of livestock
(2) import of livestock products
(3) swill feeding
(4) tourists
(5) returning livestock trucks
(6) air (airborn agents)

All factors, or attributes, could be either present or not present (two levels), which made a total of 2^6 or 64 possible profiles. Using all profiles (a complete factorial design) would be impractical; 64 profiles are too many to be examined by a respondent. The number of profiles can be decreased by using a fractional factorial design, with only a minimal loss of accuracy. The basic plans of Addelman (1962) were used to construct the necessary orthogonal fractional factorial design for this risk factor study, which resulted in eight profiles. Three randomly chosen profiles were added as 'holdouts', which are used to check the fit of the model when analyzing the results of the Conjoint Analysis (regression coefficients are based on the first eight profiles only). This gauge the respondent's consistency in answering the questions.

The most common way to perform Conjoint Analysis is to approach the respondents with a number of cards, each presenting a certain profile. The respondents are then asked to rank or score the cards.

Table 3.1
Table which was embedded in the questionnaire. Scores should be filled in for six diseases.

	Profiles										
Risk factors	1	2	3	4	5	6	7	8	9	10	11
Import of livestock	+	+	+	+	-	-	-	-	+	+	-
Import livestock products	+	+	-	-	+	+	-	-	-	+	-
Swill feeding	+	+	-	-	-	-	+	+	+	-	+
Tourists	+	-	+	-	+	-	+	-	-	-	+
Returning trucks	+	-	+	-	-	+	-	+	+	+	+
Air	+	-	-	+	+	-	-	+	-	-	-
Your risk score for											
African Swine Fever	...	...	...	...	...	...	...	...	...	...	...
Classical Swine Fever	...	...	...	...	...	...	...	...	...	...	...

The use of cards was impractical for this study, because the aim of the experiment was to make use of a group of experts from various countries at the same time. Therefore the Conjoint Analysis was embedded in the questionnaire in the form of a table (Table 3.1). Respondents were asked to give a risk score (a number between 0 and 100) for all 11 profiles for each of the six diseases. A higher score means a riskier profile with respect to the introduction of the disease. A '+' in the profile column means that the risk factor is present, a '-' means that it is not. So, in the first profile, all risk factors are present, while in the third profile only the factors 'import of livestock', 'tourists' and 'returning trucks' are present. It seems logical, therefore, that the first profile will receive a higher risk score than the third profile. In the fourth profile, only two factors are present ('import of livestock' and 'air'). For some diseases, this profile may contain less risk than profile 3. But when 'air' (airborne spread) is supposed to be of more importance than 'tourists' and 'returning livestock trucks' , this profile should obtain a higher score than profile 3.

The results were analyzed by using SPSS (SPSS Inc., Chicago), a statistical package that includes a special option for handling Conjoint Analysis (using regression techniques). The customary approach to Conjoint Analysis is disaggregate. That is, each respondent is modelled separately and the fit of the model is examined for each individual respondent (Hair et al., 1990).

The following model was used:

$$score = c + \beta_1 * x_1 + \ldots\ldots + \beta_6 * x_6$$

In this simple additive model, *score* is the estimated score for a profile, *c* is a constant, β_1 to β_6 are the estimated coefficients belonging to the risk factors, and x_1 to x_6 are the risk factors (with values 1=present, or 0=not present). The parameters of this model were estimated, using the first eight profiles. Based on the model, the method estimates the relative importance of each risk factor (all risk factors together add up to 100%). Kendall's tau and Pearson's R were used to check the fit of each individual model for the first eight profiles (test on the internal validity). Kendall's tau was also used to test the fit of the model on the last three profiles (the holdouts). For each respondent, the scores of the holdout profiles were estimated, using the individuals own model, and then compared with the scores given by the respondents in the questionnaire. This provided a measure of cross-validity, which took into account the predictive ability of the model and the consistency of the respondents (Green and Srinivasan, 1978). The results were summarized per risk factor and the Kolmogorov-Smirnov test (Lilliefors variation, samples with unknown mean and variation) was used to test whether the results could be analyzed as being normally distributed.

The questionnaire also contained a 'direct' question to investigate the relative importance of the risk factors. In this question the respondents were asked to divide 100 points among the six risk factors, for each disease. This direct questioning method can be seen as a very simple self-explicated method. Spearman's correlation test and Wilcoxon's matched-pairs signed-ranks test were used to test whether the conjoint method and the direct questioning method differed in results.

The respondents were asked to answer the questions for the six diseases of interest (ASF, CSF, FMD, SVD, NCD and AI). Their expertise with each disease was expected to vary. Therefore, a question was included that gave them the chance to quantify their level of knowledge for each on a scale ranging from 1 (low) to 5 (high). This 'knowledge level' provided a tool to distinguish between experts.

The questionnaire was handed out to 74 attendants of the 7th International Symposium on Veterinary Epidemiology and Economics (ISVEE), held at Nairobi, Kenya from 15 to 19 August 1994. Prior knowledge of the 'expert' status of the attendees was unknown. The respondents were asked to return the questionnaire during the symposium or to send it back afterwards.

3.3 RESULTS

3.3.1 General

In total, 22 questionnaires were returned (12 during the symposium and 10 afterwards, all used in the analysis), which resulted in a response rate of approximately 30%. The Kolmogorov-Smirnov test showed that it was permissible to treat the summarized results per risk factor as being normally distributed (significance > 0.2 for all risk factors). Therefore, the sample mean was used as summary statistic of the results.

Table 3.2 shows the results of the estimates of the opinion of the respondents concerning the relative importance of each risk factor for each disease. Because of the extremely large variation in results, a trimmed mean was used. The two highest and the two lowest values were excluded from this calculation (18% trimmed mean). The numbers in brackets indicate the interval in which the remaining 82% of the relative importance values were found (i.e. the 9th and 91th percentile). According to Table 3.2, the main risk factors for all six diseases are 'import of livestock' and 'import of livestock products', together accounting for more than 50%, for each disease. For the diseases ASF, CSF and FMD, the risk factor 'swill feeding' ranks third. 'Air' is considered especially important for the two poultry diseases. Risk factor 'returning trucks' is of minor importance, except for AI where this risk factor ranks the same as 'import of livestock products'.

Table 3.2
Trimmed mean of the estimated relative importance of risk factors (as a percentage), 9th and 91th percentile values in brackets.

	Diseases					
Risk factors	ASF	CSF	FMD	SVD	NCD	AI
Import of livestock	39 (14-62)	31 (2-58)	30 (3-47)	34 (11-56)	39 (3-89)	38 (11-61)
Import livestock products	18 (0-33)	24 (10-34)	17 (2-33)	16 (3-22)	16 (4-26)	18 (4-25)
Swill feeding	17 (4-41)	16 (2-43)	16 (2-49)	17 (4-27)	7 (1-20)	8 (1-16)
Tourists	13 (2-22)	14 (0-35)	15 (0-52)	17 (2-33)	11 (1-21)	11 (1-16)
Returning trucks	7 (2-13)	9 (3-19)	8 (1-21)	10 (3-15)	15 (5-21)	8 (2-13)
Air	6 (1-15)	6 (0-11)	13 (0-40)	5 (0-11)	11 (4-30)	18 (4-30)

3.3.2 Response rate

Cross-validation was used to get more insight into the influence of the response rate on the results. Ten random samples of 5 questionnaires were taken out of the total of 22 questionnaires and the remaining 17 questionnaires were used (during each sample) to calculate the values of the relative importance of the risk factors (sampling with replacement). Subsequently, the relative differences between these values and the original values were calculated (original values were based on the total number of 22 questionnaires). The results are shown in Table 3.3.

Table 3.3
Average relative deviations of 10 random samples of 17 questionnaires (absolute percentages), compared with the mean importance for risk factors based on all 22 cases.

	Diseases					
Risk Factors	ASF	CSF	FMD	SVD	NCD	AI
Import of livestock	3.8	4.3	4.5	5.6	5.0	6.0
Import livestock products	3.5	5.9	4.8	4.9	5.5	5.8
Swill feeding	6.6	7.4	10.4	6.0	7.0	8.8
Tourists	3.2	8.3	8.2	10.1	12.6	14.5
Returning trucks	8.4	11.3	3.7	10.0	11.3	7.3
Air	13.4	16.7	6.3	12.0	9.8	9.0

The average deviations ranged from 3.5% (disease ASF for risk factor 'import of livestock products') to 16.7% (disease CSF for risk factor 'air'). In general, the lower values of Table 3.2 showed higher deviations in Table 3.3 (a small deviation from a small value gives a larger relative difference than a small deviation from a larger value).

3.3.3 Internal validity

According to both Pearson's R and Kendall's tau test, the internal validity of all models (all respondents) was good. Correlation was 0.9 or higher, with a significance of 0.01 or better. The fit of the estimated model for the three holdout profiles was not as good. Although correlation was above 0.8 for all respondents, approximately half of the cases showed significance values larger than 0.1, indicating a poor fit of the model.

Table 3.4
Mean relative importance of risk factors (%). Consistent cases (fit at p = 0.05) compared with inconsistent cases (inconsistent means in brackets).

	Diseases					
Risk factors	ASF	CSF	FMD	SVD	NCD	AI
Import of livestock	39 (39)	37 (28)	31 (30)	34 (34)	42 (39)	37 (39)
Import livestock products	22 (13)	24 (24)	23 (14)	16 (16)	21 (13)	20 (13)
Swill feeding	13 (22)	12 (18)	11 (20)	18 (17)	8 (6)	9 (6)
Tourists	12 (15)	18 (11)	15 (15)	18 (16)	13 (8)	13 (6)
Returning trucks	8 (6)	5 (11)	7 (9)	10 (9)	9 (18)	8 (7)
Air	6 (6)	4 (8)	14 (13)	4 (7)	7 (15)	13 (29)

Table 3.4 presents the comparison of the two groups of respondents, based on fit (significance less than or equal to 0.1 versus larger than 0.1 respectively). The differences between the two groups changes between variables, e.g. the combination of 'import of livestock' and ASF shows no difference between cases with and without sufficient fit, where the combination of 'air' and AI shows a difference of more than 100%. However, the number of cases in each group is low, as is the number of holdout profiles (i.e. 3). Thus, for the remaining analysis no difference was made between cases with or without adequate fit. The discussion considers this point in more detail.

3.3.4 Knowledge level

Table 3.5 shows the knowledge levels per disease, as indicated by the respondents.

Table 3.5
Knowledge level of the respondents, per disease.

	Diseases					
Knowledge level	ASF	CSF	FMD	SVD	NCD	AI
High	2	3	5	1	2	1
Good	5	5	7	2	8	2
Medium	7	4	7	11	4	6
Low	4	6	2	3	2	4
Very low	3	3	1	4	6	9
Missing	1	1	--	1	--	--
Total	22	22	22	22	22	22

According to this table, the respondents rated themselves to be most knowledgeable on FMD. Only a few respondents thought themselves to be knowledgeable on SVD and AI.

To get more insight into the impact of these levels, weights can be used to examine the results. The level of knowledge ranged from 1 (low level) to 5 (high). Weighting for level of knowledge means, in this case, that a result from a respondent with a level of 5 counts 5 times as much as that from one with a level of knowledge of 1. Table 3.6 shows the results. To make comparison easier, the unweighed values are also shown in this table. The difference between weighted and unweighed results varied from 0% (for example the combination ASF and risk factor 'import of livestock') to 3% (combination NCD and risk factor 'returning trucks'). Most differences were equal to 0 or 1%.

Table 3.6
Weighted relative mean importance (%) for each risk factor. Unweighed importance percentages in brackets.

	Diseases					
Risk factors	ASF	CSF	FMD	SVD	NCD	AI
Import of livestock	39 (39)	33 (31)	31 (30)	36 (34)	40 (39)	33 (38)
Import livestock products	17 (18)	24 (24)	17 (17)	16 (16)	14 (16)	19 (18)
Swill feeding	17 (17)	16 (16)	17 (16)	17 (17)	7 (11)	8 (8)
Tourists	12 (13)	13 (14)	14 (15)	17 (17)	13 (11)	14 (11)
Returning trucks	8 (7)	9 (9)	9 (8)	9 (10)	18 (15)	8 (8)
Air	6 (6)	5 (6)	12 (13)	5 (5)	9 (11)	18 (18)

3.3.5 Conjoint versus direct questioning

Table 3.7 presents the results of the Conjoint Analysis compared with the results of the method of direct questioning. Spearman's correlation test showed that for all diseases, except FMD, there were no significant differences in ranking between both methods ($p = 0.05$). On first sight, the direct method seemed to yield more extreme results. To analyze this assumption, Wilcoxon's matched-pairs signed-ranks test was used to compare the results with the highest rank and the results with the lowest rank between both methods.

The test showed that the direct method gave higher values for the highest rank and lower values for the lowest rank, compared to the conjoint method. Because all values add up to 100, this means that the direct method gave more extreme results, i.e. the risk factors with the strongest impact (e.g. 'import of livestock') received higher values when using the direct method, while risk factors with a low impact (e.g. 'returning trucks') received lower values when using this method.

Table 3.7
Estimated relative importance of each risk factor (%), comparison of direct asking with conjoint results (conjoint results in brackets).

	Diseases					
Risk factors	ASF	CSF	FMD	SVD	NCD	AI
Import of livestock	42 (39)	38 (31)	36 (30)	42 (34)	42 (39)	46 (38)
Import livestock products	20 (18)	21 (24)	22 (17)	21 (16)	19 (16)	19 (18)
Swill feeding	13 (17)	15 (16)	6 (16)	13 (17)	2 (7)	2 (8)
Tourists	19 (13)	18 (14)	16 (15)	14 (17)	9 (11)	7 (11)
Returning trucks	6 (7)	5 (9)	10 (8)	7 (10)	7 (15)	9 (8)
Air	2 (6)	2 (6)	10 (13)	3 (5)	14 (11)	18 (18)

3.4 DISCUSSION AND CONCLUSION

3.4.1 Risk factors

In this study, an arbitrary number of six risk factors was used to describe the possible methods of introduction of virus into a country. Although the respondents were given an explanation of the risk factors, it is possible that the definitions were not clear and/or the risk factors not suitable for all diseases under study. For example, the risk factor 'air' was defined as the possibility for virus to travel by particles, driven by air current. But for the avian diseases (NCD and AI), wild birds could have been included in this risk factor as well. More research will probably produce different sets of risk factors for different diseases.

Risk factors, as used in this experiment, were only thought to be present or not present (two levels) which is a strong simplification of reality (how many tourists are entering when the risk factor 'tourists' is present?). However, more levels would make the questionnaire more complicated (more profiles to be considered). More research is needed to find the optimal balance between accuracy (realism) and the maximum complexity that can be evaluated by respondents, regarding the resulting profiles.

3.4.2 Response

Because all questionnaires were handed out personally (at the 7th ISVEE), a high response was expected. However, the respondents were not selected on the basis of their knowledge about the six diseases under consideration. It is therefore possible that questionnaires have been handed out to people who did not consider themselves experts on either one or more of the six diseases, and therefore could not, or felt they could not, complete the questionnaire. Furthermore, the questionnaire was complex and time consuming to fill out, which will have reduced the return rate. However, the results of the cross-validation presented in Table 3.3 suggest that the Conjoint Analysis results are not very sensitive to the number of respondents.

3.4.3 Internal validity

The internal validity of the regression model was adequate. Strong correlations together with a small p-value for statistical significance suggest that a simple additive model can be used to adequately explain the scores of the respondents for the first eight profiles. The cross-validation, by using the holdouts, showed that the predictive ability of the model was not satisfactory. However, Kendall's tau is a test based on ranks and with only three values to rank (the holdouts), a small difference in value can change the ranking considerably. In studies concerning consumer behaviour, the predictive ability of the model is often measured by calculating the percentage of cases in which the most preferred profile of the holdouts was predicted correctly by the model (Hair et al., 1990). In the case of risk factors concerning contagious diseases, however, all profiles are important. Although using real stimuli is the best test on predictive ability, it is impossible to carry out, but testing may be improved by using criteria other than those used in this study (values instead of ranks) and more holdout profiles.

The lack of fit of the model for the holdout profiles could also indicate an inconsistent answering on behalf of the respondent. This inconsistency could be caused by inability of particular respondents to analyze 11 profiles for each disease, due to a lack of knowledge (concerning the diseases or risk factors under study) and/or a lack of overview. However, the number of three holdouts is probably too small in order to draw sound conclusions. In a more extended research project it would also be advisable to test, the reliability of the respondent's input judgments. This can be done by asking the respondents to score a second set of profiles after they have completed some intervening tasks. This second set should contain a subset of the original set of profiles. The repeated two evaluations can be used in determining the test-retest reliability of the input preference judgments (Green and Srinivasan, 1978).

3.4.4 Knowledge level

To obtain the best estimates for the risk factors with Conjoint Analysis, it is not necessary to have a large group of respondents. A small group of 'real' experts is sufficient. It is difficult, however, to determine whether someone is a real expert or not. It may be necessary to determine the actual level of knowledge of the respondent. In this study, respondents were asked to judge their own level. Table 3.5 shows that the level of knowledge did not lead to considerable differences in results. However, 'real' level of knowledge is difficult to determine. When respondents are asked to estimate their own level, the results are, by definition, subjective. Some people may be much more modest in their estimation than others and 'pseudo-experts' might overestimate their abilities. According to Oskamp (1982), a good index of the expertise of a judge may be the relationship between his/her level of confidence and his/her level of accuracy. Van Lenthe (1993) proposes a method which combines confidence and accuracy (using scoring rules) that can help to avoid over- and underconfidence. His method may be a useful element of a more extended research project concerning identification and quantification of risk factors.

3.4.5 Conjoint versus direct questioning

Table 3.7 shows that the results of the Conjoint Analysis are less extreme than those of the direct questioning. To determine which method best reflects the opinion of the respondents, both techniques could be compared by using validation against external data. This technique is better applied if a larger sample of holdouts is available. Showing the results to a panel of experts and discussing them (without informing the panel from which method the results originate) may also provide more insight into this matter. The results of the conjoint technique as performed in this study were in agreement with the general opinion about the risk factors involved.

3.5 FINAL REMARKS

To sum up, the 'Gold standard' for the true importance of the six risk factors under consideration is impossible to obtain. We concluded, however, that the technique of

Conjoint Analysis shows promise in eliciting the opinion from experts about the relative importance of risk factors concerning contagious animal diseases.

The questionnaire experiment described in this paper is part of a project that should lead to a modelling approach which integrates risk and economic consequences of outbreaks, commencing after an outbreak occurs in a 'foreign' country and following the spread and consequences of the disease through all the various levels of the production chain, given a certain set of control measures. Part of the input to the model will be provided by a panel of experts.

The study described here provides a basis for further, similar but more extensive research. This research will focus on the opinion of Dutch experts about the risk to the Netherlands. However, the methodology of Conjoint Analysis can be applied to other countries/regions as well. We caution that much attention should be given to the selection of experts, the design of the conjoint questions, and the interpretation of the results.

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Chapter 4

CONJOINT ANALYSIS AS A METHOD TO ELICIT EXPERT OPINION: AN APPLICATION WITH RESPECT TO CONTAGIOUS ANIMAL DISEASES[1]

ABSTRACT

An effective animal disease prevention and eradication program is of major importance for meat-exporting countries because outbreaks of contagious diseases will often result in trade bans. However, historical and experimental information to base these programs on is scarce. Additional information might be obtained by consulting experts. This paper presents a method that enables an objective quantification of expert knowledge. The method, Conjoint Analysis, is a questionnaire technique that enables the quantification of the relative importance of the attributes of a product or event in relation to the overall assessment to that particular product or event. The method has already proven worthwhile in the field of consumer research. The results suggest that the method also provides a useful tool for the livestock economist.

4.1 INTRODUCTION

For many countries, export of livestock and animal products constitutes a major source of income for their livestock industry. Consequently, export bans caused by outbreaks of contagious animal diseases can have disastrous financial consequences. In the European Union, outbreaks of diseases such as Foot-and-Mouth disease (FMD) and Classical Swine Fever (CSF) are eradicated according EU-regulations, often including such trade bans. The recent major outbreaks of CSF in Belgium (1993-'94), Germany (1993-'94) and the Netherlands (1997) showed that outbreaks still present a serious danger. Therefore, adequate disease prevention and eradication programs are of major importance for both government and agribusiness industry in meat-exporting countries. Simulation models showing the impact of various factors on the likelihood of the introduction of an animal disease virus can play a key role in disease prevention and eradication programs (among others, Roe and Cannon, 1997).

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1 paper by Horst, H.S., Steenkamp, J.B.E.M., Huirne, R.B.M. and Dijkhuizen, A.A. submitted for publication to *Agricultural Economics.*

The objective of such simulation models is to support decision making on prevention programs, i.e., provide information on the efficacy of alternative prevention measures in terms of reduction of risk and losses, and in that way enable the performance of cost-benefit analyses. This article focuses on one of the major input parameters of such a virus introduction simulation model, namely the so-called 'risk factors'. Risk factors are defined in this study as the physical vehicles responsible for virus transfer, i.e., the ways in which the disease can spread from one country to another. Examples of risk factors are animal trade, animal trucks, and import of animal products. Obviously, no virus introduction simulation model can be developed without paying attention to these factors.

For a particular contagious animal disease, the key risk factors are often well-known. However, what is typically less well-known is the *relative importance* of these factors in the introduction of the disease into a country. For instance, it is said that import of livestock contains more risk than import of animal products, but this has seldomly been quantified. To use the risk factors in simulation models to assist policy making, a quantitative assessment of the influence of these risk factors is required. One source of data for estimating the relative importance of the risk factors is *time series*. However, outbreaks occur irregularly in time, place and magnitude (e.g., MLNV, 1983-1995), making it very difficult to base general properties and predictions for the relative importance of risk factors on these data. Furthermore, because of changing circumstances (changing vaccination policies, changing trade patterns due to e.g. opening up of Eastern Europe), the value of these historical data in predicting future events may be questionable.

Another option is the use of *expert judgements* concerning the importance of the risk factors. The use of expert judgements has a prominent place in management science (Little, 1970, 1975; Gatignon, 1993). Expert judgements have been used successfully in many management decision applications (see e.g., Larreche and Montgomery, 1977; Lodish, 1981, and Rangaswamy et al., 1990). Especially in forecasting future events or integrating and interpreting existing data, expert knowledge may play an important role (Meyer and Booker, 1991).

A variety of methods for eliciting expert judgements are available (among others, Meyer and Booker, 1991; Seaver, 1978; Von Winterfeldt and Edwards, 1988 for overviews). One technique which holds special promise is Conjoint Analysis. Conjoint Analysis is a general data collection and analysis procedure to quantify the impact of a number of factors on the overall assessment of an event or object simultaneously. It is well known and widely used in marketing research, to estimate the impact of selected product characteristics on consumer preferences for products (Cattin and Wittink, 1982). However, the method could be useful in all cases were one needs to elicit (in a quantitative manner) subjective knowledge on an (uncertain) event and is able to determine underlying characteristics.

The aim of the present study is to evaluate the method of Conjoint Analysis on its usefulness (criteria: validity, consistency and respondent evaluation) for the translation of expert knowledge on specific aspects of disease introduction into quantitative information for modelling purposes. The substantive topic was the introduction of the Classical Swine Fever (CSF) into the Netherlands.

4.2 CONJOINT ANALYSIS

Conjoint Analysis is a technique that enables the quantification of the relative importance of the attributes of a product or event in relation to the overall assessment of a respondent with respect to that particular product or event. The method was developed in the 1960s and is rooted in mathematical psychology (Krantz, 1964; Luce and Tukey, 1964; Krantz and Tversky, 1971). Basic assumptions of Conjoint Analysis are (Steenkamp, 1987): (1) a product or event can be described according to levels of a set of attributes, and (2) a person's overall judgment with respect to that product or event is based on these attributes.

Conjoint Analysis is a so-called 'decompositional' method. Respondents are asked to rank or rate combinations of attributes. Such combinations are called 'profiles'. Afterwards, regression analysis is used to decompose the scores given by the respondents to these profiles and estimate the importance of the attributes, i.e., 'break down' the total score into components belonging to the separate attributes. The importance of each attribute is based on its 'part-worth scores'.

Conjoint Analysis, as a decompositional method, provides a realistic situation to the respondent because attributes are evaluated in combinations (as is the case in the 'real world'). A further advantage is that the technique can be organized such that it provides information on the consistency of the answers given by the respondents. Nevertheless, it may look like a rather complicated and indirect method to reveal systematic components that underlie people's evaluations of objects. It is also possible to use a compositional method, such as direct questioning. Compositional methods ask respondents to assess values for attributes, and use these values to construct overall judgments for attribute bundles or profiles (Huber, 1974). Compositional methods, also referred to as self-explicated methods, have speed and simplicity as main advantages. However, there are also some problems, the major one being lack of realism. People have difficulty in assessing attribute importances directly, i.e., it is difficult for respondents to provide a non-biased score for one particular attribute, all else being equal (Green and Srinivasan, 1990). In a pilot experiment on the application of Conjoint Analysis in the animal health area, significant differences were observed between the results obtained by the more 'traditional' method of direct questioning and those obtained by Conjoint Analysis (Horst et al., 1996). Although these researchers were not able to determine which method reflected best the opinion of the respondents, because no external data for validation were available, there is considerable evidence from other authors that statistically derived importances represent people's actual weights more accurately than their self-stated weights (Fishbein and Ajzen, 1975; Slovic and Lichtenstein, 1971; Green et al., 1983; Huber et al., 1993). Serious biases may result from direct questioning on the importance of socially sensitive factors (Green and Srinivasan, 1990). Besides, according to Davis and Olson (1985) and Hardaker et al. (1997) a lack of understanding statistical data can considerably bias direct questions on probabilities. In these cases a more indirect approach such as Conjoint Analysis is preferable (Slovic and Lichtenstein 1971).

The most popular way of performing Conjoint Analysis is called 'full profile' (FP). When using the FP method, respondents are asked to rank or rate a number of profiles, where a profile stands for a specific combination of all attributes under consideration (full profile). A typical application of the technique has been reported by Steenkamp (1987) and concerns quality evaluations with respect to ham. In his study, important attributes when evaluating the quality of ham were considered to be: brand name, packing, store and price. These attributes had several levels, for example, the attribute 'packing' had levels such as 'vacuum-packed' and 'unpacked'. Potential buyers were shown a number of small cards, each presenting a different kind of ham. On those cards, the ham was described as a combination of attributes (brand name, packing, etc.): a profile. The respondents were asked to rank each card. Regression technique (OLS) was used to derive the part-worth scores for all attributes. The model used in this study was a simple additive one. It is also possible to include interactions between attributes. However, research has shown that interactive and multiplicative models seldom have a significantly better fit to data than the additive model (e.g., Emery and Barron, 1979; Holbrook and Moore, 1981; Levin,1985). Besides, including interactions means that more profiles have to be evaluated which could lead to fatigue-bias by the respondents.

The most accurate part-worth scores are obtained when all possible profiles (a complete factorial design) are evaluated. However, in most cases this would be impractical (for instance, when using 7 attributes, each at two levels, a complete design would mean that respondents should evaluate a number of 2^7 or 128 profiles!). The number of profiles can be reduced, with only minimal loss of accuracy, by using a fractional factorial design. Addelman (1962, 1963) designed a number of 'basic plans' for the construction of profiles.

His schemes can be used for additive models ('main effect design') as well as for models that include interactions ('compromise design').

In this paper, the conjoint technique was used to study the relative importance of various risk factors in introducing a contagious animal disease in another country. A pilot experiment on this topic was conducted during the 7th International Symposium on Veterinary Epidemiology and Economics in Kenya, August 1994 and showed promising results (Horst et al., 1996). The results and experiences of this Kenya experiment have led to and framed the use of Conjoint Analysis in the current experiment.

4.3 EXPERIMENT

4.3.1 Overview

The study included the following six highly contagious animal diseases: Foot-and-Mouth disease (FMD), Classical Swine Fever (CSF), African Swine Fever (ASF), Swine Vesicular Disease (SVD), Newcastle Disease (ND), and Avian Influenza (AI). These diseases are the ones most feared by the Dutch livestock sector and outbreaks of any of them may cause major export bans. FMD affects swine and cattle; SVD, ASF and CSF affect swine only; ND and AI are contagious poultry diseases.

The experiment was structured in the form of a workshop during which the participants were asked to individually complete a computerized conjoint questionnaire. The program was designed to be self-explanatory in order to minimize the interaction of the participants with either each other or the workshop facilitators.

All 50 people in the Netherlands considered to be expert in one of the six diseases under study were invited to join. Experts were defined as people who have a working experience with the diseases under concern and the disease prevention and eradication programmes in the Netherlands. Invited were people with a leading position in policy or research (epidemiology) as well as field veterinarians who where involved in the eradication of outbreaks of one of the diseases under study. The total sample consisted of 43 people or a response rate of 86%. Participants were given the opportunity to choose the disease about which they felt themselves most knowledgeable. Questions were only asked for that particular disease and concerned the introduction of virus into the Netherlands, the efficacy of the eradication system of the Netherlands and other European countries, and future expectations concerning outbreaks in the Netherlands and other countries. An extensive overview of the complete workshop outline and the results obtained has been given by

Horst et al. (1997a). The current paper focuses on the Conjoint Analysis part of the workshop only, and within that only on the introduction of Classical Swine Fever virus. The case of CSF will be used to examine in detail the usefulness of Conjoint Analysis as a method to elicit and quantify expert judgments in situations where suitable experimental or econometric data are not available. Nineteen experts performed the conjoint task for CSF.

4.3.2 Questionnaire

Introduction of virus from any country into the Netherlands is caused by the so-called 'risk factors', which might be seen as the physical vehichles for the disease. Literature search and in-depth interviews with experts were used to produce a list of the major independent risk factors for each of the diseases. For CSF the following risk factors were included:

- import of livestock
- import of animal products
- feeding of import swill (organic waste material, from airports and harbours)
- tourists
- empty livestock trucks returning from abroad
- wildlife
- air currents (airborne transmission)

The Netherlands interacts with almost all European countries. Thus, in principle all countries could be responsible for transfer of CSF-virus to the Netherlands (in case an outbreak occurs in one of these countries). To incorporate country differences while keeping the whole exercise of controllable size, the countries were grouped into the following five clusters (based on geographical and trade arguments):

cluster 1: Belgium, Germany, Luxembourg
cluster 2: Greece, Italy, Portugal, Spain
cluster 3: Austria, France, Switzerland
cluster 4: Eastern Europe
cluster 5: Great Britain, Ireland, Scandinavia

The results presented in this paper focus on cluster 1 (countries surrounding the Netherlands) only. The findings for the other clusters were quite similar.

As explained in section 4.2, Conjoint Analysis enables the quantification of attributes which together determine the opinion of the participant concerning a certain product or event. In this experiment, the introduction of virus into the Netherlands (originating from the cluster under concern) was seen as the 'event', the risk factors were the 'attributes'. Each risk factor could be either present (with a magnitude as in the current -real life-

situation, this to the judgment of the participants) or not present. The Conjoint Analysis technique was used to derive the relative importance of each of these factors.
Using the Addelman schemes for main effect models, the FP approach resulted in eight profiles. Three randomly chosen profiles were added as 'holdouts', which were used to check the fit of the model (regression coefficients were based on the first eight profiles only (Huber et al., 1993). These holdouts were also used to gauge the respondent's consistency in answering the questions. The participants were presented with the profiles on their computer screen (one profile at a time, as illustrated in Figure 4.1) and asked to give a score (ranging from 0 to 100, more points indicate a more risky situation) for the riskiness of each profile.

Imagine the following situation. How risky do you think this combination of risk factors is in relation to a possible introduction of CSF-virus from cluster 1 into the Netherlands?
Give a score between 0 and 100, a higher score means a more risky situation.

- Import of livestock is **present**
- Import of animal products is **not present**
- Feeding of import swill is **present**
- Tourists is **present**
- Returning livestock trucks is **not present**
- Wildlife is **not present**
- Air currents is **not present**

Figure 4.1
Question of the FP-Conjoint Analysis survey.

4.3.3 Analytical procedure

The riskiness scores were evaluated with the following model:

$$\text{(1)} \qquad \text{riskiness score} = \beta_0 + \beta_1 * x_1 + ... + \beta_7 * x_7$$

In this simple additive model, **riskiness score** is the score given by the respondent, β_0 is the intercept (a constant), the $\beta_{1\text{-}7}$ are the estimated coefficients (part-worth scores) associated with the risk factors (the attributes), and the $\mathbf{x}_{1\text{-}7}$ are the risk factor levels (with values 1 = present and 0 = not present). Interactions were not taken into account as the risk factors were assumed to be independent. Besides, also when interaction can be expected to occur, the additive model typically shows a high robustness (Emery and Barron, 1979;

Steenkamp, 1987).

The relative importance of each risk factor is estimated as its coefficient divided by the total sum of coefficients (thus, all relative importances together add up to 100), according to the following formula:

$$(2) \qquad RI = \frac{\beta_i}{\sum_{i=1}^{7} \beta_i} * 100\%$$

These parameter estimates constitute the basic 'output' of the conjoint approach to the quantification of expert opinions. Several aspects of these results were assessed including face validity, consistency and predictive validity. Moreover, the experts' evaluation of the conjoint method as such to elicit their opinions was measured.

The goodness of fit of the model was measured by the correlation between estimated and actual riskiness scores for the holdout profiles (Green and Srinivasan, 1978). Validation of the Conjoint Analysis technique was based on its predictive performance. Therefore, a 'choice task' was incorporated into the questionnaire. Participants were presented with a triplet of situations and asked to indicate the situation they thought to be the most risky. They were also asked to indicate the least risky situation. A situation was presented as a combination of selected attributes (only three or four, other factors were considered 'not present'). Figure 4.2 shows an example. Based on this choice task, individual 'hitrates' could be calculated (Huber et al., 1993). The hitrate presents the percentage of times the conjoint method correctly predicts each individual's actual choice. A higher hitrate indicates a higher predictive performance.

SITUATION 1	SITUATION 2	SITUATION 3
import of livestock	tourists	returning livestock trucks
feeding of import swill	returning livestock trucks	import animal products
tourists	import of livestock	feeding import swill

WHICH IS THE MOST RISKY SITUATION? 1
WHICH IS THE LEAST RISKY SITUATION? ---

Figure 4.2
Choice task.

Another measure for the predictive performance is the 'share of first choice', based on the conjoint model (Huber et al., 1993). This measure indicates the percentage of respondents that chooses a certain situation as the most risky one. To obtain better insight into how accurately the conjoint method estimates respondent's choices, the absolute difference between the percentage first choice as estimated by Conjoint Analysis and as given by the respondents is calculated, for each situation presented in the choice task. The summation of the results is then divided by the number of situations presented to the respondent in the choice task. The resulting number equals the so-called 'mean absolute error' (Huber et al., 1993) and can be described by the following formula:

(3)
$$MAE = \frac{\sum_{i=1}^{3} (|est_i - resp_i|)}{3}$$

where:

MAE	=	Mean Absolute Error
est_i	=	result as estimated by the conjoint model, for respondent i
$resp_i$	=	result given by the respondent i

This aggregate measure indicates the absolute difference between the estimated and the actual share of each situation, for the choice task as a whole, and can vary between 0 (estimated and values given are exactly the same) and 67 (no resemblance between estimated and values given, this maximum varies with the number of task situations presented).

The measures described above are based on the individual part-worth estimates. The ability to calculate part-worth scores at individual level is generally thought to be an advantage of the Conjoint Analysis approach, because this enables the researcher to distinguish among experts when combining the results into an overall assessment (using different weights). However, regression analysis at individual level implies that only a very limited number of degrees of freedom is available which limits the reliability of the results (in this study estimates of 7 attributes based on the scores for 8 profiles).

Grouping the respondents would improve the quality of the estimates. Cluster analysis (Hair et al., 1995) was applied to the riskiness scores to identify whether there were clearly differing points of view among the experts or whether the experts' part-worth functions could be considered homogenous. Cluster analysis is frequently applied in conjoint studies for this purpose (e.g., Steenkamp, 1987).

Ward's method with Euclidean distances was used as clustering method, as it is the generally recommended approach (Hair et al., 1995). No outliers were identified and all respondents could clearly be referred to as one group. This indicates that the expert opinions were sufficiently homogeneous to combine the data and estimate aggregate part-worth estimates[2].

4.4 RESULTS

4.4.1 Risk factors: results of the group-level regression analysis

Table 4.1 presents the major results of the multiple regression analysis concerning CSF, cluster 1 ($F_{8,144} = 63.6$, $p < 0.001$). Because all factors were evaluated at two levels ('present' or 'not present'), the regression coefficient presented in Table 4.1 equals the part-worth score of the respective risk factor for the level 'present'.

Table 4.1
Multiple regression CSF.

Variable	Regr. coeff.	T-value	Sign. T	Rel. Importance
Import livestock	47.9	19.8	0.000	59.5%
Import animal products	5.3	2.2	0.030	6.6%
Swill	12.3	5.1	0.000	15.3%
Tourists	-0.3	-0.1	0.901	not sign.
Livestock trucks	11.1	4.6	0.000	13.8%
Wildlife	4.0	1.6	0.105	4.9%
Air currents	-0.4	-0.2	0.867	not sign.
Constant (intercept)	14.7	4.3	0.000	
R^2	0.74			

According to their significance levels displayed in Table 4.1, risk factors 'tourists' and 'air currents' are not significant. 'Import of livestock' is evaluated by the respondents as the most important factor (highest part-worth score), followed by 'swill' and 'returning livestock trucks'. The significant value for the intercept indicates that, according to the respondents, there is also a certain risk when none of the evaluated risk factors are present. Table 4.1 also shows the relative importance of the risk factors, calculated using equation 2 (without including the insignificant factors 'tourists' and 'air currents'). In the opinion of

2 Principal component analysis on the correlations between the scores resulted in the same conclusion. The first factor explained 80% of the variance, and all experts loaded highly on this factor. This also indicates homogeneity of expert opinions and supports combining the data (Hair et al., 1995).

the respondents there is, in case of an outbreak in one of the countries surrounding the Netherlands resulting in virus introduction into the Netherlands, a probability of 59.5% that the risk factor 'import of livestock' is responsible for this introduction. Put differently, when aiming at reducing the risk of virus introduction from these countries, measures aimed at reducing risks connected with the import of livestock could be a sensible first option.

4.4.2 Predictive validity

Correlation tests were performed using both the holdouts and the choice task, to check the validity of the aggregate conjoint model. The results as estimated by the regression model were compared with the results as given by the respondents, for both the holdouts and the choice task. The Spearman correlation coefficient obtained for the holdouts was 0.71 ($p < 0.005$). The individual hitrate was 83.8%, indicating that in more than 80% of the cases the respondent's choice in the choice task was correctly predicted by the FP model. Table 4.2 illustrates the 'share of first choice' for Classical Swine Fever, cluster 1 (countries surrounding the Netherlands).

Table 4.2
Share of first choice, CSF (situations refer to the choice task outlined in Figure 2 and concern the cluster of countries surrounding the Netherlands).

	FP model	Choice task
Situation 1	0.0	16.7
Situation 2	0.0	0.0
Situation 3	100.0	83.3
Total	100.0	100.0

Situation 3 (see Table 4.2) was evaluated as the most risky situation, selected by 83.3% of the participants. Also according to the FP-model situation 3 is the most risky one and because the aggregate model was used (thus, the same model for all respondents) the value equals 100%.

The mean absolute error measure provides more insight into how closely the Conjoint Analysis estimates resemble the values based on the answers as given by the respondents, as described in section 3.3. Using equation 3, this measure is calculated as follows (see also table 2):

$$(|16.7 - 0.0| + |0.0 - 0.0| + |83.3 - 100.0|)/3 = 11.1$$

4.5 DISCUSSION

4.5.1 Participants

The high response rate (86%) indicated the strong motivation of the participants to help clarify certain aspects concerning the introduction of virus into the Netherlands. Given the relevance of the subject for the Dutch livestock industry, this was not a surprise. It was, however, unclear beforehand whether the Conjoint Analysis technique would be able to keep this motivation at a high level. Therefore, a small evaluation survey was included in the workshop, which the respondents completed just after they finished their conjoint task. The respondents were asked to indicate their opinion about the Conjoint Analysis task, by giving a score between 1 and 7 for sets of descriptions. A score of 1 indicated a total agreement with the description on the left, a score of 7 indicates a total agreement with the description on the right. Table 4.3 shows that the average scores were not very extreme and on the positive side of the scale for all sets of descriptions. In general, the respondents perceived the task as being realistic, rather easy to understand and not too lengthy.

Table 4.3
Evaluation results (scores between 1 and 7).

Description		Average score
Realistic	1 -----------**X**-------- 4 --------------------- 7	Not realistic
Not lengthy	1 --------**X**----------- 4 --------------------- 7	Lengthy
Easy to understand	1 ------**X**------------- 4 --------------------- 7	Not easy to understand
Not difficult	1 ---------------**X**--- 4 --------------------- 7	Difficult
Not boring	1 ----------**X**--------- 4 --------------------- 7	Boring
Interesting	1 ---------------**X**--- 4 --------------------- 7	Not interesting

High motivation may have positively influenced the consistency of the participants, indicated by the high correlation between estimated and actual scores for the holdout profiles. Inconsistency may occur when participants do not understand the task, are not motivated enough to evaluate all profiles seriously, or do not possess enough appropriate knowledge. These participants may be excluded from further evaluations. However, in the study reported in this paper, the cluster and factor analysis did not indicate the existence of outliers and therefore justified the decision not to exclude respondents.

The findings of the cluster analysis justified the use of aggregate part-worth estimates which increases the quality of the estimates. However, this need not always be the case. In a comparable Conjoint Analysis study recently conducted by some of the authors in

Switzerland, aggregating over the whole group of participants was found to be unjustified. In such a case, the results of the cluster analysis combined with information on, for example, the professional backgrounds of the respondents might be used to define subgroups. In the Swiss experiment, aggregating results of all participants with a professional background in research proved to be a good option. Follow-up group discussions with the participants may help to uncover the reasons underlying the differences in opinion, and attempts to increase the convergence in expert opinions should be made (cf. Little, 1975). Further, if the results are to be included into a simulation model, using the respective opinions as separate sets of input parameters and running the simulation model with each of them will provide insight into the consequences of the observed differences in view.

4.5.2 Validity

Holdout profiles are often used as a measure for the internal validity of the model, i.e., a test for the goodness of fit of the model (Green and Srinivasan, 1978). The results observed in this study indicate that the use of an additive model was appropriate[3]. This was not a surprising finding, as independence was one of the criteria on which the risk factors were selected. Moreover, Emery and Barron (1979) and Steenkamp (1987), among others, argue that the additive model is very robust and will be valid in most experiments.

Probably the best way to evaluate the predictive performance as a measure for the external validity of a Conjoint Analysis experiment, is to compare predictions with real stimuli. In absence of such stimuli, a choice task as used in this study provides a good alternative. Based on the choice task, two different measures for predictive performance were used, measuring different properties of the elicitation model. Traditionally, hitrates have been used in assessing the accuracy of preference elicitation techniques predicting choices. This measure depends primarily on the reliability of individual models. The choice share measure is an aggregated measure and provides more insight into the degree to which models provide unbiased predictions (Huber et al., 1993). The results obtained for both measures in this study are comparable to (or better than) those of studies aimed at eliciting consumer preferences (for example, Huber et al. 1993). The interpretation of measures such as the mean absolute error, based on the preference first choice, may be somewhat

3 As an extra check, regression analyses were performed including interactions among the most important risk factors, i.e., import of livestock, swill, returning trucks, and import of animal products. None of the included interaction terms significantly improved the goodness of fit of the model, which is in agreement with findings of, for instance, Holbrook and Moore (1981).

difficult. However, in this study the worst case scenario (no resemblance at all between model estimates and actual scores) would have resulted in a score of 67. The FP-model improved this score by approximately 85% (resulting in a score of 11.1) and therefore its performance was evaluated to be sufficient. This conclusion is supported by results based on the aggregated model (significant positive correlation between model and both holdouts and choice task).

Positive support was also provided by an evaluation meeting organized to discuss the results with the participants themselves where they evaluated the face-validity of the results. Moreover, and even more interestingly, according to the participants, the Conjoint Analysis questions forced them to think in a structured way which enhanced their insight into the issue. Besides, the meeting may have created more basis for possible implementation of expert opinion in simulation models concerning virus introduction which will enhance the implementation of such models in practice.

4.5.3 More attributes?

In this experiment 7 attributes (risk factors) were used, resulting in 11 profiles (including 3 holdouts). The results presented in Table 4.3 show that the task was not too difficult nor too lengthy. Green and Srinivasan (1990) argue that the full profile approach works well with about 6-7 attributes or less. When the number of attributes gets larger, the approach may cause information overload for the respondents and thus leads to less reliable estimates. An alternative approach in such situations might be the ACA approach. ACA stands for Adaptive Conjoint Analysis and is a PC-based system. The term 'adaptive' refers to the fact that the interview is interactive and questions are customized for each respondent. ACA is a combination of self-explicated and conjoint techniques and belongs to the group of 'hybrid conjoint models'. These models try to combine the speed and simplicity of the self-explicated approach with the realism and generality of the traditional Conjoint Analysis. Individual differences are retained while respondent evaluation time is reduced (Steenkamp et al., 1986). A detailed description of the background and estimation procedure of ACA is given in Johnson (1987 and 1993).

In the experiment described in this paper, the ACA approach was also applied. Without going into detail it was concluded that the ACA results were acceptable but, based on hitrates, full profile was preferable. However, when the number of attributes increases, ACA might outperform the full profile approach. Furthermore, ACA is available as an easy to use commercial software package, which might be important when research time is limited.

4.5.4 Use of the results

In this study, the importances of the risk factors related to virus introduction into the Netherlands were estimated. As indicated in the introduction section, the primary purpose of these estimates was to use them as key input parameters in a simulation model describing the introduction of virus into a country (in this case the Netherlands). The model, called VIRiS (Virus Introduction Risk Simulation model), is a Monte Carlo simulation model that provides insight into the number, location and cause of outbreaks of contagious animal diseases, such as CSF, in the country in question. Using the individual relative importances of the risk factors, the model is able to show the influence of one single risk factor on the total number of outbreaks, and their location, that can be expected to occur in that country. The results of the model are used to calculate the economic impact of alternative disease prevention strategies, i.e., the expected reduction in losses that will result from the various strategies (Horst et al., 1997b). An important feature of simulation models, such as VIRiS, is the ability to perform sensitivity analysis (Dijkhuizen and Morris, 1997). Sensitivity analysis allows the evaluation of the impact of uncertain input parameters, or different opinions, on the outcome (in case of VIRiS: ranking of strategies). The results of such an analysis may direct policy measures as well as additional research efforts.

4.6 CONCLUDING REMARKS

Expert knowledge is an informed opinion based on the expert's training and experience. Until historical data and/or experimental research are able to provide better data, quantitative expert knowledge will be valuable information to be used in modelling risks and economic consequences of the introduction of contagious animal diseases. As Rangaswamy (1993, p. 742) puts it: "Subjective estimation is the only option when empirical data are not available". Expert judgements often form a key component of simulation models to assist policy makers in their decision making, and research evidence shows that better decisions are reached with such models, which are partially based on subjective knowledge than using no models at all (e.g., McIntyre, 1982: Rangaswamy, 1993).

There are various methods that support the elicitation of subjective knowledge, none of them being perfect and none of them being able to change the subjective expert knowledge into objective data. However, a good elicitation method will provide the user with a good estimate of the experts' opinion. The choice for a certain method will depend on the problem at hand.

The results reported in this study show that for the quantitative elicitation of the relative importance of risk factors involved in introducing animal diseases, the Conjoint Analysis technique is a useful option. It seems justified to extend this conclusion to all situations where one is able to determine an (uncertain) event and its attributes and is interested in expert opinion on the relative importance of the latter. Therefore, it can be concluded that Conjoint Analysis constitutes a useful addition to the toolkit of agricultural economists. However, although the number of software packages to support Conjoint Analysis experiments is growing rapidly, the Conjoint Analysis method is still more complicated and time-consuming than the so-called self-explicated methods (e.g. direct questioning). In some cases the simplicity and speed of the self-explicated methods may outweigh the higher predictive performance of the Conjoint Analysis. Moreover, thus far the assumption that Conjoint Analysis has a higher predictive performance is based on experiments concerning consumer preferences. More research is needed to evaluate if this result also holds for the elicitation of expert knowledge.

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Chapter 5

INTRODUCTION OF CONTAGIOUS ANIMAL DISEASES INTO THE NETHERLANDS: ELICITATION OF EXPERT OPINIONS[1]

ABSTRACT

This paper describes an experiment aimed at the derivation of information on Foot- and-Mouth disease, Classical and African Swine Fever, Swine Vesicular Disease, Newcastle Disease and Avian Influenza to be used in an economic model to simulate introduction of a virus into the Netherlands. Several elicitation techniques, including three-point estimation, Conjoint Analysis and ELI were used in the experiment. Three-point estimation (asking for minimum, most likely, and maximum values) was used to derive information concerning the length of the High Risk Period (HRP), during which the virus may spread freely. Conjoint Analysis is widely used in marketing and consumer science and was used in this experiment to elicit the relative importance of risk factors which may introduce disease into the Netherlands (such as import of livestock, import of animal products, etc.). The ELI-technique (ELIcitation of uncertain knowledge) originates from the area of mathematical psychology and was used to derive information on the expected number of outbreaks of the diseases under consideration in European countries. The experiment was conducted with 43 (out of 50) invited people, all involved in or related to disease control in one way or another. The participants expected, for all diseases, the longest HRP in countries of eastern Europe. Import of livestock was evaluated as the most important risk factor for all diseases under consideration. Most outbreaks within the next five years were expected to occur in countries of eastern Europe, the smallest number in the Netherlands and the Scandinavian countries. Results especially showed that Conjoint Analysis and ELI are useful tools to help quantify subjective knowledge. These subjective elicitation methods may not reveal the 'Golden Standard' but as long as 'objective' predictive information is not available, use of these tools may be valuable to enhance quality of input and output of economic simulation models to support policy-making in the prevention and control of contagious animal diseases.

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1 paper by Horst, H.S., Dijkhuizen, A.A., Huirne, R.B.M. and De Leeuw, P.W. accepted for publication by *Livestock Production Science.*

5.1 INTRODUCTION

Outbreaks of contagious animal diseases may result in export bans and are therefore greatly feared in meat exporting countries. In the Netherlands, the export of meat is a major source of income for the livestock industry. In 1994, meat export had a value of more than US$ 4.5 billion (PVE, 1995). However, outbreaks do not affect only the export position, but also the internal market for meat and animals may be largely disturbed due to a temporary oversupply, resulting in a sharp fall in prices (Buijtels, 1997). Berentsen et al. (1992) estimated total losses from a (theoretical) outbreak of Foot-and-Mouth Disease (FMD) in the Netherlands, including prevention and eradication costs, at between US$60 million and US$7 billion, depending on the area of outbreak (livestock density in the affected region) and on the control strategy applied. The latter indicates that policy decisions on prevention and eradication have a significant impact on the extent of the losses.

Adequate disease prevention and eradication is of major interest to both government and private industry. To help maximize the efficacy of existing programs and evaluate in advance the consequences of possible alternatives, computer simulation is considered to be a valuable decision support tool. Such an approach provides more insight into the risk and economic consequences of virus introduction into a country (Dijkhuizen et al., 1995).

It would be ideal to base a simulation model on historical and experimental data. However, such information concerning introduction of a virus into the Netherlands (and other countries) is limited, if available at all. Since 1984, outbreaks of contagious animal diseases in EU-member states have been recorded and stored in the Animal Disease Notification System (ADNS). Table 1 is based on this database and gives an overview of the number of infected farms caused by six of the most important diseases, which are: Foot-and-Mouth Disease (FMD), Classical Swine Fever (CSF), African Swine Fever (ASF), Swine Vesicular Disease (SVD), Newcastle Disease (NCD) and Avian Influenza (AI). According to this table, ASF and CSF caused the largest number of infected farms in the past 14 years, within the EU. Most ASF-outbreaks were restricted to Spain and Portugal, whereas CSF was recorded throughout Europe. Within the Netherlands, CSF is the major disease, followed by NCD. The number of infected Dutch farms due to FMD and SVD is relatively small. So far, AI has never been recorded in the Netherlands; the nearest outbreak of this disease was recorded in Ireland in 1989.

Table 5.1 shows that outbreaks of these diseases occur irregularly over time and differ in magnitude, making it difficult to derive general properties and predictive values. Furthermore, the Netherlands ceased vaccination against CSF in 1986 and against FMD in 1991.

Table 5.1
Number of infected farms for different infectious animal diseases in Europe, 1984-1997 (ADNS)

Year	FMD	SVD	CSF	ASF	NCD	AI
1984	54	1	1261	45	29	1
1985	129	1	482	42	9	0
1986	151	0	185	961	5	0
1987	169	0	145	1463	15	0
1988	11	1	32	1334	45	0
1989	74	0	83	488	9	2
1990	0	0	252	413	11	0
1991	0	6	22	289	18	0
1992	0	38	39	178	83	1
1993	57	15	125	143	137	0
1994	95	31	191	104	242	1
1995	0	19	95	144	65	0
1996	39	5	55	65	30	0
1997*	0	3	48	2	15	0
Total	740	112	2912	5604	668	5

* by Feb 20 1997 (by Nov 11 1997, the Netherlands alone had already counted 422 CSF-infected farms)

In 1992, the European Union decided to cease preventive vaccination against all list A diseases, except against NCD (vaccination against NCD is still compulsory in the Netherlands and some other European countries). This will significantly influence the epidemiology and economics of future outbreaks and the effectiveness of prevention and eradication strategies as well. Moreover, the recent developments in the eastern part of Europe have resulted in an increasing number of countries becoming trading partners for countries of the European Union. Information on the animal health situation in these countries is (still) slender, making them an uncertain factor. Besides, the 'Iron Curtain' also constituted a physical barrier for (wild) animals that are now able to cross the border and carry viruses with them. Also, experimental data concerning the spread of a virus from country to country are sparsely available. Many researchers, including Terpstra (1987, CSF), Mann and Sellers (1989, FMD) and Becker (1987, ASF), have done work in this area, but most of their findings are only of a qualitative nature.

Despite this lack of information, decisions concerning eradication and prevention programs must be made. As an alternative, useful insights into what might be expected, and might be used as input for a model to support these decisions, can be obtained by quantifying the opinions and experiences of experts on these diseases. In this paper an investigation is reported in which 43 experts were involved. 'Experts' were defined as people who are (or could be) consulted in case of an actual outbreak.

Important aspects of the risks and consequences of a contagious disease outbreak in the Netherlands are (1) the mechanisms of introduction of the pathogen into the Netherlands (risk factors leading to a primary outbreak); (2) the expectations concerning the frequency of future outbreaks in the Netherlands and in European countries with which the Netherlands maintains some kind of relationship (e.g. trade, tourists); and (3) the efficacy of the eradication system in the Netherlands and in other European countries. Main goal of the study was to derive quantitative information regarding these three areas for use as input in the above-described economic simulation model and to gain insight into possible differences in opinion among experts from different backgrounds, including their consequences for the preferred strategy. To achieve this goal, an experiment was set up in which several elicitation methods were combined within a workshop design. Two of these techniques, 'Conjoint Analysis' and 'ELI' are new to the field of veterinary' epidemiology and economics. Therefore, besides the results, also the experiences with these methods will be reported and discussed, including their potential value for future elicitation experiments in these and related fields.

5.2 MATERIALS AND METHODS

5.2.1 Experimental design and participants

When working with human subjects as 'data sources', special attention should be paid to biasing aspects such as group behaviour and providing socially desirable answers. Besides, one has to deal with time constraints, complexity of the material, and motivation of the participants. Thus, a successful elicitation experiment needs a careful design which enables the whole task to be finished within reasonable time (strict time schedule, selection of information to be elicited), keep participants motivated (variety in tasks, clear explanation of the tasks, good atmosphere) and at the same time leading to results that are useful for the elicitors. Von Winterfeldt and Edwards (1988) argue that, because of group effects, one should not try too hard to get experts as a group together. According to these authors, elicitation of the desired uncertainty measures from each group member individually is a better alternative.

Because the number of potential experts per disease was thought to be small, the motivation issue played a major role in the final decision as to the set-up of the elicitation experiment described in this paper. It was assumed that a one-off group meeting, presented as a workshop, would be the most attractive. However, negative group effects (political and/or social causes) could be present in such a meeting. Therefore, the elicitation methods to be used should enable individual elicitation of knowledge.

Based on these reflections, the experiment was structured in the form of a full evening's workshop, containing several elicitation sessions (to cover all aspects). The sessions were computerized and self-explanatory to minimize the interaction of the participants with each other and with the workshop facilitators.

In total 50 people were invited to the workshop. This group included all people in the Netherlands thought to be knowledgeable about, or expert on, at least one of the six diseases under study. To evaluate the possible influence of the participants' backgrounds on the results (i.e. on their opinion), three groups were included: 'policy' (ministry of agriculture, animal health service), 'research' (university, research institutes), and 'field' (active during outbreaks). The participants were given the opportunity to choose the disease about which they thought themselves to be most knowledgeable. Questions were asked for this disease only.

In principle each individual country in Europe with which the Netherlands has relations could be responsible for transferring virus to the Netherlands (provided the occurrence of an outbreak). However, to keep the whole exercise at a manageable size, and yet incorporate country differences, countries were grouped into the following five clusters (based on geographical and trade arguments):

cluster 1: Neighbouring countries of the Netherlands (Belgium, Germany, Luxemburg)
cluster 2: Southern Europe (Greece, Italy, Portugal, Spain)
cluster 3: Central Europe (Austria, France, Switzerland)
cluster 4: Eastern Europe (countries of former Eastbloc)
cluster 5: "Islands" (Great Britain, Ireland, Scandinavia)

Some important results of the workshops were summarized and reported back, in writing, to the participants after the workshop. Besides group results, the participants were also presented with their personal results. They were asked to compare the group results with their own results and indicate if (and how) they would like to revise their own responses.

5.2.2 Questions and elicitation techniques

5.2.2.1 High Risk Period

The length of the High Risk Period (HRP) is one of the most important parameters that determine the magnitude of an outbreak because it defines the period in which the virus can spread freely. The period begins when the first animal is infected and ends when all eradication measures are in full operation, i.e. the region concerned does no longer involve any risk for other regions. (The latter means that the virus has been eradicated and/or sound export controls/bans have been established). The HRP can be divided into two periods:

HRP1: begins when the first animal is infected, and ends when an infected animal is detected, i.e. the period of undetected infection.

HRP2: begins with the first detection, and ends when all measures are considered effective, i.e. the period of institution of control measures.

The length of HRP1 depends on the alertness and motivation of farmers and veterinarians, the length of HRP2 on the efficacy of the animal health system of the country in which the outbreak occurs.

The participants were asked to give a three-point estimate for the expected length of both HRPs (minimum, most likely and maximum expected length), for all clusters and the Netherlands. This estimate was asked twice, for low- and high-virulent viruses respectively.

The Kolmogorov-Smirnov test (Lilliefors variation, samples with unknown mean and variation) was used to test the normality of the estimates. Although according to this test it was allowed to treat the results as being normally distributed ($p = 0.05$), it was decided to use the mid-point or median as measure for the central tendency. Because of the small number of participants, the Kolmogorov-Smirnov test will only reject the normality-assumption in very extreme cases (Hair et al., 1995).

5.2.2.2 Relative importance of risk factors

Introduction of virus from any country into the Netherlands (during the HRP) is associated with the so-called 'risk factors'. The literature (Liess, 1981; Becker, 1987; Mann and Sellers, 1989; Horst et al., 1995) and earlier interviews with experts (Horst et al., 1995) have produced a list of risk factors for each of the six diseases under study. The following factors were taken into account:

ASF, CSF, FMD, and SVD:	NCD and AI:
- import of livestock	- import of animals (excl. exotic birds)
- import of animal products	- import of animal products
- feeding of imported swill (airports, harbours)	- import of exotic birds
- tourists	- tourists
- returning livestock trucks	- transport material (crates)
- wildlife	- flying birds
- air currents (airborne transmission)	- air currents (airborne transmission)

The 'Conjoint Analysis' technique was used to obtain the relative importance of each of these risk factors. Conjoint Analysis has been developed by mathematical psychologists (Luce and Tukey, 1964; Krantz and Tversky, 1971). It is a questionnaire technique, well known and widely used in the field of marketing and consumer research, introduced by Green and Rao (1971). According to Fishbein (1963), a product or event can be evaluated as a composition of attributes or characteristics. The importance of each of these attributes is determined by the person who examines the object. For example when selecting a car, important attributes in deciding whether to buy it are: colour, price, make, maximum speed, size etc.

Conjoint Analysis is a so-called 'de-compositional method'. The technique starts with the respondents' overall judgments on a set of profiles (in the car-example, such a profile would represent a hypothetical car) and breaks these overall judgments down into the contribution of each attribute, by using ordinary least squares (OLS) regression analysis. The contributions are termed 'part-worth scores' and indicate the influence of each attribute on the respondent's preference for a particular profile (thus, in the car-example, the respondent's preference for a particular car).

At first sight, more 'direct' methods to reveal systematic components that underlie people's evaluations of objects may look less complicated. Such compositional or self-explicated methods ask respondents to assess values for attribute levels, and use these values to build up preferences for attribute bundles or profiles (Huber, 1974). However, many researchers have compared the predictive performance of Conjoint Analysis with self-explicated approaches and in most studies Conjoint Analysis outperforms the latter (Huber et al., 1993; Green et al., 1983). For a more detailed description of Conjoint Analysis, the reader is referred to Green and Srinivasan (1990), Krantz and Tversky (1971), and Luce and Tukey (1964). In general, Conjoint Analysis can be used in all cases where an object or event and its related attributes can be determined and where one's aim of study is the elicitation of the respondents' feelings towards these attributes. The method provides a handy tool to quantify subjective knowledge about attributes. A further advantage is that the technique provides information on the consistency of the answers given by the participants.

Conjoint Analysis is relatively new to the field of veterinary epidemiology and economics. A first paper-based experiment concerning risk factors for contagious diseases, conducted during the 7th International Symposium on Veterinary Epidemiology and Economics in Kenya, August 1994, showed promising results (Horst et al., 1996). The results and experiences of this Kenya experiment have led to the framework for the current (computerized) questionnaire.

The traditional way to approach participants with Conjoint Analysis is to present them with a number of cards, each containing a profile, and ask for scores or ranking. Instead of cards, the participants of the workshop analysed profiles on the computer screen. The computer presented one profile at a time, which consisted of a list of all risk factors described above with, for every factor, the remark 'present' or 'not present'. The participants were asked to imagine the situation presented on the screen as being the current situation valid for the Netherlands and to give a score between 0 and 100 reflecting the expected riskiness of each particular profile. With 7 attributes and 2 levels (present vs not present), a total of 2^7 or 128 profiles are theoretically possible, which is too large a number to deal with. The number of profiles can be reduced, with only a minimal loss of accuracy, by using a fractional factorial design. The basic plans of Addelman (1962) were used to construct the necessary orthogonal fractional design, which resulted in eight profiles. Three randomly chosen profiles were added as 'holdouts', which were used to check the fit of the model when analysing the results of the Conjoint Analysis (regression coefficients were based on the first eight profiles only). These holdouts were also used to gauge the respondent's consistency in answering the questions. Non-consistent respondents were excluded from further analysis.

The scores given by the respondents were evaluated with the following simple additive model (interactions were not taken into account):

$$\text{riskiness score} = \beta_0 + \beta_1 * x_1 + ... + \beta_7 * x_7$$

In this formula, **riskiness score** is the score given by the respondents, β_0 is the intercept (a constant), the $\beta_{1\text{-}7}$ are the estimated coefficients (part-worth scores) associated with the risk factors (the attributes), and the $\mathbf{x}_{1\text{-}7}$ are the risk factor levels (with values 1 = present and 0 = not present). Based on the regression coefficients, the relative importance of each risk factor was estimated (all factors together add up to 100%).

Regression analysis at individual respondent level implies, however, that only a very limited number of degrees of freedom is available, which makes the reliability of the results difficult to test. Grouping respondents would improve the quality of the estimates. Therefore, cluster analysis (Hair et al., 1995) was applied. If, according to this analysis, the respondents can be referred to as one group, combining the data and estimating aggregate part-worth estimates is the recommended approach (Steenkamp, 1987).

5.2.2.3 Expected number of primary outbreaks within the next five years

The participants were asked to estimate the number of primary outbreaks they expected to occur within the next five years. This question was asked for each of the five country clusters and for the Netherlands. Because it was expected that the participants would feel uncertain about this estimation, ELI, a technique which enables expression of uncertainty, was used. ELI (ELIcitation) is a graphically oriented computer program that facilitates the quantification of subjective knowledge about uncertain quantities. The program was developed by Van Lenthe (1993a; 1993b), and is aimed at helping respondents to produce unbiased Probability Density Functions (PDFs). PDFs are distributions that reflect the subjective beliefs of a human subject about an uncertain event. The modus (top) of the PDF reflects the best guess, the dispersion corresponds with the uncertainty about this best guess.

ELI uses a 'proper scoring system' (Morgan and Henrion, 1992) to reward assessors in order to motivate them to state their unbiased PDFs. In a training session with ELI, ie., when the actual answers or 'true values' are known, the scoring system makes it possible to inform the respondent about the quality of his/her answers. In an ELI training session, score feedback is given after each question and the assessors are stimulated to maximize their total scores. In this way, the scoring system could enhance the quality of PDFs and reduce over- and under-confidence bias (Staël von Holstein, 1970; Winkler, 1971).
Experiments by Van Lenthe (1993b) have shown that a training session with feedback also improves the results for new questions for which no feedback is given. These outcomes suggest that such a training could also improve estimates for questions to which no answers are known. For a more detailed description, the reader is referred to Van Lenthe (1993b).

During the workshops, the questions concerning the expected number of outbreaks were preceded by a training session (specific for each disease) with 10 questions the answers to which were known by the researchers. Feedback about the quality of the answers given by the participants was provided individually, by the computer program, after each question. The training questions were about quantitative facts, such as the number of farms involved in the latest outbreak of a particular disease, total losses due to a certain outbreak, incubation period, self-sufficiency level of the Netherlands for pork, volume of export of meat to certain countries, etc. The ELI-program provided probability distributions concerning the number of primary outbreaks.

These distributions were constrained to be normal. The Kolmogorov-Smirnov test (Lilliefors variation) was used to test whether the expected values of these distributions were normally distributed over respondents. Although according to this test it was allowed to treat all results as being normally distributed ($p = 0.05$), it was decided to use mid-points (or medians) as measure for the central tendency of the results (because of the small number of respondents, also referred to in Section 5.2.2.1).

Besides mid-points, also a distribution of the combined opinions was constructed, which will be illustrated in Section 3 for CSF. To achieve this, the following procedure was used: Out of the group of respondents answering questions on CSF, one person was randomly selected. Then, from the probability distribution for this person a random number was selected. This procedure was repeated 1000 times and resulted in a random sample of the mixed distribution[2].

5.3 RESULTS

5.3.1 Participants

The experiment was attended by a total of 43 out of 50 invited persons, which results in a response rate of 86%. Table 5.2 presents the participants by disease and background, and shows that there was an uneven distribution regarding the six diseases.

CSF was the most 'favourite' disease, followed by NCD. Only a small number of participants considered themselves knowledgeable about ASF, SVD and AI. Therefore, these results are not presented in this paper. The group 'field' was the largest group, including 20 participants; the group 'research' the smallest, represented by 10 participants.

[2] The calculations were done by using @Risk for Excel, Palisade

Table 5.2
Distribution of participants

	Background			
Disease	Policy	Research	Field	Total
Classical Swine Fever	6	3	10	19
Newcastle Disease	3	5	4	12
Foot-and-Mouth Disease	2	2	4	8
Swine Vesicular Disease	2	0	0	2
African Swine Fever	0	0	1	1
Avian Influenza	0	0	1	1
Total	13	10	20	43

5.3.2 High Risk Period

Table 5.3 presents the mid-points (or medians) and quartiles for HRP1 (period between first infection and first detection) concerning CSF, FMD and NCD. The results are given for all country clusters and for the Netherlands, for low-virulent virus. According to this table, all groups indicated that the countries of eastern and southern Europe have the longest HRP1. The results for these two clusters were also more skewed than those of the other clusters. The values for the Netherlands were much lower, and more or less equal to those of the "Islands" (ie., mid-point of 21 days). In general, the estimated HRP1s for FMD are much shorter than those for CSF. The HRP1-estimates for NCD are in between those of CSF and FMD. For all diseases the quartiles showed a substantial variation around the mid-point and a positively skewed distribution.

Table 5.3
HRP1 (days) for low-virulent virus, CSF, FMD and NCD, mid-points and quartiles

	CSF			FMD			NCD		
	25%	Mid	75%	25%	Mid	75%	25%	Mid	75%
Neighb. countries.	21	**28**	35	6	**7**	11	8	**14**	20
Southern Europe	30	**35**	60	8	**12**	19	11	**19**	28
Central Europe	21	**28**	35	6	**8**	10	11	**16**	20
Eastern Europe	30	**42**	60	11	**19**	29	14	**21**	60
"Islands"	21	**21**	30	5	**7**	9	9	**10**	15
Netherlands	20	**21**	30	3	**6**	8	10	**14**	20

The HRP2-results (period between first detection and moment that measures are effective; not presented here) show the same trend as those of HRP1. Main difference was that most estimates concerning CSF and FMD were lower for HRP2 than for HRP1. For NCD it was the opposite.

Table 5.4 provides insight into the differences in opinion among respondents with a different background. According to the table (which only presents the results for CSF; the other diseases showed a similar trend), respondents with a background in 'research' were more pessimistic about the length of HRP1 than respondents with a background in either 'policy' or 'field'. However, these differences were not significant (Wilcoxon rank sum test, " = 0.05). Within clusters, the variation in answers was rather great except for the research group.

Table 5.4
HRP1 (days) for low-virulent virus, CSF, mid-points for each background

	Policy	Research	Field
Neighbouring countries.	25	30	28
Southern Europe	30	42	35
Central Europe	23	30	25
Eastern Europe	38	60	39
"Islands"	21	29	21
Netherlands	21	28	25

5.3.3 Relative importance of risk factors

Approximately 80% of the participants were able to produce consistent estimates in the Conjoint Analysis task. This can be considered a good result when taking into account the large number of different situations participants had to evaluate. Table 5 shows the results of the group level regression analysis for the remaining (ie., consistent) participants. The table shows the relative importance of the risk factors for CSF and FMD for all significant risk factors (factors with a significance level greater than 0.15 were considered to be not significant). Risk factors 'wildlife' and 'air' were only considered for cluster 1 (neighbouring countries of the Netherlands).

According to Table 5.5, import of livestock, returning trucks and swill are found to be the major risk factors for all country clusters for CSF. Also regarding FMD, import of livestock is considered to be the most important risk factor for all clusters.

Table 5.5
Relative importance of risk factors concerning introduction of CSF and FMD, results of the group level regression analysis.

	Neighb. countries		Southern Europe		Central Europe		Eastern Europe		"Islands"	
	CSF	FMD	CSF	FMD	CSF	FMD	CSF	FMD	CSF	FMD
Livestock	0.59	0.52	0.57	0.60	0.63	0.56	0.67	0.53	0.66	0.52
Returning trucks	0.14	0.19	0.19	0.27	0.2	0.30	0.17	0.33	0.18	0.30
Swill	0.15	ns	0.18	ns	0.17	0.14	0.16	0.14	0.16	ns
Animal products	0.07	0.17	0.06	0.13	ns	ns	ns	ns	ns	0.18
Wildlife	0.05	ns	--	--	--	--	--	--	--	--
Air	ns	0.12	--	--	--	--	--	--	--	--
Total	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00

Table 5.6.
Expected number of primary outbreaks within the next five years, mid-points and percentiles by country cluster and disease.

	Neighb. countries			Southern Europe			Central Europe			Eastern Europe			"Islands"			Netherlands		
	25%	mid	75%	25%	mid	75%	25%	mid	75%	25%	mid	75%	25%	mid	75%	25%	mid	75%
CSF	10.0	**15.0**	25.0	10.0	**13.0**	21.0	3.5	**5.0**	10.0	18.5	**21.0**	25.0	0.5	**1.0**	1.5	1.0	**2.7**	5.0
FMD	1.5	**3.0**	5.0	3.5	**7.5**	12.5	1.0	**2.5**	4.5	15.0	**20.0**	24.0	0.5	**0.5**	1.0	0.5	**1.0**	2.0
NCD	5.5	**20.0**	25.0	4.0	**17.5**	20.0	1.5	**5.0**	10.0	15.5	**21.0**	24.0	0.5	**2.5**	4.7	1.5	**5.0**	14.5

Returning livestock trucks ranks second again. For both diseases, the differences between clusters were small. For NCD the major risk factors were import of live animals, transport materials (crates), and import of exotic birds which all accounted for about 30% of the total risk. If contrasted with CSF and FMD, the import of animal products was thought to be of minor importance and not significant for any of the country clusters. No major differences between clusters were observed.

More detailed analyses were done to increase insight into possible differences of opinion between groups of participants, for CSF and FMD. For CSF some differences seem to exist for risk factor 'returning trucks' which was an important factor to both 'policy' and 'field'. 'Research' thought the factor to be of minor importance. For FMD the ranking of the risk factors was almost the same for all three groups but 'research' was less extreme (differences between risk factors are smaller) in its opinion than 'policy' and 'field'. However, none of these differences were significant (Wilcoxon rank sum test, $\alpha = 0.05$).

5.3.4 Expected number of outbreaks within the next five years

ELI resulted in the parameters of a normal distribution from all participants individually concerning the number of outbreaks. The expected value of these distributions equals the best guess of the assessors. Table 5.6 shows the 'best guesses' of the participants concerning the expected number of outbreaks for CSF, FMD and NCD within the next five years (mid-points and quartiles). For all three diseases, most outbreaks are expected in eastern Europe. The smallest number of outbreaks is expected to happen in the country cluster containing UK, Ireland and Scandinavia ("Islands") and in the Netherlands. The participants expected numerous outbreaks of NCD and CSF but not so many of FMD. The variation in answers was rather great (wide range between the quartiles), especially for NCD in the Netherlands. Figure 5.1 shows a graphical representation of the combined opinions of the participants concerning the number of CSF-outbreaks, expected within the next five years, for the two most extreme country clusters (eastern Europe and "Islands", the latter include Great Britain, Ireland and Scandinavia). To construct this figure, the (normal) distributions of the participants were used as arguments in a discrete distribution function, as described in section 5.2.2.3 (20 participants, thus 20 distributions, with equal probability of occurrence because the participants were thought to be representative of the population of Dutch CSF-experts). Figure 5.1 presents a random sample of the mixed distribution. The figure shows a high probability for small numbers of outbreaks and a low probability for greater numbers of outbreaks (a tail to the right), for the cluster "Islands".

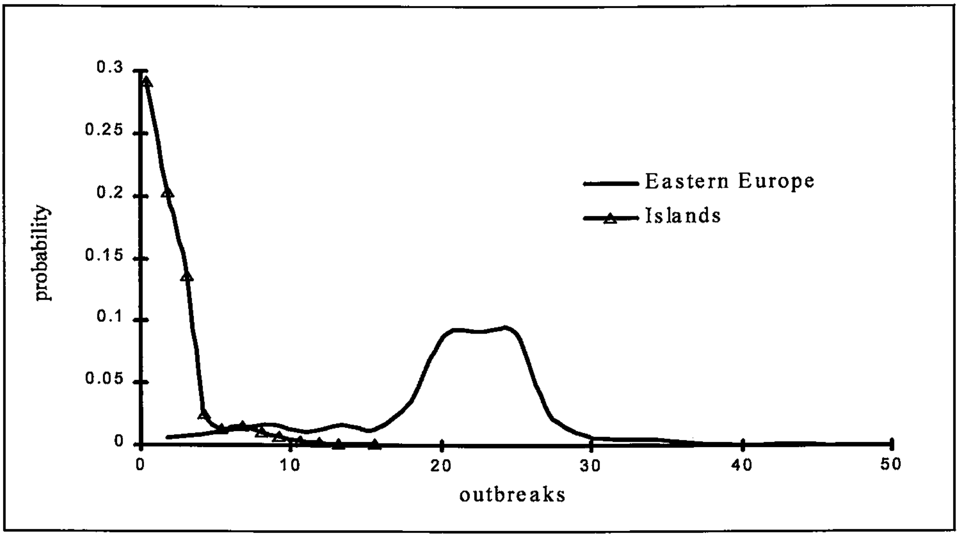

Figure 5.1
Expected number of primary CSF-outbreaks in the next five year; country clusters 'Eastern Europe' and 'Islands'.

For eastern Europe the participants clearly expect a greater number of outbreaks. The figure also shows a wide range of possible outcomes.

5.3.5 Feedback reports

All 43 participants received a feedback report about the group results together with their personal results. A total of 25 participants (58%) returned the enclosed form on which they could give their opinion on possible differences between their own and the group results with respect to HRP and the expected number of outbreaks. The risk factors were not included because Conjoint Analysis is an indirect method and 'direct' feedback would not be useful.

Concerning the HRPs, all participants except 3 were satisfied with their results, even if they differed from the group results. However, their remarks showed that the definition of both HRPs was not interpreted in the same way by everyone. Also concerning the expected number of outbreaks most participants stuck to their initial opinion, even if this opinion differed from the group results. Four participants indicated that their estimates were probably too high because they had also included secondary outbreaks, while only primary outbreaks were asked. The information provided by this feedback response was used to interpret the results of the workshops and is incorporated in the discussion section.

5.4 DISCUSSION AND CONCLUSION

5.4.1 Design

One of the major reasons for running the experiment in the form of a workshop was its expected attractiveness. The high response rate indicates that this was indeed a good formula and that aspects of potential future outbreaks of contagious animal diseases are a major issue in the Netherlands. The reactions of the participants, during and after the workshops, were very positive. Most participants indicated that it was difficult but refreshing and useful for them to think individually and in such a structured way about aspects concerning outbreaks of contagious diseases. Although this was not the primary aim of the experiment, it might be considered a positive side effect.

5.4.2 High Risk Period

The results show that, in general, policy-makers tend to be more optimistic about the alertness of farmers and veterinarians and the efficacy of the disease eradication systems than researchers. However, the opinion of the policy-makers might be too optimistic and a result of 'wishful thinking'. Researchers are more aware of the actual behaviour of viruses and therefore their estimates are probably more reliable than those of the other groups. The small variation in answers for the research group concerning the CSF estimates indicates that there are no great differences in opinion within this group. This might be due to a 'shared source', i.e. all estimates are based on the same experiences (education, outbreaks in the past).

The estimates of the HRPs concerning NCD showed a very wide variation. According to the feedback response, the wide variation in opinion may be caused by the compulsory vaccination against NCD in the Netherlands and some other European countries. Vaccination makes the symptoms of the disease less clear and thus may slow down detection. Besides, due to vaccination the consequences of an outbreak may be less serious and, therefore, the motivation for farmers to warn officials weaker.

Comparison with information originating from recent outbreaks might help to interpret the HRP1-results. Therefore, the results were compared with findings of Terpstra (1996), who established HRP1s for recent outbreaks in Europe (1986-1996). All values estimated by the experts were within the range of values found by Terpstra. However, this range was rather wide and based on only a limited number of outbreaks.

The feedback response indicated that the HRP2-definition as used in the workshop can be interpreted in more than one way. According to this definition, HRP2 ends when the affected region no longer involves a risk for other regions. Participants of the policy group interpreted this as the moment at which all compulsory measures should be taken where some other participants set the end of HRP2 equal to the end of the outbreak, indicating that the measures might not be sufficient to reduce the risk of the affected region to zero.

Assessing the HRP proved to be a more difficult task than expected. Therefore, the use of an easy-to-understand elicitation method might have been a good choice. However, the length of the HRPs is a continuous quantity and a method such as the ELI-technique might have been more appropriate and might be considered in future studies.

5.4.3 Risk factors

Much work has been done on modelling of airborne spread of the FMD virus. The importance of this factor concerning the spread of virus over short distances (within farms or between neighbouring farms) has been discussed widely, however, mainly on a within-country basis (amongst others, Smith and Hugh-Jones, 1969; Hugh-Jones and Wright, 1970; Maragon et al., 1994). The experiment showed that according to the participants the relative importance of this factor for virus introduction from neighbouring countries is thought to be just over 10%. Thus, concerning the Netherlands, efforts aimed at reducing the risks related to, for example, returning trucks and import of livestock might be more worthwhile than efforts aimed at reducing the risk of spread by air. Comparable efforts might reduce the risk of the introduction of NCD virus because also for this disease import of live animals and transport materials are thought to be of major importance. The risk associated with returning trucks and transport materials (insufficient cleaning/disinfection) might be reduced by border inspections and can be controlled, therefore, by the country which is entered by the trucks (at all times or only during periods of increased risk due to outbreaks in European countries). Reducing the risk associated with the import of livestock depends more on the country of origin.

Conjoint Analysis as a method to elicit the relative importance of the risk factors is rather new in the field of veterinary epidemiology and economics. A more traditional approach would have been the Delphi-technique, used by, for example, Forbes (1992), to reveal information concerning risk factors for a possible introduction of FMD into New Zealand, and Miller et al. (1994), to elicit expert knowledge concerning pseudo-rabies. An important advantage of the Conjoint Analysis approach over the Delphi approach is that the whole experiment can be done in one session, which makes it easier to motivate people to join. 'Losing experts' can be a serious problem with the Delphi approach. For example

Forbes, 1992, started his experiment with 28 experts, only 15 of whom completed the second round. Moreover, Conjoint Analysis provides an easy way to check the consistency of the answers given by the respondents, by using holdout profiles (Section 2.2.2). Inconsistency might be due to lack of knowledge, motivation or understanding. To avoid a false sense of reliability, results of inconsistent respondents should not be included in the analysis (regardless of the fact whether these results are 'outliers' or not). However, if a large number of inconsistent respondents is observed, the appropriateness of the model used in the regression analysis might be reconsidered (Green and Srinivasan, 1978). The results observed in this study indicate that the use of an additive model was appropriate (consistency > 80%).

5.4.4 Expected number of primary outbreaks

The ELI approach proved to be an attractive method for the respondents. Almost all participants were able to work with the program and completed the questions without much help, which is not the case for many other elicitation methods based on PDFs (see Van Lenthe 1993b). Compared with the historical data, the estimates presented in Table 5.6 and Figure 5.1 are rather high. This may indicate that, according to the participants, the changes, as described in the introduction (ceasing vaccination at European level, more trade with eastern Europe), have resulted in a riskier disease situation.

There are many ways to combine expert opinions. Table 5.6, the median of the best guesses, presents, no doubt, one of the simplest methods. But this method does not take into account information ELI provides concerning the uncertainty of the participants (i.e. the standard deviation of the distributions elicited). For simulation purposes, an option could be to include all probability distributions and select one of these at random, for each iteration. Another approach might be to fit a distribution through a sample of the mixed distribution, especially when the number of consulted experts, and therefore distributions, becomes large. The choice of the most appropriate curve will always be an arbitrary one, although guidelines are provided by goodness-of-fit tests, such as the Chi-Square test. Because these tests are very sensitive to the number of observations, feedback by experts will be a useful addition to the statistical analysis.

5.5 FINAL REMARKS

It can be concluded that the experiment provided useful information about the opinions of people with different backgrounds, involved in the area of disease control, and on some important aspects concerning outbreaks of contagious animal diseases in the Netherlands. The results will be used as input data for a simulation model aimed at the economic evaluation of measures and strategies to reduce the risk of disease introduction into the Netherlands. Because a considerable part of the input of the model will be based on estimates and assumptions, sensitivity analysis will also play a major role in evaluating the importance of uncertain data. In this way the analysis can be used to guide further (experimental) research aimed at improving input and thus improving reliability of the outcome of the model.

The truth, i.e. the 'Golden Standard', concerning many aspects of introduction of contagious animal diseases is not available and, by definition, subjective elicitation methods will never be able to reveal this truth. However, as long as historical data and/or experimental research are not available to provide better predictive results, subjective knowledge will be the only information for use in modelling risks and economic consequences of future outbreaks of contagious animal diseases. The experiment described in this paper showed that the techniques needed to handle and elicit such information could be obtained from other research areas such as marketing and consumer science (Conjoint Analysis) and mathematical psychology (ELI). Moreover, the experiment showed that incorporation of such tools into the area of animal health economics is possible and can provide a fruitful approach to enhancing the quality of input and therefore also the output of economic simulation models.

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Chapter 6

MONTE CARLO SIMULATION OF VIRUS INTRODUCTION INTO THE NETHERLANDS:

I MODEL DESCRIPTION AND BEHAVIOUR[1]

ABSTRACT

In order to enhance insight into the risk of introducing Classical Swine Fever (CSF) and Foot-and-Mouth Disease (FMD) into the Netherlands, a Monte Carlo simulation model was developed. The model, named VIRiS, (Virus Introduction Risk Simulation model) describes virus introduction into the Netherlands, originating from outbreaks in other European countries. VIRiS is aimed at supporting decision makers involved in disease prevention. The model is based on historical and experimental data, supplemented with expert judgement, and provides the expected number, location and cause of primary outbreaks in the Netherlands. The paper gives a detailed description of the design and behaviour of VIRiS. The default outcomes of VIRiS show that in the current situation, the southern and eastern regions of the Netherlands are most prone to outbreaks of CSF and FMD. Most outbreaks originate from the countries neighbouring the Netherlands and the countries of southern Europe.

6.1 INTRODUCTION

Outbreaks in EU member states of contagious animal diseases, such as Classical Swine Fever (CSF) and Foot-and-Mouth Disease (FMD) have to be eradicated according to EU regulations, laid down in the so-called 'Council Directives'. These directives prescribe measures such as: rapid detection, confirmation and subsequent stamping-out of infected herds, establishment of protection and surveillance zones around infected herds with complete movement standstill of all animals, and continuous epidemiological surveillance within these zones (CEC, 1980). It is obvious (and reported by several authors, e.g. Berentsen et al., 1992) that outbreaks of such contagious diseases will have a serious

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[1] paper by Horst, H.S., Huirne, R.B.M. and Dijkhuizen, A.A.
submitted for publication to *Preventive Veterinary Medicine*

economic impact on the livestock industry in affected countries. Therefore, adequate disease prevention strategies, aimed at minimizing the risk of introducing virus, are of major importance.

Real-life experimentation with alternative prevention strategies would be highly impractible because of the low incidence of outbreaks in most countries, and also very risky (and costly). Therefore simulation is considered a feasible approach to provide insight into the effectiveness of alternative prevention strategies. Monte Carlo simulation (Kleijnen and Van Groenendaal, 1992; Hardaker et al., 1997) seems to be especially appropriate in such a case, as it enables incorporation of variation and uncertainty inhibited in the aspects which determine the risk of introduction, for example, number and duration of outbreaks in European countries.

This paper describes the design and behaviour of VIRiS (Virus Introduction Risk Simulation model), a Monte Carlo model which simulates the introduction of virus into a country. VIRiS is aimed at supporting decision makers involved in disease prevention. The major objective of the model is to provide insight into the consequences of alternative strategies to reduce or prevent the risk of virus introduction. The model focusses on virus introduction into the Netherlands, originating from outbreaks in other European countries. The approach as such is general, however, and could also be applied to other countries and conditions. Major diseases of concern were CSF and FMD, but the model was structured in such a way that adaptation to other diseases is also possible.

6.2 MATERIAL AND METHOD

The VIRiS model is based on research by Horst et al. (1996a, 1996b, 1997), who provided qualitative and quantitative relationships between factors and mechanisms related to introduction of virus into the Netherlands. Both 'objective' information from databases and research literature, and 'subjective' information from experts were used to obtain data for simulation modelling purposes.

VIRiS was constructed in Excel 5.0 with the program @Risk (Palisade Corp.) as add-on to simplify the use of probability distributions. Being a Monte Carlo simulation model, VIRiS uses for each iteration randomly drawn numbers from specified distributions (in VIRiS-FMD, more than 250 of those distributions were used). Therefore, if the model is run repeatedly with the same input distributions, these runs will lead to a distribution of output values, reflecting the realistic aspects of chance and uncertainty (Law and Kelton, 1991; Dent and Blackie, 1979).

Figure 6.1 shows a simplified structure diagram of VIRiS. A structure diagram is read as a sequence of steps which are executed in left-to-right order and when the last is finished the sequence as a whole is considered finished (Dent and Blackie, 1979). The VIRiS model calculates the events, such as 'sample for new outbreaks' and 'check all clusters' on a day-to-day basis, i.e., it has a one-day time step. The time horizon is 5 years, i.e., after 365*5 one-day time steps totals are calculated, thus giving an overview of the situation during a five-year period. Running a number of those 5-year-periods or iterations provides the user with the distribution of possible outcomes. Below, the various steps in the model are explained.

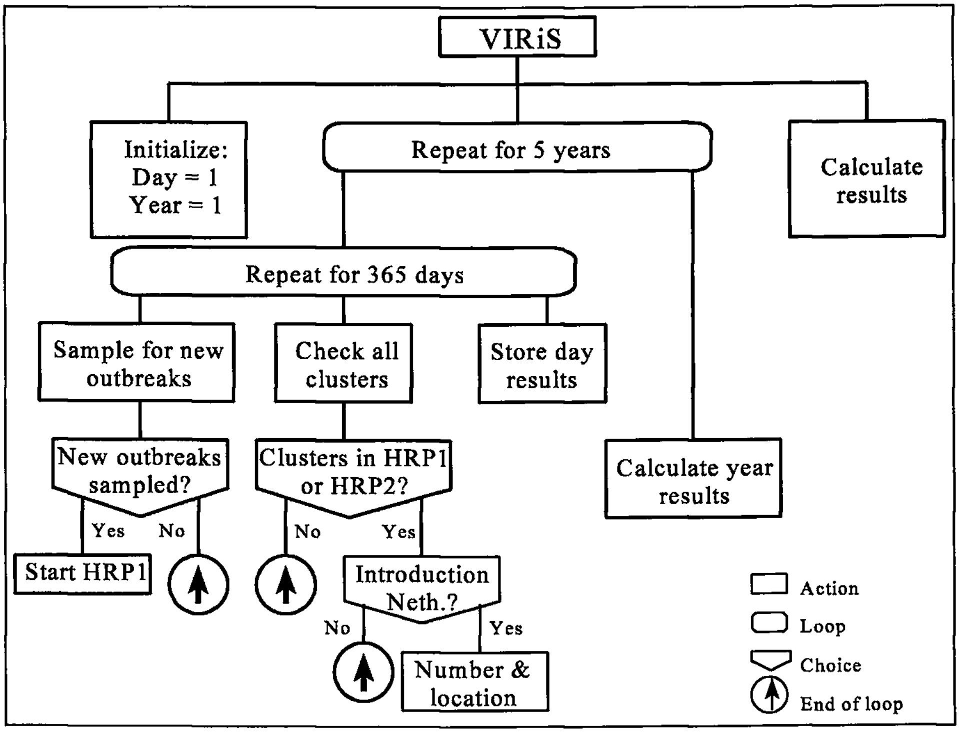

Figure 6.1
Structure diagram of VIRiS

Sample for new outbreaks in clusters

Because of the current free transport of animals, products and people within Europe, each individual country can cause virus introduction into the Netherlands. For pragmatic reasons, these countries were grouped into the following five clusters (based on geographical and trade arguments):

Neighbouring countries:	Belgium, Germany, Luxemburg
Southern Europe:	Greece, Italy, Portugal, Spain
Central Europe:	Austria, France, Switzerland
Eastern Europe:	Countries of the former East block
"Islands":	Great Britain, Ireland, Scandinavia

Virus transport to the Netherlands can only take place if at least one of these clusters suffers from an outbreak. Therefore, as shown in Figure 6.1, the VIRiS-model starts a run by sampling for new outbreaks in each of the clusters. This sampling process is led by the probability of occurrence of such an outbreak, which is a specific value for each cluster, depending on the current and historical animal health status and the expected level of current and future animal health programmes. Horst et al. (1997) provided parameters for these probability distributions, available as normal distributions and elicited from individual experts (8 and 20 experts were involved, for FMD and CSF respectively). Table 6.1 presents the results (as mid-points or medians) for CSF and FMD, for the experts as a group (the table also presents the so-called HRP-values, which will be explained later).

Table 6.1
Expected number of outbreaks in the next 5 years and duration of HRP1 and HRP2, mid-points based on expert knowledge (Horst et al., 1997)

	CSF						FMD					
	Neighb.	S-Eur.	C-Eur.	E-Eur.	Islands	Neth.	Neighb.	S-Eur.	C-Eur.	E-Eur.	Islands	Neth.
Outbr.	15.0	13.0	5.0	21.0	1.0	2.5	3.0	7.5	2.5	20.0	0.5	1.2
HRP1	28	35	28	42	21	21	7	12	8	19	7	6
HRP2	10	21	21	30	21	14	5	6	6	14	2	5

The table shows that the experts expect most outbreaks of CSF as well as FMD to occur in eastern Europe. A low number of outbreaks is expected in the Netherlands and in Great Britain, Ireland and Scandinavia ("Islands"). In general, more outbreaks of CSF than of FMD are expected to occur in the next five years.

In the FMD version of the model (VIRiS-FMD) eight individual normal distributions are included, one for each expert. At the start of each run, a discrete distribution function is used to determine, per cluster, which value for outbreak probability is used during that specific run. Weighing factors can be assigned to each expert: these are used as probability parameters for the discrete function. In the default situation, all expert distributions received equal weights, except when, per cluster, the distributions with the highest and the lowest expected value respectively were assigned a weight of 0, which excluded them from the calculations.

Formulated as such, the discrete distribution provides the number of outbreaks expected to occur in a five-year period. The process can be described by the following formula:

(1) $RE_i = Discrete[Normal(\mu_i,\sigma_i)_1 \ldots\ldots Normal(\mu_i,\sigma_i)_8; \{W_1 \ldots\ldots W_8\}]$

where:

Re_i	=	Run Estimate for cluster i, the value used in the specific run
$Normal(\mu_i,\sigma_i)_{1...8}$	=	Normal distribution for experts 1 to 8 respectively, estimates for cluster i
$W_{1...8}$	=	Weighing factor for experts 1 to 8 respectively, used as probability parameters

First calculations with VIRiS-FMD showed that the above-described procedure added a realistic but high level of variation to the model, which resulted in the need for many iterations before a stable result was reached. The results were defined to be stable when calculating an extra ten 5-year periods did not change the average outcome by more than 5%. This topic will be addressed in more detail in section 3, 'model behaviour'.

Because the number of experts involved in the CSF-model was much larger (20), VIRiS-CSF needed a different approach to avoid computer capacity becoming a limiting factor. Therefore, a continuous cumulative distribution function was used to obtain the outbreak probabilities. Such a distribution has the form of Cumulative($\{x_i\}$,$\{P_i\}$,min,max) (Vose, 1996). For VIRiS-CSF, the minimum and maximum arguments were arbitrarily set at the smallest expected value minus the corresponding standard deviation and the largest expected value plus the corresponding standard deviation respectively. The points on the cumulative curve (array $\{x_i\}$) were equal to the expected values of the normal distributions derived from experts, with cumulative probabilities of occurrence (array $\{P_i\}$) equal to the relevance of the respective experts (weighing factors, can be set by the user of the model).

For both VIRiS-FMD and VIRiS-CSF, a Poisson distribution was assumed to translate the resulting information concerning a five-year period into a number of primary outbreaks that occur on a specific day (i.e., in a specific run). The Poisson distribution is a close relative of the binomial distribution and is used, for example, for studying the number of successful events (e.g. outbreaks) given a very small probability of success (occurrence of the event one is looking at, e.g., an outbreak) (Waters, 1994).

A Poisson distribution returns a positive integer which indicates the number of individual events (x) that occur in a given unit of time (Kleijnen and Van Groenendaal, 1992) and is specified by the following formula:

(2) $$f(x) = \frac{\gamma^x * e^{-\gamma}}{x!}$$

The distribution is based on one parameter, gamma ($\gamma > 0$), which equals the expected number of events that occur. As a VIRiS-run simulates the events of a one-day period, the five-year value resulting from the discrete or cumulative function (as described above) had to be divided by (5*365) to translate it into a one-day expectation. The resulting expected number of outbreaks per day will be (much) smaller than 1. Therefore the Poisson distribution will return a 0 in most runs, indicating that no outbreaks occur.

Start HRP1 in relevant clusters

If an outbreak does occur in a certain cluster, i.e., the Poisson distribution returns a non-zero value for one or more clusters, some time will pass before the first infected animal is detected and eradication measures can be taken. During this so-called High Risk Period (HRP), there is a risk that the virus will be transferred to another country. The HRP can be divided into two periods:

HRP1: starts when first animal is infected, and ends when an infected animal is detected.

HRP2: starts with first detection, and ends when all measures are considered effective.

After the HRP2 has ended, the affected area is of no risk to other areas anymore. Using experts, Horst et al. (1997) derived estimates for both HRPs, for each of the clusters involved. They used a three-point estimation method, i.e., the experts were asked to give a minimum, maximum and most likely value for the duration of both periods, and validated the estimates against the HRPs in recent outbreaks where available (Terpstra, 1996). Table 1 presents the group mid-points (medians) for the estimates for the most likely duration of HRP1 and HRP2 for both CSF and FMD. For both diseases, longest HRPs were expected for the countries of eastern Europe, shortest for the Netherlands and Great Britain, Ireland and Scandinavia ("Islands"). HRPs for FMD were generally expected to be shorter than those for CSF.

The three-point estimates of the experts were included in VIRiS as triangular distributions, a commonly used method to model expert opinion (Vose, 1996). The HRPs used in a specific run were obtained by using discrete distributions (VIRiS-FMD) or cumulative distributions (VIRiS-CSF), similar to the procedure used to determine the expected number of outbreaks. In case of an outbreak, i.e., a Poisson distribution returning a non-zero value, the HRP-values obtained in that run for the cluster where the outbreak occurs determine the number of runs during which transfer of virus to the Netherlands from the affected cluster is possible.

Check all clusters for current outbreaks

In the next phase of the model (see Figure 6.1), VIRiS checks the HRP1 and HRP2 status of all clusters. When a cluster is in either an HRP1 or HRP2, it will constitute a certain risk of virus transfer to the Netherlands. When none of the clusters is in either HRP, the run is ended and the day results are stored. If counter value 'day' equals 365, 'annual' results are calculated (and stored). If the counter value is less than 365, it is raised by 1 and another run (day) is started. After 5 'years' (time horizon), totals are calculated and the iteration is ended.

Determine introduction risk

As indicated in Figure 6.1, for each cluster that is in either HRP1 or HRP2 (which means that it has an outbreak), the VIRiS-model calculates the probability of virus transfer to the Netherlands. Transfer of virus to the Netherlands, from a country with an outbreak, is due to risk factors. Each factor constitutes its own 'introduction risk', in VIRiS represented by P(intro). The model allows (as in reality) more than one cluster to suffer from outbreaks at the same time. Therefore, risks of introduction have to be calculated for several clusters simultaneously. These risks are then summed to determine the total risk to the Netherlands, i.e., clusters, and therefore risk factors between clusters are assumed to be independent.

Horst et al. (1997) used special interview techniques, such as 'conjoint analysis' (Cattin and Wittink, 1982) to elicit the relative importance of the risk factors. To illustrate, Table 6.2 presents a summary of the results for CSF and FMD. Import of livestock, i.e., animals susceptible to the respective disease, was considered the most important risk factor for both diseases for all clusters. Also returning trucks (both diseases) and swill (CSF) were seen as major risk factors. The risk factor 'tourists' was not statistically significant in any of the clusters, and was therefore not included in the table. Some factors (such as 'animal products') were not significant in all clusters, factors 'wildlife' and 'air' were only considered for the countries neighbouring the Netherlands

Table 6.2
Data on FMD and CSF concerning risk factors, based on expert knowledge (Horst et al., 1997)

	CSF					FMD				
	Neighb	S-Eur.	C-Eur.	E-Eur.	Islands	Neighb	S-Eur.	C-Eur.	E-Eur.	Islands
Import livestock	0.59	0.57	0.63	0.67	0.65	0.51	0.60	0.57	0.53	0.52
Animal products	0.07	0.06	n.s.	n.s.	n.s.	0.17	0.13	n.s.	n.s.	0.19
Swill	0.15	0.18	0.17	0.16	0.16	n.s.	n.s.	0.13	0.14	n.s.
Return. trucks	0.14	0.19	0.20	0.17	0.19	0.20	0.27	0.30	0.33	0.29
Wildlife	0.05	.....	.....	.....	.....	n.s.	.....	.....	.....	.....
Air	n.s.	.....	.....	.....	.....	0.12	.....	.....	.....	.....
Total	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00

n.s. = not significant

The values given in this table represent the *relative* importance of each risk factor, given a certain cluster. To transform this relative importance into an *absolute* value, which can be used to calculate the risk of virus transfer by that specific risk factor to the Netherlands (P(intro)), the so-called Basic Probability (BP) is used. The BP equals the total probability of virus transfer to the Netherlands, in the (hypothetical) situation that all clusters are in HRP1 at the same time. Therefore, the BP represents the maximum daily probability concerning transport of virus to the Netherlands.

The BP might be seen as the calibration factor of the model. By changing the value of this factor, the number of outbreaks in the Netherlands, simulated by the model, will change. Expert consultancy performed by Horst et al. (1997) resulted in an estimate of on average 2.5 primary CSF-outbreaks and 1 FMD-outbreak per five-year period (excluding the most extreme estimates). These estimates were in line with the events of the past 10 years (number of outbreaks and evolution of prevention and control programmes). The estimates were used to calibrate the models, i.e., the BP was adjusted until the simulation results equalled these expert expectations.

Not all clusters present the same risk of virus transfer to the Netherlands when they are in the HRP1-phase. For instance, as import of livestock is the main risk factor in all clusters, it is obvious that clusters that export more livestock to the Netherlands will constitute a greater risk. The Dutch Product Boards for Livestock, Meat and Eggs provided quantitative information concerning animal and meat trade flows (PVE, 1995). Weighing, within clusters, the number of the risk factors (e.g. the number of live animals or empty trucks entering the country) with their relative (and cluster specific) importance, resulted in a number of 'risk units' per cluster. Rescaling these units over clusters resulted in the cluster specific distribution factors (D_i). For example, for VIRiS-CSF, $D_{\text{(neighbouring countries)}}$ was 0.34 and $D_{\text{(eastern Europe)}}$ was 0.03, for VIRiS-FMD these values equalled 0.51 and 0.04 respectively. The great difference between 'neighbouring countries' and 'eastern Europe' is due to the fact that only very few live animals are imported from the latter.

Combining the distribution factors with the relative and cluster specific importance of the risk factors and the BP resulted in the absolute probability of virus transfer for each cluster in HRP1 (the HRP2-phase was considered by the experts to be half as risky as HRP1):

(3) $P(\text{intro})_{ij} = RI_{ij} * D_i * BP$

where:

$P(\text{intro})_{ij}$	=	Absolute introduction probability for risk factor j of cluster i
Ri_{ij}	=	Relative Importance of risk factor j of cluster i, $\sum RI_j = 1$ within cluster i (see Table 6.2, last row)
D_i	=	Distribution factor of cluster i, $0 \leq D_i \leq 1$ and $\sum D_i = 1$
BP	=	Basic Probability

Determine outbreaks

The cluster and risk factor specific virus transfer probabilities (P(intro)), determined in the preceding part of the VIRiS-model, are used as probability arguments in discrete probability functions to determine whether virus introduction into the Netherlands (from clusters in the HRP-phase) will actually occur. For each risk factor-cluster combination a unique discrete function is formulated, all according to the following general formula:

(4) $VI_{ij} = \mathit{Discrete}[\{0,1\};\{P(\text{intro})_{ij},(1-P(\text{intro})_{ij})\}]$

where:

VI_{ij}	=	Virus Introduction of the risk factor j-cluster i combination, possible values of VI are 1 and 0, indicating 'introduction' and 'no introduction' in the Netherlands respectively
$P(\text{intro})_{ij}$	=	Absolute introduction probability for risk factor j of cluster i

If, according to the results of this discrete distribution function, introduction into the Netherlands does occur, another discrete distribution function is used for determining if this introduction leads to an outbreak. The probability that virus introduction leads to disease outbreak is determined by the so-called 'catch-on' probability. FMD and CSF are considered to be extremely contagious such that this probability equals 1 (thus, each introduction leads to an outbreak).

When the model simulates an outbreak (see Figure 6.1), the causing cluster and risk factor determine in which part of the Netherlands this outbreak will occur; four regions are considered: east, west, north and south. Data, provided by the Dutch Statistical Office and the Dutch Product Boards for Livestock, Meat and Eggs, provided insight into the region-specificity of risk factors. As to risk factors 'swill' and 'wildlife' expert opinion was used. Table 6.3 presents an overview of the probabilities for the significant risk factors for CSF. As shown in this table, an outbreak caused by the risk factor 'import of livestock' is more likely to occur in the southern part of the Netherlands than in the western part, whereas

Table 6.3
Relative outbreak probability (P) for each region, per risk factor and cluster.

	P(North)	P(East)	P(South)	P(West)	Total
CSF					
Import livestock	0.04	0.38	0.55	0.03	1.00
Animal products	0.12	0.26	0.22	0.40	1.00
Swill	0.20	0.20	0.20	0.40	1.00
Returning trucks	0.24	0.31	0.28	0.17	1.00
Wildlife	0.20	0.20	0.40	0.20	1.00
FMD					
Import livestock					
- neighbours	0.05	0.42	0.46	0.07	1.00
- Southern Europe	0.08	0.35	0.57	0	1.00
- Central Europe	0.08	0.27	0.54	0.11	1.00
- Eastern Europe	0.05	0.67	0.24	0.04	1.00
- "Islands"	0.10	0.64	0.2	0.06	1.00
Animal products	0.12	0.19	0.22	0.47	1.00
Swill	0.20	0.20	0.20	0.40	1.00
Returning trucks	0.24	0.26	0.28	0.22	1.00
Air	0.28	0.33	0.20	0.19	1.00

outbreaks caused by the risk factor 'swill' are more likely to occur in the western part than elsewhere. Concerning FMD, the animal information and recording (I&R) system provided information on the origin of imported cattle. Therefore, for this disease cluster specific data were available. Such a system is currently being implemented for swine; its reliability however is not (yet) high.

The relative probabilities presented (Table 6.3) were used as probability arguments in a discrete distribution function, which had 'north', 'east', 'south', and 'west' as possible outcomes.

Storage of results

The one-day results of each run are stored. Then, the counter variable 'day' is raised by 1 and a new run (new 'day') is started. When the variable 'day' equals 365, total results over the preceding 365 runs are calculated and stored as annual results. After five years (time horizon), totals are calculated. To gain insight into the results and their variation, the model has to be run for a large number of '5-year periods'. 'Days' within a 'year' are linked to each other because epidemics (if they occur) will normally not be over within a one-day period (an affected cluster poses risk to the Netherlands during HRP1 and HRP2). The same applies to between 'years', i.e., a 'year' may start with some clusters half-way their HRP-period, as in reality.

6.3 MODEL BEHAVIOUR

VIRiS is a Monte Carlo simulation model and, as stated before, this implies that the model has to be run a number of times before the output represents a reliable overview of the most likely and possibly extreme outcomes of the model. To evaluate the number of iterations needed, the overall mean values were calculated, after every ten iterations. Each such iteration represents a 5-year period (as said before, a 5-year period represents the time horizon of the model). Figure 6.2 shows the results of this process, for VIRiS-CSF, for the outcome 'expected region-probability for primary outbreaks'.

For VIRiS-CSF, after 100 iterations the change in mean value from an extra 10 iterations was less than 5%; for VIRiS-FMD, this stage was reached after 140 iterations periods. It was decided that these numbers were sufficient to provide stable outcomes.

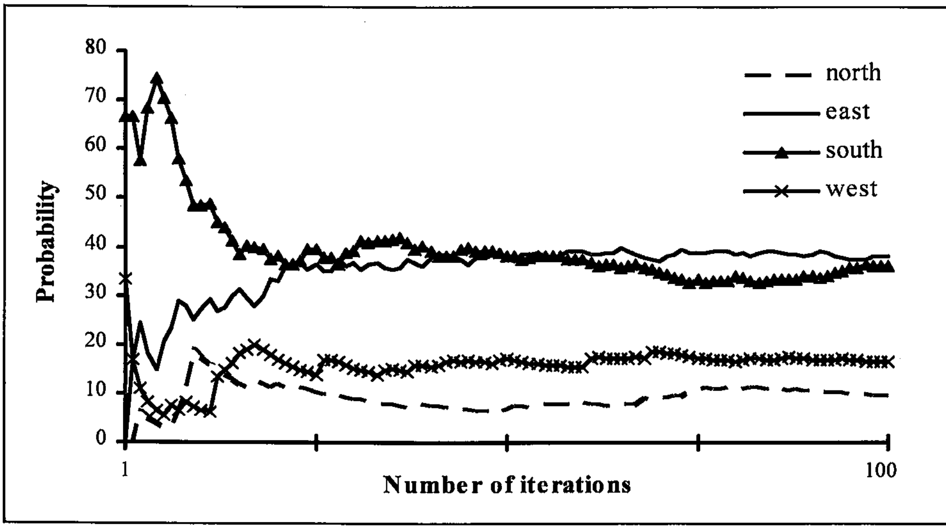

Figure 6.2
VIRiS-CSF: effect of the number of iterations on the expected region-probability for primary CSF outbreaks in the Netherlands

Figures 6.3 and 6.4 present the relative importance of risk factors which cause outbreaks of FMD and CSF respectively in the Netherlands. For both diseases, import of livestock (animals susceptible to the respective disease) causes the major part of the primary outbreaks. Other important risk factors are returning trucks, i.e., trucks used for Dutch export, returning to the Netherlands, and, only for CSF, swill feeding.

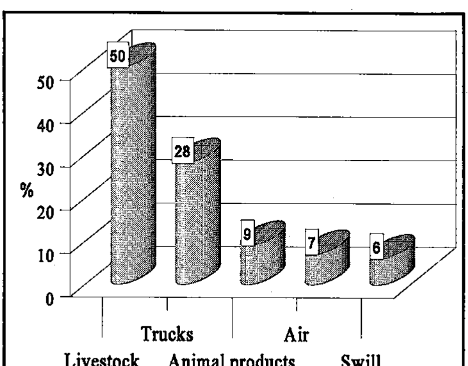

Figure 6.3
VIRiS-FMD: Primary outbreaks of FMD in the Netherlands, causing risk factors

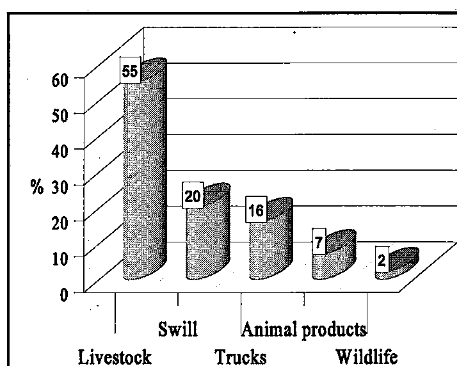

Figure 6.4
VIRiS-CSF: Primary outbreaks of CSF in the Netherlands, causing risk factors

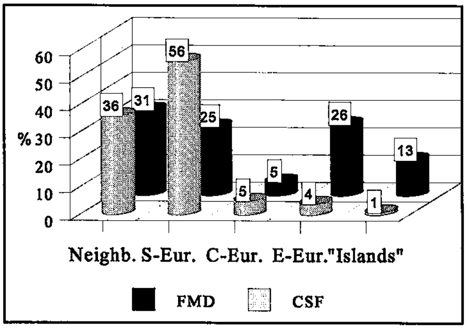

Figure 6.5
VIRiS: Primary outbreaks of FMD and CSF in the Netherlands, causing country clusters.

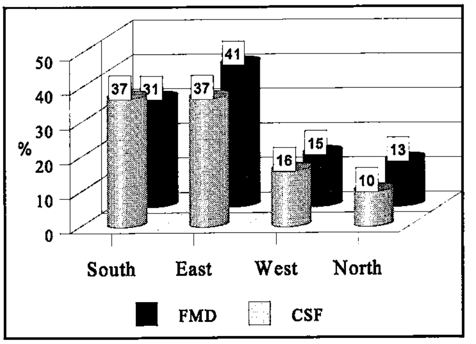

Figure 6.6
VIRiS: Region-probability for primary outbreaks of FMD and CSF in the Netherlands (total within diseases equals 100%).

Figure 6.5 shows that most primary FMD-outbreaks originate from virus introduction from countries neighbouring the Netherlands. Most primary CSF-outbreaks are expected to originate from countries of southern Europe (Greece, Italy, Portugal, Spain). Although the countries of eastern Europe were expected to have the highest frequency of CSF-outbreaks and the highest HRP (Table 6.1), they only rank fourth in Figure 6.5, because trade in CSF-susceptible animals, the major CSF risk factor (Figure 6.4), between the Netherlands and these countries is of minor importance.

According to the VIRiS model, the eastern and southern regions of the Netherlands are most prone to primary outbreaks of both CSF and FMD, as shown in Figure 6.6. The western and northern regions have lower average probabilities for both diseases, mainly due to the lower farm density. Farm density is highly correlated with import of livestock, which is the most important risk factor for both diseases (Figures 6.3 and 6.4). Farm density is also the major factor explaining the differences between FMD and CSF probabilities. However, if only farm density determined the outbreak probability, the probability for region west for CSF would even be lower. Other risk factors are important as well, for example, risk factor 'swill' (Figure 6.4), which has more influence on region west than on other regions (Table 6.2), because of the presence of airports and seaports in this region.

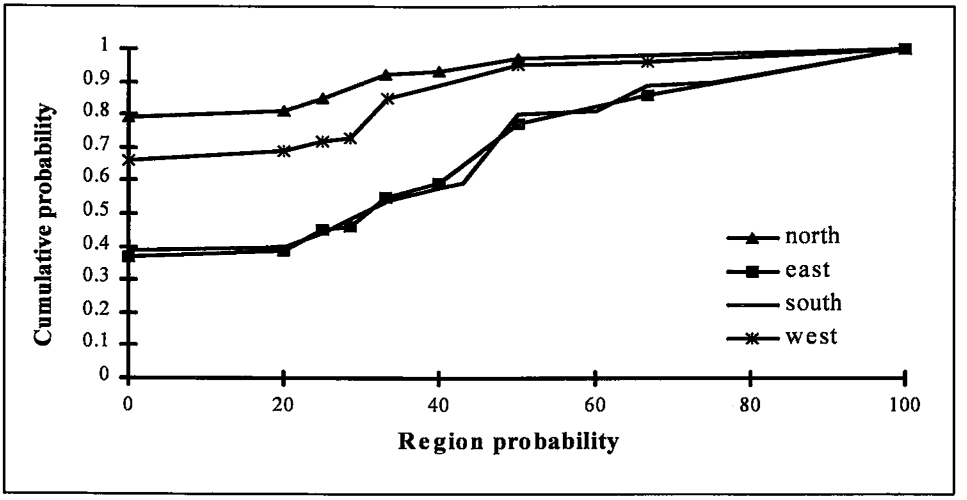

Figure 6.7
VIRiS-CSF: cumulative probability of the region-probability for primary outbreaks of CSF in the Netherlands.

Figure 6.7 shows the cumulative probability graph for the region probabilities for VIRiS-CSF. The figure provides insight into the variance in the results presented in Figure 6.6. According to Figure 6.6, region north faces on average a region-probability of 10% for primary CSF-outbreaks. According to Figure 6.7 this probability will not exceed 30% in 90% of the cases. As the average number of CSF-outbreaks expected to occur in the Netherlands in a 5-year period equals 2.5 (see section 6.2), it is obvious that many iterations will result in a region-probability for primary outbreaks of 0%, for one or more regions. As Figure 6.7 shows, this probability is larger for the regions with a low density of farms and animals. For example, in 80% of all iterations or simulated 5-year periods, no primary CSF-outbreaks occurred in region north; for region east this was only in 38% of the iterations the case.

Especially the parameters involving the HRPs were expected to have an important influence on the results. To analyse the behaviour of both VIRiS models, the models were run with the HRP1-parameters multiplied by 2. Figure 6.8 shows the results for VIRiS-CSF. The cumulative probability curve representing the default scenario is situated left from the curve representing the scenario in which HRP1 is doubled, indicating that the latter results in more outbreaks. Approximately 80% of the iterations (5-year periods) in the default situation resulted in 3 outbreaks or less. Doubling HRP1 resulted in a decrease to 50%. The VIRiS-FMD model showed similar results.

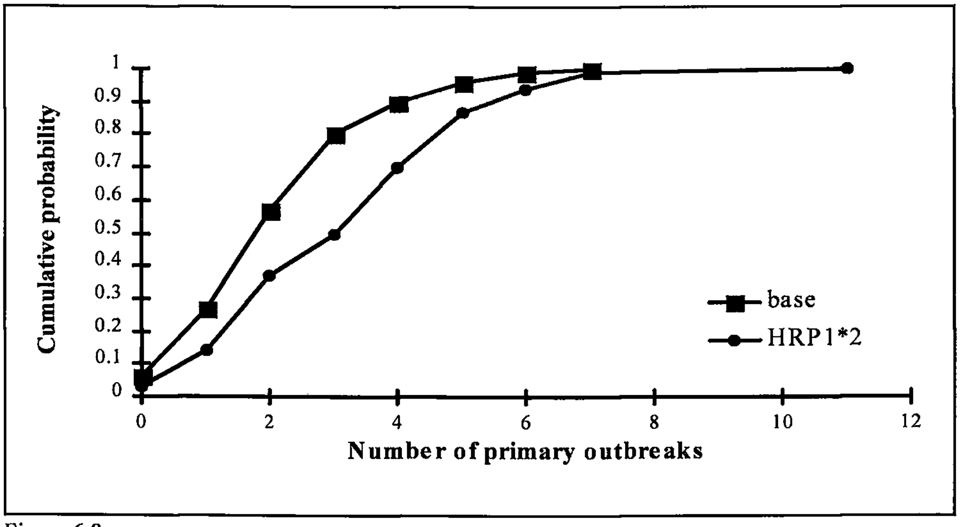

Figure 6.8
Cumulative probability graph for the CSF base scenario and the HRP*2 scenario.

6.4 DISCUSSION AND CONCLUSION

The use of probability distributions of input values has the advantage that uncertainty can be modelled. In this way, expert information, which, based on real-life experience, always includes uncertainty, can be described realistically and used as model input. However, as the number of distributions increases, also the number of runs needed to provide stable outcomes increases. The current version of the VIRiS-FMD model includes more than 275 different probability distributions. This number might be reduced when (research) information becomes available that leads to more certainty concerning input parameters and/or mechanisms. In that case the model can be updated easily.

As validation is concerned with agreement between model-behaviour and behaviour of the real system (Dent and Blackie, 1979), unavailability of an abundant number of those data might hamper a very detailed validation process. In those cases, consulting experts is a logical alternative (Law and Kelton, 1991). The results of both VIRiS-CSF and VIRiS-FMD were discussed with several groups of experts to evaluate the face validity of the model (Law and Kelton, 1991). During these discussions the experts used historical facts (about recent outbreaks) as well as their own knowledge and experience in order to evaluate the results, and generally concluded that the model results were in line with their expectations and experiences.

Of course, the above-described validation process is not ideal. However, as stated by Kleijnen (1993), it is neither necessary nor possible that a validation process results in a perfect model. By definition the only perfect model is the real system itself and any model is a simplification of reality. The model should be 'good enough', which means that its validation should be assessed in relation to its prescribed use.

In case of VIRiS its prescribed use is to provide policymakers in the area of animal disease prevention with insight into aspects that influence the number and geographical position of primary outbreaks of CSF and FMD in the Netherlands. The model is meant as a decision support tool and not as a decision-making machine in itself. Therefore, providing insight into the mechanism is more important than predicting precise figures. The validation process, based on both 'real data' and expert information, showed that the VIRiS-model is able to produce plausible results and provide insight into the mechanism under study, i.e., virus introduction into the Netherlands. Sensitivity analysis can be used to evaluate the importance of the input parameters (for example, the duration of the HRPs). Also, alternative prevention strategies may be translated into the parameters of the model and thereafter judged on their merits concerning risk reduction (example: more sanitary controls results in lower risk associated with the risk factor 'trucks'; VIRiS may be used to evaluate the effect on total risk reduction).

The model as such provides information on the number and location of primary outbreaks. An urgent addition, which would simplify the evaluation of alternative strategies, would be the incorporation of spread of epidemics within the Netherlands and their economic impact. Then strategies could be compared based on cost-benefit analysis. Research is under way to perform this next step.

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Chapter 7

MONTE CARLO SIMULATION OF VIRUS INTRODUCTION INTO THE NETHERLANDS

II ECONOMIC EVALUATION OF PREVENTION[1]

ABSTRACT

If serious epidemics of diseases such as Classical Swine Fever (CSF) and Foot-and-Mouth Disease (FMD) were to occur in the Netherlands, the eradication measures required by the European Union, including a possible ban on export, would have severe economic consequences. Therefore, an effective disease prevention and control policy is of great importance, for the Netherlands and similar meat-exporting countries. An integrated approach which combines the various aspects of outbreaks and risks with economic consequences could be an important tool to support policy makers in their evaluation of current and alternative prevention and control strategies. In this paper, such an approach is applied to evaluate the outcome of the simulation model VIRiS (Virus Introduction Risk Simulation model), which provides insight into the effect of current and alternative prevention strategies on the risks of CSF and FMD introduction. The integration of VIRiS with models describing spread and economic consequences of epidemics enabled evaluation of alternative prevention strategies on their ability to reduce the expected annual losses due to epidemics. The results show that a considerable economic window is available for measures aimed at minimizing the size of epidemics. Complete elimination of the risk associated with the risk factor 'returning trucks' reduces the annual losses due to FMD and CSF epidemics by approximately US$ 9 million.

7.1 INTRODUCTION

In the European Union, outbreaks of contagious animal diseases such as Classical Swine Fever (CSF) and Foot-and-Mouth Disease (FMD) are eradicated following strict EU-prescriptions, including measures such as the establishment of surveillance zones with

[1] paper by Horst, H.S., Meuwissen, M.P.M., Dijkhuizen, A.A. and Huirne, R.B.M.

submitted for publication to *Preventive Veterinary Medicine*.

complete movement restrictions for all animals and the eradication of infected herds (CEC, 1980). The 1997 outbreak of CSF in the Netherlands has proved once again the great economic impact of these measures when an outbreak occurs in a region with a high density of pig farms and an export-oriented production. Within the first five months of the epidemic, more than 300 farms were infected and more than a million hogs had been destructed. The total losses from this epidemic are not yet known but will most probably exceed a billion Dutch guilders. Obviously, an adequate disease prevention and control policy is of major importance, for the Netherlands and similar (meat-exporting) countries.

Notwithstanding their strong impact on all participants of the production chain, policy decisions on disease prevention and control programmes are usually based on scarce and incomplete information. While real-life experiments are not a feasible option to overcome this lack of information (time-consuming and risky), simulation modelling provides an alternative way to obtain information and insights. Simulation models are able to calculate the effects of alternative sets of input variables (scenarios, strategies) and are therefore attractive to evaluate current strategies and explore strategies that have not yet been applied (Dijkhuizen and Morris, 1997). As outlined by Horst et al. (1996), real additional value for policymakers would be obtained by an integrated approach in which the various aspects of outbreaks and risks with economic consequences are combined. Such an approach could be an important tool to support policymakers in their evaluation of current and alternative prevention and control strategies.

In this paper the integrated modelling approach is used to evaluate the results and insights obtained by the Monte Carlo simulation model VIRiS (Virus Introduction Risk Simulation). The model VIRiS provides insight into the risk of CSF and FMD introduction into the Netherlands, given current and alternative prevention strategies (Horst et al., 1997b). The model provides the expected number, location and cause of primary outbreaks, but does not include any details concerning secondary outbreaks and economic consequences, while this would be essential to evaluate alternative prevention strategies. Therefore, in this paper, the results obtained by VIRiS are combined with information from models concerning the spread of virus within a country (Jalvingh et al., 1996; Saatkamp, 1996) and thereafter translated into their economic consequences. The integrated approach thus evaluates the entire "development path" of animal disease outbreaks, from an outbreak somewhere in Europe, to a possible virus introduction into the Netherlands, including consequences for the Netherlands such as primary and secondary outbreaks, economic losses and potential benefits of alternative prevention measures.

First the paper gives a brief description of VIRiS and the models describing the secondary spread and the economic consequences caused by outbreaks. Then the current and some alternative prevention strategies are presented. The results section describes the economic consequences of these strategies, based on the integrated approach. The last section of the paper evaluates the method and its results and offers suggestions for further research.

7.2 MATERIAL AND METHOD

An essential prerequisite for the evaluation of disease prevention strategies is insight into introduction and spread of virus and economic consequences of outbreaks. Figure 7.1 visualizes this process. The impact of a strategy on 'introduction', 'spread' and 'losses' determines its attractiveness. If all three elements are included in the simulation model, the user has the possibility of 'experimenting' with alternative strategies in a risk-free way, i.e., determine a new set of input values, run the model and evaluate the outcomes. The various parts of the integrated approach presented in Figure 7.1 will be summarized in the next sections.

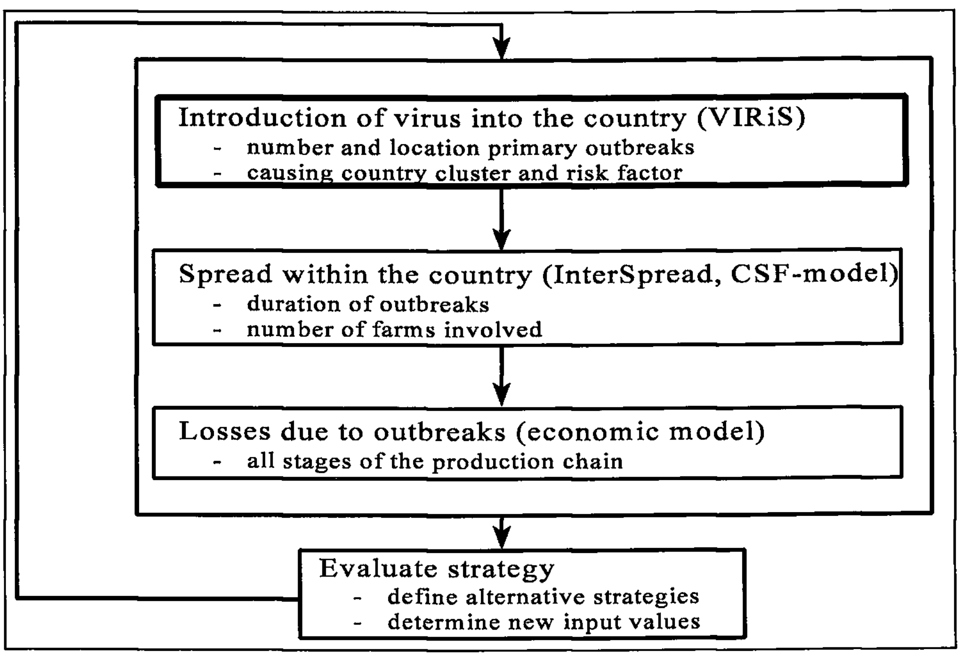

Figure 7.1
Schematic representation of the integrated approach.

7.2.1 Introduction of virus into the country

The Monte Carlo simulation model VIRiS simulates the introduction of a virus into the Netherlands, originating from outbreaks in other European countries. Three major aspects determine such an introduction risk:
1) Frequency of outbreaks in European countries;
2) Duration of the High Risk Period in European countries;
3) Risk Factors.

Frequency of outbreaks in European countries
Most of the time, the Netherlands is free of CSF and FMD, and introduction of virus of either one of these diseases is caused by an outbreak in another country. Therefore, a higher frequency of outbreaks in countries with which the Netherlands is involved in any kind of relationship (e.g. trade) results in a higher introduction risk tor the Netherlands.

Duration of the High Risk Period
The High Risk Period (HRP) defines the period in which virus is already present in a country but not yet detected or under control. During this period virus might be transferred to another country. The HRP can be divided into two periods:
HRP1: starts when a first animal is infected, and ends when an infected animal is detected
HRP2: starts with first detection, and ends when all measures are considered effective (i.e., no risk of spread to other regions or countries)
The duration of HRP1 depends on the alertness and motivation of farmers and veterinarians and the effectiveness of any monitoring system (if available). HRP2 is determined by the efficacy of the animal health system of the affected country.

Risk factors
During the HRP the virus might be transferred to another country by means of risk factors, which are defined as 'virus vehicles'. Examples of risk factors are: import of livestock, import of animal products, and returning trucks (empty trucks, used for export of animals, now returning to their home country).

The model VIRiS is based on historical and experimental data, if available and applicable. However, outbreaks of CSF and FMD occur irregularly in time and place, making it difficult to derive general properties and predictive values. Therefore, expert knowledge was needed and used as an additional source of information (Horst et al., 1997a).

VIRiS uses the technique of Monte Carlo simulation. This type of modelling uses randomly drawn numbers from specified probability distribution functions and therefore acknowledges the fact that there is variation and uncertainty in the system to be modelled (Kleijnen and Van Groenendaal, 1992). When such a Monte Carlo model is run repeatedly, the distribution of output values will realistically reflect the possible behaviour of the system under study.

The VIRiS model has a time-step of one day and a time horizon of 5 years. The model starts with sampling for new outbreaks in Europe. For pragmatic reasons, these countries were grouped into clusters describing the various parts of Europe. If an outbreak in one or more of these country clusters is sampled, the virus is 'followed', taking into account aspects such as HRP and importance and volume of risk factors, until a possible introduction into the Netherlands. Distribution functions based on quantitative information concerning epidemiology, farm density, and trade flows determine the geographical location of the possibly resulting primary outbreaks in the Netherlands. Number, location (North, East, South, West), and cause (cluster and risk factor) of these outbreaks are stored by the simulation model for each run. The time-steps, or 'days', are linked to each other in order to simulate realistically the evolution of outbreaks. After 365 days, 'year'-results are calculated. After 5 years, total results are calculated. Running a repeated number of those 5-year periods provide the user with a distribution of possible outcomes. For a more detailed description of the VIRiS model, the reader is referred to Horst et al. (1997b).

7.2.2 Spread within the country

FMD-model

InterSpread is a spatial and stochastic simulation model that simulates from day to day the spread of FMD between farms within a certain area (Jalvingh et al., 1996 and 1997). Starting point of the simulation is infection seeded to an individual farm. Via different mechanisms (animal/people/vehicle movements; local spread by dogs, cats, and vermin; airborne transmission) the infection can be spread to other farms, and if infected the disease spread is simulated for these farms as well. Once the first infected farm is diagnosed, several control mechanisms can be put into place such as tracing, surveillance, movement-control, pre-emptive slaughter, and vaccination. The geographic location of individual farms is used in simulating disease spread and its control.

Like VIRiS, InterSpread is also a stochastic simulation model. The main output results of the model are the probability distribution of the number of infected farms, the duration of outbreaks (in days), and the number of farms that face movement restrictions.

CSF-model

Saatkamp (1996) developed a state-transition model (also referred to as the Markov-chain approach) to describe the spread of CSF among individual farms after a primary outbreak in Belgium. The model could easily be adapted to Dutch circumstances. The model characterizes herds in a population, using four disease states: (1) susceptible (herds that can be infected), (2) carrier (herds that have been infected but do not spread the virus yet to other herds), (3) outbreaks (herds that spread virus and thus can infect susceptible herds), and (4) removed (herds that have been slaughtered). Besides these, the model simulates the so-called blocked herds, which are situated in either a protection or surveillance zone and are subject to transport restrictions. An important transition probability in the CSF state-transition model is the probability of becoming infected. This probability describes the spread of the disease and is simulated in a dynamic way, using the following formula:

$$P_{infected,t} = 1 - e^{-DRtot(t-1)*Fou(t-1)}$$

In this formula, DR_{tot} represents total dissemination rate of CSF, being the average number of susceptible herds becoming infected by one affected herd. F_{ou} is the fraction of outbreaks in the population, and t is the time step (two weeks). The dissemination rate is one of the most important parameters of the model and is influenced by demographic factors of the region under study and the effect of prevention and control strategies (based on expert opinion).

The results of the CSF model provide probability distributions for the number of infected herds, the number of herds affected by pre-emptive slaughtering and movement restrictions, and the duration of the outbreak (in weeks).

7.2.3 Losses due to outbreaks of CSF and FMD

As probabilities are always difficult to interpret, enhanced insight into the significance of the results of VIRiS and the spread models might be obtained by calculating their economic consequences. The economic effects were calculated for both CSF and FMD outbreaks in the Netherlands, including all stages of the production chain. Five categories of losses were distinguished (Meuwissen et al., 1997):

1) Losses due to slaughtering of infected herds;
2) Additional losses, due to movements restrictions and production standstill on infected farms, supply problems for the processing industry, etc.;
3) Costs of market support of the so-called 'purchase measure': government purchase and

destruction of pigs from farms located within the restriction zones where animal movements are prohibited: the government buys fattening hogs and piglets to avoid welfare problems; Because the meat cannot be transported, the animals are worthless and are therefore killed and destroyed;

4) Organizational costs of disease eradication;
5) Trade losses, due to export bans causing market and price disruptions.

As market behaviour is extremely difficult to predict and quantify, the last category, trade losses, was not included in the calculations.

The calculations were performed in close cooperation with representatives of the respective stages of the production chain in order to obtain good estimates.

7.2.4 Alternative strategies

The initial or default scenario of VIRiS, alternative 1, describes the current situation in the Netherlands, based on literature and expert opinion. In this situation, 1 primary FMD outbreak and 2.5 primary CSF outbreaks are expected to occur in a five-year period (Horst et al., 1997a). Primary outbreaks and their resulting epidemics are eradicated according to minimal EU-standard measures. The prevention strategy used in this scenario is the strategy currently applied in the Netherlands, i.e., import of animals and animal products is only allowed from countries holding a disease-free status, trucks used for export of animals have to be cleaned and disinfected before re-entering the Netherlands, swill feeding is not allowed, and farmers, animal traders and animal transporters have to obey certain sanitary protocols.

This default scenario serves as a comparison standard. Besides, the scenario could be used when outbreaks occur in countries neighbouring the Netherlands and policy makers need insight into the risks to the Netherlands at that moment. VIRiS provides an estimate for the daily probability of outbreaks in the Netherlands, due to outbreaks elsewhere. Combining this daily probability with an estimate of the duration of HRP1, i.e. an estimate of the interval (in days) during which the virus has the opportunity to spread freely (not detected), and economic consequences due to outbreaks in the Netherlands, might add to the discussion on what measures are to be taken within the Netherlands when an outbreak is detected somewhere else in Europe. In the results section this potential use of the model will be illustrated with CSF.

Based on discussions with people involved in policy-making concerning disease prevention and control, alternative prevention strategies were defined for both VIRiS-CSF and VIRiS-FMD. All other parameters were held equal, i.e., the consequences of primary outbreaks, once they occurred (secondary spread), were equal to those in the initial situation.

A seemingly straightforward method to reduce the number of primary outbreaks of FMD and CSF in the Netherlands is to reduce the risk associated with the risk factors, i.e., deprive the virus of its means of transport. For both diseases, the effect of elimination of the risk factors 'import of livestock' and 'returning trucks' was evaluated. For FMD, import of livestock could be divided into import of cattle and import of other livestock. For CSF also the elimination of the risk factor 'swill' was evaluated.

Discussions with experts made clear that much uncertainty exists about the risk associated with the upcoming trade and other contacts with the countries of eastern Europe. Therefore a strategy was evaluated in which the importance of these countries was multiplied by 3.

7.3 RESULTS

7.3.1 Default scenario

Introduction of CSF and FMD

In the VIRiS default scenario, the most likely areas in the Netherlands for a primary CSF-outbreak are the southern and eastern parts (both approximately 37%). Fewest outbreaks are expected in the northern and western parts, 10 and 16% respectively. For FMD, most outbreaks are expected in the eastern part (41%). In the southern, western and northern part the expected percentage of primary outbreaks is 31, 15 and 13% respectively.

In Table 7.1 it is shown that with these probabilities there is a high correlation between the animal and farm densities of the respective areas, which is due to the great influence of the risk factor 'import of livestock'. About 50% of the primary FMD outbreaks in the Netherlands are caused by this risk factor. Also for CSF, import of livestock is the most important value. However, other risk factors are important as well, which makes the distribution of outbreaks over regions not completely correlating with animal density. A risk factor such as 'swill feeding' influences mostly region west, because the majority of Dutch airports and seaports are in this region.

Most outbreaks of both diseases originate from southern European countries and countries neighbouring the Netherlands.

Table 7.1
Animal and farm densities of the Dutch regions

	South	East	North	West	Netherlands
FMD					
swine (*10^5)	82.8	48.7	6.0	8.1	145.7
swine/km^2	1 135	573	48	72	367
swine farms/km^2	1.2	1.3	0.1	0.3	0.6
cattle (*10^5)	11.4	17.8	10.9	7.1	47.2
cattle/km^2	156	209	87	62	119
cattle farms/km^2	1.7	2.7	1.0	1.0	1.5
CSF[a]					
swine (*10^5)	82.8	53.1	6.0	3.8	145.7
swine/km^2	1 784	818	78	75	611
swine farms/km^2	1.9	2.0	0.1	0.3	1.0

[a] The CSF model uses the 'agricultural area', and slightly different definitions for regions West and East

Spread within the country

Table 7.2 presents some results of both 'spread models' for the default scenario, in which, as explained, the minimum EU-control strategy is applied. The results describe the effects of a primary outbreak, i.e., the secondary spread, for each of the four regions in the Netherlands (North, East, South, West), which were used in the VIRiS model (Table 7.1).

Table 7.2
Consequences of FMD and CSF epidemics in the Netherlands (by region)

	FMD			CSF		
	5%	50%	95%	5%	50%	95%
South						
- duration[a]	39	51	69	79	135	303
- # affected farms[b]	1100	3803	7213	784	1005	1332
East						
- duration[a]	42	58	74	79	135	303
- # affected farms[b]	1572	4793	9085	769	1041	1385
North						
- duration[a]	32	48	61	65	79	79
- # affected farms[b]	306	1019	2258	48	54	56
West						
- duration[a]	38	45	63	65	79	121
- # affected farms[b]	407	1177	2850	97	112	125

[a] Starts when first measures are taken, ends when all measures have been cancelled (in days)

[b] Number of farms affected by movement restrictions on average per day

Largest epidemics of CSF and FMD are expected to occur in the southern and eastern regions of the Netherlands. As expected, the severity of epidemics is closely related to animal and farm densities of the area involved. In general, CSF epidemics last longer but involve fewer farms.

Losses due to outbreaks

Table 7.3 presents the 5, 50, and 95 percentile values for the losses due to epidemics of FMD and CSF. The percentile values present the distributions that were calculated using the 'spread models', described above and presented in Table 7.2. The value for the Netherlands as a whole was calculated combining the losses per region with the distribution of primary outbreaks over regions, provided by VIRiS. The table shows that the 50% percentile value for losses from a FMD or CSF-epidemic is approximately US$ 70 million.

Table 7.3
Losses due to CSF and FMD in the Netherlands, per epidemic and per year (million US dollars)

	South	East	North	West	Netherlands	Annual losses
FMD						
- 5%	25.9	16.5	1.3	1.6	15.2	3.0
- 50%	118.9	78.9	6.8	5.7	70.9	14.2
- 95%	215.0	135.0	19.2	17.1	127.1	25.4
CSF						
- 5%	47.4	24.8	0.6	2.1	27.1	13.5
- 50%	117.4	64.7	0.8	3.2	68.0	34.0
- 95%	293.8	165.8	0.7	5.8	171.1	85.5

The last column of the table presents the annual losses. Comparing Table 7.3 with Table 7.1 shows that a high density of animals and farms results in high losses due to outbreaks, as could be expected. In general, CSF incurs higher losses than FMD, mainly due to the fact that CSF outbreaks last longer (Table 7.2), which means that losses due to the purchase measure are higher. This category of losses makes up for almost two thirds of the 50%-value. The categories 'slaughtering of animals from infected farms', 'additional losses' and 'organizational costs' account for US$ 1.5, 15.7 and 4.8 million respectively, when considering the median point.

The differences between CSF and FMD are even greater when the losses are considered on an annual basis, due to the differences in expected frequency of primary outbreaks (1 and 2.5 per 5-year period, for FMD and CSF respectively).

CSF outbreaks in European countries, risk to the Netherlands

In case an outbreak occurs in, for example, one of the countries surrounding the Netherlands, the initial scenario provides insight into the risk to the Netherlands. The VIRiS results show that when one of the countries surrounding the Netherlands suffers from a CSF outbreak, this causes during HRP1, i.e. during the period that the virus is not yet detected and thus able to spread freely, a daily probability of primary outbreaks in the Netherlands of 0.155% (Table 7.4). Taking into account the expected duration of HRP1 in this country group (Horst et al., 1997a), the total probability that the virus has already been transferred to the Netherlands before the initial outbreak is detected (and HRP1 ended) equals 4.3%. Although by then it might be too late to prevent such an outbreak, there is still a lot to be gained by reducing the resulting epidemic to a minimal size. As Table 7.3 showed, the difference between a small (5%-percentile) and median (50%-percentile) CSF epidemic is about US$ 40 million. To put it differently, the financial window available for measures able to reduce such a potential CSF epidemic to a minimal size, is approximately 4.3% * US$ 40 million = US$ 1.7 million.

Table 7.4

Probability of CSF introduction into the Netherlands, by day and by HRP1, during outbreaks in Europe, and the associated potential 'financial window' formeasures aimed at keeping the epidemic at a minimum size.

	Prob./day	HRP1	Prob/HRP1	Financial space[a]
Neighb. countries	0.0015	28	0.043	1.75
S-Europe.	0.0022	35	0.077	3.16
C-Europe	0.0005	28	0.014	0.57
E-Europe	0.0001	42	0.006	0.23
Islands	0.0002	21	0.004	0.15

[a] Financial window: probability that virus has already been introduced into the Netherlands multiplied by the difference in losses between a small and a median (50%-percentile) sized outbreak

Table 7.4 presents the results of such calculations for all country groups. The HRP1 values are the median values (50%-percentiles) of the distributions incorporated into the VIRiS model, which were based on research by Horst et al. (1997a). The table shows that the financial window for measures aimed at reducing the size of potential outbreaks is largest when the potential source is one of the countries of southern Europe, which is due to the high daily probability of virus transfer and long duration of HRP1 in these countries.

7.3.2 Alternative strategies

Tables 7.5 and 7.6 present the results of the default (which is the current) and some alternative prevention strategies, for both FMD and CSF. The calculations were based on the losses distributions, presented in Table 7.3.

Table 7.5
Number of FMD epidemics and corresponding losses per year, current and alternative strategies, median values (50%-percentiles).

Scenario	outbreaks/year	losses/year (million US$)
Current strategy	0.2	14.2
Eastern Europe*3a	+ 0.10	+ 7.1
Elimination of risk associated with:		
-import of cattle	- 0.064	- 5.6
- import of other livestock	- 0.034	- 4.7
- returning trucks	- 0.056	- 4.7

[a] Importance of Eastern Europe multiplied by 3

Table 7.6
Number of CSF epidemics and losses per year, current and alternative strategies, median values (50%-percentiles)

Scenario	outbreaks/year	losses/year (million US$)
Current strategy	0.5	34.0
Elimination of risk associated with:		
-import livestock	- 0.28	- 24.6
- feeding of swill	- 0.10	- 12.9
- returning trucks	- 0.08	- 4.3

Table 7.5 shows that the magnitude of trade contacts with Eastern European countries has a considerable effect on the number of primary FMD outbreaks in the Netherlands. As could be expected, eliminating the risks associated with the most important risk factors according to the VIRiS model, i.e., import of livestock, results in the highest reduction in losses. For FMD, eliminating this risk results in a reduction of more than US$ 10 million, for CSF the potential reduction amounts to approximately US$ 24.6 million (Table 7.6), both are reductions of approximately 70%. Because the effect of the elimination of a risk factor is not the same for all regions in the Netherlands, the distribution of outbreaks over regions is influenced, which, of course, also influences the share of each region in the total amount of

losses. Thus, for example, eliminating the risk associated with import of cattle results in 32% less primary FMD outbreaks but almost 40% less annual losses due to such outbreaks.

7.4 DISCUSSION AND CONCLUSION

The analysis of consequences of European outbreaks for the Netherlands, shows that a considerable financial window is available for measures aimed at minimizing the size of a potential outbreak. As the import of livestock is the major source of virus introduction, tracing animals that entered the country during HRP1 might be one of the options. A reliable Identification and Recording (I&R) system will enhance and simplify tracing those animals.

The analysis also shows the strong impact of the HRP1s of European countries on the Dutch total risk of virus introduction. Expert estimates derived by Horst et al. (1997a) as well as evaluation of recent outbreaks (Terpstra, 1996) show large variation for HRP, indicating that measures aimed at reducing the duration of this parameter, such as monitoring systems and extension programmes, might pay off easily. The results also lead to the conclusion that helping other countries reducing their HRPs has a potentially positive effect on the introduction risk in one's own country, which makes the eradication and control of contagious animal diseases an international issue.

The analysis of alternative strategies (Table 7.5) shows that the Eastern European countries have a considerable potential impact on the number of primary FMD outbreaks in the Netherlands, which is explained by the high frequency of outbreaks and the long duration of the HRP expected in these countries (Horst et al., 1997a and 1997b). In the current (default) situation, (trade) contacts between the Netherlands and these countries are minimal, therefore only a minor effect on the Dutch total risk of virus introduction is observed. However, as every contact as such involves a high risk of virus transfer, the total effect rapidly increases when the number of (trade) contacts increases.

Elimination of the risk associated with risk factors is a straightforward method to reduce the losses due to epidemics. The results show that complete elimination of the risk associated with the factor 'returning trucks' reduces the annual losses due to FMD and CSF epidemics by more approximately US$ 9 million. This amount might be seen as the financial window available for the realization of measures which are able to achieve complete risk elimination for this factor. Of course, a zero risk situation will be hard to obtain, but measures such as intensification of control and realization of more cleaning and disinfection centres will contribute to reduction of the risk.

To conclude: the study showed that the integration approach provides a powerful tool to evaluate the results of the VIRiS model. Integration has a synergic effect: the information provided by the integrated approach is more useful than the information provided by all models separately. This study was aimed primarily at the evaluation of the benefits of several prevention strategies, in terms of risk reduction. The same integration of models could be used to evaluate the benefits of various control strategies. However, calculating and quantifying risk and risk reduction associated with the various strategies do not tell the whole story. In some cases the expected profits of accepting a certain risk (i.e., trade with Eastern European countries or import of live animals) might outweigh the expected losses. Research on this aspect would be a logical further step in the project.

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Chapter 8

GENERAL DISCUSSION

8.1 INTRODUCTION

The research described in this thesis focused on the risk and economic consequences of the introduction of contagious animal disease into the Netherlands, in particular Classical Swine Fever (CSF) and Foot-and-Mouth Disease (FMD). First the problem under study and the materials already available were reviewed in order to develop an integrated approach (Chapter 2). The review showed that especially information and insights as to the introduction of virus into a country were lacking. Therefore, the project was directed towards the development of a simulation model describing the introduction of virus. As more objective and quantitative information on aspects concerning virus introduction was only scarcely available, additional and more subjective information to base the proposed simulation model upon was required and therefore obtained from experts. In order to collect this information in an objective and quantitative way, various questionnaire techniques were evaluated and combined within a computerized design, with which a selected group of Dutch experts was confronted during a full evening's workshop. One of the techniques included in the questionnaire was the so-called Conjoint Analysis method. Chapter 3 described a pilot experiment with this method, aimed at the elicitation of the relative importance of risk factors which could be responsible for the introduction of virus into a country. The pilot experiment showed positive results and was used to frame the set-up of the Conjoint Analysis element of the final questionnaire. Chapter 4 evaluated the use and results of this final Conjoint Analysis experiment. Chapter 5 was devoted to the description and analyses of the entire expert workshop and evaluates in detail the set-up, techniques used and results obtained. Together with quantitative data obtained from databases and literature, these results were used as input for the Monte Carlo simulation model VIRiS (Virus Introduction Risk Simulation). VIRiS simulates the introduction of virus into the Netherlands. Chapter 6 described the structure and behaviour of the VIRiS model. In Chapter 7 the focus of the project has been directed back towards the original aim of the study; the integration of epidemiology and economics as a tool to support policy-making on disease prevention. Insights and results obtained by VIRiS were combined with outcomes of models describing the spread and economic consequences of epidemics. In this way alternative prevention strategies were evaluated on their ability to reduce the losses due to epidemics. In this general discussion experiences and outcomes of the research are reviewed and discussed. The discussion focuses on the use of expert opinion, the modelling approach applied, and the application of the approach and the results. Finally, the main conclusions of the entire study are given.

8.2 USING EXPERT OPINION

When 'objective' data sources such as databases and scientific literature are not able to provide sufficient information for policy-making and the performance of additional experiments is not possible, turning to experts might be a sensible (if not the only available) option. The choice for the appropriate method to translate the experts' subjective knowledge into quantitative information which accurately presents the experts' views and is useful for modelling purposes is a difficult one. As the appropriateness of the elicitation method depends on the nature of the problem, various techniques were needed in order to cover all aspects of virus introduction, among others Conjoint analysis and ELI.

8.2.1 The workshop approach

Because the number of people with useful expertise was considered to be limited, major attention was given to the motivation issue. The question 'how to involve the maximum number of experts?' played a major role in the decision for the set-up of the elicitation experiment. The pilot experiment described in Chapter 3 showed that a paper questionnaire was not the appropriate method to obtain a high response. The workshop approach, described in Chapter 5, proved to be much better in this respect. Such a workshop is a one-off group meeting, which means that the participants have to show up only once and have the possibility of discussing issues with other experts; both aspects may be attractive.

Major attention during the workshop was given to the completion of a questionnaire on the PC by the participants. The choice for such a computerized, self-explanatory questionnaire including several elicitation techniques proved to be fruitful. In a relatively short time-span much information was obtained from a group of experts, but without group biases. The large quantity of information obtained can be explained by the highly structured nature of such a questionnaire which ensures that answers to all questions are obtained. To get such a result is more difficult when using, for example, group discussions. However, the individual approach does, of course, not allow inclusion of possible advantages of group discussions, such as new ideas emerging from interaction (synergy). As the questionnaire ought to be completed individually, it enables an individual approach of each expert instead of organizing a group session. It will even be possible just to provide the experts with the diskette including the questionnaire and allow them to go through it at any convenient moment. However, such a procedure reduces the level of control and may also decrease the level of response.

A self-explanatory questionnaire simplifies knowledge elicitation but can only be developed when the information to be elicited can be translated into clearly structured, unambiguous questions, easy to understand and of a closed form. The usefulness of the approach is therefore related to the problem under study. When, for example, one has to elicit information for an expert- or knowledge-based system and is therefore interested in the underlying reasoning process of the expert, individual, face-to-face in-depth interviews may be a more useful approach (see, among others, Turban, 1990).

8.2.2 The elicitation techniques

The workshop experiment showed that it can be beneficial to keep an open mind to the developments in other research areas. In the computerized questionnaire several methods were used that were new to the area of animal health economics, but not to other research areas. The method Conjoint Analysis is well known in the area of marketing and consumer research. ELI was developed in the area of mathematical psychology.

8.2.2.1 Conjoint Analysis

In the area of marketing and consumer research, Conjoint Analysis is used to quantify the subjective ideas and preferences of consumers (Green and Srinivasan, 1978). Elicitation of expert knowledge might also be evaluated as the quantification of the subjective ideas of experts. The results presented in Chapter 3 show that the parallel worked out alright and that the method resulted in useful information for computer simulation modelling. A major advantage of Conjoint Analysis over more direct approaches is that the approach confronts the participants with a more realistic situation, i.e., questions are asked about combinations, as is the case in the real world. Moreover, the technique allows an easy check on the consistency of experts' answers. Such a check cannot be used to judge the quality of the participating experts, as also lack of motivation or misunderstanding of the task may cause inconsistency. However, inconsistency does indicate inferior quality of the information elicited and might be used to judge which estimates are to be used in further research.

Conjoint Analysis was evaluated to be a useful addition to the toolkit of the animal health economist. However, the method has its limitations. Conjoint Analysis is only applicable to problems that can be defined as 'events and attributes'. Moreover, the resulting estimates have limited reliability when based on individuals. Reliability increases when the experts can be referred to as one group and aggregate estimates can be calculated. The latter was the case in the experiment described in this thesis (Chapter 4). If such a clustering is not possible, sub-groups must be formed, which has implications for the interpretation of the results. If there is any reason to weigh experts' opinions individually, or in sub-groups, the importance of this weighing might outweigh the lower reliability of Conjoint Analysis estimates on individual or small-group basis. Section 2.2.3 deals with this issue in more detail.

8.2.2.2 ELI

The ELI (ELIcitation)-program (Van Lenthe, 1993) provides an attractive technique to help participants produce subjective probability density functions (PDFs). It provides a tool easy to understand to elicit quantitative information and was used in this thesis to elicit opinions of experts on, among other things, the number of epidemics expected to occur in various European countries within the next 5 years.

A disadvantage of the current ELI-version is that there are limitations on the shape of the curve which the participants have to manipulate. Such limitations might frustrate the participants and reduce their motivation to cooperate. Furthermore, the limited number of distributions might reduce the reliability of the results, i.e., it is questionable if a normal distribution is the correct approach to describe the number of CSF-outbreaks expected to occur within the next 5 years. A lognormal distribution may be a more appropriate option. Another disadvantage is that questions asking for very small probabilities are usually difficult to answer by the respondents, as the difference between 0.00005 and 0.0005 is hard to imagine (see, among others, Hardaker et al., 1997).

The additional value of ELI is in the training questions. The training informs the participant on his or her level of knowledge about the issue at hand which should result in less over- and under-confidence bias. However, as no 'Golden Truth' was known about the questions asked in the workshop experiment (for example, the number of FMD-outbreaks in Southern Europe within the next 5 years), this claim could not be evaluated.

ELI provides distribution parameters describing the PDFs elicited. If ELI is used for a group of participants and one is interested in the overall assessment, special attention should be given to the combination of the individual distributions (Chapter 4). Combining a large number of random drawings from each of the individual distributions will provide an interesting graphical insight into the overall distribution. Including such a procedure into the ELI-software would make the program even more attractive for use in knowledge elicitation. The overall distribution might be translated into its parameters, using one of the many commercially available curve-fitting software packages. However, a dangerous pitfall in using such software is that the user may accept the distribution with the best fit as being the distribution that describes the data best, without critically reviewing the appropriateness of the goodness-of-fit criteria used (evaluating, for example, how much emphasis is placed on the fit of the tails) and the features of the distribution suggested (for example, possibility of occurrence of negative values).

8.2.2.3 Weighing expert opinions

If the cluster analysis on, for example, the results of a Conjoint Analysis experiment shows the existence of sub-groups, this might lead to the conclusion that several 'camps' exist, within the group of consulted experts. If the results are used in simulation modelling, sensitivity analysis may be used to evaluate the importance of existence of such camps. Do the different opinions really lead to different results, i.e., different decision outcomes? If that is the case, thorough evaluation of the possible reasons behind these different opinions is essential. One might conclude that some experts are 'better' than others because their background provide them with more appropriate knowledge about the issue at hand. For example, questions on the duration of high risk period 1 (HRP1, i.e., the interval between infection and detection) may result in more reliable estimates when answered by a person with a background in research on that specific disease than by one with a background in policy-making. An important aspect determining the duration of HRP1 is the clearness of clinical symptoms, which might be known better by veterinary researchers than by policymakers. Such 'research' experts might be given more weight when combining the estimates assessed on this particular subject.

However, weighing experts will always be arbitrary as, in absence of any validation data, it is very difficult to judge the 'expertness' of the expert. Many researchers have studied this issue and have proposed various complex variations on the idea of simply using the average of the values assessed. An interesting review has been given by Von Winterfeldt and Edwards (1988). They describe several combination methods but conclude that simply averaging is still a good option. Also in this study all experts were treated equally. However, if one has sound grounds on which to distinguish the experts on their 'expertness', using this information will enhance the quality of the final estimates and it

seems not more than wise to use different weights in such situations.
An interesting approach is proposed by Goossens and Cooke (1997) who ask their experts to provide PDFs for known quantities and use the 'correctness' or 'calibration' (high statistical likelihood) and 'informativeness' (width of the curve) of the answers as basis for weighing. Actually, this method is very similar to the ELI-method used in the workshop and described in Chapter 5. However, the ELI-program uses the questions involving known quantities only to familiarize the experts with the program and to give them feedback about their own level of knowledge in order to reduce over- and under-confidence bias. The potential use of the ELI-training results as a 'weighing tool' is an interesting topic for further research.

8.3 MODELLING APPROACH

8.3.1 The simulation model VIRiS

A simulation model is a useful tool for studying the consequences of alternative strategies to prevent introduction of contagious animal diseases. The major advantage of such a model is its time-saving property, i.e., a simulation model is able to account for the fact that it often takes years before the full consequences of a certain, usually costly, strategy are apparent. An important property of the VIRiS model is its flexible structure which allows easy updating to new information and insights. Because the model is partly based on subjective knowledge and estimates, this property should not be evaluated as a nice 'extra' but as a necessity which enables the model to include always the best information available. It also recognizes the fact that the model, as every model by definition, is not perfect and that improvements are always possible.

The Monte Carlo technique used in the VIRiS model provides the user with distributions of the outcomes. These distributions show the most likely as well as the worst and best case situations. In fact, such outcome distributions reflect uncertainty involved and also allow for non-neutral risk attitudes. Several authors have studied uncertainty and tried to define its sources, among others Finkel (1990) and Morgan and Henrion (1990); however, no agreement on definitions seems to have been reached thus far. In this study uncertainty might be introduced by the fact that many of the parameters are at a high level of aggregation. For example, the duration of the HRP involves aspects such as the clearness of the clinical symptoms, which is correlated with the virulence of the virus strain involved. As both FMD and CSF have more virus strains, an aggregate description of the

HRP will be a distribution. In principal such 'aggregation uncertainty' might be reduced by obtaining information for each strain separately (for example by performing experiments). However, such detailed observations might also introduce extra uncertainty due to imprecision of the measurement procedures, i.e., imperfections in measuring instruments and observational techniques. Another source of uncertainty relates to the representation of the mechanisms under study and involves, for example, the uncertainty about the choice for (in)dependency among variables or the choice for a certain distribution. Such 'model uncertainty' might be reduced by further analysis of the problem to be modelled. However, one might argue that all uncertainty can be reduced by splitting up the original problem into increasingly smaller parts, performing more experiments and developing better measurement procedures. Following that line of thinking, reducing uncertainty is limited solely by the availability of time and research capacity (knowledge, material, etc.). For example, the current VIRiS model involves uncertainty about several aspects of virus introduction because expert estimates were used. Experiments were not a feasible option and carefully elicited expert estimates produced the least uncertain input available at the time of development. However, when, in the future, field data and/or experiments do become a feasible option, these results can replace the estimates and reduce the total uncertainty related to the model.

8.3.2 The integrated approach and the link to risk analysis

According to many authors, *risk assessment* belongs to the basics of risk analysis (among others, Ahl et al., 1993; Morley, 1993). Ahl et al. (1993) define risk assessment as 'the process of identifying a hazard and evaluating its risk, either in absolute or relative terms'. In this definition, the development of the simulation model VIRiS is a risk assessment study. Most risk assessment studies published thus far, describe in detail the possible risks connected to the import of a single commodity, such as 'garbage from Alaska cruise ships' (McElvaine et al., 1993), 'green hides' (MacDiarmid, 1993) or 'bovine embryo transfer' (Sutmoller and Wrathall, 1995). These studies analyse in detail the pathway of the commodity under study, from origin to destiny, and quantify the risk of disease transfer at every step of that pathway. Compared with such studies, the VIRiS approach is aimed at a much higher level of aggregation, making 'bigger steps' and taking into account groups of commodities instead of single products. The more aggregated, more 'rough' approach might introduce some (unknown) amount of error (although it is also possible that such an integrated approach involves less error than the cumulation of very detailed approaches). However, the advantage of the VIRiS approach is that it enables an overview of the whole problem area and provides insight into the economic importance of the various risk factors and countries, compared with each other. Such insights may be sufficient to base the framework of prevention policies upon and may also help to prioritize research aimed at a more detailed level of risk assessment, i.e., the level of a single commodity of single country. If such detailed studies become available, they can be incorporated into the VIRiS model and may enhance the quality of the model outcome.

The risk assessment studies having been published thus far, normally end with a statement about the probability of introducing the disease into a certain amount of the commodity (kilograms of garbage, number of hides) or within a certain period. The usefulness for policymakers, which may not be probability experts, of such an abstract representation might be questioned, the more so because the probabilities involved are usually very small numbers. Even MacDiarmid (1993), who states that risk assessment ought to examine the *effect* of the introduction of an exotic animal disease, presents the results of one of his studies as 'the probability of introducing anthrax by the import of green hides in any one year is 7.72 * 10-7 '.

In this thesis, an attempt was made to translate the outcome of a risk assessment study into less abstract terms, i.e., in monetary values or the economic consequences due to outbreaks. To achieve this goal, an integrated approach was necessary (developed in Chapter 2, applied in Chapter 7). The integration of introduction, spread and economics provided a 'complete tool' for the evaluation of prevention strategies. The approach has a synergic effect, i.e., the combination of models is more useful than the sum of the separate models. In this thesis the approach was used to evaluate alternative prevention strategies. The same approach might be used to evaluate other parts of the 'integration chain', for example, to evaluate alternative eradication measures.

8.4 APPLICATION AND RESULTS, NOW AND IN THE FUTURE

According to the definitions given by Ahl et al. (1993), *risk analysis* is 'the process which includes risk assessment, risk communication and risk management'. As described above, the main part of the thesis covered the risk assessment aspect of risk analysis, i.e., the evaluation of the risk (expressed as annual economic consequences) of introduction of FMD and CSF into the Netherlands. However, also *risk communication*, defined by Ahl et al. (1993) as the 'open two-way exchange of information and opinion about risk', and *risk management*, defined by the same authors as the 'decision-making process of identifying and implementing measures which can be applied to reduce the risk and document the final decision' were part of the project. The risk communication part is covered by extensive discussion meetings with policymakers and researchers on model input and results. The insights obtained by the project are useful for the evaluation of alternative strategies aimed at risk reduction and may serve as material for risk management.

The results presented in Chapters 6 and 7 showed that import of livestock is the major cause for primary outbreaks of CSF and FMD in the Netherlands. As, within the EU, checks on imports at the individual country borders are no longer safeguards for the health of livestock to be imported have to be provided by the country (i.e., farm) of origin. Therefore, measures aimed at the reduction of the risk associated with those imports have to be organized at EU-level, which makes animal disease prevention an international issue. The strong impact of the HRP on the total probability of virus transfer (Chapters 6 and 7) emphasizes this international aspect. The more so because reducing the HRP at the European level will not only benefit the Netherlands but all other European countries as well. Moreover, HRP-duration influences not only the spread between, but also within countries. Reducing HRP will reduce the size of the epidemic. Tracing animals imported from a country that is in the HRP may help to detect epidemics at an early stage. The tracing process will be simplified if I&R (Identification and Recording) data are internationally exchangeable. Shorter HRPs might be realized by improvement of disease monitoring and eradication systems. An essential element might be the compensation earned by the farmer whose diseased animals are to be destroyed. Sufficient compensation will enhance farmers' motivation to report suspected animals. The high variation found in the duration of HRPs of recent outbreaks (Terpstra, 1996) leaves room for the improvements suggested above. An important element of any risk-reduction program on introduction and spread of contagious animal diseases will be risk communication at farmers' and veterinarians' levels, a topic which has not been covered in this project thus far. Risk perception and risk attitude of farmers and veterinarians may have a strong impact on the potential spread of virus, as it influences their motivation to practise serious risk management. The results show a substantial economic window for measures at national level, such as measures aimed at the reduction of risks associated with re-entering livestock trucks. More legislation, intensification of control, and more disinfection and cleaning facilities are obvious methods to reduce this risk. However, the outcome of the integrated model presented in this study only provides the raw material for the evaluation of the cost-effectiveness of prevention strategies. The analysis of the elimination of risk factors, for example, was based on a very black-and-white and not very realistic all-or-nothing situation. In order to pass a final judgment on the value of specific measures, insight into their specific effectiveness, including their implementation costs, has to be obtained. The

results of this study may be used to prioritize such further research efforts.
This thesis presents the risk and economic consequences of contagious disease outbreaks, under current and alternative prevention strategies. But that is only one side of the picture. No insight is given into the benefits of the current strategy and therefore it is difficult to decide whether or not certain risks are acceptable. If information on the benefits was available, a risk-neutral decision maker could decide on the acceptability of the risk, simply by multiplying the probability of occurrence of outbreaks (risk) with the economic consequences of such an event (Hardaker et al., 1997). The study was aimed at disease prevention at a governmental level and according to some authors (Little and Mirrlees, 1974) governments should be risk neutral. However, Dijkhuizen et al. (1994) note that risk neutrality at governmental level is jeopardized when the consequences are not evenly spread among the population, and when the consequences are very large. The outcomes of this study therefore suggest that policy decisions on contagious animal diseases should be based on a risk-averse attitude. Moreover, the recent serious CSF epidemic in the Netherlands has shown that the great number of animals that had to be destroyed in order to eradicate the outbreak increasingly shocked the public at large. 'Ethical' arguments (eradication of healthy animals) might therefore also direct governments to a more risk-averse direction.

The research presented in this thesis was aimed at the risk and consequences of introduction of FMD and CSF into the Netherlands. However the approach is general and (parts of it) can be applied to other diseases and other countries as well. Within the Netherlands, programs are being developed and applied to eradicate diseases such as IBR and Aujezsky. Adapting the VIRiS model to these diseases might provide information to help maintain the 'disease-free-status' after it has been reached. The workshop approach, described in Chapters 4 and 5, has already been applied to elicit opinions from Swiss experts on the risk of virus introduction into and spread within their country (Stärk et al., 1997). Extension of such experiments to more countries may provide insight into how experts of different countries view the risk of virus introduction into their respective countries. It also provides insight into how these experts perceive the riskiness of each other's home countries. Such information might be useful for the development of disease prevention policies at international level.

To conclude: the integrated approach developed and worked out in this study enables the evaluation of alternative prevention strategies. The approach therefore provides building materials for sound economic decisons. However, in the end, it will always be the decision maker who makes the final decision.

8.5 MAIN CONCLUSIONS

- The integration of models describing the introduction, spread and economic consequences of outbreaks of Classical Swine Fever (CSF) and Foot-and-Mouth Disease (FMD) in the Netherlands provides a useful tool for the evaluation of alternative prevention strategies on their ability to avoid (or reduce) the losses due to epidemics.
- Objective information on aspects that influence virus introduction is scarce. However, additional information can be provided by experts. Methods such as Conjoint Analysis and ELI prove to be fruitful tools for the quantitative elicitation of such knowledge.
- The results show that the southern and eastern parts of the Netherlands are most prone to primary outbreaks of CSF and FMD. Most Dutch epidemics are expected to originate from Southern European countries and countries neighbouring the Netherlands.
- Important causes of outbreaks are import of live animals and trucks used for export and re-entering the country. These two factors together are considered to account for more than 70% of the primary outbreaks of CSF and FMD, in the Netherlands.
- The duration of the High Risk Period (HRP) has a strong impact on the total risk of virus transfer. Shortening this period will be highly beneficial to both the Netherlands other EU-members. The great variation found in HRPs of recent outbreaks leaves considerable room for improvement.
- The complete elimination of the risks related to the import of live animals reduces the expected annual losses due to FMD and CSF epidemics together by approximately US$ 35 million; elimation of the risk factor 'returning trucks' reduces these losses by approximately US$ 9 million. These amounts can be seen as the economic windows available for the realization of measures which are able to achieve such an elimination.
- A considerable economic window is also available for measures aimed at minimizing the size of a possible epidemic. As the import of livestock is the major source of virus introduction, tracing animals imported from a country that is in an HRP, might well be cost-effective. Internationally exchangeable I&R (Identification and Registration) data will simplify the tracing process.
- Both the duration of HRP and the international livestock trade have a strong impact on virus spread within Europe. It may therefore be cost-effective for export-oriented countries such as the Netherlands, to invest in the improvement of the animal health status and programs of other European countries. Joint international efforts will reduce the risk of virus introduction for all countries.

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SUMMARY

Introduction

Within the European Union, epidemics of contagious animal diseases such as Classical Swine Fever (CSF) and Foot-and-Mouth Disease (FMD) are to be eradicated according to strict EU-prescriptions including stamping-out of infected herds, establishment of control and surveillance zones with complete standstill of animals and possible export bans on live animals. Epidemics clearly have a serious impact, in particular on countries with a high farm density and an export-oriented production, such as the Netherlands. Therefore, an effective animal disease prevention policy is of major importance for these countries.

This thesis is a result of a joint action by the government and private industry in the Netherlands that have funded a research project aimed at gaining more insight into the risk and economic consequences of virus introduction into the country.

Real-life experiments on strategies to reduce animal disease introduction and spread is not an option because such experiments would be too risky (and hence too costly). In principle, simulation modelling is an attractive alternative. It calculates the effects of pre-defined sets of input variables and therefore also offers the possibility of exploring strategies that have not been applied yet. Literature search showed that simulation models describing spread and economic consequences of epidemics within a country were already available. However, an integrated approach which combines the various aspects of outbreaks and spread with economic consequences of outbreaks was still lacking. Therefore, this research project emphasized the development of a model describing introduction of virus into the Netherlands and on the integration and combination of the models.

Expert knowledge

General

As with every model, the quality of the outcome of a simulation model is strongly influenced by the quality of the input ('garbage in = garbage out'). Therefore, a considerable part of the research was devoted to the gathering of information on aspects influencing virus introduction. It would be ideal to base the simulation model on relevant historical and experimental data. However, such information on virus introduction is limited, if available at all. Furthermore, outbreaks of contagious animal diseases occur

irregularly over time and differ in magnitude; moreover circumstances change. Therefore it is questionable if historical data are relevant in simulating current and future events. Experimental data are also sparsely available. Literature search has shown that many researchers have done work in the area of contagious animal diseases, but most of their findings are of a qualitative nature. Despite this lack of 'objective' information, decisions on eradication and prevention of outbreaks must be made. Currently, such decisions rely on the expertise (a combination of experience and understanding of current/future circumstances) of those working in this area. Such expertise is a useful and necessary addition to the data available from research and databases. The elicitation of this 'expert knowledge' in an objective way, resulting in quantitative information useful for modelling purposes, was one of the major topics in the thesis.

Pilot experiment

For the elicitation experiment a format was sought which would guarantee a high response from experts and would provide the ability to elicit individual opinions in an objective way. Literature search showed that many elicitation methods were available, all with their own pros and cons. One of the methods, Conjoint Analysis, was considered an interesting technique for the elicitation of the relative importance of the risk factors. Conjoint Analysis is well known in consumer and marketing studies, but thus far has not or only scarcely been used in the field of animal health economics. A pilot experiment was conducted in which the potential of the method for elicitation of the relative importance of risk factors was explored. In this experiment, the Conjoint Analysis technique was used to draw up a paper questionnaire which was handed out during the 7th International Symposium on Veterinary Epidemiology and Economics (ISVEE) held at Nairobi, Kenya, August 1994. Relevant ISVEE-participants asked to assign scores to profiles of six contagious animal diseases (African and Classical Swine Fever, Foot-and-Mouth Disease, Swine Vesicular Disease, Newcastle Disease, and Avian Influenza). The Kenya-experiment showed promising results. However, also some lessons for future use were learned. The 'paper-approach' resulted in a low response (30%) and the participants, who were not selected on the basis of their expertise, indicated that is was very difficult and time-consuming to evaluate six diseases at one time.

Basic experiment: elicitation of opinion of Dutch experts

The results and experiences of the Kenya experiment have led to and framed the use of Conjoint Analysis in a second and much bigger experiment during which the subjective knowledge of Dutch experts was elicited. Experts were defined as people that were involved in either research or policy-making on animal disease prevention and people that would be consulted in case of an outbreak. As the number of experts was limited, an approach was needed which would guarantee a high response rate. Therefore, the experiment was framed as a full evening's workshop. Such a workshop is a one-off group meeting, which means that the participants have to show up only once and have the possibility of discussing issues with other experts: both aspects may be attractive and incentives to join. This approach worked out well: the experiment was attended by a total of 43 out of 50 invited persons, a response rate of 86%.

Although it was acknowledged that group discussions may have the advantage of resulting in new and better approaches because people are able to share, evaluate and stimulate each other's opinions, the risk of possible negative effects of such discussions, such as individual dominance, was too high. Therefore, the workshop participants were asked to individually complete a computerized questionnaire. The program was developed to be self-explanatory, which minimized the interaction among participants and between participants and facilitators. The participants were given the opportunity to indicate on which disease they felt themselves most knowledgeable and were only asked questions about that disease. Furthermore, in order to keep the whole exercise at a manageable size, the questions were confined to Europe, the countries being grouped into five clusters.

Relative importance of risk factors

The relative importance of risk factors responsible for the introduction of virus into the Netherlands was elicited by using the above-described Conjoint Analysis method. Questions were asked per country cluster. The results showed that, for both FMD and CSF, major risk factors were import of livestock and returning trucks. Differences between country clusters were small. For NCD, major risk factors were import of live animals, transport materials (crates) and import of exotic birds.

As a follow-up on the Kenya experiment, the Conjoint Analysis element of the workshop experiment was evaluated in detail on its usefulness as a tool to elicit expert knowledge in the field of animal health economics. Criteria were validity, consistency and respondent evaluation. The results obtained were comparable to or better than the results obtained in consumer and marketing studies. It was concluded that Conjoint Analysis provided a useful addition to the toolkit of the animal health economist.

Frequency of outbreaks in Europe

Each time an outbreak occurs in a European country, there is always a chance that the virus will be transferred to the Netherlands. A higher frequency of outbreaks in Europe means a higher risk of virus introduction to the Netherlands (and to all other countries). It was expected that estimates on the frequency of outbreaks would be difficult to make. Therefore, a method was chosen which enabled expression of uncertainty. This method, called ELI (elicitation), is a graphically-oriented computer program which facilitates the quantification of subjective knowledge about uncertain quantities. The program helps respondents produce subjective probability density functions (PDFs) and is based on so-called proper scoring rules. The top of a PDF indicates the best guess or most likely value, according to the respondent. The dispersion corresponds with the uncertainty as to this estimate.

The ELI-element of the workshop resulted in the parameters of a normal distribution from all participants individually concerning the expected number of outbreaks within the next five years. The workshop participants expected numerous outbreaks of NCD and CSF but not so many of FMD. For all three diseases, most outbreaks were expected to occur in Eastern Europe (midpoints were 21, 20, and 21, for CSF, FMD and NCD respectively). The smallest numbers were expected in the country cluster containing the UK, Ireland and Scandinavia (midpoints were 1, 0.5, and 2.5, for CSF, FMD and NCD respectively).

High Risk Period

The High Risk Period (HRP) defines the period in which the virus is already present in a country but not yet detected or under control. During this period, the virus may spread freely within the country and/or transferred to other countries. The HRP can be divided into two periods, the first one starting with infection of the first animal and ending when an infected animal is detected (HRP1), the second period starting with detection and ending when all measures are considered effective (i.e., no spread to other countries) (HRP2).

The participating experts were asked to give a three-point estimate (minimum, most likely and maximum expected length) for the duration of both periods, for all country clusters and for the Netherlands. The HRP1s with the highest duration were expected for Eastern Europe (midpoints of 42, 19, and 21 days for CSF, FMD and NCD respectively). Shortest duration was expected for the cluster including the UK, Ireland and Scandinavia (midpoints were 21, 7, and 10 days for CSF, FMD and NCD respectively). Short durations were estimated for the Netherlands as well.

The HRP2 estimates showed the same distribution over countries, but were longer for FMD and CSF and shorter for NCD.

Simulation of virus introduction

The information elicited from the experts, together with information from data sources such as databases and literature, formed the input for the Monte Carlo simulation model VIRiS (Virus Introduction Risk Simulation). The VIRiS model simulates the introduction of virus into a country. Monte Carlo simulation was used because this technique enabled the incorporation of variation and uncertainty inhibited in the input parameters and mechanisms under study. The model starts with an outbreak in one of the country clusters and 'follows' the disease (taking into account HRP, importance and volume of risk factors) up to a possible introduction of virus into the Netherlands. VIRiS is aimed at supporting decision makers involved in disease prevention. The major objective of the model is to provide insight into the consequences of alternative strategies to reduce or prevent the risk of virus introduction. The model provides the number of primary outbreaks to be expected within the time horizon of 5 years, their location (northern, southern, eastern or western part of the country) and their cause (country of origin, risk factor). The model has been worked out for FMD and CSF for the Netherlands. The default outcomes of VIRiS, which describe the current situation according to experts and objective data sources, show that the southern and eastern regions of the Netherlands are most prone to outbreaks of CSF and FMD. Most Dutch outbreaks originate from the countries neighbouring the Netherlands and the countries of southern Europe. The countries of Eastern Europe are only of minor importance in this respect. These countries present a high risk 'per unit risk factor', and therefore constitute an important potential risk. However, trade in livestock between the Netherlands and these countries is on such a low level that the actual risk is also low.

Integration of introduction, spread and economic consequences: economic evaluation of prevention

Information obtained by the VIRiS model was combined with information from models describing the spread and economic consequences of epidemics within a country. The integrated approach thus evaluates the entire 'development path' of animal disease outbreaks, from an outbreak somewhere in Europe to a possible virus introduction into the Netherlands, including consequences for the Netherlands, such as primary and secondary outbreaks and economic losses. With this approach it is possible to evaluate current and alternative prevention strategies on their ability to reduce economic losses due to epidemics of CSF and FMD.

In the default scenario (current situation in Europe, outbreaks eradicated according to standard EU regulations), annual losses due to CSF-outbreaks were simulated to be US$ 34 million (midpoint). For FMD annual losses in the default situation were US$ 14.2 million (midpoint). The results have shown that there is a considerable economic window for measures aiming at minimizing the size of a potential epidemic. The analysis also shows the strong impact of the HRPs of European countries on the total risk of virus introduction for the Netherlands and suggests that measures aimed at speeding up detection of diseases, i.e., shortening HRP, in those countries might pay off easily.

Complete elimination of the risk associated with risk factors is a straightforward way to reduce losses due to outbreaks. The analysis has shown that elimination of the risk associated with the risk factor 'import of livestock' reduces annual losses due to FMD and CSF epidemics by approximately US$ 35 million; elimination of the risk factor 'returning trucks' reduces these losses by approximately US$ 9 million.

Final remarks

When objective information is only scarcely available, the use of expert knowledge is a good additional source of information. The study has shown that by using several elicitation techniques, i.e., attempting to use the most appropriate method for each specific aspect, a large amount of useful information can be obtained within a workshop approach. The basic structure of the resulting questionnaire program is general. Therefore the program is applicable, and has been applied already, to experiments in other countries and for other diseases. Extension of such experiments will enhance insights into how experts view disease risk for their own and for each other's countries. Such information is useful for the development of disease prevention policies at international level.

The Monte Carlo model VIRiS provides insight into the aspects that affect the risk of virus introduction into the Netherlands and may therefore be considered a risk assessment tool. However, much extra value is obtained when the 'abstract' risks are transformed into monetary values, which are easier to understand and interpret. Therefore, the integrated approach has a synergic effect. The combination of introduction, spread and economic consequences enables the evaluation of current and alternative prevention strategies on their ability to reduce the annual losses due to epidemics. In this way the integrated approach presents policy makers in the area of disease prevention with material to base sound economic decisions on.

SAMENVATTING

EFFICIËNTIE IN PREVENTIE

Inleiding

Nederland is internationaal gezien een belangrijke producent en exporteur van vee, vlees, eieren en zuivel. Ruim driekwart van de productie gaat de grens over. In 1996 bedroeg de waarde van de uitvoer van de totale veehouderijsector bijna 20 miljard gulden.

Het beleid in de Nederlandse agrarische sector (en de andere EU-lidstaten) wordt in toenemende mate beïnvloed door Brussel. Dit geldt ook voor de maatregelen die genomen moeten worden bij uitbraken van besmettelijke dierziekten zoals Mond- en Klauwzeer (MKZ) en Klassieke Varkenspest (KVP), ook wel 'veewetziekten' genoemd. Bij uitbraken van veewetziekten worden de dieren van besmette bedrijven vernietigd en worden beschermings- en toezichtsgebieden ingesteld waarbinnen geen dieren vervoerd mogen worden. Daarnaast kunnen bedrijven die in de buurt van een besmet bedrijf liggen 'preventief geruimd' worden en kan de EU exportbelemmeringen afkondigen voor de regio of het land waarbinnen de epidemie plaatsvindt. De recente uitbraak van KVP in Nederland (feb. 1997) liet eens te meer zien dat deze maatregelen, in combinatie met een intensieve en exportgerichte varkenshouderijstructuur, tot grote economische gevolgen kunnen leiden. Voor Nederland en voor landen met een vergelijkbare intensieve en exportgerichte veehouderij is een effectief preventiebeleid dan ook zeker geen overbodige luxe.

Om een effectief maar ook economisch efficiënt preventiebeleid te kunnen ontwikkelen is inzicht nodig in de risico's en economische gevolgen van de 'insleep' (het binnenkomen) van besmettelijke dierziekten in het land. Gezamenlijk initiatief van de Nederlandse overheid en het Nederlandse landbouwbedrijfsleven heeft geleid tot een onderzoeksproject dat het verkrijgen van dergelijk inzicht tot doel had. Dit proefschrift beschrijft de onderzoeksopzet en de resultaten.

Een integrerende benadering

De gang van zaken rond een ziekte-uitbraak bestaat uit drie elementen:
1) insleep van het virus ('ziekte-veroorzaker') in een land, het ontstaan van de epidemie;
2) verspreiding binnen het land, de omvang van de epidemie;
3) resulterende economische schade, de economische gevolgen van de epidemie.
Als het gaat om de evaluatie van de (economische) efficiëntie van preventiestrategieën kunnen deze elementen niet los van elkaar gezien worden. Verschillende preventiestrategieën leiden immers tot een andere kansen op virus-insleep. Neemt de kans op virus-insleep af, dan zullen minder vaak epidemieën optreden en zullen de jaarlijkse kosten ten gevolge van uitbraken afnemen. Om dit alles goed te kunnen onderzoeken, moet er dus een 'integrerende' benadering gevolgd worden.

Simulatiemodellen

Het is niet wenselijk om 'zomaar' een nieuwe preventiestrategie in te voeren en dan gewoon maar af te wachten hoe deze uitpakt. Uitbraken komen immers maar weinig voor en de economische consequenties zijn zeer groot. 'Uitproberen' ofwel het uitvoeren van 'real-life' experimenten kost teveel tijd en brengt teveel risico met zich mee. Eigenlijk moet al voordat een nieuwe strategie ingezet gaat worden bekend zijn wat de verwachte effecten zijn.

Een alternatief voor real-life experimenten is het gebruik van simulatiemodellen op de computer. Een simulatiemodel bootst de werkelijkheid zo goed mogelijk na. Het voordeel van simulatiemodellen is dat hiermee in korte tijd situaties kunnen worden 'nagespeeld' die in de werkelijkheid (nog) niet zijn voorgekomen. Ook de gevolgen van wellicht risicovolle strategieën kunnen zo zonder gevaar beoordeeld worden. Simulatiemodellen leveren dus informatie die anders niet, of pas na lange tijd, beschikbaar komt.

Zowel voor 'insleep', 'verspreiding', als 'economische gevolgen' kunnen simulatiemodellen ontwikkeld worden. Voor de elementen 'verspreiding' en 'economische gevolgen' zijn dergelijke modellen, voor Nederland, al beschikbaar. In dit onderzoek is voornamelijk aandacht besteed aan het ontwikkelen van een simulatiemodel dat de insleep van virus beschrijft. Dit model heeft de naam VIRiS (Virus Introductie Risico Simulatie) meegekregen. Daarnaast is gewerkt aan het koppelen of 'integreren' van de diverse modellen.

Virus-insleep

De kans op virus-insleep, ook wel het 'insleep-risico' genoemd, wordt beïnvloed door de volgende aspecten:
1) uitbraakfrequentie in de diverse landen van Europa;
2) lengte van de Hoog Risico Periode (HRP);
3) aantal en omvang van de risicofactoren.

Uitbraakfrequentie in Europa
Nederland is in principe vrij van veewetziekten als MKZ en KVP. Dit betekent dat een uitbraak in Nederland altijd vooraf gegaan zal moeten worden door een uitbraak in het buitenland. Elke keer dat een uitbraak zich voordoet in een land waarmee Nederland contact heeft (bijvoorbeeld door de handel in levende dieren), bestaat de kans dat virus Nederland binnenkomt. Een hogere frequentie van uitbraken in het buitenland betekent dus een groter insleep-risico voor Nederland. In het onderzoek is het 'buitenland' overigens beperkt tot de Europese landen, de belangrijkste handelspartners van Nederland.

Lengte Hoog Risico Periode
Als virus binnenkomt in een ziekte-vrij land en daar leidt tot een uitbraak, zal het enige tijd duren voordat het eerste zieke dier ontdekt wordt. Vervolgens gaat er nog enige tijd overheen voordat bestrijdingsmaatregelen effectief zijn. Dat betekent dus dat gedurende een zekere periode de ziekte zich min of meer onbelemmerd kan verspreiden. Deze periode wordt de Hoog Risico Periode (HRP) genoemd.
Juist gedurende deze HRP is het goed mogelijk dat virus het betreffende bedrijf en zelfs het land verlaat en een ander land binnenkomt.

Risicofactoren
Tijdens de HRP kan de ziekte (het ziekte-virus) het bedrijf en de regio verlaten en ingesleept worden in andere regio's. De factoren die deze verplaatsing van ziekte veroorzaken worden 'risicofactoren' genoemd. Voorbeelden zijn de import van levende dieren, de import van dierlijke producten en het terugkeren van lege veewagens, gebruikt voor export, die niet goed zijn schoongemaakt. De ziekte kan als het ware 'meeliften' met bijvoorbeeld dieren of transportmaterialen.

Voor het bepalen van het insleep-risico is het van belang om te weten hoe belangrijk de risicofactoren ten opzichte van elkaar zijn, bijvoorbeeld: brengt de import van levende dieren meer risico met zich mee dan de import van dierlijke producten? Daarnaast is ook de omvang van de risicofactor van belang. Dan gaat het om vragen als: Hoeveel dieren importeert Nederland per jaar? En hoeveel 'vuile' veewagens komen jaarlijks het land binnen?

De kwaliteit van de uitkomsten van een model is erg afhankelijk van de kwaliteit van de input. Daarom is in dit onderzoek veel aandacht gegeven aan het verkrijgen van betrouwbare gegevens over de bovengenoemde aspecten. Informatie over deze aspecten is te vinden bij drie soorten bronnen:
1) historische statistieken/databases (van bijvoorbeeld EU, Productschappen en CBS);
2) onderzoek (epidemiologie, analyse van uitbraken);
3) deskundigen.
De eerste twee soorten bronnen bevatten op het eerste gezicht wellicht de meest betrouwbare informatie. Maar omstandigheden veranderen voortdurend: de marktstructuur in Europa wordt steeds opener, het IJzeren Gordijn bestaat niet meer, preventieve vaccinatie tegen KVP en MKZ is sinds 1992 in de EU niet langer toegestaan. Dit maakt het moeilijk om op basis van gegevens uit het verleden (zonder meer) uitspraken te doen over de situatie in de toekomst. Daarom is, ter aanvulling, de derde informatiebron 'aangeboord'. Deskundigen worden in staat geacht om feitenkennis (bron 1 en 2) te combineren met inzicht in huidige en toekomstige ontwikkelingen.

Informatie van deskundigen

In het project is een deskundige gedefinieerd als een persoon die bij een actuele uitbraak zou (kunnen) worden geraadpleegd. Het gaat dan om onderzoekers, beleidsmakers en dierenartsen. Er zijn verschillende methoden gebruikt om de kennis van deskundigen in kaart te brengen. Om ervaring op te doen met de methoden is eerst een 'pilot-experiment' uitgevoerd, met buitenlandse deskundigen. Dit experiment vormde de basis voor het uiteindelijke experiment, met Nederlandse deskundigen als deelnemers.

Omdat het aantal deskundigen beperkt was, moest een opzet gekozen worden die een hoge respons zou opleveren. Daarom werd voor een avondvullende workshop gekozen. Hierdoor werd slechts éénmaal een beroep op de deskundigen gedaan. Ruim 85% van de beoogde deskundigen deden mee aan de workshop (43 van de 50 genodigden). Tijdens de workshop werd een enqueteprogramma op de PC afgewerkt. Iedere deelnemer had daarbij de beschikking over een eigen computer zodat onderlinge beïnvloeding vermeden kon worden.

Het PC-programma bevatte een combinatie van enquête-technieken om de kennis van de deskundigen te kwantificeren. Een van de technieken was bijvoorbeeld het vragen om driepuntsschattingen. Hierbij moet de deelnemer een minimum, maximum en meest waarschijnlijke waarde geven voor bijvoorbeeld de duur van de HRP. Daarnaast zijn de technieken 'Conjoint Analysis' en 'ELI' gebruikt. Deze worden onderstaand kort toegelicht.

Conjoint Analysis

CA wordt vaak gebruikt in onderzoek op het gebied van marktkunde en consumentenwetenschappen. Dan gaat het meestal om het meten van consumentenvoorkeuren. Bijvoorbeeld om erachter te komen welke zaken consumenten belangrijk vinden bij het kopen van een auto. In dat geval wordt aan de proefpersonen een aantal kaartjes getoond. Op elk kaartje staat de omschrijving van een auto, bijvoorbeeld:

Kaartje 1		*Kaartje 2*	
Merk:	Speedy	Merk:	Speedy
Kleur:	Wit	Kleur:	Rood
Km-stand:	330.000	Km-stand:	125.000
Prijs:	2500 gulden	Prijs:	6000 gulden

De proefpersonen krijgen de opdracht om aan elk kaartje een score te geven, bijvoorbeeld een getal tussen 0 en 100. Een hogere score betekent een grotere voorkeur voor de beschreven auto. De proefpersonen geven dus een 'overall-scores' aan combinaties van factoren (merk, kleur, km-stand, prijs). Wanneer nu een groot aantal van dit soort combinaties gescoord worden, is het mogelijk om met behulp van statistische technieken (regressie-analyse) de overall-scores op te splitsen in het belang dat, impliciet, aan elk van deze factoren afzonderlijk gegeven is. Op deze manier wordt duidelijk waar de ondervraagde proefpersonen op letten, hoe belangrijk zij bijvoorbeeld 'merk' vinden in verhouding tot 'prijs' en 'kleur'.

Conjoint Analyse lijkt een wat omslachtige methode. Het is natuurlijk ook mogelijk om consumenten rechtstreeks te vragen naar hoe belangrijk ze 'merk' vinden in verhouding tot 'prijs'. Door verschillende onderzoekers is echter aangetoond dat dergelijke 'directe' methoden minder goed werken. Dat komt waarschijnlijk doordat het in de werkelijkheid bijna altijd zal gaan om situaties waarin meerdere componenten tegelijk voorkomen. De CA-techniek benadert de werkelijkheid dus beter dan de directe methoden. Overigens kan met de CA-techniek ook de consistentie van de antwoorden van de proefpersonen getest worden. Dit geeft enig inzicht in de kwaliteit van de informatie.

Het auto-voorbeeld geeft aan dat de CA-techniek uitgaat van het simpele basisprincipe dat een product of een situatie opgesplitst kan worden in onderliggende componenten. In dit onderzoeksproject is de techniek gebruikt om een schatting te krijgen van het relatieve belang van de risicofactoren, bijvoorbeeld het belang van de import van levende dieren in vergelijking tot de import van dierlijke producten, wanneer het gaat om de kans op virus-insleep. Het ging dus om de situatie 'kans op virus-insleep in Nederland'. De onderliggende componenten waren de aan- of afwezigheid van bepaalde risicofactoren, zoals bijvoorbeeld import van levende dieren, import van dierlijke producten, terugkerende veewagens, etc. De deskundigen moesten voor steeds wisselende combinaties van risicofactoren aangeven hoe groot het risico van virus-insleep was. Naderhand werden (met behulp van regressie-analyse) de overall-scores voor deze 'totaalsituaties' uitgesplitst naar de onderliggende componenten, de risicofactoren. Op deze manier kwam kwantitatieve informatie beschikbaar over het relatieve belang van elk van deze factoren.

ELI

ELI (ELIcitation) is een grafisch georiënteerd, interactief computerprogramma voor het in kaart brengen van onzekere kennis. Het programma helpt deelnemers bij het maken van goede ('unbiased') subjectieve kansverdelingen. Een subjectieve kansverdeling weerspiegelt (onzekere) kennis. Op de x-as staan de mogelijke waarden van de gevraagde parameter, op de y-as staat de kans die de deelnemer toedicht aan de juistheid van een bepaalde waarde. De top van de curve komt overeen met de waarde die de respondent het meest waarschijnlijk acht voor de gevraagde variabele (de 'beste schatting'). De spreiding of 'breedte' van de curve weerspiegelt de onzekerheid die de respondent heeft over de juistheid van deze 'beste schatting'. Hoe breder de curve, hoe onzekerder de respondent.

Een belangrijk onderdeel van een ELI-sessie is de 'training'. De deelnemers krijgen een aantal vragen voorgeschoteld die nauw met het onderwerp te maken hebben en waarvan de juiste antwoorden bekend zijn, en ingebracht in het programma. Geeft de respondent een antwoord dat in de buurt van het juiste antwoord ligt dan levert dat punten op, meer punten naarmate de voorspelling met meer zekerheid gedaan is (een 'smallere' curve, minder spreiding om de beste schatting). Een antwoord dat ver verwijderd ligt van het juiste antwoord levert een negatieve score op. Deze score is sterker negatief naarmate het 'foute' antwoord met meer zekerheid gegeven is. Op deze manier krijgen de deelnemers een goed beeld van hun eigen kennis betreffende het onderwerp en worden ze gestimuleerd om zorgvuldig na te denken over hun antwoorden, niet alleen over de beste schatting maar ook om de onzekerheid daar omheen. Zowel over- als onderschatting van de eigen kennis levert immers een minder optimaal aantal punten op.

Onderzoekers hebben aangetoond dat een dergelijke training resulteert in betere schattingen voor vervolgvragen, waarvoor de deelnemers geen score krijgen. Op deze manier kunnen naar verwachting ook betere schattingen verkregen worden voor vragen waarop de antwoorden niet bekend zijn. Dat maakt de methode interessant als techniek om onbekende en subjectieve kennis te kwantificeren.

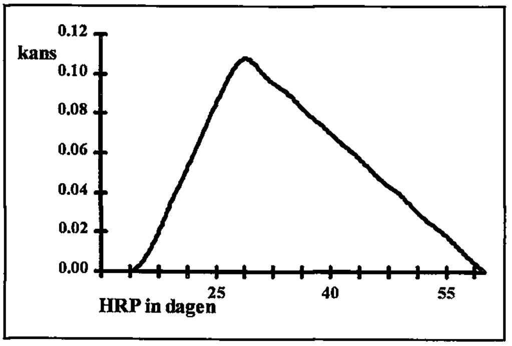
Tijdens de workshop in het onderhavige onderzoek is ELI onder andere gebruikt om schattingen te krijgen voor het aantal uitbraken dat in de komende jaren in de diverse landen van Europa verwacht mag worden.

Het simulatiemodel VIRiS

De informatie over de diverse aspecten van virus-insleep vormt de basis voor het simulatiemodel VIRiS. VIRiS begint bij een uitbraak in een land in Europa en 'volgt' het virus tot aan een mogelijke uitbraak in Nederland.

De informatie waarop VIRiS is gebaseerd kan lang niet in alle gevallen in één getal worden weergegeven. Dat geldt bijvoorbeeld voor de lengte van de HRP (de periode waarin de ziekte zich kan verspreiden). Bij de ene uitbraak kan sprake zijn van een korte HRP, bij een andere uitbraak kan het ontdekken van de ziekte langer op zich laten wachten. Dit hangt onder meer af van de oplettenheid van veehouders en dierenartsen. Ook zit in sommige insleepaspecten een stukje onzekerheid, het gaat immers vaak om voorspellingen over de situatie in de toekomst. Dat geldt bijvoorbeeld voor de voorspellingen over de uitbraakfrequentie in de diverse landen van Europa. Tot slot zal lang niet elke uitbraak van bijvoorbeeld Klassieke Varkenspest in Duitsland leiden tot een uitbraak in Nederland. De ziekte wordt soms wel, maar vaak ook niet van het ene land naar het andere verspreid.

Om het proces van virus-insleep op een goede manier te kunnen nabootsen (simuleren), moet dus rekening gehouden worden met 'variatie' en 'onzekerheid'. Daarom is voor het VIRiS-model gekozen voor de zogenaamde *Monte Carlo* benadering. Een Monte Carlo simulatiemodel werkt met lotingen uit kansverdelingen. Een kansverdeling beschrijft de verzameling van alle mogelijke waarden voor een bepaalde variabele, met daarbij per waarde de kans op optreden van die waarde. Figuur 1 geeft een voorbeeld. In deze figuur gaat het om een inschatting van de duur van de HRP, voor Nederland, volgens één van de deskundigen. De deskundige is gevraagd om het geven van schattingen voor een minimum waarde, een meest waarschijnlijke waarde, en een maximum waarde voor de duur van de HRP. Een dergelijke driepuntsschatting kan worden weergegeven met een zogenaamde driehoek-verdeling. Volgens deze deskundige een HRP van 28 dagen het meest



Figuur 1
Driehoek-verdeling, schatting HRP in Nederland

waarschijnlijk. Een HRP korter dan 15 dagen lijkt hem zeer onwaarschijnlijk, langer dan 60 dagen ook. De figuur laat zien dat het hier gaat om een scheve verdeling. De curve heeft een 'staart' naar rechts. De deskundige verwacht dus eerder uitschieters richting een heel lange HRP dan richting een heel korte HRP. Tijdens het doorrekenen van een Monte Carlo model wordt uit elke kansverdeling een waarde geloot. Deze waarde wordt gebruikt in de verdere berekeningen. De waarde zal meestal een 'veel voorkomende waarde' zijn (in de buurt van de 'top' van de grafiek). Maar het is ook mogelijk om juist een 'zeldzame' waarde te trekken, uit de staart van de verdeling. Het eenmalig doorrekenen van een Monte Carlo model is daarom ook niet zinvol. Het zou dan namelijk best kunnen gebeuren dat 'toevallig' voor alle berekeningen met zeldzame waarden gewerkt wordt en de einduitkomst een situatie beschrijft die bijna nooit zal voorkomen. Bij een Monte Carlo model wordt daarom altijd gewerkt met het veelvuldig herhalen van de berekeningen (iteraties). Bij elke herhaling wordt opnieuw uit de kansverdelingen getrokken. Dan wordt duidelijk wat bijvoorbeeld het insleep-risico is in een 'gemiddelde' situatie en wat er verwacht kan worden wanneer alles mee dan wel tegen zit (de zogenaamde 'best case' en 'worst case' situaties). Het VIRiS-model is uitgewerkt voor Klassieke Varkenspest (KVP) en Mond- en Klauwzeer (MKZ), maar kan ook voor andere ziekten gebruikt worden.

Resultaten

Het VIRiS-model laat de gevolgen zien van diverse preventiestrategieën. De uitkomsten van VIRiS geven aan waar en met welke kans zich in Nederland een uitbraak zal voordoen, waar deze uitbraken vandaan komen en door welke risicofactor ze veroorzaakt worden. Nederland is hierbij opgedeeld in 4 regio's (zuid, oost, noord en west) en Europa in 5 groepen (buurlanden, zuid-Europa, midden-Europa, oost-Europa, en de restgroep 'eilanden'). Om de resultaten van VIRiS goed te kunnen interpreteren, zijn de uitkomsten gebruikt als input voor modellen die de verspreiding van virus binnen Nederland beschrijven. Vervolgens is de schade ten gevolge van de resulterende epidemieën berekend. Op deze manier wordt zichtbaar wat de VIRiS-resultaten betekenen voor de jaarlijkse schade ten gevolge van uitbraken in Nederland. Dan is het ook mogelijk om de diverse preventiestrategieën te beoordelen op hun efficiëntie.

Het basisscenario

Het basisscenario van VIRiS-KVP gaat uit van 2,5 uitbraken per 5-jaar in Nederland. Het basisscenario van VIRiS-MKZ gaat uit van 1 uitbraak per 5 jaar. De getallen zijn gebaseerd op schattingen van de deskundigen.

Volgens de basisscenario's komen de meeste uitbraken van zowel KVP als MKZ in het zuiden en oosten van Nederland voor. Voor KVP gaat het voor beide regio's om ongeveer 37%, voor MKZ gaat het om 41% voor de regio oost en om 31% voor de regio zuid. Veel minder risico lopen de noordelijke en westelijke regio's. Van de KVP-uitbraken komt 16% in het westen terecht en 10% in het noorden. Voor MKZ zijn deze getallen respectievelijk 15 en 13%.

De verwachte schade ten gevolge van een KVP-epidemie in Nederland is gemiddeld ruim 140 miljoen gulden. Per jaar moet dus rekening gehouden worden met een schade van ruim 70 miljoen gulden. Voor MKZ is de jaarlijkse schade veel lager (komt naar verwachting minder vaak voor), maar nog altijd bijna 30 miljoen gulden. De schade ten gevolge van KVP- en MKZ-epidemieën verschilt echter sterk per regio. In het zuiden en oosten is de dier- en bedrijfsdichtheid veel hoger dan in het noorden en westen. Een uitbraak heeft hier dan ook veel grotere financiële consequenties.

Veruit de belangrijkste risicofactor voor virus-insleep is de import van levende dieren. Dit is, volgens het VIRiS-model, de oorzaak van meer dan de helft van de KVP- en MKZ-uitbraken in Nederland. Een andere belangrijke factor wordt gevormd door onvoldoende schoongemaakte veewagens, gebruikt voor de export van vee vanuit Nederland naar andere landen. Bij de verdeling van uitbraakkans over risicofactoren spelen zowel het risico per eenheid risicofactor als het aantal eenheden (aantal dieren, aantal veewagens) een rol.

Volgens de modelberekeningen wordt een KVP-uitbraak in Nederland meestal (57%) veroorzaakt door een voorafgaande uitbraak in Zuid-Europa (Griekenland, Portugal, Italië, Spanje). Dit komt door het grote aantal varkens dat vanuit deze landen richting Nederland gaat (in 1995 exporteerde Spanje ruim 55.000 varkens, waarvan ruim 30.000 biggen, naar Nederland). Op de tweede plaats komen de buurlanden van Nederland. Ook voor MKZ geldt dat de meeste uitbraken in Nederland vooraf gegaan worden door uitbraken in Zuid-Europa of in één van de landen rondom Nederland.

De deskundigen hadden geen positieve indruk van de dierziektesituatie in de landen van Oost-Europa (langdurige HRP, hoge uitbraakfrequentie). Toch wordt slechts een klein percentage van de Nederlandse uitbraken veroorzaakt door virus-insleep vanuit deze landen. Dit komt doordat vanuit Oost-Europa, volgens de officiële statistieken (PVE), nauwelijks levende dieren (vooral weinig varkens) naar Nederland worden verhandeld.

Economische evaluatie van preventiestrategieën

Niet elke epidemie veroorzaakt evenveel schade. Berekeningen geven aan dat bijvoorbeeld voor KVP het verschil in schade tussen een kleine en een gemiddelde epidemie ongeveer 80 miljoen gulden bedraagt. Het verschil tussen een gemiddelde en een (extreem) grote epidemie is nog veel groter (zoals ook de echte uitbraak in Zuid-Nederland heeft laten zien). Dit betekent dat maatregelen gericht op het beperkt houden van de omvang van een epidemie al snel kosteneffectief zijn. Vooral de duur van de HRP is erg belangrijk voor de uiteindelijke omvang van de epidemie. Hoe korter de HRP, hoe kleiner de epidemie. En dus ook: hoe korter de HRP, hoe minder kans op verspreiding van de ziekte naar andere landen. Dat betekent dat investeren in bijvoorbeeld het snel kunnen ontdekken van zieke dieren belangrijk is. Het gaat om belangen op Europees niveau: Nederland is erbij gebaat als andere landen in staat zijn epidemieën eerder te ontdekken. Het omgekeerde geldt natuurlijk ook: als Nederland een eventuele epidemie snel onder controle heeft, blijft het risico voor de buurlanden beperkt.

Nederland kan veel 'verdienen' door, zodra KVP of MKZ uitbreekt in Europa, maatregelen te nemen om een eventuele insleep in Nederland op te sporen. Vooral bij uitbraken in Zuid-Europa of in één van de buurlanden van Nederland is het risico relatief groot en 'mag' dus veel geld besteed worden aan het opsporen van eventuele insleep. Een internationaal systeem van Identificatie en Registratie (I&R) van vee zou het opsporen van eventuele ziekte-verspreiding sterk vereenvoudigen en versnellen.

Een voor de hand liggende manier om de schade ten gevolge van epidemieën te verlagen is het 'uitschakelen' van risicofactoren. Dat vermindert immers de kans op virus-insleep. Uitschakelen van de risicofactor 'import van vee' vermindert de jaarlijkse schade ten gevolge van KVP- en MKZ-uitbraken met ongeveer 70%. Ook voor maatregelen gericht op de risicofactor 'terugkerende veewagens' is een aanzienlijke financiële ruimte beschikbaar. De berekeningen geven aan dat het volledig uitschakelen van deze risicofactor de jaarlijkse schade vermindert met meer dan 15 miljoen gulden. Overigens zal het moeilijk zijn om de risico's verbonden met de risicofactoren echt helemaal naar nul terug te brengen. Duidelijk is wel dat ook maatregelen als intensievere controle en uitbreiding en verbetering van de reiniging- en ontsmettingsplaatsen al snel kosteneffectief zullen zijn.

Belangrijkste conclusies

- De integratie van modellen gericht op respectievelijk de insleep, verspreiding en economische gevolgen van uitbraken van Klassieke Varkenspest (KVP) en Mond- en Klauwzeer (MKZ) biedt mogelijkheden om dierziektepreventiestrategieën te beoordelen op hun vermogen de jaarlijkse schade ten gevolge van uitbraken te verminderen.
- Objectieve informatie over aspecten die de eventuele insleep van ziekte beïnvloeden is schaars en qua voorspellend vermogen niet altijd betrouwbaar. Aanvullende informatie kan verkregen worden door het raadplegen van deskundigen. 'Conjoint Analysis' en 'ELI' zijn nuttige hulpmiddelen voor het in kaart brengen van deze informatie.
- Volgens de modelberekeningen hebben het zuiden en oosten van Nederland de grootste kans op uitbraken van KVP en MKZ. De Nederlandse epidemieën zullen meestal afkomstig zijn uit Zuid-Europa of uit de Nederlandse buurlanden.
- De lengte van de Hoog Risico Periode (HRP) heeft een sterke invloed op de mate van virusverspreiding. Verkorten van deze periode is zeer voordelig, zowel voor Nederland als voor de andere landen van Europa. De grote variatie die gevonden wordt in de HRPs van recente uitbraken suggereert dat er veel ruimte voor verbetering is.
- De risicofactoren 'import van levende dieren' en 'terugkerende veewagens' (gebruikt voor export) veroorzaken tezamen naar verwachting meer dan 70% van de epidemiëen van MKZ en KVP in Nederland.
- Volledig uitschakelen van het risico, verbonden met de risicofactor 'import van levende dieren', vermindert de jaarlijkse schade van MKZ- en KVP-epidemieën met ongeveer 70% of ruim 70 miljoen gulden. Voor de factor 'terugkerende veewagens' levert uitschakeling een schadevermindering op van meer dan 15 miljoen gulden. Deze bedragen geven een indruk van de maximale financiële ruimte die beschikbaar is voor het nemen van maatregelen tegen het risico verbonden aan de betreffende risicofactoren.
- Ook voor maatregelen gericht op het verkleinen van de omvang van een potentiële uitbraak is, volgens de berekeningen, een grote financiële ruimte beschikbaar. Het opsporen van dieren die geïmporteerd zijn gedurende een HRP in hun land van herkomst is daarom al snel kosten-effectief. Een internationaal uitwisselbaar I&R-systeem (Identificatie en Registratie) zal dit opsporingsproces vereenvoudigen.
- Zowel de duur van de HRP als de internationale handel in vee hebben een sterke invloed op de ziekteverspreiding binnen Europa. Voor export-georiënteerde landen zoals Nederland kan het daarom interessant zijn om te investeren in de verbetering van de dierziektepreventieprogramma's en de diergezondheidsstatus van andere Europese landen. Gezamenlijke internationale inspanningen zijn nodig om het ziekterisico voor Europa als geheel te verlagen.

Related Publications

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Curriculum Vitae

Heleen Suzan Horst werd op 13 oktober 1969 geboren in Amsterdam. In 1987 behaalde zij het diploma ongedeeld VWO aan het Atheneum College Hageveld te Heemstede. In september van datzelfde jaar werd een start gemaakt met de studie Zoötechniek aan de Landbouwuniversiteit Wageningen. In juni 1993 sloot zij deze studie af, met als afstudeervakken Veefokkerij en Agrarische Bedrijfseconomie. Vervolgens was zij gedurende een half jaar werkzaam bij de Vakgroep Agrarische Bedrijfseconomie van de Landbouwuniversiteit Wageningen, met als opdracht het verrichten van een haalbaarheidsstudie naar de mogelijkheden om de risico's en economische consequenties van uitbraken van veewetziekten in kaart te brengen. De haalbaarheidsstudie leidde tot een vervolgonderzoek waarvoor ze in februari 1994 bij genoemde vakgroep voor een periode van 3 jaar werd aangesteld als toegevoegd onderzoeker. Het onderzoek werd uitgevoerd in opdracht van het Centraal Bureau Slachtveeverzekeringen en het Ministerie van Landbouw Natuurbeheer en Visserij en heeft geleid tot dit proefschrift. Sinds februari 1997 heeft ze zich, naast het afronden van het proefschrift, bezig gehouden met projecten met betrekking tot de varkenspestepidemie in Nederland, de diergezondheidszorg in de toekomst en de herstructurering van de Nederlandse varkenssector.