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FAO ANIMAL PRODUCTION AND HEALTH

guidelines

ECONOMIC ANALYSIS OF ANIMAL DISEASES

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ECONOMIC ANALYSIS OF ANIMAL DISEASES

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Preface

One of the promises of medicine is the promotion of health and the prevention of disease. While the adage that '*prevention is better than cure*' is a hallmark for addressing problems early and avoiding costly efforts for recovery and rehabilitation, the truth is that we do not invest sufficiently in prevention. Prevention is a difficult 'sale' but an important message for transboundary animal disease control, and one that will need to be supported by strong economic evidence.

A veterinary approach to transboundary animal diseases focuses on controlling disease in the affected animal or livestock population, ignoring the fact that livestock owners and society as a whole are affected by the impacts of diseases and the measures taken to contain them. Economic analysis is a discipline that can help to close this gap by supporting stakeholders in assessing whether a particular investment on the prevention or control of a transboundary animal disease (TAD) is likely to result in an overall benefit for society, and what the associated investment might be.

These guidelines are designed for professionals and technicians who recognize – or wish to better understand – the importance of economic studies to justify (or not) the use of public funds and those of private investments in the prevention, control and management of transboundary animal diseases. The impacts of these diseases can be wide-ranging, including the immediate loss of livelihood to those in the livestock sector, disruption of domestic trade or the cessation of access to international markets, and threats to public health. The guidelines are also helpful for an individual to better interpret economic studies already undertaken and to obtain greater insight into what was included in the analysis, how and why.

While having a standard methodology would, arguably, be an ideal, it is not a realistic aim, given the wide range of questions to be addressed and the economic techniques available to analyse them. The guidelines provide a framework for conducting economic analysis for different purposes and provide an introduction to the language, techniques, assumptions, and approaches of animal health economics, rather than proposing a prescriptive method. It is anticipated that the guidelines will encourage productive dialogue when animal health issues are discussed with economists and will encourage fruitful, well-informed collaboration between veterinarians, animal health experts, economists and social scientists.

The impact of transboundary animal diseases under endemic settings or their incursion into free regions is of great concern in protecting efficiencies in animal production, ensuring availability of quality nutrition and food security to the communities, and achieving resilience and prospects for poverty reduction, and in the stability of markets.

Animal health practitioners often have difficulty in communicating the importance of their work in safeguarding animal production, the safety of the food chain, and the economic value of the industry – large and small – as well as in their own ability to mobilize the required financial or human resources for their work in disease management, research in vaccine development, diagnostic networks and bio-surveillance, pathogenesis, contingency funds well-honed responses, or border protection. The key to successful resource mobilization would be the incorporation of substantive economic evidence and the rationale for such investment. Government or private sector managers in the financial and planning realm need these to better understand the threats, and to provide the case for further and adequate investment in protecting animal production and health through preventive and pre-emptive efforts as cost effective, cost efficient and lifesaving. Economic analysis is an essential part of transboundary animal disease policies and management strategies.

As with diagnostic laboratory assays, disease risk models, or new technological tools, the strength of the conclusions or their utility depends on knowing the weaknesses of the inputs, the assumptions made, and the predictive values or limitations of the instruments so that their use is properly gauged. Investment in prevention and a system for timely response and preparedness for outbreak events saves lives, livelihoods, and money.

Combining the disciplines of the animal health professional to include those of epidemiologists and economists is invaluable to managers to discern the impacts of disease, and the options available, or otherwise have an objective rationale to justify decisions. The value of combining these disciplines is priceless, as is their effective communication to management and to the public at large.

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Acronyms

ASF	African swine fever
CBPP	Contagious bovine pleuropneumonia
CCPP	Contagious caprine pleuropneumonia
CSF	Classical swine fever
DALY	Disability-adjusted-life-year
DFID	Department for International Development of the United Kingdom
FAO	Food and Agriculture Organization of the United Nations
FMD	Foot and mouth disease
CGE	Computable General Equilibirum
GDP	Gross Domestic Product
GNI	Gross National Income
GOK	Government of Kenya
HS	Hemorrhagic septicaemia
HPAI	Highly pathogenic avian influenza
LSD	Lumpy skin disease
ND	Newcastle disease
ODI	Overseas Development Institute
OIE	World Organisation for Animal Health
PPR	Peste des petits ruminants
QALY	Quality-adjusted-life-year
RVF	Rift Valley fever
SPS	Sanitary and phytosanitary
TAD	Transboundary animal disease
USDA	United States Department of Agriculture
WHO	World Health Organisation
WTO	World Trade Organization

Glossary of technical terms

Cost-benefit analysis — A method for estimating the economic viability of an investment when both the benefits and costs are estimated in monetary terms.

Cost-effectiveness analysis — A method for estimating the economic viability of an investment when the costs are estimated in monetary terms and the benefits expressed as a targeted outcome. Often used for human health projects, where the benefits are expressed as avoided deaths, DALYS or QALYs.

CGE (computable general equilibrium) model — A model of an economy based on simultaneous equations that takes into account the flow of resources between sectors.

Economic (as opposed to financial) analysis — Analysis using economic ("shadow") prices. Shadow prices are values used in cost-benefit or cost-effectiveness estimates when market prices are considered to be a poor estimate of economic value. A shadow price is the "opportunity cost" of a good or service, which is the value lost by not using it in the next best alternative use. Shadow prices are estimated by removing the distortions caused by fixed prices, taxes and subsidies. Shadow prices for foreign exchange and labour can often be obtained from the finance or planning ministry or a development bank.

Ex-ante analysis — Analysis done for a proposed project (also "appraisal").

Ex-post analysis — Analysis done for a completed or partly completed project (also "evaluation").

Externality — Occurs when the production or consumption of goods and services by one individual or business imposes costs or benefits on others which are not reflected in the prices charged for the goods and services being provided [OECD glossary of statistical terms]. An example of a negative externality is when a farmer chooses not to participate in a TAD eradication programme, and contributes to creating a reservoir of infection, thereby increasing the risk for farmers who do participate.

Financial analysis	Analysis using market prices.
Financial capital	When used in a sustainable livelihoods framework, this refers to the financial resources that people use to achieve their livelihood objectives [DFID 1999].
Food security framework	A conceptual framework designed to assist in assessing the state of food security (or insecurity), and in designing policies and strategies to improve food security. The definition, published by FAO in 2006, includes four "pillars" (availability, access, stability and utilization) and two temporal dimensions (chronic and transitory).
Gross domestic product (GDP)	The sum of the gross value added by all resident producers in the economy plus any product taxes and minus any subsidies not included in the value of the products [World Bank, 2014].
Gross national income (GNI)	The sum of value added by all resident producers plus any product taxes and minus any subsidies not included in the valuation of output, plus net receipts of primary income (compensation of employees and property income) from abroad [World Bank, 2014].
Gross output value	A measure of the total market value from an industry or sector, used in national accounts.
Human capital	When used in a sustainable livelihood framework, this refers to the skills, knowledge, ability to work and good health that together enable people to pursue different livelihood strategies and achieve their livelihood objectives [DFID, 1999].
Internal rate of return (IRR)	A measure of the rate of return on investment, used in cost-benefit analysis. A project is economically viable if the IRR is greater than or equal to the cost of capital.
Natural capital	When used in a sustainable livelihood framework, this refers to the natural resource stocks from which resource flows and from which services (e.g. nutrient recycling, erosion protection), useful for livelihoods, are derived [DFID, 1999].

Net present value (NPV) A measure of the economic profitability of an investment, used in cost-benefit analysis. The sum of the discounted values of benefits-costs over all project years. If the NPV is greater than or equal to zero, the investment is economically viable at the discount rate applied.

Notifiable disease A disease that is required by law to be reported to national authorities. National authorities of countries belonging to the OIE must report occurrences of OIE listed diseases.

Opportunity cost The value lost by using a scarce resource for one purpose instead of its next best alternative use.

Partial budget A method for estimating the economic viability of making a small change over a short period of time. Often used for analysis at farm level.

SAM (social accounting matrix) A matrix of resources and resource flows across an economy that can be used to predict the impacts of changes.

SPS agreement The Agreement on the Application of Sanitary and Phytosanitary Measures that entered into force with the establishment of the World Trade Organization on 1 January 1995. It concerns the application of food safety and animal and plant health regulations. [WTO, 1998]. Under the SPS, OIE is recognized by the WTO for International Animal Health Standards.

Sustainable livelihoods framework A systematic approach to livelihood analysis developed principally by the United Kingdom's Department for International Development (DFID). It defines three types of outcome (higher income; reduced vulnerability and a more sustainable natural resource base) and four types of livelihood asset or "capital" (financial, physical, natural and human). It specifically includes the "vulnerability context" of households and communities.

Value chain approach A school of approaches for analysing a business strategy. It analyses the flow of resources, materials and information within the chain of activities that goes towards the production of a particular product, between the start of the production process and sale to the final customers. It encompasses: mapping of value chains; estimating value added at each step; analysing "governance" (controlling influences and mechanisms).

Value chain

"The full range of activities which are required to bring a product from conception, through the different phases of production (involving a combination of physical transformation and the input of various producer services), delivery to final consumers, and final disposal after use" [Kaplinsky, 2003]. A dairy value chain, for example, might include milk production, transport of milk to a processing facility, processing, transport to wholesale and retail outlets, and sale to consumers. Supporting services might include feed supply, animal health services and supply of drugs, credit and information provision.

1. Background

These guidelines are intended for animal health practitioners working for international, regional and national public institutions who wish to commission economic studies, oversee the economists who carry them out, and make use of the results to guide work on transboundary animal diseases (TADs). They may also be of interest to economists and other professionals who are familiar with the economic techniques discussed but are unfamiliar with animal health issues and wish to learn more about them.

Economic analysis has an important part to play in TADs policy and strategy, and increasingly it is a part of legislation development in many countries and regions. However, public animal health programmes do not always include economists. Animal health practitioners working in public programmes do not always feel confident to reach out to economists and other social scientists, yet they must take responsibility for ensuring that TADs programmes include sufficient economic content, by commissioning work, overseeing it and interpreting the results. In order to do this well, they do not need to become livestock economists, but they do need a sound understanding of the scope of economic analysis as applied to TADs. They must become good at asking clear, well-framed questions for economists to answer and interpreting information in the reports written by economists. One of the aims of these guidelines is to encourage fruitful, well-informed collaboration between veterinarians, animal health experts and social scientists.

The guidelines are intended to provide a structured way of looking at the economic analysis of TADs that helps to highlight the kinds of questions that may be important. They are not a manual on how to carry out an analysis; there are many other publications that explain how to use economic techniques. Instead, they explore the questions about TADs that can be answered with the help of economic analysis, and use examples to illustrate a variety of analyses.

The guidelines are organized as follows:

- Introductory material. This chapter sets the scene. It discusses what is understood by the term "transboundary animal disease", the reasons why economic analysis is applied to TADs and the kinds of questions that it is used to answer (Chapter 2).
- A framework relating economic methods to commonly posed questions about TADs. (Chapter 3).
- Chapters 4, 5 and 6 expand on the topics introduced in the framework, providing more detailed descriptions and many examples from published reports.
- Practical suggestions on designing studies on the economics of TADs and a word of warning about gaps and deficiencies in data are provided in Chapter 7.

2. Introductory material

2.1 WHAT IS A TRANSBOUNDARY ANIMAL DISEASE?

Transboundary animal diseases (TADs) are defined as animal diseases "of significant economic, trade and/or food security importance for a considerable number of countries; which can easily spread to other countries and reach epidemic proportions; and where control/management, including exclusion, requires cooperation between several countries" [FAO, 1997]. The prevention and control of TADs is expected to have a positive impact on food security, thereby contributing to the Millennium Development Goals.

There is no fixed or exhaustive list of TADs. At the time of writing, animal health experts in FAO provided lists of TADs considered important, and a still longer list was available in Chapter 2 of the Terrestrial Animal Health Code of the World Animal Health Organisation (OIE).

One reason why the list is not fixed is that diseases that were previously unknown or considered unimportant can, nevertheless, enter a livestock population, spread and cause damage. These are known as "emerging" infectious diseases. Another reason is that that the description of a TAD allows for some ambiguity and misinterpretation. It includes three elements: (a) significant impact for a number of countries; (b) rapid spread, including across borders, and (c) the need for regional or international cooperation. Some diseases, although important, are clearly not TADs; an example is anthrax. The critical distinguishing feature of the TAD is point (b), the ability to spread rapidly and cross borders. This potential for rapid spread creates the sense of urgency by which people instinctively recognize a TAD. It is also the reason why regional or international initiatives are always considered to be necessary for the prevention and control of TADs.

However, there is still some room for ambiguity, because the spread of TADs is influenced by man-made factors, and these vary depending on local conditions. *Brucella melitensis* is an example of a disease that is sometimes but not always treated as a TAD. It is transmitted between animals mainly through ingestion of contaminated material when females abort, and to humans through contaminated milk [Blood and Radostits, 1960]. As it does not usually transmit very rapidly, in many areas it is not considered a TAD. However, in the Middle East and Central Asia it can spread far and quite fast as a result of transhumance and unrecorded transport across borders; and regional co-ordination is considered necessary to contain it [FAO, 2010a]. For practical purposes, therefore, it is treated as a TAD in this region.

In these guidelines the emphasis is on the core characteristics of a TAD, rather than on the definition or composition of a fixed list of diseases. The combination of production losses, rapid spread across borders and sense of urgency give rise to the economic impacts discussed in later chapters.

2.2 WHY ECONOMIC ANALYSIS IS APPLIED TO TADS

Transboundary animal diseases result in several kinds of economic impact. They cause livestock production losses, which may be very high if the disease in question spreads very rapidly, and particularly if it causes high levels of mortality. They can also result in considerable disruption to trade, causing particular concern in countries where export is an important source of revenue for the livestock sector. The prevention and control of TADs add to the cost of livestock production and to the national veterinary budget. Zoonotic TADs (those that can infect humans and cause human disease) cause economic impacts from human sickness and costs to public health systems. Governments spend scarce resources controlling outbreaks of TADs and applying prevention measures; farmers must deal with the impacts in their livestock production systems, and consumers experience the effects of local or widespread market disruptions caused by TADs. Economic analysis is needed by planners and policy-makers to assist them in deciding how best to allocate the limited resources available for animal health.

Economic analysis is used by planners and policy-makers:

- To discover which TADs have the greatest economic impact. This can contribute to the justification for giving a particular disease or issue a strong policy focus, or for earmarking a large expenditure from public budget or private investment to deal with it.
- To assess whether a proposed policy or programme to control a TAD or mitigate its impact is likely to provide a positive return to public spending, or to compare alternative approaches.
- To discover whether a TAD policy or disease mitigation or control programme has been a good public investment.

Economic analysis is used by research managers and those funding research programmes:

- To prioritize the activities included in animal health research programmes.
- To assess the likely (or actual) uptake of technologies and practices to control TADs and the economic or financial impact on those who may adopt (or have adopted) them.
- To guide the design of research studies.

It is used by designers of extension programmes and by extension workers:

- To help in determining which TADs management practices and technologies will be most suitable for livestock owners in a particular geographic location or food system.
- As a component of extension advice and training, to help farmers review and understand a new technology or approach to dealing with TADs.

The questions asked of animal health economists fall into three broad groups:

a) "What is the economic (or socioeconomic) impact"? This question is usually asked to help in planning and prioritizing expenditure or to justify expenditure on TADs control.

b) "Will this TAD policy or project be economically viable (or was a former initiative economically viable)?" This question is important to development funding agencies and governments when designing animal health policies and projects, and may be part of a research prioritization process. It can also contribute to a risk analysis in the context of livestock trade.

c) "Why do farmers, traders and others not listen to our advice?" or "…follow our instructions?" This question is sometimes asked by veterinarians in State Veterinary Services when TAD prevention and control strategies are not proceeding according to plan.

Each of these questions is addressed in the chapters that follow.

At times it may appear that economic analysis is being used to "rubber stamp" a policy or planning decision that has already been made, or to attempt to justify research to which funds have already been committed. It can also be the case that economists are asked to contribute in one of the areas listed above, but are unable to do so because the necessary data cannot be collected within the time and budget available. These situations are less likely to occur when economic analysis is built into the planning process from the start.

3. A framework for analysis

3.1 OVERALL FRAMEWORK

In an ideal world, the economic impacts of TADs would always be measured through surveys especially designed for the purpose. In the real world it is often difficult and expensive to do this. Instead, estimates are made drawing on information extracted from published reports, secondary data from published databases and primary data from surveys, using arithmetic calculations and statistical and mathematical models. A range of frameworks, tools, techniques and approaches have been applied to the economic analysis of TADs.

The three broad questions identified in section 2 can be addressed at different levels as shown in the simple framework in Table 1. A framework for analysis within each of the three areas of interest is described in sections 3.2 to 3.4.

3.2. ECONOMIC IMPACT OF A TAD

The economic impact of a TAD can be assessed at different levels and from the perspectives of different stakeholders. For example:onal government or a regional coalition, it may represent a threat to national income, a potential drain on budget, and an impediment to international trade.

- For livestock producers, traders, and the processors and retailers of livestock products, the presence of a TAD may represent a threat to livelihood, a need to invest in prevention measures, and a source of friction with state veterinary services.
- Animal health providers and the suppliers of vaccines and drugs may see a TAD as a source of revenue from drug and vaccine sales.
- Consumers may perceive a TAD as a threat to health (if the disease is zoonotic), and may be disadvantaged if a severe disease outbreak affects food prices or disrupts the food supply.

TABLE 1
Overall framework

	Area of interest		
Possible level of analysis	**Economic impact of a TAD**	**Economic viability of an intervention to prevent or control a TAD**	**Motivation for stakeholders to comply with TAD control regulations**
Global or Regional	●	●	
National	●	●	
Livestock sector	●	●	
Stakeholder	●	●	●

- The presence of a TAD can reduce revenue from tourism if it restricts access to rural areas or discourages people from visiting an infected country.

Table 2 relates the level at which the impact of a TAD is assessed to the economic methods that may be applied. These guidelines do not attempt to provide a comprehensive methodological review of the kind given in Rushton [2009], but only to illustrate the range of methods that are in common use. The choice of methods for a given analysis will depend on the precise question to be answered, the availability of data and time for the analysis, and the preference of the economist. Examples of use of the methods are given in chapter 4.

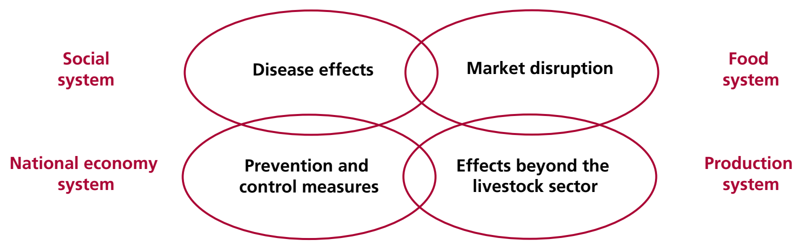
When analysing the impact of a TAD it can be helpful to divide the impact into component parts. Some analysts distinguish between "direct" and "indirect" effects [e.g. Rushton and Knight-Jones, 2012; Rushton, 2013]. Others identify different sources of impact, such as production losses and costs of control [e.g. Tambi *et al.*, 2006]. These guidelines identify impacts based on their source, because the author has found this to be the simplest and most intuitive approach when discussing TADs impacts with animal health planners.

TABLE 2
Methods for estimating the economic impact of a TAD

Level	Reasons	Possible methods
Global / Regional	• Explain or justify the focus on a particular disease on the part of the international community. • Determine future policy directions of governments and inter-governmental organizations with regard to "emerging" TADs, or those that are spreading or have changed location.	Spreadsheet modelling. Macroeconomic modelling May be supported by epidemiological studies/ modelling.
National / Sector +/- Stakeholder *	• Explain or justify the focus on a particular disease on the part of a government. • Demonstrate to the government the savings that may be gained by financing TADs prevention measures. • Estimate the costs incurred in controlling an outbreak as a matter of public accountability. • Estimate impacts on food supply or consumption.	Comparison of national statistics pre- and post-outbreak. Macroeconomic modelling Simulation modelling Choice models and related methods May be supported by epidemiological studies/ modelling
Stakeholder	• Assess where control efforts should be directed, or who might contribute to funding them.	Choice models and related methods Simulation modelling Sustainable livelihoods analysis Choice models and related methods Value chain analysis May be supported by epidemiological studies/ modelling.

(*) An analysis at national level will often include impacts for specific stakeholder groups as well as the national impact

FIGURE 1
Context and sources of the impact of a TAD



There are four main sources of impact (Figure 1). The first three are experienced within the livestock sector, namely:

- **Disease effects:** the mortality and loss of production caused by clinical or subclinical disease.
- **Market disruption:** as a result of consumer fears, or supply shortage causing market shocks, or as a consequence of restrictions on international trade in livestock and livestock products that are applied because of TADs.
- **Control measures:** the costs and benefits of measures applied by farmers, governments and industry to prevent or control disease outbreaks.

In addition to effects within the livestock sector, there is also a fourth source of impact:

- **Effects beyond the livestock sector:** these may include impacts on human health, the public health system, tourism and wildlife.

In developed countries, TADs hardly ever occur without control measures being applied or markets affected, and in these countries the main economic impact often results not from the disease itself but from market disruption and costs of disease control. In developing countries, losses from disease infection or the costs of control applied by farmers can be more important. For example, TADs of small ruminants or poultry that occur at low levels of incidence can move within flocks for many weeks with only minimal prevention or control measures being applied by farmers, the main economic impact resulting from sporadic waves of mortality. In parts of Africa, contagious bovine pleuropneumonia (CBPP) receives little preventive action by governments for long periods, and the impacts of disease are mitigated by farmers using antibiotics.

The impact of a TAD is also affected by the context in which it occurs. When designing programmes to mitigate the impact of TADs, context has a strong influence on what will be successful. Context includes:

- **Production system.** Scale and intensity of production affect the way that livestock owners experience the impact of TADs. The timing of outbreaks relative to the production cycle or the cropping season can also be important. Each type of producer has a perception of TADs that relates to their own experience, and this affects the way they react to and deal with TADs.

- **Food system.** Disease spread and the effectiveness of prevention and control measures are affected by the way that production and marketing of food are organized and regulated.
- **National economy.** Rich countries focused on export trade have different concerns from those that are poor and mainly concerned about food availability.
- **Social system.** Social traditions may limit the ownership of livestock by certain groups, restricting their options to diversify and protect against TADs risks.

3.3 ECONOMIC VIABILITY OF AN INTERVENTION TO PREVENT OR CONTROL A TAD

A TAD control intervention could be anything from a large government programme to the measures applied by an individual farmer. An intervention is more likely to be implemented if it is economically viable, although political, ethical, humanitarian or social considerations will also influence the decision.

As previously mentioned, an intervention can be analysed at global, national or sub-national level. The question "is it economically viable?" means simply "does the outcome in economic terms justify the resources invested?" The question may be asked:

- By a government developing a disease prevention policy, or analysing the impact of an existing or previous control policy, or deciding how much to depend on disease control.
- By a funding agency that has supported or is considering a disease control programme.
- By a government writing a contingency plan for outbreak control (although in practice many contingency plans omit a budget, and some fail in their implementation because it takes too long to obtain the necessary finance).
- By a development agency or extension service, as part of the advice provided to farmers about a technology or management practice.
- By a private livestock or food company, or an industry association, considering a new TAD control strategy or a change to existing practice.

In addition to the question "is this economically viable?" there may be several subsidiary questions, for example:

- What is the likelihood that reasonable conditions will not be achieved and the benefits will be delayed? What is the possibility that the strategy will fail completely? What needs to be done to prevent this?
- Will everyone benefit or at least be no worse off? Or will some groups be worse off, and if so, do they need to be compensated?
- What are the economic and social implications of getting this wrong?
- If an investment is needed to make this strategy work, how long will it take to pay it off? This is particularly important for private sector stakeholders.
- How should the costs be shared between the public and private sector?

There may also be questions that are more challenging to address within a conventional economic analysis, such as:

- Will this intervention reduce or increase access to natural resources that people use for livestock production, or will it change their social status?
- Will this intervention make vulnerable people more vulnerable to shocks and stress?

Table 3 relates the level of analysis to the economic methods that may be applied.

TABLE 3
Methods for estimating the economic viability of an intervention

Level	Reasons	Possible methods
Global / Regional / National	• Determine whether or not to implement a publicly-funded disease control policy or programme. • Analyse the impact of an existing or previous control policy. • Assess financing requirements for a contingency plan for outbreak control. • Assess whether some groups will need to be compensated. • Identify potential undesirable effects e.g. increasing vulnerability of the poor or depletion of natural resources. • Determine how costs should be shared between the public and private sector. • As part of a risk assessment related to importation of live animals or livestock products.	Economic* cost-benefit analysis. Economic cost-effectiveness analysis. Cost comparison. May be supported by epidemiological studies and modelling.
Stakeholder	• Develop extension advice for farmers. • Assess whether a TAD control strategy offers a good return on investment for a farmer, private production company or industry association. • Assess the cash-flow implications of investing in TAD control.	Financial* cost-benefit analysis and cost-effectiveness analysis. Partial budget analysis. Optimization modelling. Choice models and related methods. Value chain analysis. Decision tree analysis. Cash flow analysis. May be supported by epidemiological studies and modelling.

(*) "Economic" and "financial" refer to the prices used in the evaluation. Also see Chapter 5.

An intervention is economically viable when the benefits it generates are at least as high as, and ideally higher than, the costs it incurs.

Table 4 shows a classification of costs. Costs of TAD prevention and control are mostly incurred within the livestock sector, but there may also be costs beyond the sector, for example to public health. There may be new costs incurred in order to implement the intervention, as well as opportunity costs – the output value that is lost as a result of implementing the intervention. Costs may be further subdivided into investment (infrastructure, human capacity development, vehicles and large items of equipment), which are often covered by a grant or loan, and recurrent (the fixed and variable costs associated with maintaining the investments and carrying out the implementation). Costs within the livestock sector are described in more detail in section 5.3.

TABLE 4
Classification of costs of TAD prevention and control interventions

Within the livestock sector			Beyond the livestock sector		
Prevention and preparedness costs	Outbreak control costs	Costs of changes to management or production systems	Public health investment	Higher food prices for consumers	Costs to tourism or wildlife
(New costs)		(Opportunity costs)	(New costs)		(Opportunity costs)

TABLE 5
Classification of benefits of TAD prevention and control interventions

Within the livestock sector			Beyond the livestock sector		
Increased asset and output value	Reduced prevention and treatment costs	Reduced costs of outbreak control	Human lives saved or quality-life-years increased	Public health treatment costs reduced	Tourist sector outbreak control costs reduced
(New output)		(Reduced costs)	(New output)		(Reduced costs)

Table 5 shows a classification of potential benefits within and beyond the livestock sector. They are of two types: additional output and reduced costs. Prevention and outbreak control appear as both benefits and costs. This reflects the fact that early investment and more stringent outbreak control measures may be needed to create later savings from reduced disease incidence. Benefits within the livestock sector and those to public health are described in more detail in sections 5.1 and 5.2. Those in other sectors are beyond the scope of these guidelines.

3.4 MOTIVATION FOR STAKEHOLDERS TO COMPLY WITH TAD CONTROL REGULATIONS

Veterinary services sometimes appear surprised when farmers or livestock traders fail to report suspected cases of a TAD, or prolong outbreaks by selling infected animals or failing to observe basic biosecurity measures. Outbreak investigations uncover risky practices by drivers of milk tankers and feed lorries who fail to clean their vehicles, and animal health practitioners who move from farm to farm without washing their footwear, or use the same needle to vaccinate more than one animal. Surveys of livestock markets reveal practices that allow viruses to spread between animals and from animals to people. Consumers practise poor kitchen hygiene or import unprocessed meat from places where TADs are common.

Even when regulations are in place to minimize the spread of TADs, they are often ignored or improperly implemented. This is a source of frustration to governments, and reduces the effectiveness and economic viability of prevention and control programmes. Estimates of economic viability are based on assumptions about the way things will happen. To provide a useful analysis the assumptions need to be credible.

There are valid economic and social reasons behind the failure of TAD control policies.

- Private stakeholders may not share the government's perception of the risk posed by a TAD and the importance of prevention and control. Individuals modify their behaviour based partly on their own perception of risk – which may or may not be the same as the real risk – and this in turn affects the actual risks and costs of a control programme. They will be more inclined to modify their behaviour if they perceive an immediate risk to their own animals or livelihood from failing to comply.
- It may be inconvenient for farmers and others to implement the changes required by a policy, which may include changes to daily routines and the way livestock are managed and traded. Even something that appears simple, such as restricting access of vehicles onto a farm or changing footwear before entering an animal enclosure, takes extra effort. Some policies require major changes of practice on farms, and in markets or slaughterhouses.
- Complying with a government policy may result in loss of income or require expenditure on training, equipment or infrastructure. Financial penalties may be experienced even by farmers whose animals are not infected by a TAD, if government policies restrict movement or require animals to be slaughtered as a precautionary measure.

Table 6 relates questions addressing reasons for compliance (or non-compliance) to the economic methods that may be applied to answer them. Chapter 6 provides further details.

3.5 IDENTIFICATION OF STAKEHOLDERS

If analysis at stakeholder level is required, the first step is to identify the stakeholders on whom to focus.

There are a number of possible approaches to stakeholder identification, all of which are forms of "systems thinking". All have in common the fact that they try to identify the key stakeholders in a particular issue; how each one may be affected by the issue in question, and the relationships between stakeholders, but each approach has particular ways of arriving at results.

TABLE 6
Methods for analysing motivation to comply

Questions	Reasons	Possible methods
How important is TAD control to private stakeholders?	• Understand how much priority each stakeholder places on TADs and TAD control. • Understand how each stakeholder perceives the risk from TADs.	Sustainable livelihoods analysis. Qualitative assessments of risk perception.
How costly and inconvenient will it be for stakeholders to comply with prevention/control policies?	• Understand the economic incentive in complying or not complying . • Identify non-financial barriers to compliance.	Cost-benefit analysis. Decision tree analysis. Use of economic theory e.g. principal-agent models.

Stakeholder analyses are carried out during project planning exercises by consulting a group of people knowledgeable about the sector. They are asked to develop a list of potential stakeholders and classify them according to a subjective assessment of potential impact (those most likely to be affected by a TAD would be prioritized for analysis), or according to their vulnerability (those least able to cope with the impact of a TAD might be prioritized for analysis), or using other criteria of interest.

It may also be helpful to map the food system in which the TAD occurs. This can be done geographically (showing where feed production, livestock production, markets, processing facilities, transportation routes, etc., are physically located), or schematically (showing the main actors or functions involved and the ways in which they are likened to each other). A decision might then be made to focus on stakeholders located in one "foodshed" supplying a city, or those that have a functional connection.

Value chain approaches are a type of systems thinking used in economics and business management. They are becoming increasingly common in the titles of animal health economics publications, and will therefore be examined here in more detail. The use of this approach reflects a recognition that animal health does not begin and end at the farm, but also contributes to making food safe for consumers and protecting the livelihoods of traders, processors and others working in or contributing to the livestock sector. However, the terms "value chain approach" and "value chain" are often applied very loosely by people unfamiliar with them and there is a danger that this will result in sloppy methodology and poor analytical results. Box 1 provides a brief explanation of the value chain approach in the context of TAD economics.

Livestock products produced within informal food systems in developing countries do not always pass through a recognizable value chain. However, it is still possible to adapt the value chain approach outlined in Box 8 to assist in making sense of the food system and to assess where the economic impacts of TADs, or TADs prevention and control programmes, may occur. It is rare to find a complete value chain analysis associated with an economic study of a TAD, but several authors have applied elements of the value chain approach to analysing some aspect of impact. Rich *et al.* [2013] describe value chain analyses of RVF in Kenya and HPAI in Nigeria. McLeod *et al.* [2009] ; Ayele and Rich, 2010; Mensah-Bonsu and Rich; 2010, Cocks *et al.*, 2010; FAO, 2011a].

BOX 1

A quick guide to the value chain approach

The terms "value chain approach", "value chain analysis" and "value chain" have become more widely used in animal health economics in recent years – sometimes without a real understanding of what they mean.

The confusion arises, to some extent, from the fact that value chain approaches are part of a group of methods that also includes supply chain analysis and "filière" analysis. In addition, value chain approaches have undergone changes since they were originally made popular in the business management literature of the 1980s. The description here follows that provided by the Institute of Development Studies in the UK. A value chain approach analyses the flows of resources, materials and information within a chain of activities that go towards the production of a particular product, from the start of the production process up to sale to the final customers. It pays particular attention to linkages between different agents/actors, how their activities are coordinated and the needs of final users. The analysis aims to discover why the chain performs in the way that it does and how it can be made more efficient. It may look for barriers to entry (factors that prevent some people from having access to the chain), governance (who influences the performance of the chain and how) and/or distribution of income and profit through the chain.

The first step is always to find a "point of entry" at one of the links in the chain - this is determined by the question that the analysis is trying to answer. For example, when trying to improve surveillance for TADs the point of entry may be the livestock producer; when trying to improve food safety it may be the informal trader or the large retailer.

The next step is to map the chain, mapping backwards and forwards from the point of entry. A map for the livestock sector will show the main links in the chain (e.g. producers, traders, market operators, processors, retailers, consumers), the strength of connections between them (e.g. whether formal contracts are in place), the volumes and values of product flowing from link to link, and the concentration at each link (e.g. many producers; few large retailers).

The direction of the analysis after mapping depends on the question that the analysis has set out to answer. Some examples related to the economic impact of TADs might be:

- What is the impact on profitability at different links in the chain of an outbreak if it goes unchecked?
- Where in the chain are the costs of disease control greatest?
- At what point(s) in the chain do the largest numbers of people and animals come into contact? How far could a disease agent spread along the chain unnoticed by the veterinary service and how might this affect impact?
- If the domestic market or an export market closes, whose livelihood will be affected?
- Where in the chain will it be most cost-effective to apply pressure to introduce a change in disease control practices?
- If the structure of the chain changes, who will benefit and who will lose?

Sources: Kaplinsky and Morris [2004]; Humphrey and Napier [2005]

4. Economic impact of a TAD

This chapter discusses in more detail the sources of economic impact identified in section 3.2, and provides examples of analyses of impact at global/regional level, at national level and for specific stakeholder groups.

Depending on the context of the analysis, an estimate may be made for one TAD or a group of TADs, on any scale from a small local area to a global impact. It may be confined to the livestock sector or expanded to include knock-on effects to human health and other sectors.

When assessing the economic impact of a TAD it is important to be aware of the issue of "attribution", or in other words, to ensure that the economic impact estimated is the only impact that can be attributed to the TAD being analysed. If there are other factors occurring at the same time that might create a similar effect, these need to be examined and their effect removed. For example, in a year when there is both a TAD outbreak and a drought, there is likely to be unusually high livestock mortality, but this may be partly attributable to the drought and only partly to the TAD outbreak.

4.1 SOURCES OF IMPACT

Disease effects

When livestock are affected by a TAD, clinical or subclinical disease may result in the loss of animals as productive assets, or may reduce their productivity.

If disease kills animals with a long production life, such as those used for breeding or traction or kept for wool or hair, this represents a serious loss of productive assets. Most TADs cause high rates of mortality in naïve herds and flocks, sometimes in animals of any age, or sometimes only in the young as with peste des petits ruminants (PPR) and foot and mouth disease (FMD). Sometimes an animal does not die but is so seriously affected that the farmer sells or culls it.

As well as the lost value of the asset, there may be a delay in replacing it. This is common if the farmer relies on home-bred animals and the animal in question is one with a long breeding cycle. If mortality is very high, a herd or flock may shrink to the point where it is no longer self-replicating. Even when farmers regularly buy replacement animals, a widespread TAD outbreak may result in a shortage of replacement animals for purchase.

Animals that do not die from disease may become less productive for a short or long period of time. Effects include abortion, reduced milk or egg production, slower growth rates, loss of work days in draft animals and reduced crop yields.

Box 2 describes a variety of disease losses experienced by livestock owners in different types of production systems.

If mortality or culling of animals results in greatly reduced herd sizes, the impact of disease can spread beyond the farm family to affect employment of casual farm labour and employment of others in livestock market chains.

BOX 2

Examples of losses from disease experienced by livestock owners

ND (Newcastle disease)

ND causes high rates of mortality in susceptible poultry flocks. The greatest economic impact is through loss of productive assets. The impact can be very severe in the following situations:

- For children or poor women who have no other livestock assets.
- If most of the breeding birds in a village are killed, making it hard for farmers to replace their flocks.
- For small-scale commercial farmers who have a large part of their asset base in poultry and have bought feed on credit.
- If a supplier of day-old chicks loses a laying flock, disrupting business for the farmers they supply.
- If a high-value grandparent or parent breeding flock is lost. This not only results in the loss of valuable breeding birds, but can have widespread effects on the supply of birds to layer flocks.

PPR (Peste des petits ruminants)

PPR causes high levels of mortality in unprotected goat and sheep flocks, resulting in a loss of productive assets and a reduction in the growth of herds and flocks.

- In Bangladesh goat mortality from PPR in one year was valued at USD34.08 million [Honhold and Sil, 2001].
- In North Cameroon, Awa, Njoya and Ngo Tama [2000] estimated that the lost value of herd growth and sales in a mixed village sheep and goat flock with a starting population of 5 200 animals was USD53 902 over a five year period.
- A household study in Kenya [FAO, undated] found that PPR caused livestock asset losses ranging from 65 to 100 percent in a single outbreak. Loss of livestock income ranged from 21 to 100 percent. In some cases the flock became unsustainable, i.e. could no longer reproduce itself.

(cont.)

Market disruption

Market disruption is a component of the economic impact of TADs. It takes two forms, each with economic consequences, namely market shocks and export market restrictions.

Market shocks

If consumers fear that animal products or exposure in markets will make them ill, this can lead to a sharp fall in consumption of certain livestock products when an outbreak of a TAD is announced. The fall in demand results in a fall in prices and loss of revenue for producers until consumer confidence is restored.

Zoonotic diseases, whether transboundary or not, often cause this type of shock. Poor risk communication may exacerbate demand shock from a zoonotic disease, with exaggerated media messages heightening consumer reactions. H5N1 highly pathogenic avian influenza (HPAI) resulted in market shocks related in many countries arising from consumer fears of contracting the disease from poultry meat (Box 3).

FMD (Foot and mouth disease)
FMD causes blisters and erosions on the mouth, teats and feet of ruminants and pigs, reducing appetite, preventing suckling and milking and making animals lame. It can sometimes cause abortion or the death of young animals. Farmers most affected by FMD include:

- High-yielding dairy farmers, who operate on tight financial margins per litre and per cow. Temporary reduction in milk yield has serious impacts on cash flow. Animals are culled if they become chronically infected or if they abort and lose the subsequent lactation [Rushton *et al.*, 2012].
- Small scale commercial dairy farmers, who lose income when milk yields are reduced by as much as 30 percent. Abortion may result in the loss of calves intended for breeding or beef production.
- Mixed farmers who own or use draft animals. If they become infected at ploughing time, this delays the planting of crops and prevents the owners from hiring out their animals [James and Ellis, 1976; Perry *et al.*, 1999]. Replacement animals can be in short supply. Use of draft animals is declining in much of the world but is still important in Western and Southern Africa and in many remote areas [Starkey, 2010].
- Pig farmers in South East Asia and China, where pig meat is important in the diet and demand is growing, FMD causes case fatality of 15 to 35 percent, mainly in piglets, and weight loss of up to 5kg per animal [Randolph, Perry, Benigno and Santos, 2002]
- In a pastoralist herd during a drought when animals are already stressed from lack of feed and water. At other times, animals will be treated to relieve symptoms and most will make a full recovery.

Wealthy consumers tend to react more strongly than poor ones to food safety scares, including those related to zoonotic-diseases, by refusing to buy food products they consider risky. The poorest consumers tend to be more price-conscious and less risk-averse, and may take advantage of lower prices during a demand shock.

A second type of shock occurs when the livestock population is severely depleted by disease or culling; supplies of livestock products become short and prices rise until production can be restored to normal levels or supply gaps filled by imports.

When a supply shock affects only one type of livestock-source food, consumers may be able to adjust to higher prices by temporarily switching their consumption to substitute foods. However, if the price shock affects a commodity that is usually cheap and widely consumed by poor people, they may not be able to afford an exact equivalent. Among livestock products, milk, eggs and poultry meat tend to be the cheapest. If their prices rise as a result of a supply shock, poor people may substitute with vegetable proteins, or they may eat a higher proportion of starch and as a result have a less well-balanced diet.

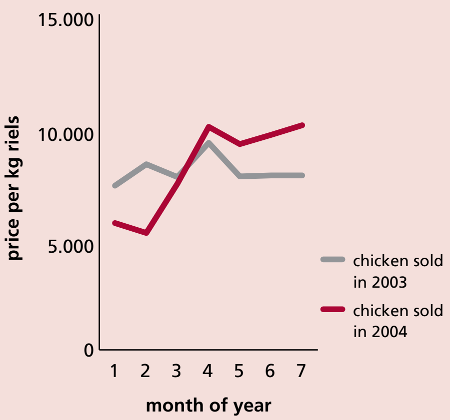
BOX 3

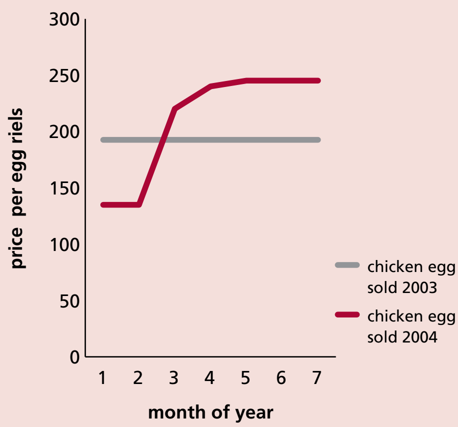
Market shocks caused by H5N1 HPA

H5N1 HPAI causes high levels of mortality in most poultry. It can also be transmitted from poultry to humans, and while human infection rates appear to be very low, case fatality is high. Outbreaks between 2004 7 resulted in fear and panic among consumers in several Asian and European countries as well in Egypt [McLeod, 2009]. A sudden fall in demand, leading to a short-term price drop, was experienced to different degrees. Demand and prices recovered within a few weeks. In some cases, the original demand shock was followed by a brief period of supply shortages and unusually high prices.

The worst impacts were seen in the first wave of the epidemic. Subsequent waves resulted in much less dramatic consumer reactions and the long term consumption of poultry was hardly affected. The shocks had the worst effect on poor consumers who could not afford substitute animal proteins, and on the small-scale poultry producers and traders who depended on poultry for their livelihood. Although the shocks were temporary, the most vulnerable people had only limited safety nets to cushion them.

An example of impact on prices comes from Cambodia, where the first outbreak was reported in January 2004. There was an immediate and dramatic fall in demand for chickens and chicken eggs [Sothyra, 2004, see graphs below] and in prices for both commodities, followed by a rebound when consumer confidence recovered. Prices of pork, beef and fish were higher during most of 2004 than they had been in 2003.





Sometimes, both types of shock occur in succession. This was the case with H5N1 HPAI in some of the most heavily affected countries. The impacts are usually short in duration, although they may be severe and alarming when they occur.

Trade restrictions in export markets

A 'notifiable' disease is a disease that is required by law to be reported to government authorities and one which a government is obliged to report to the OIE under the agreement on sanitary and phytosanitary regulations (SPS agreement) of the World Trade Organization (WTO). Most TADs are classified by the OIE as notifiable diseases and as such they can constitute the reason to limit or ban imports of livestock and livestock products under the SPS agreement. According to this agreement a country is entitled to restrict imports of livestock products in order to minimize the risk of transmitting TADs to its own livestock population.

Some diseases, such as contagious bovine pleuropneumonia (CBPP) and Rift Valley fever (RVF), mainly affect exporters of live animals, while others, notably FMD, affect exporters of a wide range of livestock products. Of all TADs, FMD causes the greatest restrictions to international trade; although it does not cause high mortality and in some production systems has very limited productivity effects, it is expensive to prevent and very hard to eradicate[1]. The virus can be carried by infected live animals and a wide range of livestock products. Much of the economic impact of FMD is a direct or indirect effect of trade restrictions and for this reason the disease tends to take centre stage in discussions about TADs and export markets.

Access to premium export markets depends on being able to establish freedom from certain TADs within the whole of a country or a defined zone or compartment. While freedom from disease does not guarantee access to premium export markets, the presence of certain TADs makes it highly likely that access will be barred. Alternatively, it is possible to sell products deemed to be of "negligible risk" of carrying disease agents even when they come from a country or area where notifiable livestock diseases are present; this is termed "commodity- based trade". Livestock products that have been processed by heat treating to approved standards and then packaged, fall into this category. However, chilled, deboned meat that has been slaughtered and matured according to OIE guidelines, although also at a negligible risk level, is not always treated as such in trade agreements.

The economic impact of restricted access to export markets takes the following forms:

- It distorts the development of the livestock sector, both globally and within countries. For example, in 2009, almost 70 percent of world trade in animals and meat from species susceptible to FMD came from a small number of countries that were officially free under OIE regulations, or historically recognized to be free. [OECD/FAO, 2009]. Namibia and Botswana each has an FMD-free zone, an area of the country protected by a stock-proof and wildlife-proof fence, from which meat is exported to countries with FMD-free status. In both countries commercial ranches are concentrated within the zone and communal grazing outside it.
- For countries that need or strongly wish to export, investments will be needed in facilities and infrastructure, to either process products so that they are deemed to be of negligible risk, or to set up disease-free zones and compartments (Box 4).

[1] FMD affects live animals and animal products, ruminants and pigs. Vaccination is expensive because there are several virus strains and each vaccination is protective for only a short period. Being recognized as officially free from FMD or maintaining an FMD-free zone is seen as an indication of a competent veterinary service.

BOX 4

Examples of impacts associated with trade restrictions

Cost of investment in SPS compliance

The Zambezi Region in north-east Namibia is home to 90 000 people and a cattle population of 150 000. This region needs to export between 260 000 and 430 000 kg of meat per year to maintain the livelihoods of cattle keepers. Although the export abattoir applies OIE standards, Zambezi can only export to a very limited number of regional markets because it is FMD-infected. Eradication is not a practical option as Zambezi is located within a regional wildlife conservation area. A recent study recommended investment in a processing plant, because heat-treated processed meat is easier to export than frozen deboned beef [SATOTO, 2013].

A TAD outbreak in an exporting country

Small ruminants are exported from extensively grazed flocks in the Horn of Africa to the Middle East, with Saudi Arabia representing a particularly important market. A local industry has grown up around the export with forage being produced specifically for animals destined for export. Outbreaks of RVF cut off exports from the Horn of Africa to parts of the Middle East in 1997-1998, 2000 and 2007. The 1997-1998 outbreak affected 75 percent of the approximately 3 million animals exported from Somalia. Some traders were able to avoid the bans but other traders and livestock owners suffered badly from low prices and the inability to sell animals. [Aklilu and Catley, 2009]. An estimate made in 2003 showed a loss of 25 percent of GDP compared with a normal year from the Somali region of Ethiopia, the country's main source of exports. The total loss in value added was USD132 million, 42 percent below what would be expected in a normal year. [Nin Pratt *et al.*, 2005].

- It causes serious market disruptions when an outbreak occurs in a previously disease-free, exporting country (Box 4).
- A TAD epidemic involving several countries in trade restrictions can create an international market shock, although this usually only occurs for a short period as global livestock markets adjust very rapidly to supply disruption. Disruption can be more severe if outbreaks occur in more than one major exporting country, or if outbreaks of TADs affecting different species occur in rapid succession.

Trade restrictions can potentially work against importing countries in the event that a TAD outbreak affects the domestic supply of a widely-consumed food product at a time when there are restrictions on the import of livestock products. The only example in recent history was for a short period during a protracted HPAI epidemic in Egypt, when import bans on poultry products were in place to protect the domestic livestock sector. The usual response to a shortage of one livestock-source food is that consumers will switch to another. If the supply shortage is very severe, this can lead to temporary price rises.

Establishing the economic impact of restricted markets can be challenging, as it depends on being able to make a reasonable assessment of opportunity cost, i.e. what might happen if the restrictions did not exist. Many factors – in addition to freedom from disease – affect the ability to export: quality and price of products; volume and reliability of supply; and the ability of governments to negotiate trading agreements [McLeod and Leslie, 2001; McLeod and Honhold, 2012]. In the current economic climate, even when it is possible to overcome SPS barriers to export, the cost of feed can be prohibitive.

Prevention and control measures

Prevention and control measures for TADs aim to reduce the negative impacts of disease losses and market disruption discussed previously. Because of the externalities associated with TADs, governments as well as farmers invest in prevention and control. However, control initiatives have their own costs and these contribute to the total impact of TADs.

The extent of government involvement will be influenced by the local situation and the official disease status of the country. Where a disease is considered to be mainly a local problem the government may not take action, leaving farmers to protect their own herds through measures such as biosecurity and vaccination.

When an area is in transition to becoming officially disease-free for the purposes of international trade, a progressive approach will often be applied. Initially, the level of disease incidence is reduced through surveillance and vaccination, if this is possible. Once incidence is very low, animals are tested and infected animals or herds slaughtered.

Government action tends to be especially decisive when part or the whole of a country has been officially declared disease-free and there is a strong public or private interest in keeping it so. Within that free area, any outbreaks will be "stamped out" by slaughtering infected herds and those considered to be dangerous contacts, and by very strict movement controls during the time of the outbreak.

Each of these approaches has different consequences for the costs of prevention and control and for particular farmer groups. Depending on the prevention and control measures being applied, any of the following economic impacts may occur:

- Costs incurred for prevention and preparedness (quarantines, certification schemes, vaccination, biosecurity, surveillance and early warning).
- Outbreak control costs (operational costs incurred in disease detection, movement control, culling of animals, disposal of carcases and disease tracing; the loss of animals culled; costs incurred by farmers waiting to restock). If culling is very widespread or movement control occurs over a long period, employment of casual labour can be affected, on farms and along livestock market chains.
- Opportunity costs, when as a result of a TAD control policy farmers cannot do what they otherwise would have done (for example, if a cordoned fences are installed to protect a disease free zone, this cuts farmers off from their traditional access to dry season grazing).

Box 5 provides one example of the costs of interventions against PRRS in Viet Nam.

BOX 5

An example of the impact of prevention and control measures

PRRS in Viet Nam

Porcine reproductive and respiratory syndrome (PRRS) has probably been present in Viet Nam for some time, but in 2007 it began causing high mortality in pigs and this attracted the attention of farmers and the government. Since 2007, outbreaks have been controlled by culling and quarantine. Initially, both infected and at-risk communes were involved, but since 2008, only infected herds have been culled and infected communes quarantined. An estimate was made of the total economic impact of PRRS within the livestock sector. The costs associated with disease control activities are shown below. The government incurred costs for prevention and preparedness as well as outbreak control. Some farmers incurred outbreak control costs when pigs were culled with minimal compensation; others incurred losses when quarantine measures delayed sales and reduced gross margins.

	Total	**2007**	**2008**	**2009**	**2010**
Government surveillance & outbreak control	289.6	72.4	72.4	72.4	72.4
Value of pigs culled	346.1	36.4	163.4	3.7	142.7
Gross margin loss resulting from quarantine	498.4	24.8	150.1	84.3	239.2
Total	**1,134.1**	**133.6**	**385.9**	**160.4**	**454.3**

(Values in 1995* billion Viet Nam Dong, exchange rate VND15959 = USD1)

Sources: Calculations done for McLeod *et al.* [2013]

* If an analysis covers several historical years it may be useful to convert all prices to those of one base year, thus removing distortions resulting from inflation.

Impacts beyond the livestock sector

Human health

Transboundary animal diseases can have direct and indirect impacts on human health. Direct impacts occur when humans are infected by zoonotic TADs (those that are naturally transmitted between vertebrate animals and humans), and become ill. The costs of human clinical illness are visible, measurable and have been estimated in a number of published reports. Indirect effects can occur if the presence of TADs severely disrupts the food supply or the ability of poor families to access food.

Zoonotic TADs can have economic impacts if they cause mortality in people, or through illness prevent them from doing the things that they would normally do, or oblige them to require medical treatment. Brucellosis, certain strains of AI, rabies, West Nile fever and Rift Valley fever are all examples of zoonotic TADs. The first two have economic impacts within the livestock sector and in human health. The last three are primarily diseases of humans, with wildlife and/or domestic animals involved in transmission; neither the disease nor the control process has any notable economic effect in livestock.

The economic impact of zoonotic diseases on human health includes the value (or number) of human lives lost; the value of lost productivity through illness; and the cost of treating sick individuals, either privately or through the public health system.

When infection with a TAD shortens human lives, economic analysis requires us to put a monetary value on a human life. A great deal of literature is devoted to ways of calculating this and reasons why we feel discomfort in doing it. The value of a statistical life (VSL) is used to express an "average" value of an adult life, based on the life of a young adult and assumed to be equivalent to 40 life-years. There is no standard VSL – it must be calculated for each country and time period. Sometimes it makes more sense to assess the value of life-years rather than lives. Life-years are expressed as disability-adjusted-life-years (DALYs) or quality-adjusted-life-years (QALYs). There is no simple method for estimating the value of a life or a life-year. Probably the best method is willingness-to-pay studies that attempt to measure what individuals would be willing to pay to reduce the risk of illness or death – but these are problematic to apply in countries where much of life is organized outside of the formal cash economy.

If the main impact of interest is lost human lives or lost years of productive life, it is often simpler and more consistent to express impacts in terms of numbers of lives or life-years lost, rather than attempting to put a monetary value on them. The World Health Organization's Global Burden of Disease Project measures the burden of human diseases in terms of deaths and DALYs.

When dealing with zoonotic diseases like brucellosis that have effects on human health and in the livestock sector, economists face a choice between attempting to put an economic value on human life-years, with all of the limitations mentioned above, or trying to deal simultaneously with two different estimates of impact, a monetary value and a DALY, that cannot be added together and expressed as one total.

Rabies, brucellosis and HPAI are the zoonotic TADs most represented in economic studies. Rabies has minimal impacts on livestock and control programmes do not involve livestock, except in countries where dogs are eaten. Until now it has been treated as a solely human disease. Zoonotic AI viruses have so far killed very few people and impacts have mostly been measured in terms of losses to the livestock sector and costs to public health. One attempt to model the impacts of a human pandemic included loss of human lives, medical costs, disruptions to business, banking and transport [McKibbin and Sidorenko, 2006; Box 6]. Economic analyses of brucellosis have either focused on the livestock sector, or have been reported separately as economic costs and DALYs [McDermott *et al.*, 2013; Roth *et al.*, 2003].

In addition to impacts caused by diseases, a TAD could potentially impact human nutrition by disrupting the food supply, or by reducing household incomes and hence access to food. However, it is very challenging to effectively demonstrate these links and very few people have attempted to do so. One reason is that the "signal to noise" ratio is very loud; so many things can potentially affect diet and nutrition that it is hard to tease out the impacts that can truly be attributed to TADs. In the past ten years there have been many TADs outbreaks, but there have also been floods, droughts and a global economic crisis, all of which have affected food supplies and contributed to rises in food prices. A further problem is that in the households most likely to suffer, it takes prolonged hard work to record changes in diet, and is very difficult to assess whether any dietary changes found can be attributed to TADs outbreaks or to control measures.

During the spread of H5N1 HPAI to some 60 countries, there were several situations where the food security of some families might temporarily have been affected, and there were also some in which changes of diet related to death or culling of poultry were observed but no strong evidence of a link between HPAI outbreaks and malnutrition. A recent report on food security in Egypt suggested that “the nutritional status of children in Egypt is not directly related to food access indicators”, although it also suggested that the abrupt disruption of the poultry meat and egg supply by culling of poultry to control HPAI could have contributed to malnutrition [WFP, 2011].

Tourism, wildlife and biodiversity

The presence of a zoonotic TAD or the measures taken to control a TAD may have impacts on tourism, if tourists are discouraged from visiting an infected area or access to the countryside is restricted by control measures, this results in loss of revenue for the tourist industry. In the event that a zoonotic disease in livestock resulted in an epidemic of human disease, this could cause very widespread disruption of businesses and the operation of public sector services.

Transboundary animal disease prevention and control can potentially lead to impacts on wildlife and biodiversity if, for example, they require wild animals to be culled to remove a potential disease reservoir, or result in an expansion of feed and forage production that encroaches on forest and grassland used by wild animals.

BOX 6

Examples of TAD impacts beyond the livestock sector

The potential costs of HPAI

H5N1 HPAI caused much alarm when it began spreading across Asia in 2004-5. Previous experience with SARS showed the extent to which a fast-spreading zoonotic disease could affect business and day-to-day life. An analysis by McKibbin and Sidorenko [2006] modelled the wider effects on human health and national economies. Uncertainty about the ability to contain a pandemic meant that a very wide range of potential costs was reported, ranging from several billion to several *trillion* dollars in lives lost, and in the disruption to national economies. The estimate has not been tested because a human pandemic did not occur between 2004 and 2013 (the time of writing).

FMD in the UK

The UK’s National Audit Office published an assessment of costs incurred during the 2001 outbreak. The total cost was estimated at over GBP8 billion, of which approximately GBP5 billion was the cost to tourism and supporting industries. Access to the countryside was reduced in many scenic rural areas of the UK and visitors were deterred by the sight of burning pyres of culled animals. The number of foreign visitors making holiday visits fell by 15 percent over three months of the summer, and 30 percent of UK visitors changed their holiday plans. [NAO, 2002]

Food security

It is often stated that TADs have an impact on food security and programmes that control TADs are by definition assumed to be good for food security.

Very few attempts have been made, however, to assess the impacts of TADs or TADs control programmes against a formal food security framework. The Food and Agriculture Organization's conceptual food security framework includes four "pillars" (Box 7). It also has two temporal dimensions, since food insecurity can be defined as chronic, resulting from a persistent shortage in supply or a systemic weakness that limits individuals' ability to access food, or transitory, arising because of a crisis such as conflict or weather-related problems. Both need to be addressed at the same time, because individuals and communities facing chronic food insecurity lack safety nets and are highly vulnerable to transitory problems, while an inappropriate response to a crisis may weaken the base for long term food security by destroying local markets or creating dependencies.

Intuitively, it is easy to see how TADs can be linked to the pillars of food security. Death or illness of animals can potentially reduce the supply of meat, milk or eggs, the income that livestock owners have to buy food, and the social capital of livestock owners and their access to safety nets. Zoonotic diseases affect nutritional well-being; for example, brucellosis makes consumers ill if they drink contaminated milk, and HPAI can be transmitted to people from the carcasses or meat of infected poultry.

However, very few publications have attempted to demonstrate a causal link between TADs and the pillars of food security, and fewer still have quantified the link. Most studies

BOX 7

Four pillars of food security

Food availability: The availability of sufficient quantities of food of appropriate quality, supplied through domestic production or imports (including food aid).

Food access: Access by individuals to adequate resources (entitlements) for acquiring appropriate foods for a nutritious diet. Entitlements are defined as the set of all commodity bundles over which a person can establish command given the legal, political, economic and social arrangements of the community in which they live (including traditional rights such as access to common resources).

Stability: To be food secure, a population, household or individual must have access to adequate food at all times. They should not risk losing access to food as a consequence of sudden shocks (e.g. an economic or climatic crisis) or cyclical events (e.g. seasonal food insecurity). The concept of stability can therefore refer to both the availability and access dimensions of food security.

Utilization: Utilization of food through adequate diet, clean water, sanitation and health care to reach a state of nutritional well-being where all physiological needs are met. This brings out the importance of non-food inputs in food security.

Source: FAO [2006]

have focused on aspects of food access, such as income of livestock producers or consumer surplus. A small number of studies have demonstrated the direct effect of TAD outbreaks on the food supply of pastoralist societies. For example, Barasa *et al.* [2008] found that in South Sudan, outbreaks of FMD often occurred just before the "hunger gap" in the dry season when households were especially dependent on milk as a source of food. Jibat *et al.* [2013] also reported dry-season FMD outbreaks in pastoralist areas of Ethiopia.

A literature search for these guidelines found only one publication on TADs that followed the food security framework – this described the results of a survey conducted by the OIE with veterinary services, in which the effects of TADs on food security were reported against what chief veterinary officers believed to be true [Bonnet *et al.*, 2011].

It can be challenging to establish clear causal links between TADs and food security. Food systems are dynamic and resilient; families and communities have coping mechanisms that help them deal with many transitory crises, and world markets adjust themselves to fill gaps in supply. However, given the importance attached to food security by UN agencies, there would be value in identifying more systematic links between the economic impacts of TADs and the food security framework.

Good references on food security include Pingali *et al.* [2005], World Committee on Food Security [2005] and FAO [2009 and 2010b]. FAO [2011a] provides a detailed description of the role of livestock in food security.

4.2 EXAMPLES OF GLOBAL ANALYSES

As suggested in chapter 3, the global or regional impact of a TAD may be estimated to explain or justify the focus on a particular disease by the international community, or to determine future policy directions.

Ideally, a global estimate would be made by combining the results of existing, detailed national assessments, but it is rarely possible to find a sufficient number of high-quality, comparable studies. An alternative is to build estimates for selected countries or regions based on secondary data, and combine the results.

The OIE commissioned a study to model the costs to the livestock sector of a global HPAI epidemic (Box 8). An estimate of the global impact of FMD was provided as part of the evidence gathered in support of an international initiative on "progressive control" (Box 15). The assessment was based on two components of impact, production losses and vaccination costs, for which it was possible to obtain data across all of the regions studied.

McKibbin and Sidorenko [2006] analysed the potential impacts of a human influenza pandemic originating from HPAI, by modelling the effects of four different scenarios on the GDP of twenty economies that interact through trade and capital flows. There has not been an equally comprehensive effort for a disease of livestock.

4.3 EXAMPLES OF NATIONAL/SECTOR LEVEL ANALYSIS

As suggested in chapter 3, a national estimate of the impact of a TAD may be needed to justify the focus on a particular disease by a government, or to demonstrate to the government the savings that may be gained by financing TADs prevention measures. After a severe outbreak it may be necessary to estimate the costs incurred as a matter of public accountability. It may also be important to estimate the impact of a TAD on food security as

BOX 8
Global economic impacts

HPAI
The OIE commissioned a study to model the costs to the livestock sector of a global HPAI epidemic at three possible levels of outbreak severity, based on findings from three case study countries, and estimated that direct costs could be between USD5.3 and 9.7 billion, if consequential costs were excluded, and as much as USD21.3 billion if consequential on-farm costs were included. [Agra-CEAS, 2007]

FMD
The global economic impact of FMD under current control conditions was calculated using spreadsheet models. Estimates were made for each of five regions: China, India, the rest of Asia, Africa, Europe, the Middle East and South Africa, and added together. Impacts were categorized as direct (represented by production losses) and indirect (represented by vaccination costs). Using data from FAOSTAT and published papers, the authors estimated that 20 million cattle, 11 million pigs, 11 million goats and 9 sheep are affected by FMD in a year.

The value of impacts was estimated as follows.

	Value in USD million
Direct (production losses)	2,693 (of which 24% in China)
Indirect (vaccination cost)	2,350 (of which 68% in China)
Total	**5,043 (of which 44% in China)**

[Rushton *et al.*, 2012]

measured by changes in food supply and consumption. The examples provided here cover several of the methods previously identified in Table 2.

Comparison of national statistics

It is sometimes possible to deduce the economic impact of a TAD at national or sector level from a comparison of published macroeconomic indicators, such as a reduction in gross domestic product (GDP) or gross output value, in years with and without an outbreak. This is a simple method that requires limited data but will only provide an approximate estimate of impact. TADs will only have an easily detectable effect on a macroeconomic indicator when a) the livestock species affected makes a notable contribution to the economy; b) the disease is very widespread, as for example when a large outbreak occurs, causing high mortality and/or controlled by very strict "stamping out" measures; and c) when it is possible to separate the effect of the TAD from the other effects on a livestock sector (this is known as attribution).

BOX 9

Macroeconomic effects of H5N1 HPAI

Viet Nam: impact of H5N1 HPAI on gross output value of poultry in 2004

Viet Nam experienced a major outbreak of H5N1 HPAI that began at the end of 2003. After spreading widely, it was brought under control by culling almost 40 million poultry. Prior to the outbreak, poultry gross output had grown by approximately 7 percent a year since 1997. Between 2003 and 2004 the value of gross output fell from VND8 694 billion in 2003 to VND7 380 billion, when it could otherwise have been expected to grow to VND 9 302 billion. The difference of VND1 922 billion between the probable and actual output values can reasonably be attributed to HPAI, since there was no other livestock disease or market factor at the time that would have accounted for such a dramatic downturn in output value.

	2002	2003	2004
Value of poultry gross output VND billion (from GSO website)	7 928	8 694	7 380
Probable value of in absence of HPAI (extrapolation from previous trend)	7 928	8 694	9 302
Loss of output that could be attributed to HPAI (official 2004 exchange rate 15746)			VND1 922 billion USD122 million 21% of probable output

Source: McLeod [2013]

Box 9 shows an example of when it was possible to arrive at a rough estimate of the severity of impact by making a crude comparison between the gross value of livestock output after an HPAI outbreak, and what might reasonably have been expected in the absence of HPAI.

Macroeconomic modelling

Where national effects are complex it is necessary to use a macroeconomic model. This requires skill and makes heavy demands on data. The following are examples of macroeconomic modelling to estimate TADs impacts on national economies that have also generated results by sector, or for specific stakeholders.

- The social accounting matrix (SAM), a matrix of resources and resource flows across an economy, can be used to predict the macro-level impacts of changes and the effect that changes in one sector have on other sectors. The livestock sector is often economically linked to other sectors, such as retail and tourism. Townsend and Sigwele [1998] used a SAM in their calculations of the economic impact of CBPP in Botswana. Rich and others used a SAM in their estimation of the impact of rinderpest eradication in Chad (Box 10).

- The computable general equilibrium (CGE) model (a model of an economy based on simultaneous equations), takes into account the flow of resources between sectors. It may draw on a SAM for data. A CGE model can estimate the knock-on impact of changes in one sector on the output of another sector. Blake *et al.* [2003] used a CGE model to estimate the effect of an FMD outbreak on the UK tourism sector. CGE modelling has also been used to estimate impacts of FMD and HPAI (Box 10).
- Models that estimate economic surplus by comparing supply and demand curves can be used to estimate effects on producers and consumers. Consumer surplus represents the welfare that consumers gain from being able to consume a commodity at less than they would be prepared to pay for it, while producer surplus represents the welfare that producers gain by producing a commodity at a higher price than the lowest one at which they would be prepared to produce it. The presence of TADs may affect consumer and/or producer surplus by increasing the costs of producing livestock and the prices paid for livestock products. Paarlberg *et al.* [2002] combined a US model incorporating supply, demand and trade with an epidemiological model to estimate the potential impact of an outbreak of FMD. Pendell *et al.* [2002] combined a partial equilibrium model, an input-output model and an epidemiological model to estimate the economic impact an FMD outbreak in south-western Kansas, USA. An economic surplus model was used to prioritize the animal health programme of the Kenya Agricultural Research Programme in 1997, covering TADs and other diseases [Wanyangu *et al.*, 2000].

Simulation modelling

The impact of disease in the livestock sector can be estimated by developing a mathematical model of a livestock population and comparing the value of output in conditions that simulate disease with those that simulate a healthy population. It is useful, though not always essential, to combine the population model with an epidemiological model simulating disease spread. Simulation models can be developed in spreadsheets or by programming and may be dynamic (one value is entered for each input variable) or stochastic (certain input variables can be represented as a range of values and the model produces a range of outputs with an estimated probability of each output). Simulation modelling requires a good understanding of livestock systems and reliable data, but can be less demanding than macroeconomic modelling.

Simulation models are common in assessments of the economic viability of animal health interventions, which will be discussed in chapter 5. Examples include Leslie, Barozzi and Otte, [1997] (FMD), McLeod *et al.* [2003] (CSF), Perry *et al.* [1999] (FMD) and Rich *et al.* [2009] (implementation of SPS measures).

4.4 EXAMPLES OF STAKEHOLDER-LEVEL ASSESSMENTS

As previously discussed in section 4.3, an assessment made at national level may provide results by stakeholder as well as national totals. It is also possible to make an assessment that only considers selected stakeholders.

BOX 10

Impacts of TADs estimated using macroeconomic models

Rinderpest in Chad and India

An analysis of the economic impacts of rinderpest eradication used a SAM matrix to compute macroeconomic effects. In Chad, rinderpest was formerly endemic but by 2000, after ten years of a high level of vaccination coverage under the PARC and PACE programmes, the disease was no longer being reported. The SAM analysis estimated that had rinderpest remained endemic, Chad's GDP would have been 1 percent lower in the year 2000, and rural incomes would have been 2.6 percent lower. The analysis was extrapolated into the future and across West Africa, using CGE models.

India also had a long history of rinderpest outbreaks, becoming free of the disease in 1995. No SAM was available for 1995, so the research team constructed a SAM for 2008 and used this to make estimates of the economy-wide impact of freedom from rinderpest. They estimated that the impact on household consumption was probably higher than that on household incomes, because of the impact that rinderpest might be expected to have on food prices [FAO, 2012].

FMD in the USA and Australia

Public expenditure on disease prevention can be justified using economic estimates of the loss that could be incurred in the absence of preventive actions. Estimates made in the USA using a combined epidemiological and economic model suggested that there could be a USD14 billion loss in farm income in the event of an FMD outbreak [Paarlberg *et al.*, 2002].

In Australia, another FMD-free country, it was estimated using a CGE model that a multi-state outbreak could result in revenue loss of between AUS$49.3 and 51.8 billion (equivalent to USD46.2 to 49.2 billion, at the prevailing exchange rates), with a further cost of AUS$6.3 to 60.2 million (USD6.0 to 57.2 million) for disease control and compensation [Buetre *et al.*, 2013]. Industries that compete with livestock, such as horticulture and grain production, could benefit by as much as AUS$15 million.

HPAI in Thailand

The Thailand Development Research Institute used a CGE model to make a preliminary assessment of the economic impact of H5N1 HPAI, and estimated that GDP growth rate would decline by between 0.7% and 0.9% for a year. Poultry output accounts for 4 percent of agricultural GDP in Thailand. The model predicted that the impact on GDP would be limited and short term, but effects on employment in small and medium-sized farms could be more severe and of longer duration, resulting from short-term interruption in production and longer-term restructuring of the poultry sector [Poapongsakorn, 2004].

Simulation modelling

Spreadsheet simulation models (also see 4.2) are a highly accessible tool for assessing impacts at sub-national level, and particularly those that occur within the livestock sector. A recent example was an assessment of the impacts of CBPP on pastoralists in Kenya using a stochastic spreadsheet model [Onono *et al.*, 2014]. The assessment took account of mortality, reduced milk yield, reduced weight gain and reduced fertility rate, and estimated that the total cost of CBPP in the pastoralist system was USD7.6 million per year.

Spreadsheet simulation models have also been used to review differential impacts of CSF outbreaks on pig farmers and traders in Viet Nam [Mcleod *et al.*, 2003; Taylor *et al.*, 2003] and to differentiate FMD impacts in backyard and commercial production systems.

Sustainable livelihoods analysis

When assessing the impact of a TAD on smallholders and vulnerable people, it is important to acknowledge that their livelihood may be affected in ways that are not easily quantified. While financial livelihood (i.e. the ability to earn an income) is important to almost everyone, a livelihood also has other facets. The sustainable livelihoods framework described by DFID [ODI, 1999] is probably the most comprehensive attempt to develop a systematic approach to livelihoods analysis. It defines three types of outcome, all of which are considered in the analysis: higher income; reduced vulnerability and a more sustainable natural resource base.

The framework defines four types of livelihoods asset or "capital". These are financial (income), physical (asset value), natural (for example soil fertility or water quality), human (health and education) and social (access to support networks and sources of prestige). Economic analyses of livestock disease impact tend to focus on the first two (income and asset value) because they are the easiest to value. Natural capital values may be captured if it is possible to assess the impact of livestock disease on crop production. Impacts on human capital can be valued if livestock disease has a measurable effect on human illness or nutritional status. Social capital is perhaps the hardest to value, and least likely to be quantified.

Another important feature of the sustainable livelihoods framework is that it specifically includes the "vulnerability context" of households and communities. Animal diseases, as well as having immediate and measurable economic impacts, may also increase the vulnerability of rural households to other shocks by taking away a safety net. Disease control programmes can have the same effect if they result in culling of animals without compensation, or prevent poor people from keeping livestock.

A third element is "processes and structures", namely, the local and government institutions and culture that affect the way that people behave and how policies play out in practice. Culture and institutions affect whether livestock owners will choose to report a TAD and which animal will be presented for vaccination.

The standard economic tools, if applied with care, will capture a large part of the livelihood impact of TADs. However, when livestock are owned by smallholders and vulnerable people the full value of their contribution to the household is less easily expressed in monetary terms. When this is the case it is sometimes worthwhile to apply the sustainable livelihoods framework in addition to an economic analysis, or as part of the process of identifying impacts, because it may highlight points that might otherwise be overlooked.

Very few publications apply a sustainable livelihoods framework in a systematic way to a TADs control project (or any other animal health intervention). One of the few that even describes the framework is Perry *et al.* [2002]. However it is possible to deduce livelihood impacts from other reports (Box 8).

BOX 11

Examples of the impact of TAD prevention and control measures on livelihood assets

Biosecurity measures imposed to control HPAI on duck-keepers in the Mekong Delta area of Thailand

Measures imposed: confinement of birds that were previously herded in rice paddies.

Positive impacts:

- Reduced risk of transmission to humans (positive effect on human capital).
- Reduced circulating virus and incidence in ducks (only a very small improvement to this physical asset as ducks rarely die of HPAI).
- Some confined duck flocks became larger and more commercial (increase in finances).

Negative impacts:

- Reduced access of duck-keepers to paddy fields (natural capital).
- Many stopped keeping ducks (reducing the diversity of their livelihoods. No study has been made to assess whether former duck-keepers become more vulnerable to poverty and food security, or whether they found substitute livelihood activities).
- Ducks no longer ate snails in rice paddies, the owners of the paddies had to use chemical snail control (negative impact on natural capital, and a cost to the paddy owners).

Biosecurity measures imposed to control HPAI on urban poultry keepers in Jakarta, Indonesia

Measures imposed: banning of poultry keeping within Jakarta city limits.

Positive impacts:

- Probably reduced the risk of exposure of humans, both poultry-keepers and non-poultry keepers to H5N1 virus (positive effect on human capital).
- Reduced dirt and flies in some residential areas where poultry had been kept and marketed in gardens (positive effect on the environment).

Negative impacts:

- Reduced income source for many former poultry-keeping households, particularly the women in those households (negative impact on financial capital).
- Some women who had previously earned income from poultry keeping at home and sale of eggs or birds had to find work outside the home and this interfered with the contact they had with their children (negative impact on social capital). Others chose not to work outside and suffered a loss of income.

Source: Heft-Neal *et al.*, 2010; identification of livelihood assets by author

TABLE 7
Some estimates of the impact of TADs

Disease	Value of impact	Scale/period	Reference
FMD	Up to USD21 billion	Global annual impact taking into account only production losses and vaccination costs.	Knight-Jones and Rushton [2013].
FMD	GBP8 billion	Cost of controlling the 2001 UK outbreak (3 billion public sector and more than 5 billion private sector).	NAO [2002].
H7N9 HPAI	USD6.5 billion	Chinese livestock sector 2012–2013.	Chinese Ministry of Agriculture estimates in 2013.
H5N1 HPAI	USD5 to 10 billion	Cost to Asian economy.	Bio-Era [2004].
FMD	GBP481 million	Direct cost to agriculture (231) and gross cost to tourism (250) of the 2001 FMD outbreak in Scotland.	Royal Society of Edinburgh [2002].
CSF	USD2.34 billion	Cost of controlling the 1997–98 outbreak in the Netherlands.	[Meuwissen *et al.*, 1999].
CBPP	USD2 billion per year	Annual cost to African famers.	Otte, Nugent and Mcleod [2004] citing published research.
FMD	USD2 700 million	South Korean livestock sector 2010–2011.	AsiaOne Health [2011].
FMD	USD1 600 million	Taiwan, direct costs and loss of exports, 1997.	Yang *et al.* [1999].
FMD	USD230 million	Cost to Kenyan farmers in the early 1980s.	Ellis and Putt [1981].
H5N1 HPAI	USD214 million at 2005 prices	Vietnamese poultry sector 2003–2010.	McLeod *et al.* [2013].
H5N1 HPAI	USD124.7 million	Direct costs to Vietnamese farmers.	OIE [2007].
H5N1 HPAI	USD107-120 million	Direct costs of 2003-4 outbreaks.	World Bank [2004].
CBPP	Euro44.8 million per year	Annual cost in Africa.	Tambi, Maina and Ndi, [2006].
PPR	USD12 million per year	Annual value of disease losses and control costs.	GoK [2008].
FMD	USD7-9 million per year	Cost to the Uruguayan economy through lost export opportunities prior to eradication in 1997.	Leslie, Barozzi and Otte [1997].
CSF	USD2.7 million per year	Cost to smallholders in Haiti.	Otte [1997].
CSF	USD2.5 million	Direct costs of reported outbreaks in Chile.	Pinto [2000].
CSF	USD50 million	Annual losses in Mexico, Brazil and Dominican Republic from 1997–2001.	Pinto [2003].
HPAI	USD2.65 million	Cost of an outbreak in the United States of America in 1983–84 .	USDA [2005a]

4.5 COMPARING ESTIMATES OF ECONOMIC IMPACT

Animal health planners like to compare the costs of different TADs, to assist with prioritization or to emphasize the importance of a specific disease when soliciting funding. A few "horizon scanning" publications provide comparative information – for example, Bio-Era [2005] has published a chart comparing the costs of several TADs derived from a number of studies that is often used in presentations.

However, comparisons need to be made with caution. One report [OIE, 2007] estimates HPAI costs in three countries and FMD costs in a fourth using a standardized approach, but it is unusual to find this kind of comparative analysis in a single publication; more commonly a report will deal with a single disease over a limited time period. A reviewer trying to make a comparative assessment for several diseases or to discern a trend over time is faced with the challenge of trying to standardize results from different studies.

Table 7 provides several examples of estimates of the impact of TADs, listed in descending order of financial value. Each of the estimates adds something to the sum total of knowledge about the economic impacts of TADs, but care needs to be taken in making direct comparisons between them because the estimations and variables included differ widely. They are all "totals" but each estimates a different "total". The estimates differ in terms of their scale, time period over which the analysis was done and the base year for prices. Each estimate was made by a different group of researchers, for a different reason, using the methodology that they considered appropriate. None of the estimates is based on complete data, very few used primary data, and all required approximations, expert opinion and modelling to make up for the lack of hard data.

5. Economic viability of interventions

The economic viability of an intervention to control a TAD may be of interest to a government needing to justify use of public resources, or a private company or individual deciding whether to invest in vaccination or biosecurity. It also plays a part in farmers' decisions to comply with government regulations. Depending on the context of the analysis and the resources available, an estimate may be made for one TAD or a group of TADs, on any scale from local to global. It may be confined to the livestock sector or extended to include effects on human health and other sectors.

Methods to assess economic viability all in some way compare "benefits" (positive economic impacts) with "costs" (negative economic impacts). An economically viable initiative is one in which the benefits are at least equal to the costs, and ideally, higher. Differences between methods arise from the scale at which they are applied, the way that benefits and costs are quantified, and whether the analysis explores a variety of possible situations, or attempts to arrive at an optimum outcome.

This chapter examines in more detail the benefits and costs of interventions mentioned in chapter 3 that occur within the livestock sector, discusses the methods used to analyse economic viability and provides examples of their use. It also discusses benefits within the public health sector, but does not cover benefits and costs in other sectors.

It is important to be realistic about the impact of controlling a single TAD. If the incidence of one TAD is greatly reduced, the impact of others may become more visible. Conversely, if control of one TAD is achieved by improving animal health services, there may be collateral benefits through reduced levels of other diseases.

With regard to impact assessments, "attribution" can be an issue; the effects included in the analysis should only be those attributable to the intervention in question. This can be problematic when analysing the economic impact of a single TAD control project that forms part of a larger programme of disease control, or when investments to control TADs are made at the same time as other investments in the livestock sector.

5.1 SOURCES OF BENEFIT WITHIN THE LIVESTOCK SECTOR

Increased output and asset value

Increased output and asset values are the most obvious benefits from controlling a TAD and the easiest to estimate. They may result from reduced disease incidence within an existing system, allowing livestock owners to consume more at home or sell more into an existing market. If the intervention makes it possible for livestock products to be sold into new markets, such as export markets or supermarket chains, benefits may result from higher farmgate prices for livestock products.

Increased output is likely to have associated costs related to raising additional animals or producing them to the standards and quality required for a new market. These costs, as well as the additional output value, must be included in the analysis. This can be done by adding them to the cost side of the estimate or by estimating increased output value net of associated costs, for example as a gross margin.

Asset values are important in extensive systems, where animals are kept more as assets than for sale, or in any situation where controlling a TAD has a notable effect on the number of animals kept. When the asset value is included in a cost-benefit analysis, it is calculated as the difference between the value of the herd at the start and end of the analysis period.

It is advisable to be cautious when estimating the value of increased output, particularly when estimates of disease incidence are based on reports that have not been verified by laboratory diagnosis, clinical examination or an unambiguous description of clinical signs. It is also possible to overestimate the impact of controlling a single disease, as when one disease is removed another problem may become more apparent.

Box 12 provides examples of benefits from increased outputs and asset values, and a cautionary tale on the possibility of overestimating the impacts of a TAD.

A TAD control programme is likely to work best if it not only targets a single disease but generates a broader spectrum of benefits. There are two reasons for this:

- Farmers are usually dealing with multiple animal health problems and it is rare that one TAD is consistently at the top of their priority list. They are more likely to do what is needed to make the intervention work if it helps them to solve a range of problems.
- It may take time to realize the benefits to be gained from controlling the targeted TAD. Since methods such as cost-benefit and cost-effectiveness analysis use discounted values, benefits realized early in an intervention carry more weight in the final estimate of economic viability than those realized later on.

BOX 12

Examples of the impact of TAD prevention and control measures on livelihood assets

Rinderpest. An evaluation of the economic impact of rinderpest control by the PAN African Rinderpest Campaign between 1989/90 and 1996/7 concluded that the benefit resulting from avoided losses in the value of cattle outputs in ten countries amounted to ECU99 179. Of this, ECU80 999 came from cattle meat, 11 806 from milk and 654 from traction and manure. [Tambi *et al.*, 1999a]

CBPP. An ex-ante assessment of the economics of CBPP control in pastoralist herds in Western Uganda found that approximately 95 percent of the benefit would come from increased output and asset value. [Twinamasiko, 2002]

A cautionary tale. Okuthe [1999] studied the impacts of vaccinating free-range poultry in Western Kenya against ND. Although there had previously been verbal reports that ND caused serious losses, during the two years of his study Okuthe recorded only low incidence and found regular vaccination against ND to be economically marginal. Other diseases such as fowl pox appeared to cause higher losses. He also found poultry theft to be a problem, and introduced simple cages of a local design so that birds could be caged at night; these were spontaneously adopted by many farmers in the control group.

It may not turn out to be economically realistic to think in terms of a single TAD. The costs of a control programme may be too high if they are addressing only one disease or targeting only one market. The collateral benefits of an intervention may turn out to be of greater value than the immediate benefits that it was designed to provide. Box 15 gives two examples.

Reduced prevention and treatment costs

An intervention that controls a TAD reduces the need for preventive vaccination or clinical treatment if these were previously used. The benefit may be seen:

- When comparing two possible approaches to control, one emphasizing vaccination and the other emphasising movement control and biosecurity. When implementing a disease-free zone without vaccination, any preventive vaccination previously done within the area is stopped – although vaccination frequency and coverage may increase in the surveillance zone.
- When assessing the impacts of control in an endemic area where farmers have been using vaccination and/or treatment. The benefit from reduced costs is likely to be small compared with the benefit from increased output value. For example, Twinamasiko [2002] found that in Western Uganda where CBPP was endemic, emergency vaccination, treatment with antibiotics and care of sick animals accounted for less than 5 percent of the loss from the disease.

5.2 SOURCES OF BENEFIT TO PUBLIC HEALTH

Benefits to public health from the control of a zoonotic TAD can be of two kinds:

- Saving of human lives or life-years when a zoonotic TAD is targeted.
- Reduced costs to public health systems when fewer people need to be treated.

Both kinds of benefit were found in a study of brucellosis control in Mongolia described in Box 14.

5.3 SOURCES OF COST WITHIN THE LIVESTOCK SECTOR

Prevention and preparedness costs

Prevention and preparedness costs include animal health intelligence, biosecurity and vaccination.

Animal health intelligence

Animal health intelligence, defined by FAO [2010c] as "all the activities related to the identification of potential hazards that may represent a risk to animal health" includes surveillance activities, animal health information systems development and tools for reporting, and the collection and analysis of disease and non-disease information. Although in theory applicable to all livestock diseases, it tends in practice to be heavily weighted towards TADs.

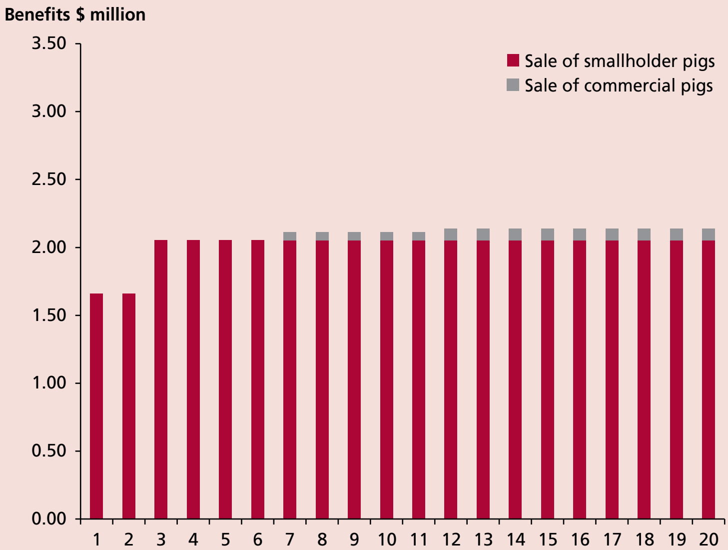
Costs include:

- "Active" surveillance (i.e. surveys and monitoring carried out on farms, in markets and at abattoirs).
- "Passive" surveillance (reporting of disease by farmers).
- Investigation of disease reports.
- Maintenance of national and international information systems and networks.

BOX 13
Collateral benefits

FMD eradication in Rukwa Region, Tanzania. A study carried out in Rukwa Region showed that the costs of FMD resulted mainly from loss of draught power for ploughing and therefore depended more on the seasonality of the disease than its annual incidence. It was estimated that while FMD eradication alone would be economically marginal and a risky investment, introducing an "animal health package" aimed at general productivity enhancement rather than FMD eradication, appeared to be economically viable. [Tyler *et al.*, 1980] *(cont.)*

Cautious export assumptions



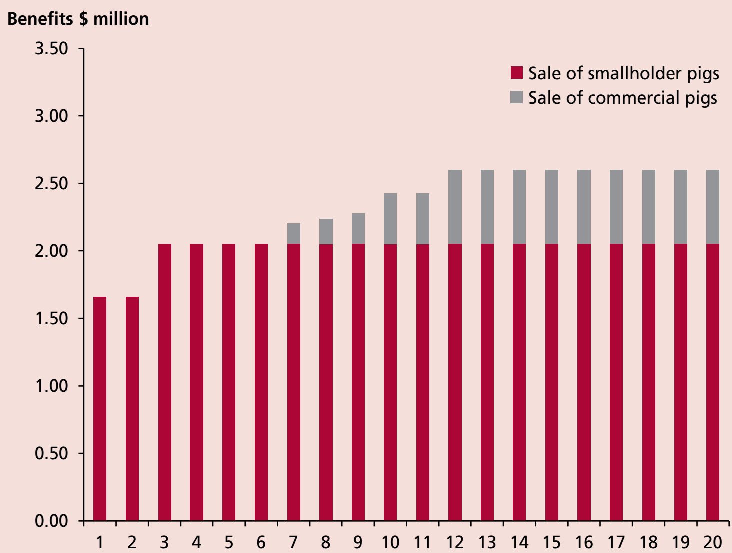
Biosecurity

The best way to protect a herd or flock from TADs is to prevent disease agents from crossing the farm boundary [FAO, 2008]. This requires good biosecurity practices: restricting access to animals by people who do not normally live and work on the farm, cleaning the footwear and vehicles of anyone who enters the farm, including the farm family and employees. In some cases where animals are very valuable, visitors may be required to change clothes before entering the animal unit.

The high levels of biosecurity applied to intensive, high-output systems can be expensive, requiring specially designed buildings as well as dedicated clothing and footwear and frequent cleaning. However, in some small-scale, less intensive systems it is possible to apply simple biosecurity measures at a low cost such as soap and water, cheap rubber footwear for animal handlers, and management routines adapted to minimize the chance that people and animals will carry disease agents from infected to uninfected herds.

Disease-free zone Viet Nam. An ex-ante evaluation was carried out on a CSF - and FMD—free zone in Viet Nam. The aim in establishing the zone would have been to increase exports of pig meat from large-scale commercial pig units. The area proposed for the zone also contained a large number of smallholder pig enterprises that were not expected to be part of the export initiative, but did need to become disease-free. The analysis showed that the largest benefit would come from reduced incidence of CSF in smallholder pig herds, increasing the value of pig meat sold on the domestic market. The value of exported meat alone was insufficient to make the project

Optimistic export assumptions



Vaccination

Most TADs are caused by viruses (exceptions are CBPP and CCPP, caused by mycoplasmas). The most common preventive measure applied at the level of the individual animal is vaccination. Vaccines are available for many TADs (African Swine Fever is a notable exception), with some providing more effective protection than others.

Vaccination can be a high recurrent cost, and this is one reason why governments are reluctant to commit to long-term programmes. At the same time, however, it offers a means to protect livestock assets. Individual farmers in high-risk areas may be willing to finance the vaccination of their own breeding animals. There may also be good food security and social reasons for protecting the livestock of the poor through vaccination. However, countries that are free of specific TADs may choose not to allow preventive vaccination if it limits their access to export markets; for example, in the EU, vaccination against FMD is only used as a temporary measure for the control of outbreaks.

BOX 14

An example of human health benefits from TAD control

Brucellosis in Mongolia

In 1999, 1 482 cases of human brucellosis were reported in Mongolia, 0.6 percent of the total population. The rate of reporting was very low and the number of cases was suspected to be more than double those reported. The percentage of infection in animal herders was much higher; a survey conducted during 1990-95 found that 16 percent of herders examined were infected. People suffering from brucellosis can experience weakness, joint and muscle pain and night sweats, sometimes lasting several years, and occasionally the disease is fatal. The disease is treatable but costly. An economic assessment was made of a proposed programme to control brucellosis by vaccination.

Depending on the assumptions about vaccination efficacy and coverage, the benefit in life-years ranged from 42 400 to 63 200 DALYs.

In monetary terms, benefits to the public health system were estimated at between 11 and 13 percent of total benefit of USD20.5 to 34.2 million, while savings to private individuals through not having to pay treatment costs were 18 to 21 percent of the total. [Roth *et al.*, 2003]

The cost per protected animal of vaccination varies enormously (see Box 15) depending on:

- The number of vaccinations needed in an animal's life.
- The ability of the vaccine to protect against multiple lineages of the disease agent.
- The cost of delivering the vaccine to livestock farmers, whether this is done through an official government campaign or by private purchase.
- The capacity (human and equipment) and of the public and private veterinary service to produce or import, test and deliver vaccines so that they are available when needed and of good quality.

Outbreak control costs

Outbreak control costs include:

- Operational costs of disease confirmation, movement control, culling of animals, disposal of carcases, disease tracing.
- The loss of animals culled.
- Loss of production value through delayed sales or delays in restocking.

Quantifying operational costs and the value of lost animals is straightforward, but the effects of quarantine and delayed restocking are less obvious. Box 16 gives examples of each.

In countries that have a strong motivation to control TADs, compensation is paid to livestock owners for animals culled and feed destroyed within official outbreak control campaigns. Compensation is rarely paid for the death of sick animals that have not been officially culled, and even more rarely for lost production. Compensation is a transfer payment, a payment from one stakeholder group to another that does not change the value of outputs or costs but

BOX 15
Per-animal costs of vaccination

The cost of vaccinating an animal against rinderpest during the PAN African Rinderpest Campaign was estimated to vary between USD0.271.71, with the vaccine making up between 533 percent of the total [Tambi *et al.*, 1999a].

The cost of vaccinating a chicken or duck against HPAI during the epidemics of 2004-2007 was USD0.055-0.061 in Viet Nam, USD0.13-0.14 in Côte d'Ivoire and USD0.08-0.15 in Indonesia. Only in Indonesia was there a notable effect on the production system, with backyard birds costing almost twice as much to vaccinate as the large-scale commercial birds [McLeod *et al.*, 2007].

The cost of vaccinating a bovine against FMD in the EU in 1987 was estimated to vary from USD0.74 in Greece to USD2.66 in the UK [Horst *et al.*, 1999].

The cost of vaccinating a broiler chicken against Newcastle Disease was estimated to be approximately US cents 4.1 per bird in Cambodia in 1994, and US cents 1.5 in the Netherlands in 1997 [Horst *et al.*, 1999]. In Cambodia, a bird was vaccinated four times in a cycle, making the cost per bird per cycle approximately US cents 16.5. In the Netherlands, vaccination was only done once in a cycle, so the per-cycle cost per bird was US cents 1.5.

simply distributes them more evenly. In an assessment at national or sector level, compensation payments are not included, only the value of the birds culled. If an impact assessment is made for a farm, compensation payments are subtracted from the value of lost animals.

Opportunity costs of management and system changes

Compulsory changes to livestock systems, such as improvements to infrastructure and the introduction of new regulations in live animal markets, banning of livestock-keeping in urban areas, or introduction of a disease-free zone and restriction of movement into it, result in two types of cost.

The first is the cost of infrastructure when live animal markets are moved or upgraded, new slaughter or processing facilities, animal housing and feedlots built or cordon fences constructed. New infrastructure brings with it new maintenance and operational costs.

The second is opportunity costs: the losses experienced when, as a result of a control policy, farmers cannot do what they are used to doing. A striking example is the case when an area within a country is developed as a disease-free zone, with strict constraints on movement of animals and livestock products into the zone, so that farmers or traders cannot access the grazing lands that they formerly used, or move their animals into or across the zone to sell them. Opportunity costs can also occur if TADs control policies result in long-term changes to the sector of livestock structure. Policies might include regulations on where livestock can be kept and how they are managed, movement controls that are routinely enforced even in the absence of disease outbreaks, and regulations on the operation of livestock markets. Over time these factors create conditions that make household livestock enterprises illegal or

BOX 16

Lost production value resulting from outbreak control

Losses as a result of delayed restocking and downtime in Botswana and the Netherlands

In the 1997/8 epidemic of CSF in the Netherlands, farmers were compensated for the value of destroyed herds, but not for lost production from idle facilities [Horst *et al*., 1999].

In Botswana, even though compensation was paid to Ngamiland farmers for cattle slaughtered to control CBPP, it may not have been sufficient to restore their herds or their livelihoods. If restocking by the government is chosen as an option (this was one of the options offered to the Ngamiland farmers), this can create its own problems of locating and purchasing appropriate animals, potential distortion of local markets and trader livelihood, maintenance costs of animals brought in from distant areas and not adapted to local conditions and diseases. [Mullins *et al*., 1999].

Impact of applying a quarantine as part of outbreak control against CSF in Viet Nam

An ex-ante analysis in 2003 of measures to control CSF in Viet Nam showed that the distribution of outbreak control costs along the market chain was strongly affected by whether a quarantine period was applied (movement control for a total of 7 weeks). Without quarantine, the costs were fairly evenly distributed between pig producers and traders. With quarantine, growers and finisher producers suffered badly but traders in finished pigs made a higher profit than normal. [McLeod *et al*., 2003]

Nam Dinh Province	Percent reduction in annual gross margin	
Impact on	**without quarantine**	**with quarantine**
All piglet producers in commune	-3.90%	-3.90%
All grower producers in commune	-1.10%	-40.60%
All finisher producers in commune	-1.10%	-50.80%
Commune total	-2.40%	-26.40%
Commune total adjusted for compensation	-1.30%	-25.30%
Assemblers	-0.70%	-2.40%
Piglet/grower wholesalers	-0.80%	-3.20%
Finisher traders	0.00%	34.00%

uneconomic. The sector "scales up" and former small-scale producers lose a livelihood they once had. Box 17 provides examples of opportunity costs resulting from system changes.

The livestock sector is dynamic – it changes with or without TAD control – but if disease control measures speed up the changes in the sector, the people who may suffer most are poor farmers who need time to make changes to their livelihood activities.

5.4 EXAMPLES OF ANALYSES AT GLOBAL/REGIONAL/NATIONAL LEVEL

Cost-benefit analysis

Cost-benefit analysis (CBA) is perhaps the best known method for economic analysis of animal health programmes and projects. It is suitable for sector-wide or nationwide analysis,

BOX 17

Opportunity costs of management and system changes

A disease-free zone. A study of the potential for an FMD-free zone in Zambia found that traders were transporting goats through the area proposed for the zone, to sell them at a lucrative market on the northern border. If the zone were to be established, the traders would no longer be permitted to move through it, and the only alternative route was much longer and more difficult. The loss of revenue to the traders from having to sell into less lucrative markets could amount to a lost profit of USD44 per animal, and a total of between USD2.44.8 million a year. People bringing transhumant animals into the area to graze would also find their grazing ground and access to water restricted. [McLeod and Honhold, 2012]

Banning of swill feeding. When swill feeding of pigs was banned in the UK as part of an initiative to control CSF, small family pig herds were affected and almost disappeared since it was uneconomic to buy feed for the pigs.

New regulations on poultry-keeping for HPAI control. H5N1 HPAI changed the structure of the poultry sector in Thailand when free-ranging ducks were banned [Heft-Neal et al., 2010]. Regulations also pushed poultry production out of Jakarta, Indonesia. Some women who had previously kept chickens at home had to stop doing this and find paid work outside the home [ICASEPS, 2006].

and also for farm- or business-level interventions where the effects of changes will develop over several years. A number of excellent references explain the use of CBA in agriculture [Gittinger, 1974; Ward *et al.*, 1991], and one was specifically designed for veterinary epidemiologists [Putt *et al.*, 1988].

Cost-benefit analysis constructs a benefit minus cost flow year by year and uses this to estimate the "net present value" (NPV)of the project (the total discounted "profit" from the project) and the "internal rate of return" (IRR), the rate of return on the investment made in the project). Discounted values are used to account for what is called "time preference", meaning the preference to receive benefits immediately rather than waiting for them. An NPV of zero or greater, or an IRR equal to or greater than the opportunity cost of capital indicates an economically viable investment.

A CBA can be used for appraisal (estimating the economic viability of a proposed project, also known as *ex-ante* analysis) or evaluation (estimating the economic viability of a project that is partly or fully completed, also known as *ex-post* analysis). Analyses can be financial (using market prices) or economic (using economic or "shadow" prices).

Many studies on the economic viability of TADs interventions use CBA. A few examples of national level analyses include:

- **CSF.** The first study to apply cost–benefit analysis techniques to an animal disease was conducted by Ellis [1972] for the CSF eradication programme in UK in 1972. The success of this study led to the interest to start applying this approach to other animal diseases including zoonoses such as anthrax and brucellosis. Mcleod *et al.* [2003]

used CBA to analyse the economic potential of CSF control in Viet Nam. Mangen and Burrel [2003] analysed impacts of restricting export control in the Netherlands.

- **FMD.** James and Ellis [1978] published one of the earliest papers on CBA of FMD. Perry *et al.* [1999] and Randolph *et al.* [2002] analysed the economic viability of control in South East Asia while Perry *et al.* [2003] did the same for Southern Africa. McLeod [2010] estimated costs and benefits of the South East Asia FMD Campaign.
- **Rinderpest.** Tambi *et al.* [1999a] retrospectively analysed the economic impact of the Pan African Rinderpest Campaign. Omiti and Irungu [2010] carried out a cost-benefit analysis of rinderpest eradication in Kenya and Ethiopia using secondary data from many sources.
- **Disease-free zones.** Taylor *et al.* [2003] analysed the economic viability of an FMD- and CSF-free zone in Viet Nam. McLeod and Honhold [2012] reviewed the viability of setting up a disease-free zone in Zambia.

Cost-effectiveness analysis

Cost-effectiveness analysis (CEA) has many similarities to CBA but measures benefits differently. Like the CBA it is suitable for sector-wide or nationwide initiatives or for interventions on a smaller scale; like CBA, it can be used for appraisal or evaluation. Similarly, figures are discounted. Unlike CBA, which estimates both costs and benefits as monetary values, CEA does not monetize benefits but instead expresses them as units of an effectiveness measure. The result of the analysis is the cost per unit of the chosen outcome. Cost-effectiveness analysis may be used to compare the cost of achieving the same level of outcome in different ways, or the cost of achieving different levels of a particular outcome. For a more complete discussion on CEA, see Krupnik [2004] or Abelson [2008].

Cost-effectiveness analysis is often used for human health projects when the outcome of interest is the number of human lives saved or the DALYs or QALYs added, rather the monetary value of those lives or life-years. It is useful for assessing the economic viability of projects to control zoonotic TADs whose impact is on human health as well as or instead of animal health.

Cost-effectiveness analysis can also be used to evaluate animal health interventions where the intention of an intervention is to improve a single measureable target, such as the number of days taken by the veterinary service to respond to a disease report, or of the number of animals protected by vaccination.

This type of analysis has the limitation that it only allows for one type of outcome, for example the number of lives saved. When the control of a zoonotic disease results in improved human health and increased livestock outputs, a CEA cannot fully express the potential benefits.

Examples of CEA applied to TAD control include:

- The analysis of brucellosis control in Mongolia [Roth *et al.*, 2003] previously described in Box 14. It estimated that the cost per DALY saved would be between USD19.1 and 71.4 depending on assumptions made about vaccination efficacy and coverage. It also separately estimated the value of benefits to agriculture and public health.
- Estimation of the cost–effectiveness of rinderpest vaccination in Africa under the strategies used by different countries, using the cost per animal vaccinated as the measure of effectiveness [Tambi *et al.*, 1999a].
- Estimation of the cost-effectiveness of avian influenza virus surveillance in Switzerland, combining a qualitative risk assessment with an estimate of surveillance costs.

The analysis indicated that surveillance in both wild birds and poultry was unlikely to reduce the probability of primary and secondary outbreaks in Switzerland, although the expenditure might still be justified if it produced non-monetary benefits such as peace of mind [Häsler *et al.*, 2011].

Other methods

Both CBA and CEA are the most commonly used methods for economic analysis of TAD control programmes. They are well-understood and do not necessarily place high demands on data (although this depends on the methods used to provide input data).

However, both methods have limitations. They can indicate whether an intervention is economically viable, but they cannot suggest what the "best" intervention might be or the "best" combination of approaches to control. They do not deal effectively with "intangible" losses (those that cannot easily be quantified); CBA leaves them out, while CEA takes one intangible and uses it as the denominator when estimating cost-effectiveness. They do not provide guidance on who should contribute to financing TAD control programmes, although analysis undertaken by stakeholders can indicate those that benefit most from a programme and might reasonably be asked to pay for it. Several authors have pointed out the theoretical and practical limitations of CBA, which include the danger inherent in extrapolating an analysis of a small livestock population into a national estimate, or of wrongly interpreting the results [McInerney, 1991; Tisdell, 1994]. An excellent critique of the use of CBA in animal health was written by Howe and Christiansen [2004].

The following are some examples of additions or alternatives to CBA and CEA.

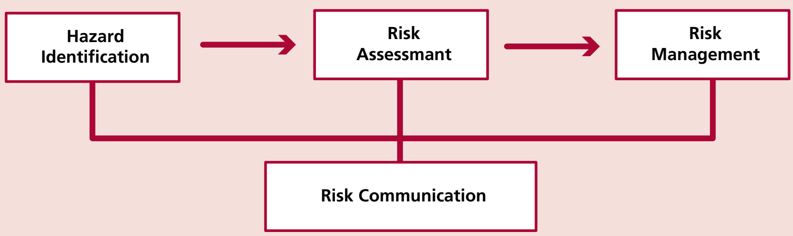
- Optimization models try to estimate the best combination of limited resources to achieve an outcome. They are data-demanding and generally used for analyses at local or farm-level. However, Carpenter *et al.* [2011] used an optimization model to estimate the impact throughout the USA of an outbreak of FMD in California and to examine the effect of delayed disease detection. Assuming a detection delay of 21 days, it was estimated that for every additional hour of delay, there would be an additional economic loss of $565 million.
- Häsler *et al.* [2013] propose that a new approach is needed for evaluating programmes that use both surveillance and vaccination. The two cases partially substitute for each other and methods are needed to assess the optimum combination. However, they do not suggest how to put this concept into practice.
- Decision-tree analysis can provide a framework for decision-making about TAD control. It uses a sequence of decisions, each of which has two possible answers, to provide a step-by step guide to a final choice. Rushton and Upton [2006] describe a generic decision-tree framework for making choices about the balance of active and passive measures to control an outbreak. Tomassen *et al.* [2002] used a decision-tree as the framework to estimate benefits and costs of FMD control.
- Methods that assess stakeholder preference can sometimes be used to value intangibles, making it possible to include them in a CBA or CEA. Contingent valuation and choice models have been used in environmental economics, to place a value on attributes such as biodiversity, beautiful landscapes, or conservation of natural habitat [Winpenny, 1991; Moran, 1994; Hanley *et al.*, 1998]. Contingent valuation has also been used to evaluate

BOX 18
Assessment of economic viability using cost comparison

Junker *et al.* [2009] compared FMD control strategies by analysing the potential impacts of a trade ban following an FMD outbreak on the economies of the USA, Canada and the Netherlands. Costs associated with the outbreak were compared under four different control scenarios: stamping-out or vaccination, with or without regionalization (movement control confined to a defined geographic region rather than affecting the whole country). The analysis used two different macroeconomic models, namely GTAP (a CGE model) and Aglink-COSIMO (a global partial equilibrium model). It found that the control strategy used did not affect the extent of market disturbance, but control strategies that minimized the time needed to resume exports were most effective in minimizing the cost of the trade ban. Regionalization was effective in limiting the opportunity costs of the ban, particularly when small regions were defined.

BOX 19
Use of economic techniques within a risk analysis framework

Risk analysis framework [OIE 2013]:



Techniques that may be useful:

Value chain analysis

Mapping of livestock market chains and food systems within a country and internationally can assist in:

- Hazard identification. It can help to identify the points at which a disease agent may enter the population at risk.
- Risk assessment. This has three parts: entry assessment; exposure assessment; consequence assessment and risk estimation. Quantifying the volume and value of products passing along the chain and the numbers of people involved, and identifying transport links and processing steps could be useful in entry and exposure assessment. Quantifying the value added at each link in the market chain helps to assess the economic consequences of a disease entering the livestock sector.

(cont.)

animal welfare [Bennett, 1998]. The methods are less commonly applied in animal health. A TAD-related example of the use of choice experiments was to elicit the preferences of Kenyan farmers for the design of a disease-free zone [Otieno *et al.*, 2010].

- Contingent valuation can also be used to evaluate the willingness of farmers to pay for the disease control measures undertaken on their farms [Ahuja and Sen, 2006]. For example, it has been used to assess farmer willingness to contribute to the cost of brucellosis vaccination in Tajikistan [Ahuja *et al.*, 2009].
- Rather than comparing costs and benefits, one analysis compared control strategies for FMD outbreaks by estimating their costs (Box 18). The desired outcome was for affected countries to be able to resume exporting. The strategy that was most effective in avoiding costs would be the preferred one.

Economic analysis as part of a risk analysis

When trading partners are members of the WTO, a decision to ban or restrict livestock or livestock product imports because of an animal health risk must be based on a formal risk analysis, using the framework laid out in the Terrestrial Animal Health Code of the OIE [OIE 2013] and reproduced in Box 19. Sometimes a qualitative analysis is sufficient to provide evidence and sometimes quantified estimates are needed.

- Analysing the "governance" of the chain (who controls and influences its operation) helps to identify how a risk can be managed and communicated.

A guide to value-chain mapping in an animal health context is provided in Humphrey and Napier [2005]. Guidelines on the use of value-chain analysis for risk assessment and risk management of animal diseases have been published by FAO [2011b] .

Willingness to pay for studies

These can help to assess the willingness of farmers and consumers to share the costs of risk management. For example, consumers in several countries have been shown to be willing to pay higher prices for meat that is traceable and well labelled [Chevenix-Trench *et al.*, 2011].

Cost-benefit analysis

This can be used to assess the consequences of an outbreak and the costs of risk management options, and to provide evidence for communicating risks to stakeholders. An assessment of the potential economic consequences of an outbreak of FMD in Australia estimated that the cumulative loss of export revenue would be between AUD39 billion (USD1.68-5.04 billion), with a large share borne by the beef industry. There would be a price drop on the domestic market resulting in a decline in domestic revenue of AUD23 billion (USD1.12-1.68 billion). In addition, there would be control and compensation costs of between AUD30450 million (USD16.8-252 million). The total loss of GDP, including knock-on effect on businesses reliant on the livestock sector, would be AUD213 billion (USD1.12-7.28). The report recommended establishment of FMD-free trade zones as a possibility for reducing outbreak costs. [Productivity Commission, 2002].

Animal health risks are strongly affected by human behaviour, so inclusion of economists and other social scientists in risk analysis teams can be helpful, as this brings in the perspective of professionals trained in analysing human behaviour. It can also be useful to apply formal economic methods within the components of the risk analysis framework. Box 19 provides examples of three different methods and their possible application.

5.5 EXAMPLE OF ANALYSES AT SUB-NATIONAL LEVEL

Cost-benefit analysis

A cost-benefit analysis may be carried out for a stakeholder group, to find out whether a proposed TAD control policy is likely to benefit them, or for an individual stakeholder, to assess whether it would be financially viable for them to invest in TAD control.

Box 20 describes an analysis made to assess whether supply of CSF vaccine through feed and drugs shops would be financially viable for the animal health workers who owned the shops, and would therefore be likely to succeed as an approach.

BOX 20

Cost-benefit analysis for CSF vaccine supply through a distributor

A study was made of the economic viability of controlling CSF in smallholder pig herds in Viet Nam. Control was to be achieved by making vaccines more widely available in feed and veterinary drug shops run by animal health workers. As part of the study several assessments was made of the viability of supplying CSF vaccine through distributors, one of which is shown here. The positive NPV indicates that this would be a financially viable investment [McLeod *et al*., 2003]

Year	**1**	**2**	**3**	**4**	**5**	**Total**
Costs in Viet Nam Dong						
Investment						
Fridge	4 000					
Back-up cold box	1 000					
Recurrent costs						
Electricity	669	730	730	730	730	
Variable costs						
Vaccine	7 066	14 132	14 132	14 132	14 132	
Ice bags	298	595	595	595	595	
Total cost	12 735	14 862	14 862	14 862	14 862	
Benefits in Viet Nam Dong						
Vaccination						
Sale of vaccine	7 440	14 880	14 880	14 880	14 880	
Vaccination service	3 125	6 250	6 250	6 250	6 250	
Total benefit	10 565	21 130	21 130	21 130	21 130	
Benefit - Cost	-2 170	6 268	6 268	6 268	6 268	
Cumulative cash flow	-2 170	4 097	10 365	16 633	22 900	
Undiscounted Benefit - Cost						22 900
NPV at 15% discount rate						13 673

Box 21 shows three examples where analyses have been carried out by stakeholder. One compared approaches in two different geographical areas of Bolivia; a second made separate assessments for different types of producer and the third compared effects on producers and consumers.

Cost-effectiveness analysis

As previously described, CEA is a useful method for economic analysis of zoonotic disease control. One example at sub-national level is the analysis of rabies control in N'Djamena, described in Box 22. In this case, controls were carried out on dogs and all of the economic benefits were observed in the human population.

Partial budget analysis

A partial budget is used to make comparisons on a small scale and over a short period, analysing changes to the profit of a farm or a single enterprise as a result of an intervention. It is useful for finding out whether it is worthwhile for farmers to apply disease prevention and control measures such as preventive vaccination or biosecurity on their

BOX 21

Impacts of TADs control on different stakeholders

FMD control in Bolivia

A study compared the impacts of FMD in two areas of Bolivia and found that the epidemiology of the disease was very different in each. One area was mostly free of disease. In the other, disease was endemic but the economic impacts were seen so long after an outbreak that there was little incentive for farmers to use vaccination as a preventive measure. The report proposed that government efforts should focus on the endemic area and aim at very high levels of vaccination coverage so that there would be a chance of demonstrating a positive impact [Rushton, 2008].

FMD control in Thailand

Perry *at al.* [1999] modelled potential impacts, making separate assessments for dairy, large-scale pig farms, village pigs and village cattle and buffalo, based on differences in productivity effect and vaccination coverage. They predicted that the commercial pig sector could capture up to 60 percent of the benefits.

CSF in the Netherlands

A computer simulation was used to estimate the costs of a CSF outbreak to producers and consumers, based on information from the 1997/8 outbreak. If no export restriction applied, consumer surpluses would fall by Euro552 million. If live pig exports were banned, all pig producers would lose and the effect on consumers would be very small. [Mangen and Burrel, 2003].

BOX 22
Cost-effectiveness of rabies control in N'Djamena

In Africa and Asia, 24 000–70 000 people die each year from rabies. In urban areas with free-roaming dog populations in countries where rabies is endemic, dogs may be the main means of infecting humans. The incidence of human rabies can be greatly reduced by vaccinating dogs against the disease. A study was made of the economic viability of a project to vaccinate dogs against rabies in N'Jamena, Chad. If all the dogs in the city were vaccinated, the average cost per dog vaccinated would be USD2.45, including the cost of vaccination and lost work time of dog owners bringing their animals for vaccination. The total cost to vaccinate 23 600 dogs would amount to USD57 717 per year. Based on reported deaths from rabies this would result in 69 avoided exposures per year, at a cost of USD837 per averted human exposure. Assuming that 16 percent of exposed persons would become ill with rabies and die, the cost-effectiveness of the vaccination programme would be USD57 717 per 11 averted deaths (USD5 227 per averted death). Since there is under-reporting of rabies cases in Africa by 10 to 100 percent, the cost-effectiveness could be as low as USD52 to 523 per averted death.
Zinsstag *et al.* [2007]

Note: there appears to be an error in this paper. The authors use a total cost of USD57 717 to estimate the cost per exposure and a total of USD57 774 to calculate cost per averted death, which they then estimate at USD5 252. Nevertheless, this minor error does not alter the conclusions.

own farms. There are many descriptions of partial budget analysis in published documents. The simplest and most practical are found in agricultural extension and farm management publications, for example USDA (undated) and Tigner [2006].

There are two ways of constructing a partial budget. One is to compare the benefits (new revenue and costs saved) with costs (new costs and revenue foregone). An alternative that produces the same conclusion is to compare the change in gross margin for a livestock enterprise with the cost of making an intervention (the gross margin is a measure of enterprise profit calculated as the value of output minus the value of variable costs).

Gari *et al.* [2011] used partial budget analysis to assess the economic viability of vaccinating against LSD in the Oromo region Ethiopia and found a net benefit of USD1 per animal for local zebus and USD19 for exotic and crossbred cattle. Young *et al.* [2012] used partial budget analysis to assess the economic viability of vaccinating Cambodian smallholder cattle against FMD and estimated a net benefit of USD31 per animal. Box 31 shows a partial budget for CSF vaccination in Viet Nam based on gross margins.

Other methods

The following methods were discussed in section 5.4 for use in national analysis but can also be used to analyse TAD control interventions from the perspective of specific stakeholders.

BOX 23

Partial budget analysis for application of CSF vaccination in a Vietnamese smallholder pig herd

A study was made of the economic viability of controlling CSF in smallholder pig herds in Viet Nam. Incidence of the disease was low, between 1 and 3 percent. Control was to be achieved by making the vaccine more widely available in feed and veterinary drug shops run by animal health workers. Farmers were expected to pay for the vaccine. The study included partial budget analyses for three different types of smallholder pig enterprises, one of which is shown here. From this analysis it is financially worthwhile to vaccinate "finisher" pigs since the expected gain in gross margin is higher than the cost of vaccination. [McLeod *et al.*, 2003]

Values per finished pig (95kg finisher) in Viet Nam Dong	**Intervention (0% incidence)**	**Baseline (3.0% incidence)**	**Intervention – baseline**
Value of pigs sold	**985.5**	**979.5**	
Feed cost	710.5	708.1	
Pigs purchased	247.2	247.2	
Treatment cost	0.0	0.3	
Gross margin per pig	27.84	23.86	3.98
Cost to vaccinate a pig			1.2
Net benefit from vaccination			**2.78**

- Optimization models are well suited to analysis at farm level or within a limited geographic area. Kobayashi *et al.* [2007] used a dynamic optimization model to analyse the economic impacts of controlling an FMD outbreak affecting part of California, USA. They ran the model firstly with the objective of minimizing disease incidence and then with the objective of minimizing pre-emptive culling.
- Decision-trees, a tool to guide a decision through a series of choices, can be used by a farmer, trader, dairy processing plant or slaughterhouse owner to analyse decisions about investment in animal health. One example of use for TAD control was described by Onono [2014], analysing CBPP control in Kenya. Decision-tree analysis was used to analyse the net benefit of vaccination compared with no action for a single herd.
- Choice models can be used to guide the design of TAD control programmes based on the choices made by stakeholders about animal health control. Chilonda, and Van Huylenbroeck [2001] describe the use of econometric analysis to analyse choices that livestock keepers make about animal health services or measures. Econometrics is the application of regression analysis (a form of statistical analysis) to economic data to test the strength of the link between a cause and an effect. Broadly, it attempts to produce a mathematical equation that describes as closely as possible the relationship between one or more causes ("explanatory variables") and an effect (termed the "dependent variable"), and also provides information on how well the set of data

being analysed "fits" the equation. Gujarati [2004] provides a very comprehensive description of econometric analysis. Regression techniques suitable for explanatory variables with only two possible values include probit, logit and Tobit analysis, all of which have been used to analyse farmers' choices about animal health care in African countries [Tambi *et al.*, 1999b; Chilonda, 1999; Mutambara *et al.*, 2013].

6. Motivation to comply with TAD control regulations

Farmers, traders, consumers and others may choose to comply or not to comply with TAD control measures. Their decisions will be affected by their perception of the risk faced, and the level of difficulty and cost associated with compliance.

These factors should be considered when making an assessment of the viability of a TAD control policy or programme. Over-optimistic assumptions about the implementation of animal health projects can result in over-estimates of benefits, undue optimism about how soon benefits will be realized, underestimates of recurrent costs (with implications both for project viability and future government budgets), or failure to build in the possibility of a temporary breakdown in a control programme. Motivation factors may also need to be reviewed if a control programme has failed and needs to be redesigned.

6.1 PERCEPTION OF RISK

The economic impact of a TAD is a product of the likelihood (risk) that it will affect animals and the cost if it does affect them. Individuals modify their behaviour based on their perception of risk – which may or may not be the same as what would really occur – and this in turn an affects actual risks and costs.

- When farmers are asked to "prioritize" diseases, their answers are likely to vary depending on how recently they saw each one, and whether they have ever experienced a very severe loss from a particular disease. A recent shock or a very severe loss at any time tends to raise the priority of a disease, and hence the likliehood that a farmer will take active steps to prevent it, while familiarity with having it in the environment without a severe personal loss may lower its priority.
- Farmers may choose to ignore vaccination in favour of treatment based on their own experience or the recommendation of their neighbours. Amanfu [2006] commented that many African farmers used antibiotics to treat CBPP, and also that animal health practitioners prescribed antibiotics, even though this was against government policy in many countries, and despite the fact that an effective vaccine was available.
- Fear of loss can lead farmers to sell animals that they suspect have been exposed to disease agents, thus spreading disease more quickly and creating the externalities that are a characteristic of TADs. Traders may choose to buy animals in spite of the possibility of spreading disease, because they can obtain them at a very low price. A related effect is that farmers in many countries are reluctant to report TADs and estimates of incidence are often unreliable.
- Some livestock owners insure their animals to reduce losses from disease outbreaks. This is most commonly done for individual animals with high value or within industry-initiated insurance schemes. Insurance schemes usually require those who insure to apply

biosecurity to a high level. In Chile in the late 1990s, the pig industry set up a private insurance programme against CSF outbreaks after eradication, with different levels of premium reflecting the biosecurity practices put in place to prevent disease [Pinto, 2000].

- Consumers are also likely to place a high value on social costs (human death, change in social status, serious disruption of daily life) that are hard to estimate in financial terms. Any of these social costs add to the "panic factor" associated with a TAD, and this is the reason why emerging zoonotic TADs are a great cause for concern. The example of H5N1 HPAI in Box 24 illustrates this point.
- The behaviour of governments, civil servants and veterinarians is also modified by perceptions, even if these are backed up by scientific analysis. They have assumptions about disease epidemiology and modelling that may or may not be accurate.

It is not unknown for governments, consumers, producers and veterinarians to have different notions of risk, or for large and small-scale farmers to see it differently. Box 24 provides examples of situations when perceptions of risk affected TAD control.

BOX 24

Risk perception and economic impact

Rinderpest in northern Kenya: disease impacts vs. bandits

In 1995, when rinderpest was diminishing in incidence but was still found in pockets in northern Kenya, the Government of Kenya provided free vaccination, yet the uptake of vaccine was low. Veterinarians were concerned that resources were being wasted and cattle not being protected. A survey of livestock keepers revealed that they did not see rinderpest every year – there was perhaps a 25% chance of infection in a year. When infection did occur, it did not always kill the animal. At the time of year when vaccination was offered, to coincide with the available government budget, animals were grazing at a distance from the vaccination site. To be vaccinated, they would need to be trekked across an area known for cattle theft by armed raiders, with perhaps an 80% chance of losing the entire herd. In the circumstances, the decision not to have animals vaccinated was economically rational. [Ngotho, McLeod, Wamwayi and Curry, 1999].

FMD in rural Cambodia: variance between financial analysis and farmer choice

A partial budget analysis of the financial impact of FMD was carried out in four villages in southern Cambodia after an outbreak of FMD in 2010. This is an area where cattle have multiple uses including draft power. The analysis suggested an annual benefit of vaccination of USD31.80 per animal, but vaccination rates at the time of the study were low. [Young *et al.*, 2012]. The authors suggested that farmers might be unaware of the value of vaccination or the full cost incurred when disease occurs, or have insufficient disposable income to vaccinate, and proposed various ways to raise awareness.

Consumers and HPAI: fear creating market shocks

HPAI began spreading globally in poultry in 2004, and human mortalities from the disease were reported in the media. Some consumers reacted very strongly although the real risk to them was very small. For example, the demand for poultry meat dropped sharply in Italy although there were no outbreaks of HPAI

(cont.)

6.2 ECONOMIC ANALYSIS

Assessments of the kind discussed in section 5.5 can help to identify situations where farmers will have little motivation to comply with TAD control regulations.

Nin Pratt *et al.* [2005], reporting on the economic impact of a ban on exporting live animals from Ethiopia to the Gulf States during an RVF outbreak, noted that even during export bans some animals are still exported. It is hardly surprising that some people choose to ignore the regulation, since pastoralists and livestock traders experience particularly high losses.

A study of FMD control in two areas of Bolivia, previously described in Box 21, found that in one area disease incidence was so low that farmers would be unlikely to be motivated to vaccinate their animals. An analysis of FMD control in Thailand [Perry *et al.*, 1999] found that up to 60 percent of the benefits would be captured by commercial pig producers, who would presumably have an incentive to participate in the government vaccination control programme and comply with animal movement regulations. The much larger number of smallholder pig, cattle and buffalo owners would capture only 40 percent of the

in that country and the risk of disease being carried by imported meat was minimal. The risk to small scale poultry traders in South East Asia was higher, since they had regular direct contact with live birds that were likely to be infected, and yet they hardly changed their behaviour at all. Thai and Vietnamese consumers reduced their consumption of poultry quite sharply in the first wave of outbreaks, but consumption recovered and in later outbreaks the drop in demand was much smaller. Consumer perceptions of risk were fuelled by inconsistent reports from the media, the health services and the veterinary services [McLeod, 2009]

Brucellosis vaccination in Tajikistan: encouraging farmers to share costs.

When designing a pilot B. melitensis vaccination campaign in Tajikistan, where farmers were asked to share the cost, a market survey was used to assess what cost was likely to be acceptable [Ahuja *et al.*, 2009]. A communication campaign was run to bring the problem to the attention of farmers. The percentage of vaccination uptake was high in most villages, and more than 80 percent overall.

FMD in the UK: incorrect judgement through over-reliance on models.

During the FMD outbreak in the UK in 2001, two different perspectives influenced the way that culling was used to control disease spread. One was the official government policy, driven by mathematical models produced for the Science Group that advised the Chief Scientific Adviser to the government. Based on the model results, a policy of "contiguous culling" was adopted, meaning that all farms within a specified distance of an infected farm were to be culled out. In one area of North Cumbria it was not possible to implement an automatic contiguous cull owing to resource constraints. Here, the FMD control team used their veterinary judgement and knowledge of the local situation to assess which farms were likely to have been infected. In the area where culling was determined by the vets, fewer farms and animals were culled than would have been the case with contiguous culling, but the outbreak was contained as rapidly as in the areas where contagious culling was used. Subsequent analysis showed that some of the data used in the models were incorrect and many animals had been culled unnecessarily. [Kitching *et al.*, 2006; Honhold *et al.*, 2004]

BOX 25

Principal-agent relationships and the design of compensation schemes

When a compensation policy forms part of a TAD control strategy it can be considered to be a contract between farmers and the government. The farmer is expected to make a reasonable attempt to prevent disease, and to report disease when it occurs, and in return the government makes an effort to prevent the introduction of the disease and pays compensation if diseased animals are culled. In economic theory, this is an example of what is termed a principal-agent relationship, where one person (the agent, in this case the farmer) acts on behalf of the other person (the principal, in this case the government). If the contract between them is well designed, the agent will have an incentive to act in the way the principal wishes. In the case of TAD control there is disparity of information between principal and agent, as the farmer knows more than the government about disease in the herd. It may also be in the farmer's interest to delay reporting. In some cases farmers whose herds are culled could be better off than those with healthy herds who suffer losses because of movement restriction. This situation creates the potential for "moral hazard", where there is a lack of incentive to guard against risk because one is protected from the consequences. A compensation programme must be designed in a way that minimizes the moral hazard; this might be done by paying compensation at less than market price, so that farmers bear part of the risk of delaying reporting, or by paying only for animals that are culled and not those that die of disease. However, there may be political considerations that prevent either of these solutions. Wolf [2013]; Alleweldt [2013]

benefit, and some would lose income if they could no longer unofficially export buffaloes and cattle to Thailand. Another evaluation of FMD control, in Zimbabwe, also found that FMD would have very different impacts on commercial and traditional farmers. Commercial farmers would accrue most of the benefit while traditional farmers would see very little impact [Perry *et al.*, 2003]

It is also useful to consider the theoretical basis of non-compliance when designing TAD control policies. Box 25 describes recent thinking behind the design of compensation schemes.

7. Designing an economic analysis

This chapter provides a few suggestions to guide animal health planners in commissioning economic analyses studies. Most of what is written here is common sense and may seem obvious, but many studies are commissioned with terms of reference that do not accurately reflect what is required, or expect a result that is highly unrealistic given the time and resources available.

7.1 DESCRIBING WHAT NEEDS TO BE DONE

Start early

Many economic studies of animal health impact have been commissioned as an afterthought and designed by people with a limited understanding of what is possible. An economic analysis is much more likely to be appropriate and useful if it is anticipated at the start of an animal health programme, built in and budgeted, and involves economists in specifying the design.

Frame the question

The key to an informative economic analysis is to frame very carefully the question that it must answer. An apparently simple question "how much does this disease cost?" covers a large range of possibilities that must be clarified before designing a study and assessing the resources needed to carry it out. A checklist for framing a question follows:

a) *Why is this question being asked?* This gives a guide to the type of analysis that is needed and where the study should focus. Should it, for example, estimate the total cost of a disease to the economy, or the impact on a particular stakeholder, or highlight the cost elements that could be reduced, or the factors that may affect the implementation of a control programme?
b) *What is the scope of the study?* Is a global estimate needed, or a national estimate, or something more local? Should it examine all production systems or only some of them? Should it differentiate between impacts experienced by men and women, or by small-scale and large-scale producers? Should it include impacts through the entire food system? Does it need to examine knock-on effects in sectors other than livestock?
c) *How accurate and how precise does the estimate need to be, and how soon is the answer needed?* It is rare that all of the data needed for an estimate are available, but primary data collection is expensive and time consuming. It may be possible to find reasonable estimates of some of the necessary parameters from literature or by interviewing experts. It may be necessary to build a new computer model or modify an existing one.

Specify the work

The scope of work will be affected by the question to be answered and resources and data available. It may require: a desk review of literature; a desk modelling exercise using readily available information; key informant interviews; field surveys to collect new data.

To arrive at anything better than a back-of-envelope estimate, the minimum information needed is likely to include: the livestock populations at risk and their productivity; the population of livestock owners who might be affected and their dependence on livestock; the incidence of disease and its impact on production parameters; trade restrictions applied; disease prevention measures that are already being applied; outbreak control measures applied; all applicable prices and costs. Information may also be needed on trade patterns, value chains, consumption patterns and sectors with which the livestock sector interacts, such as tourism.

Lack of data and information often limits the scope, accuracy and precision of economic analyses of TADs. Economic analysis requires a wide range of data and often uses secondary data because there is insufficient time and resources to collect primary data. This is discussed in section 7.2.

It is worth specifying at the start what should be covered in the final report. Economic analysis should be transparent, and this means including detailed annexes listing assumptions made and critical input variables.

Plan for feedback

It is important to reality-check the results of estimates with stakeholders. This may require one or more meetings, including meetings in field locations. In one study carried out by the author and colleagues in Viet Nam, a pig population model was developed as a basis for a cost-benefit analysis. Graphs from the population model were shown to pig owners and traders to check that the pattern of production and sales was realistic. When discrepancies were spotted, the variables were adjusted and the model recalculated on the spot until the results matched what people saw in real life.

7.2 DATA NEEDS AND DATA DEFICIENCIES

Economic analyses of disease control programmes need to be situation-specific. It is highly unlikely that the necessary data will be easily available, and even if it is available it needs to be verified. This means that a good deal of field work, interviewing of experts and mining of government data can be anticipated. The substantial input required is one reason why only a limited number of economic analyses have been published. Senturk and Yalcin [2005] tested the Delphi technique, a formalized method for eliciting expert opinion, to learn about FMD impacts on productivity from veterinarians. They concluded that it had been reasonably effective but would be improved if the sample of experts included farmers.

Data collection is expensive, and no public agency anywhere keeps good, up-to-date records of livestock populations and distribution, on the off-chance that they may be needed. When an unfamiliar problem crops up there is not even an institutional memory on which to base reasonable judgements.

Estimates of the possible future impact of a disease rely heavily on the ability to predict when and where it might occur and how widely it will spread. Unfortunately, the record on prediction of livestock diseases is quite poor. This is partly because global databases on livestock and diseases are very patchy, and partly because the spread of livestock diseases is strongly influenced by human behaviour that is very hard to predict.

The predictive value of most disease models is poor, even for known diseases, and models require well-maintained databases on livestock populations and trade. The FMD outbreak in the UK in 2001 took most people by surprise as the UK was not considered to be the most risky point of entry in the EU, and the very rapid initial spread occurred partly because knowledge of livestock market chains was scattered and local, with no common institutional knowledge or database on which to draw.

When HPAI began spreading across Asia in 2004, it was discovered that the global database on smallholder poultry systems was almost non-existent. Large-scale commercial production was well documented, but the production and marketing systems of smallholder poultry keepers were hardly recorded at all. It was not until 2009 that both tacit and explicit knowledge were sufficient to make reasonable economic estimates [author's experience]. Those estimating the cost of PPR, spreading in Africa and the Middle East, are likely to encounter the same problem.

Any of the following types of data and information may be needed for an economic analysis, and it is common to find that there are gaps in secondary data:

Livestock population size and structure

Any economic assessment will require information on the size of the livestock population at risk for the disease under investigation, and the value of the animals.

In the author's experience this information is missing or of poor quality in most developing countries. Censuses may only be held every ten years or more, and other attempts to collect data tend to be incomplete and fragmented. It is common to find more than one database containing conflicting information about the same sub-population and with no easy way of calibrating them. Attempts have been made to improve the existing databases, for example by using GIS models to fill in gaps between data points [FAO, 2007], and by adding more questions about livestock to routine farm household surveys [Livestock data innovation in Africa, 2012], but there is still much to be done to improve data quality and reliability.

There may also be gaps in the livestock population data for developed countries, for example, when herds and flocks under a certain size are not required to be registered, or when animals are illegally traded, but these tend to be less problematic than those for developing countries.

Disease incidence and impact on production parameters

Data on the incidence of TADs is kept in some systems such as OIE's WAHID and WAHIS systems, FAO EMPRES-i (Global Animal Health Information System) and regional systems, and suspected outbreaks are often publicised through ProMed/Health Map. Data on TADs are more readily available than on non-TADs because of the requirement to report to the OIE and the interest generated by outbreaks, but they are still patchy and unreliable in many countries owing to limitations in disease reporting and surveillance. The best information available relates to free countries that experience outbreaks and need to maintain credibility within international markets.

Information on incidence is usually poor and hard to check in places where TADs are endemic, which is the case of most of the developing countries. There is little incentive for livestock producers to report outbreaks and only a small part of the information on livestock disease is captured by official information systems [McLeod *et al.*, 2010].

Some TADs are sufficiently well-established that their effects on mortality and production have been recorded in a variety of production systems. For an emerging TAD they may not be known. They tend also to be poorly recorded in areas where disease is endemic. Even when local reports of incidence and effects are available, diseases with similar symptoms can be confused with each other.

Most economic estimates of disease require information on basic productivity parameters, such as reproduction and mortality rates, age and weight of animals at sale, and offtake rates. This information may be available for large-scale commercial production from herd recording systems and published industry data; for small-scale and less commercial herds, economists usually rely on a few published reports of variable quality, or may need to collect their own primary data.

Profitability of livestock production and trade

Data on profitability in the market chains associated with small-scale and pastoralist systems tend to be quite scanty. The most numerous reports relate to smallholder dairying, but even these are relatively few.

Consumption of livestock products

If a TAD affects the availability or price of a particular type of livestock-source food, this may affect the welfare of consumers – negatively if food prices rise and positively if they fall. To compute the effects it is necessary to have information on consumption patterns and the price elasticity of livestock commodities. The latter may be available; the former are often in short supply, particularly for poor households who may be the worst affected.

Quantified relationships between the livestock sector and other sectors of the economy

As previously discussed SAM, CGE and economic surplus models and trade models such as the OECD's COSIMO are used to establish macroeconomic impacts of developments in the livestock sector, including the emergence and control of TADs. Not all countries have access to these models or good livestock data to put into them. In many cases additional modelling is needed to generate the necessary input data for the livestock sector.

Data deficiencies have not prevented economists from analysing the impacts of TADs and TAD control programmes, but they have undeniably affected the quality of the results and the cost of obtaining estimates.

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Animal health and economics are closely linked. Any decision taken to prevent, control and eliminate an animal disease is based not only on the technical knowledge available about a particular disease but also on the effectiveness and socio-economic aspects associated with interventions and mitigation measures implemented by governments, producers and all the actors along the livestock value chains. Economic rationale drives decisions in assessing particular investments which are likely to result in a benefit for society or for a specific stakeholder, including livestock farmers and communities.

These guidelines prepared by FAO will contribute to a better understanding of the importance of economic analysis when assessing the impact of a particular animal disease in production, trade, market access, food security and livelihoods of rural communities, or when designing or implementing an animal health strategy at national, regional or global level. This framework will provide a good communication tool between animal health technicians, veterinarians and economists in developing countries and will encourage a well informed collaboration between veterinarians, animal health experts, economists and social scientists for livestock and socio-economic development. Economic analysis should be an essential part of animal disease policies and disease management strategies.

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