ECONOMIC ANALYSIS IN ANIMAL HEALTH MANAGEMENT

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INTRODUCTION

Although humans have been treating diseases since prehistoric times, successful disease control and eradication programs are relatively recent developments in history. These programs have been directed against living agents capable of producing unusual damage, and except for the recently addition of some significant noninfectious diseases (chemical poisoning, industrial pollution), there is no reason to expect that infectious diseases problems will be eliminated, at least in the short term.

Historically, disease agents have migrated with humanity and their animals. During the centuries when travel was slow and difficult, and trading in animals and animal products was limited, infectious agents moved slowly. Even before the work of Pasteur and Koch and the subsequent explosion of knowledge concerning disease, observation of the association of the introduction of disease with animal importation resulted in the beginnings of quarantine and control systems. Slow sea voyages provided a long, natural "quarantine" period for live animals, and land movement of livestock was on foot and proceeded slowly over the few trails or roads available. However, land movement resulted in the possibility of spreading disease agents along the route of travel (Galloway, 1972; Gelfand, 1973; James & Ellis, 1980).

It is only in the last few generations that we have begun to understand the mechanisms through which diseases operate and been able, in any informed way, to move beyond superstition and empirical remedies in handling the impact of disease. The explosion of scientific and technical knowledge that commenced in the latter half of the nineteenth century changed the patterns of trade and increased opportunities for the spread of pathogens. These changes, coupled with expanded studies of the mechanisms of disease occurrence, resulted in altered awareness, as illustrated by recently changed perceptions of healthy foods (Howe & McInerney, 1987).

Nowadays, disease is a main limiting factor in the inefficiency of animal husbandry in many countries; it is a burden that can be greatly lessened, even if it cannot be entirely avoided. Economic losses occur not just from the death of animals, but from the loss of meat, milk, or fiber production, when animals become debilitated, and also from the prevention to access to better and/or other markets. The livestock industry is continuously challenged to reduce these losses. Worldwide losses due to animal diseases and parasites because the above reasons, account for the largest economic drain on the livestock industry (Galloway, 1972). The list of epidemic diseases deserving attention remains far greater than those scheduled for control or eradication efforts.

Nowadays, public interest over substantive issue such as food safety, nutrition, sustainable production systems, animal welfare and animal rights, are being more under consideration in order to answer the question of consumer “perceptions”. Barnett & Grant (1996) defined eight major research areas for the New Zealand Red Meat industry till 2006. Three of these themes; namely, food safety, meat quality and animal production, are seen as being paramount and of equivalent importance on an on-going basis, although it is recognised that from time to time other themes may assume a higher ranking depending on circumstances in the market place.

1. RESEARCH OBJECTIVES

The main goal of this work is ***to identify procedures which could improve the efficiency of programs to eradicate or control livestock infectious diseases.*** The quantitative insight into the effect of diseases and diseases control or eradication gained in this way can be used for:

1. *Assistance in indicating the lines on which veterinary and animal sciences research should develop by providing economic criteria.*

2. *Broadening the basis for decisions when a choice must be made from alternative preventive, control or eradication strategies.*

3. *Supporting the livestock owner's policy with respect to animal production and animal health.*

2. ECONOMIC ISSUES OF LIVESTOCK DISEASES

The objectives of the literature survey within the present work, are to examine the literature which has reported economic studies in epidemiology and to identify the methods used in those studies to measure financial, environmental and social effects and their private, sectoral and national distribution.

Systematic research on animal health economics includes three interrelated phases (see Dikhuizen et al.1991; Renkema & Dijkhuizen, 1984; Huirne et al.1991; Jalvingh et al.1992 and Dikhuizen et al., 1995):

1. quantifying the financial effects caused by animal disease.
2. the profitability of preventive measures, determining the costs and benefits of disease control or eradication measures, and
3. developing methods for optimizing decisions when individual animals, herds, or populations are being affected.

All three issues concern complex problems which have to be studied under imperfect veterinary knowledge and under a high degree of uncertainty. The importance of a close link between economics and epidemiology is stressed for future development, as well as the need and possibilities for an international exchange of models and procedures.

2.1. The changing environmental and livestock health picture:

The explosion of scientific and technical knowledge that commenced in the latter half of the nineteenth century changed the patterns of trade and increased opportunities for the spread of pathogens: steam replaced sails for sea travel; regions, formerly weeks or months apart, were separated by only hours or days with the coming of railroads. The industrial revolution created many new commercial processes and products that could be distributed quickly and widely, including products of animal origin. These changes, coupled with expanded studies of the mechanisms of disease occurrence, resulted in altered awareness, as illustrated by changed perceptions of healthy foods (Ngategize and Kaneene, 1985).

The risk of spreading disease increases when distance becomes of little consequence and time in transit can be measured in hours. Within a few hours jet aircraft from any part of the world can reach the interior of any country. Huge, well-constructed shipboard containers discourage complete inspection of animal products at the port of entry. Traditional concepts of quarantine and control systems are now insufficient: oceans, mountains, deserts, swamps and rivers no longer provide effective barriers. Although most animals disease control and eradication programs continue to be carried out on a country-by-country basis, the overall concept of animal disease now needed is multinational rather than national. Political boundaries are not barriers to disease, and political and economic considerations that may favour increased trade with selected countries may have little to do with the realities of disease risk (Schnurrenberger et al., 1987).

This new scenario brought a new dimension to disease prevention. Control over animal products is, in many ways, more difficult to determine and administer than those over international traffic in the animals themselves. Such items (animal products) are diverse and result from a variety of industrial processes, some of which may reduce disease risk to a negligible level, whereas others do not significantly change the danger. Entrepreneurs frequently have little understanding of disease or the impact of pathogen introduction and often resist what they perceive as bureaucratic obstacles to trade (Burridge, 1981).

Considerable advances in the control of animal infections have led to the effective elimination of many of the traditional causes of acute disease. This has been achieved by a combination of appropriate vaccine usage, good drug therapy and the development of disease-free strains of livestock. These advances have made it possible to keep animals in much larger groups and more densely housed than hitherto but the results have by no means led a gradual disappearance of infectious diseases. On the contrary, a number of complex diseases have emerged, difficult to diagnose and induced by a multiplicity of pathogenic agents. (Sainsbury, 1983).

2.3. Public perception:

Historically, the public perception of the degree of economic loss caused by a disease has been through impressions from direct observation by livestock owners. Also, structured analyses of economic losses that are now expected to be measured cost/benefit studies for governments are valuable for convincing industry that a disease is in fact causing significant economic damage. As the use of such studies has grown for proposed government programs, including health programs, the economic analysis required is much more sophisticated than was necessary in earlier years.

These studies are now required before approval and funding of most public programs. The time required to develop the model must be taken into account in considering the time frame for a new program, not only in the timing of a program against an established disease, but also in planning for future emergency situations. A preliminary economic analysis of the potential impact of a dangerous exotic disease can save vital time if the emergency actually develops.

Although consumerism has received much publicity in recent years, the adverse effects of buyer concern over animal health is not new. German consumers, fearful of trichinosis, were an important reason for the initiation of a mandatory meat inspection system in the United States at the turn of the century. Imposed knowledge and media communication have made today’s consumers feel strongly about protecting the safety and quality of their food supply. They see this as more important than food producers’ concerns over adverse effects of control or eradication programs. Consumers of animal products feel that they deserve protection from disease risk when using these products. However, producers are inclined to think first in terms of making a profit from their operation. Human health risk may be of little concern to producers unless the regulatory steps taken to protect public health interfere with their economic return (Schnurrenberger et al., 1987).

Disease control or eradication programs do not readily conform to the measures or requirements to fit the interests of both consumers and producers. Differing areas of primary interest of consumers and producers need to be recognised and taken into consideration in planning disease control or eradication programs.

2.4. Farm animal health and welfare and human implications:

Apart from the members of a few religious sects, such as Buddhists and Hindus, an interest in animal welfare by human beings is a relatively new phenomenon, not much more than 100 years old in the western world. In many societies, in other parts of the world, a direct interest in animal welfare seems almost non-existent (Blackmore, 1992). These days, the welfare of farm animals has become an important issue for consumers, producers and policy makers. Legislation and changes in livestock production practices to improve farm animal welfare have assumed a higher public profile in recent years. Previously, judgements about the welfare of farm animals were left largely to the farming industry. Animal welfare is now a prominent issue internationally and as such will be used increasingly as a trade lever. Whether motivated by genuine concern or political expediency, accusations of animal welfare abuses (real or imagined) are likely to be made by trading nations to justify their imposition of import restrictions (McInerney, 1991; 1993).

Nowadays, farm animal welfare has become an important area of study for animal scientists (see Dawkins, 1980; Broom, 1988, 1991; Ebel et al., 1992) but perhaps surprisingly, has been almost entirely neglected by economists until relatively recently. This is despite the important resource and human welfare implications of changes to livestock production imposed by animal welfare considerations. Perceptions that certain aspects of livestock production give rise to poor farm animal welfare are a potential source of disutility for many people. This disutility may be associated with the individual's own consumption of livestock products and/or with that of other people. The latter is a negative externality of society’s consumption, resulting in common real indirect costs associated with livestock production (McInerney; 1991,1993).

Animal welfare is also pertinent to the question of health since there is no dispute that one of the essential criteria for the provision of good welfare is the maintenance of health in the animals. Good health is the birthright of every animal that we rear, whether intensively or otherwise. If it becomes diseased we have failed in our duty to the animal and subjected it to a degree of suffering that cannot be readily estimated (Bennet, 1994). It has also become apparent from recent activities in the research field that the eventual goal of establishing what constitutes good welfare in a scientific way is going to be difficult indeed, if not impossible (Sainsbury, 1986).

3. BASIC ECONOMICS CONCEPTS

As Howe & McInerney (1987) stated, the basic conceptual model underlying economic analyses includes three major components: people, products and resources. This has always to be kept in mind when analysing the economic effects of livestock disease. It is people who think and make decisions providing the driving force for economic activity. Products are goods and services that satisfy what people want, and may be regarded as the outcome of an economic activity. For McInerney (1987), resources are the physical factors, and services that are the basis for generating the products, and as such, are the starting point of economic activity.

Animal disease in this context can be considered as an influence, which affects the transformation process of resources into products, and causes extra resource use and/or less production than before. The effects may be immediately visible (death, abortion), or obscured (reduced weight gain). To express the physical effects in economic terms, the "value" of products and "cost" of resources are required. According to Dijhuizen et al. (1995), the idea of value is not intrinsic in any product or service, but is determined by peoples' request for products, and is relative to its availability ("supply and demand").

3.1. Losses due to animal diseases

According to McInerney (1987), the losses caused by animal disease are determined to a large extent by a combination of three factors:

1. *The form of disease:*

From the risk point of view, and because of the economic effects of disease, a distinction should be made between:

- Diseases prevailing in the area under consideration, whose incidence varies from farm to farm. Individual livestock owners can do much to prevent, control or eradicate them (so-called *enzootic diseases*).
- Contagious animal diseases, rarely occurring in a certain area, which require regional and/or national measures (so-called *epizootic diseases* i.e. FMD). Such diseases can rapidly affect large numbers of animals.

2. *The animal species:*

The effect of the losses on a certain animal species is especially influenced by the normal ratio between net profit and cost of production. In the pig and poultry industry an increase of 1 % in the cost of production will have a greater impact on a farmer's profit than it would have in the dairy or red meat sector.

3. *The economic level involved:*

The economic effects of animal disease can be considered from the point of view of the individual farmer, the sector or the national economy. The potential effects vary considerably between the beneficiaries.

Table 1 contains a list of how the market price realised for the animal products is likely to react in each case. In the case of column A, supply and demand changes force prices to move over time with the average disease level. The adjusted price is transferred to the consumers, and conversely it is the consumer who benefits from improved animal health. In a sufficiently large market there is hardly any relation between the extent and seriousness of these diseases and the average income of the joint livestock owners. For the individual farmer this linkage does exist. The affected farm may suffer more (or less) from disease than is compensated by the average "disease margin" included in the market price.

Table 1. Losses due to animal diseases, considered for different economic levels. (Dijkhuizen et al., 1991)

Economic level	Form of disease		
	Disease generally present through varying in degree farm (A)	Incidental outbreaks of contagious animal diseases on a national or regional scale	
		(B1) Foreign trade restrictions	(B2) no restrictions to foreign trade
(1) Farm	Direct relation between loss and degree of occu-rence of the disease per farm (particularly im-portant for pig or poultry farming).	Large incidental, even if the farm is not affected by the di-sease. Possible compensation for des-troyed animals.	Great loss on the affected farms (possible compensation for destroyed animals); advantage for farms not affected.
(2) Sector	Loss, insofar as the price does not adapt itself.	Spectacular loss, particularly in the case of export products resulting from dropping prices due to failing demand.	Moderate loss (depending on possible compensations and on degree of price adaptation.
(3) National economy	Loss for consumers due to higher prices. Loss due to inefficient use of resources.	Incidental advantage for consu-mers, and disadvantage consi-rably less than loss collective stock farmers for the national economy (2.B1)	Slight loss for consumers, and for the national economy disadvantage can be greater than loss top collective stock farmers (2.B2) But loss 3.B1 probably greater than 3.B2

Stoneham and Johnston (1986) pointed out that livestock disease control or eradication externalities may extend far beyond a particular geographical region when overseas markets are at risk. Rubinstein (1977) demonstrated this concept with an empirical example involving the control of FMD in Colombia. This *externality* issue has been identified in Uruguay, as a major issue for eradicating FMD as suggested by Leslie et al. (1997). Eradication of FMD in Uruguay where there is no natural boundary and where animals and/or animal products easily cross the borders without, or with a minimum control, could have been impossible if similar campaigns were not implemented with equal rigour in the regions surrounding Uruguay. In fact, as suggested by Carpenter & Howitt (1982), externalities associated with infectious diseases may justify government intervention in the form of subsidised control.

In this respect, Ebel et al. (1992) found that a common problem with economic research of livestock disease is a failure to consider types of probable changes in market equilibrium when the disease is controlled or eradicated. These include changes in producer and consumer surplus, changes in market prices as well as the quantity demanded and produced.

3.2. Benefits due to livestock disease prevention, control or eradication

Benefits may commonly be much harder to estimate than costs. According to Hollis (1988) three kind of benefits can be expected when preventing, controlling or eradicating a disease:

3.2.1. Profit improvement.
3.2.2. Avoidance of risk.
3.2.3. Personal satisfaction.

Most analyses of possible programs have concentrated on profit improvement, but risk aversion strategies are also recognised. Personal satisfaction is the hardest goal to quantify, but decisions are often made on the basis of utility improvement.

3.2.1. Profit improvement

Profit improvement relies on the *equimarginal principle*. Optimal returns from a scarce or limited resource are maximised when the input is allocated to its most profitable use in such a way that the returns from the last unit of resource is not only equal or higher than the cost of the last unit of resource, but also the same in each of the alternative uses. Profit therefore, is maximised where marginal cost and return are equal. Yet for Ngategize & Kaneene (1985), all too often decisions in animal health management (and elsewhere) are not made in accordance with this principle. It is difficult to operate in practice as inputs and outputs may not be divisible in use. Profit or financial benefits may include cost reductions, increased profits accruing from reduced production losses, as well as access to new markets.

3.2.2. Avoidance of risk

It refers to the uncertainty involved in some economic decisions. According to Anderson et al. (1977), most farmers tend to be risk averse, but their attitude towards risk varies depending on their objectives and financial resources. With respect to livestock diseases (specially for FMD), farmers will often choose a strategy, such as herd vaccination, even though it is expected to be slightly unprofitable, because that strategy negates the potential for big losses from an outbreak of infectious disease (Dijkhuizen et al., 1994).

According to Little & Mirrlees (1974), policy makers often tend to react in a risk-averse fashion, fearing the personal consequences of being seen to have made decisions that turned out incorrectly. The uncertainties of particular public programme, however, are often rather insignificant when measures against the total performance of the economy. Goh et al. (1989) suggest that according to the economic theory, governments make the best economic choice among risky projects by using risk-neutral decision rules.

3.2.3. Personal satisfaction

For Hollis (1988) personal satisfaction, social, or nonfinancial benefits are difficult to estimate in monetary terms. They include lack of suffering, prestige of freedom from disease, avoidance of inconveniences such as treatment of sick animals that may disrupt management routines, and increased human productivity in the case of zoonotic infections: e.g. farmers might choose to vaccinate their animals simply because they do not want their animals to be sick, or because they prefer to be able to plan when a livestock program is implemented rather than having to worry about administering treatments on an inconvenient day (or night). There may well be no economic justification for this approach, just personal satisfaction, but it is nevertheless a legitimate basis for decisions. Here the utility gain outweighs the economic justification. This factor could be important for control or eradication programs in developed countries, but it is still of not major priority in developing countries where the two previous factors prevail.

4. ECONOMIC DECISION MAKING IN ANIMAL HEALTH MANAGEMENT

4.1 Basic Methods of Economic Analysis

Regression analysis

In epidemiology, contagious and endemic diseases tend to follow cyclical, seasonal or trend patterns over time. Identification and measurement of these patterns can be useful in the treatment and control of the diseases and in making evaluations and planning projects. In this sense, regression analysis is useful for quantifying the relationship between one or more explanatory variables and a dependent variable.

Shanks et al. (1981;1982), used *regression analysis* to evaluate postpartum distribution of costs and disorders of health. An interesting application of this technique was made by Hunt & McCauley (1974), who specified a production function to measure the relative contribution of various resources to US dairy farm income. According to them an extra dollar spent on veterinary services was estimated to make a positive contribution to income of $ 2.96.

Peralta et al. (1982) used time series analysis to determine the pattern of FMD in cattle in Paraguay. The method allowed them to identify a seasonal variation in the incidence of FMD. They concluded that it could have been due to vaccination programs which would allow for close contacts with animals, and hence more cases of FMD would be reported during the vaccination months than otherwise.

Factor analysis

Factor analysis refers to a variety of statistical techniques whose common objectives is to present a large set of variables in terms of much smaller number of mutually independent, unobserved variables. Usually it is used when it is not possible to specify beforehand a set of explanatory variables to describe the variation in the variable of interest. In comparison with regression analysis, it does not require assumptions to be made about the nature of the statistical relation nor does it require that independent variables be quantitative (they may be qualitative). According to Neter & Wasserman (1974), factor analysis is an expedient way of ascertaining the minimum number of linear factors that can account for covariation among the observed variables.

Sol & Renkema (1984) used *factor analysis* for analysing the profitability of a broad dairy-herd health program in the Netherlands.

Discriminant analysis

Discrminant analysis is used to distinguish statistically between groups of cases. These "groups" are defined by the particular research situation. To distinguish between the groups, the researcher selects a collection of discriminating variables that measures characteristics on which the groups are expected to differ. The mathematical objective then is to weigh and linearly combine the discriminating variables in some fashion so that the groups are made as distinct as possible. The method attempts to discriminate between groups in the sense of being able to tell them apart. This is achieved by forming one or more linear combinations of the discriminating variables. Discriminant functions are of the form:

$$D = \sum_{i}^{n} d_i Z_i \qquad (1 \leq i \leq n)$$

D = the score of the discriminant functions,

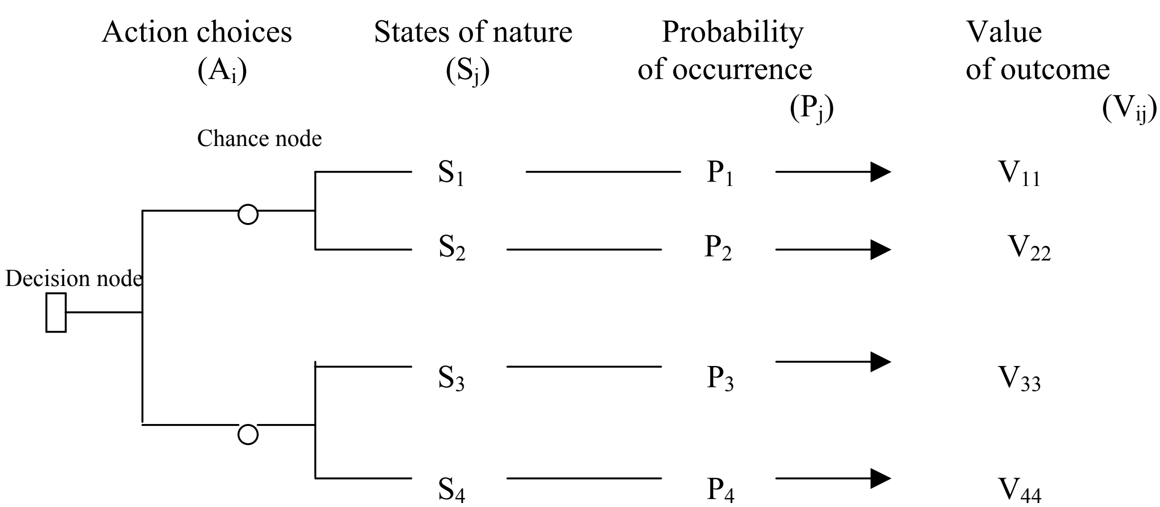
d_i= weighting $(1 \le i \le n)$ coefficients,
Z_i= standardised values of the discriminatory variables used in the analysis.

Dohoo & Martin (1984) used *discriminant analysis* for the simultaneous evaluation of several production parameters and previous disease history as determinants of disease in subsequent lactations. Vandegraaff (1980) used the same procedure to identify the most important environmental and host factors contributing to discrimination between affected and non-affected dairy farms with respect to salmonellosis. Erb. et al.(1981) used this procedure to investigate production variables, as causes of variability in production including other diseases.

Decision analysis
If there are multiple possible outcomes from the proposed courses of action and chance is an important factor in determining which outcome occurs, then decision analysis is the approach to use. One of the various forms of decision analysis considers the riskiness of decisions. Hiller & Lieberman (1990), defined it as "any framework or strategy for handling complex decisions so that they can be more readily evaluated by the human mind".

Carpenter (1980) designed a poultry health program using decision analysis. This method was also used in an eradication program of *Mycoplsma meleagriditis* at the commercial turkey breeder level. Parson et al. (1986) used this analytical method to evaluate the economic effects of *Porcine parvovirus,* in assessing the economic usefulness of vaccination.

Gregory (1988) included four economics tools within this approach : Path analysis; Mathematical equations; Payoff matrices and Decision -Tree. From all these *Decision-Tree analysis* is probably the most frequently used technique of decision analysis. It is defined as a graphical method of expressing, in chronological order, the alternative actions available to the decision maker and the choices determined by chance (Hiller & Lieberman, 1990; Ngategize et al., 1986).



This technique can easily include probability distributions of possible outcomes with respect to failure or success of a treatment. In decision-tree analysis, choices such as whether or not to eradicate a certain disease are presented by rectangles, called *decision nodes*. Circles called chance nodes present chance events, such as response to treatment. The lines, or branches, following each decision node must be exhaustive and they represent the possible strategies to follow. That is, they must include all possible outcomes, and the outcomes must be mutually exclusive (Fetrow et al. 1985). After each chance node, there is a probability (Pj) that an event occurs. The expected value of outcome for each action (V_{ij}) is entered at the far right of the tree branches.

Partial budgeting

Partial budgeting is a technique very commonly used in Animal Health economics. The basic principle consists of making a comparison between the cost of the disease *without* an eradication program, and its costs *with* one. When the latter is subtracted from the former, the difference, which should be positive, reflects the improvement in the situation, or the benefit due to the eradication program.

This can be summarised using the following equation:

$$\boxed{\begin{bmatrix}\text{LOSSES due to the disease} \\ \text{WITHOUT an eradication program}\end{bmatrix} - \begin{bmatrix}\text{LOSSES due to the disease} \\ \text{WITH an eradication program}\end{bmatrix} = \text{BENEFIT}}$$

In this discussion, only the costs of the disease, with and without the control program are taken into account. The actual cost of the eradication program is left out. The term Net Benefit describes the 'net benefit', which remains after the eradication costs are subtracted:

$$\boxed{\begin{bmatrix}\text{LOSSES due to the disease} \\ \text{WITHOUT an eradication program}\end{bmatrix} - \begin{bmatrix}\text{LOSSES due to the disease} \\ \text{WITH an eradication program}\end{bmatrix} + \begin{bmatrix}\text{COST of the disease} \\ \text{eradication program}\end{bmatrix} = \text{NET BENEFIT}}$$

In other words, it is possible to envisage a very expensive disease eradication program, which would always cost more to implement than the resulting reduction in disease losses was worth. Such a program would generate an improvement, and hence a benefit, but no 'net benefit' or profit, in the usual sense of the term.

The next step is making an assumption about the improvement in the various measures of disease frequency and production parameters (mortality, morbidity, yields, etc.) induced by the disease eradication program, and then recalculating the costs of the disease, once these measures and production parameters have been modified by the program.

The table's structure is based on two columns, for costs and benefits, each including positive and negative items:

COSTS	BENEFITS
a. Extra costs	c. Extra revenue
b. Revenue lost	d. Cost saved

a. Extra costs, which are equivalent to the costs of eradicating the disease.
b. Revenue lost, covers various side-effects caused by the preventive measures implemented.
c. Extra revenue, which is represented by the increase in productivity and the reduction in mortality induced by the preventive measures undertaken.
d. Cost saved, refers to the reduction in expenditure associated with the treatment of animals affected by the disease in the absence of the eradication program.

The benefit is equivalent to the difference between the initial cost of the disease and its new cost.

The assumptions about the improvement caused by the disease eradication program can be based on the results of similar programs undertaken in similar conditions, in other areas or countries.

An example of this the classic study of mastitis control in the UK by Ashby et al. (1975), updated by applying current prices by Shaw (1995). Other applications of this method include analysis of fertility problems, parasitism and mastitis in dairy cattle (for examples see Esslemont, 1982; Zeddies, 1982; Dijkhuizen et al., 1985; Rougoor et al. 1994). In relation to infectious livestock diseases, partial budgeting is appropriate when endemic diseases are involved, or for retrospective analyses of disease outbreaks that already have taken place. Ellis (1994) used, in Thailand, partial analysis to illustrate how financial effects of FMD and control costs can be evaluated (see Figure 1).

If the proposed analysis concerns a simple economic comparison of disease control or eradication on a farm, and the outcome does not involve a specific time pattern nor a great degree of chance (being neither dynamic or stochastic) then partial budgeting is the method of choice. It is simply a quantification of the economic consequences of a specific change in farm procedure e.g. a herd health program.

But, Partial budgeting has some limitations, first as with other models, it is not always possible to identify clearly the costs and the returns associated with the change in question. Secondly, as Harsh et al. (1981) state, many decisions may be rejected or accepted based on other criteria. The essential difference between partial budget analysis and the previously described methods, is that there is no element of probability in the partial budget.

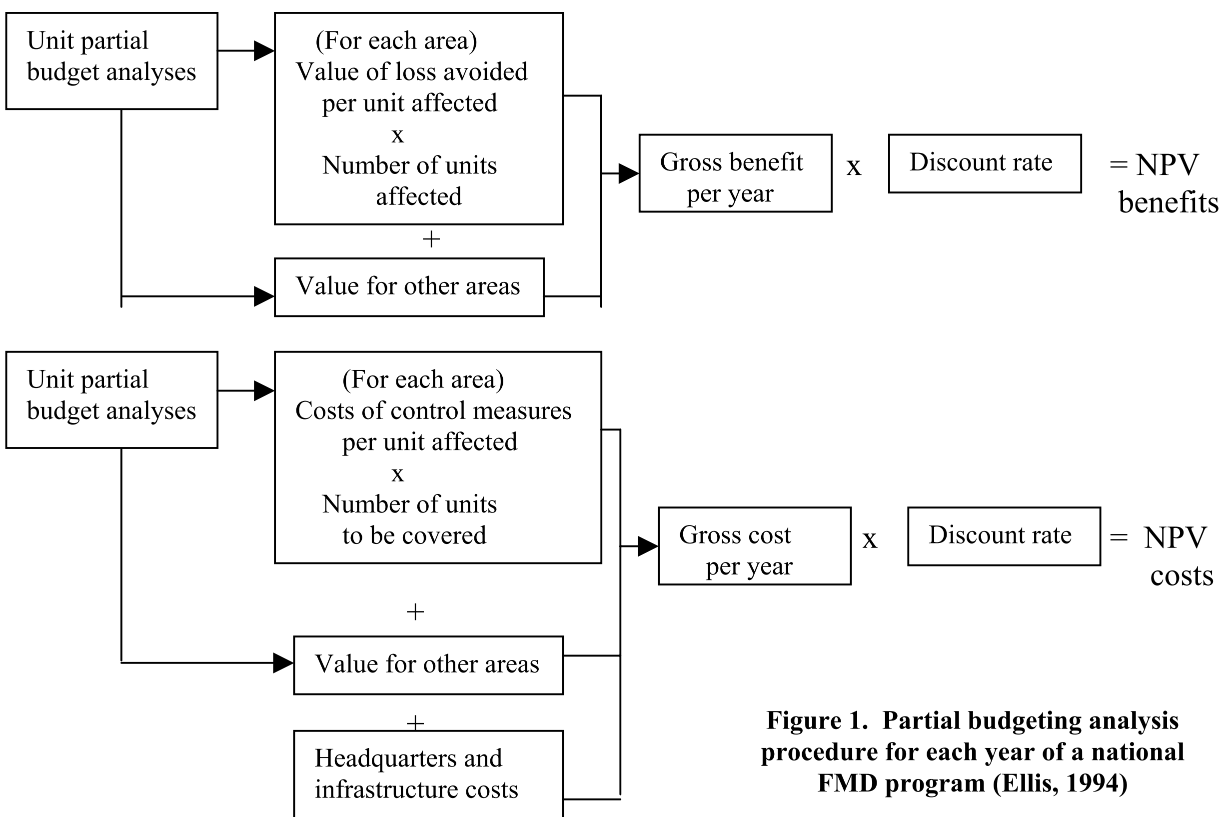


Figure 1. Partial budgeting analysis procedure for each year of a national FMD program (Ellis, 1994)

4.2. Cost-Benefit Analysis (Cba)

4.2.1. General appraisal

After many years of controversial discussions about its application, CBA continues to have a central role in achieving economically efficient investment decisions in developing countries (Kirkpatrick & Weiss, 1996). It is a procedure for determining the profitability of programs over an extended period of time, i.e. sufficiently long so that the addition of an extra year does not materially influence comparative rankings (James, 1987; Kaneene, 1982).

In a sense, CBA is the public sector analogue to the private sector's profitability analysis. The former attempts to determine whether social benefits of the control or eradication program out-weigh the social costs, whereas the latter attempts to determine whether the private benefits (that is, revenue) of the private sector investment out-weigh the private costs (Little & Mirrlees, 1974). There are many variants of CBA applications in animal health economics, some are:

THE COST MINIMISATION METHOD

This method can be used to compare different eradication strategies to each other, on the assumption that each one is equally effective in controlling the disease and thus has the same impact. Subject to this condition, it is possible to avoid having to make a precise estimate of the actual impact of these control strategies. In fact, minimising the costs comes down to making a comparison of the costs of the different eradication programs and then selecting the least expensive.

This method has the advantage of being relatively simple to carry out. Nevertheless, it is rare for different eradication programs to produce truly identical effects, and thus the results of this type of analysis would have to be used carefully, and considered in light of how correct the basic assumption is likely to be (Phillips, 1997).

Studies of this type have been undertaken in France, in particular in order to compare different strategies for detecting enzootic bovine leukosis (Toma et al. 1999).

THE COST-EFFECTIVENESS METHOD

Here, the impact of the eradication program is assessed using a single measure of effectiveness, for example a measure of disease frequency such as the mortality rate, the morbidity rate, or the prevalence. This method which is relatively straightforward to apply, makes possible to compare disease eradication programs which do not have the same effects. Nevertheless, the difficult part is choosing the measure which is best suited to determining the impact of the disease eradication program.

Projects such as FMD surveillance (McCauley et al. 1979) and programs for swine fever eradication in the E.U. (Ellis et al., 1977), were evaluated using *cost-effectiveness analysis*. Habtermariam et al. (1983) evaluated the cost-effective and benefit maximising strategies for controlling trypanosomiasis using net present values (NPV) and benefit-cost ratios as the selection criteria.

THE COST-UTILITY METHOD

Used in the field of human health economics, this method makes it possible to take into account the multi-dimensional character of disease eradication work. In this case, the program’s efficiency is assessed by using a ‘synthetic’ indicator of the masure, which is designed to combine various aspects, both quantitative and qualitative, of the impact of a disease eradication program.

Several indicators of this type exist in the area of human medicine. QALY (quality adjusted life years) should be mentioned in this context. This is an indicator in which the years survived are weighted by an indicator of the quality of life. In the area of animal health no such synthetic or combination indicators have yet been developed.

4.2.2. CBA decision criteria for quantifying economic costs and benefits

The economic techniques for comparison of benefits and costs are essentially the same but with different values for the physical resources used and production obtained. Many criteria have been suggested:

Consumers' surplus/Producers' surplus

One promising approach to the measurement of utility changes, which has had a chequered history in the literature of economics, is the concept of surplus. This basic concept can be applied to a number of activities. Transactions can be viewed in different ways, with the consequence that different manifestations of surplus have appeared with profusion and some confusion. We have consumers' surplus, producers' surplus, rent, factor rent, and so on. These various forms of surplus arise from the application of the principle in alternative partial equilibrium contexts. Mishan (1982) notes that while the partial equilibrium applications are often the more fruitful, the basic concept of a surplus is best understood in a general equilibrium setting.

Price (P)

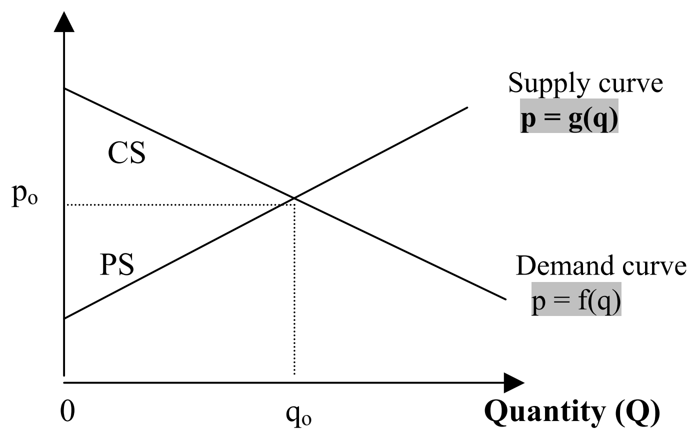


Figure 2. Consumers' and Producers' surplus

It is common to express demand and supply schedules in graphical form, with prices on the vertical axis and quantity on the other. For Howe & McInerney (1987), the area between the supply and demand curves (shown in figure 2) to the left of their point of intersection is very important with respect to the indirect losses from disease. It provides basic information on the welfare effects for producers, consumers and the society as a whole.

Consumers' surplus (CS) represents the total gain to consumers who are willing to pay more than the equilibrium price. Geometrically, consumers' surplus is represented by the area CS between the line $P = p_o$ and the demand curve $p = f\,(q)$ from $Q = 0$ to $Q = q_o$.

Some of the producers also benefit from the equilibrium price, since they are willing to supply the product at prices less than p_o. under certain conditions (market equilibrium) the total gain to the producers (PS) is represented geometrically by the area between the line $p = p_o$ and the supply curve $p = g\ (q)$ from $q = 0$ to $q = q_o$.

As an example of the use of this concept, an effective control or eradication of livestock contagious disease increases the (long-term) productivity of resources in the affected population. Following figure 3, the outcome is to shift the supply curve for livestock products to the right (from S to S_1), i.e. farmers are able to produce more at whatever is the current price.

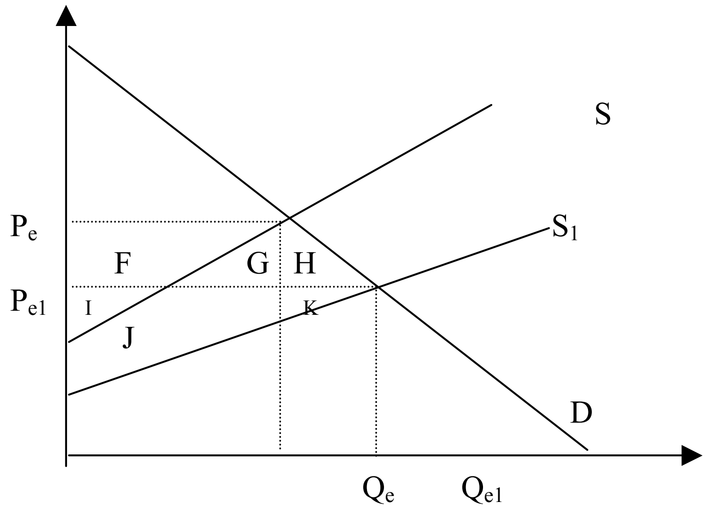


Figure 3. Changes on consumers'/producers' surplus due a change on the demand curve when eradicating a infectious animal disease

The welfare consequences of the change can be summarised as follows

	Gain	Loss	Net
Producers	I+J+K	F+I	J+K-F
Consumers	F+G+H	-----	F+G+H
National level	(I+J+K+F+G+H)	(F+I)	(J+K+G+H)

Notice that is not only possible to identify the net effects on producers and consumers respectively, but that it is also possible to summarise the consequences for a society as a whole, i.e. for people irrespective of whether they are producers, consumers or both. Within the theory of welfare economics, however, there is a discussion about the aggregation of benefits and costs at the national level (Just et al, 1982). Simple aggregation of these effects presumes an equal weight of benefits and costs for each group and individual, which is usually not the case (Varian, 1992). From an investigation of EU dairy policy over the years 1980 to 1987, for instance, it emerged that one dollar of producer income was considered twice the weight of one dollar of consumer income (Oskam, 1988).

As far as the use of consumers' surplus is concerned, Little (1957) advanced three main criticisms that still could be valid:

- The demand curve could not in fact be linear.
- It suffers all the defects associated with the assumption of constant marginal utility of income. A serious problem of measurement immediately arises. In practice, some CBA analysts dispense altogether with the attempt to measure consumers' surplus, mainly on grounds of impracticability.
- The demand curve is only partial and fails to take account of the effect of the investment on the prices of all other goods, i.e. there will be changes in surplus elsewhere which are not accounted for by the analysis of the project in question.

Net Present Value (NPV)

This expresses the difference between the total benefits and the total costs when controlling or eradicating a disease, after allowing for any value adjustments and the time at which they occurred. In general terms, *if the Net Present Value (NPV) is greater than zero, the investment is justified.*

The Net Present Value (NPV) or Present Worth (PW) method reduces a stream of costs and benefits, which are projected to occur in the future by "discounting". The suggested formula is:

$$NPV = \sum_{t=0}^{n} \frac{B_t - C_t}{(1+i)^t}$$

B_t = benefits in year t, t = 1,2, ... n
C_t = Costs in year t, i = interest (discount) rate.
n = number of the years,

When evaluating a control or eradication program, the formal selection criterion for the NPV measure of project worth is to accept all projects with a positive NPV, when discounted at the chosen discount rate (opportunity cost of capital). The higher its NPV, the better is a project. But the selection criterion cannot be applied unless there is a relatively satisfactory estimate of the opportunity cost of capital (discount rate). The determination of the appropriate discount rate is the principal problem associated with the use of the NPV method. However, this is not a fault of the method itself and consideration of a range of reasonable values is often sufficient in a CBA.

Ranking of independent projects is not possible using the NPV criterion unless the projects have similar costs and cash flows. The criterion does however give the most reliable ranking of mutually exclusive programs and alternatives for the same program, since it is an absolute, not a relative measure. In practice, it is desirable to have a ranking of independent projects as well as the yes/no criterion provided by the NPV measure. For this reason an IRR measure is also commonly required.

Furthermore, NPV by itself gives little indication of the scale of a project, or by how much the benefits outweigh the cost in percentage terms, this is especially important when resources are limited and must be used effectively (Sassone & Schaffer, 1978). Because of this, the use of the benefit-cost ratio is also recommended.

Internal Rate of Return (IRR)

The internal rate of return (IRR) is a measure popularised by John Maynard Keynes and has received a good deal of attention. Until recently, this criterion was considered by many to be as good as the NPV criterion, however, it is now generally regarded as inferior (Zerbe & Dwight, 1994). This measure is much used because it in some way expresses the return to the investment in terms analogous to an interest rate. This concept is widely understood, and it allows easy comparison of activities competing for the same funds.

The IRR of a project is defined as the discount rate which results in the NPV of an investment being equal to zero (Sell,1991). Thus, the IRR is that value of the discount rate (i), at which the following hold:

$$NPV = \sum_{t=o}^{n} \frac{B_t - C_t}{(1+i)^t} = O$$

B_t = benefits in year t, t = 1,2,.....n

C_t = Costs in year t, i = interest (discount) rate.
n = number of the years,

The IRR is a useful measure of project worth. The project would be considered profitable if the IRR were greater than the discount rate, which in turn should reflect the real rate of interest applying to the country or in the relevant sector of the economy. It uniquely represents the earning power of the capital invested in a project. Its correct interpretation is the rate of return on capital outstanding, per period while it is invested in the project. The measure does not assume that all returns from the project may be reinvested at the IRR. Returns withdrawn from a project may be reinvested at any other rate, or consumed without affecting the IRR of the project (Sassone & Schaffer, 1978).

Independent projects can be ranked in order of their IRR value. However, in the case of mutually exclusive projects and alternatives of the same project, direct comparison of IRRs can lead to erroneous investment choices. This danger can be avoided either by discounting the differences in the benefit and cost cash flows of alternatives and obtaining the IRR of this new flow, or by using the NPV criterion (Zerbe & Dwight, 1994).

Some problems are encountered with this criterion by James & Ellis (1980):

- The discount rate that solves the above equation is not necessarily unique.
- The criterion implicitly assumes a single discount rate over the life of the project.

Benefit Cost Ratio (B/C)

The benefit-cost ratio is calculated by dividing the Total Present Value of the benefits by the Total Present Value of the costs. Here, no indication of the scale of the activity is given, but it does indicate by how much the benefits outweigh the costs in percentage terms. The B/C measure can be represented generally as:

$$B/C = \frac{\sum_{t=0}^{n} \frac{B_t}{(1+i)^t}}{\sum_{t=0}^{n} \frac{C_t}{(1+i)^t}}$$

B_t = benefits in year t, n = number of the years,
C_t = Costs in year t, t = 1,2,....n
i = interest (discount) rate.

This measure is commonly used to reflect capital intensity, to reflect efficiency when capital is scarce (Wolfe,1973). When the B/C measure is used to evaluate projects, the formal economic decision criterion is *to accept all projects with a ratio of one or greater*, except in the case of mutually exclusive projects and in situations where capital is constrained. According to Ellis (1994), governments usually consider favourably any project that gives a B/C greater than 2:1.

4.2.3. Sensitivity analysis

Independently of the criterion or the discounting rate used, every CBA should be accompanied by a sensitivity analysis. It would be a rare economic decision that was based on data known to be completely free of error. More typically, some of the data are based on estimates and expert opinion. The "best" estimates are commonly used at the beginning of the analysis but, as a final step reasonable upper and lower limits on the estimates should be substituted in the analysis. In this way, it can be determined whether the system used is "sensitive" to reasonable variation in the data (Dijkhuizen et al.,1995).

4.3 Advanced Methods of Economic Analysis

This section presents a brief overview of advanced methods used in the evaluation of the economic impact of infectious animal diseases. In most of the examples discussed here, the techniques have been extensively developed and used in disciplines such as economics and statistics, but their application to animal health according to Dijkhuizen et al. (1995), has been minimal.

4.3.1. Modelling the economics of contagious diseases:

There is a wide range of modelling techniques available to help perform economic analysis of animal diseases control or eradication (see France & Thornely, 1984; Dijkhuizen, 1992, 1993; Howitt, 1982). As more strict demands on control and eradication of a wide range of diseases may be expected, and in order to anticipate these demands, it is desirable to have a modelling environment in which "what if" scenarios can be performed to explore the epidemiological and economic effects of the various diseases and control-eradication strategies. Thus the use of models to optimise the application of herd health programs is on the increase. Model calculations may be also used to quantify the significance of gaps in veterinary and animal sciences knowledge, while knowledge obtained from this technical research increases the reality of economic models (Korver & Van Arendok, 1987; Marsh, 1986). This interaction is fundamental to the study of diseases and control or eradication at the farm level.

But, model calculations in Animal Health economics often suffer from a serious lack of accurate data. Further research in this field is necessary and can be of great practical value. In this way a valuable interaction between economic research on the one hand and veterinary and animal sciences research on the other is possible (Dijkhuizen, 1988).

4.3.2. Linear programming

Linear Programming (LP) is a technique for determining the optimal allocation of resources among competing activities. It is a very useful tool in finding the optimal solution for complex problems. Most common applications are in determination of least-cost ration and in planning the farm business organisation. In other words to meet management targets and restrictions.

Although the application of LP in animal health is still in its early stages, examples of its application do exist. Carpenter and Howitt (1980) reviewed the application of linear programming to minimise the cost of brucellosis control in California beef herds over a fifteen year time horizon. A regression equation linking the annual change in prevalence to various control strategies formed the basis of their constraint on the progression of disease through time. Additional constraints on the control strategies included upper and lower bounds on vaccination and an upper bound on testing activities.

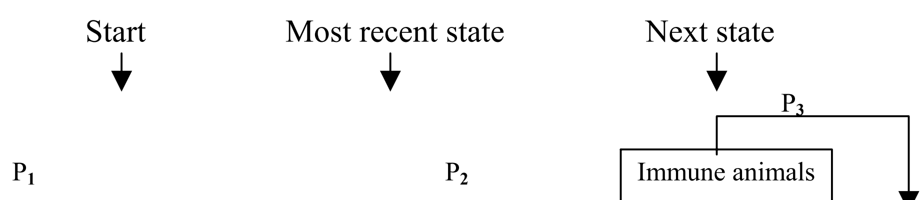
Christiansen & Carpenter (1982) evaluated linear programming as a planning tool in the eradication of Brucellosis in New Zealand. They used a similar model to determine the economically optimal strategy for the eradication of brucellosis in New Zealand dairy herds. Their objective was to minimise the discounted cost of eradication over a ten year time horizon, and the various control strategies included test and slaughter, herd depopulation and calf vaccination. In this paper the authors presented the optimal solution to their respective empirical problems, and then performed post-optimality and sensitivity analyses on a number of key parameters.

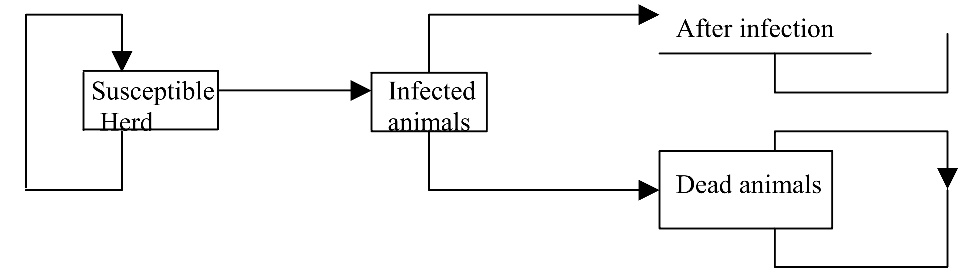
In spite of the fact that LP could be set up as a form of CBA, the advantage of LP over CBA is that it can expand the feasible set which researchers are able to optimise. Carpenter & Howitt (1980) pointed out the fact that when time is added as an additional variable, LP can incorporate the dynamic nature of disease control or eradication problems and yield valuable economic information.

4.3.3. Markov chain simulation

Markov chains is the study of events and sequential decision making under uncertainty. Intervals of time separate the stages at which events occur and decisions can be made, and the effect of a decision at any stage is to influence the transition from the current and succeeding state. When applying Markov chains the concepts of states and of transitions are crucial (Hillier & Lieberman, 1990). They are used to model the evolution of systems or processes over repeated trials or successive time periods. In animal health economics, as the probability of becoming infected is often assumed to depend on the fraction of herds or animals being infected during the previous time period, Markov chains are especially used to simulate contagious disease control. This approach is in fact a stochastic model using probability distributions, taking into account uncertainty about future behaviour of the system. Markov chains are usually simplified to make computations where the units under consideration (animals or herds) can exist under a number of mutually exclusive states, and probabilities can be specified for chances of the units transferring probabilities (James, 1977). Markov chains have been used most extensively to evaluate the impact of alternative control strategies on the spread of disease (Carpenter, 1988).

Dijkhuizen, (1989) used a *Markov chain* model to examine the economics of a variety of control strategies with respect to FMD in cattle and pig herds in the Netherlands, where the economic feasibility of continued prophylactic vaccination was under discussion. From the epidemiological point of view, the most favourable results for the Netherlands were obtained under the strategy currently being applied, i.e. annual vaccination of the cattle population in combination with stamping out affected herds and ring vaccination when the disease does occur. From the economic point of view, however, it was found that the annual costs are considerably reduced when ceasing the prophylactic routine vaccination, provided that adequate measures are carried out in case of an outbreak (stamping out and ring vaccination). This conclusion in favour of a non-vaccinated population was stable and more pessimistic values for the major (uncertain) input factors, were not likely to be outranged by indirect cost due to an increased risk of export bans. A graphical representation of a Markov chain in this case could be:





□ = states
→ = transitions
P_1 = transition probability of state 1 (being infected)
P_2 = transition probability of state 2 (immune after infection)
P_3 = 1 (probability of remaining immune or of death)

4.3.4. Monte Carlo simulation

Monte Carlo simulation models are most useful when the aggregate results of multiple runs are pooled to provide estimates of expected values and associated variability. In fact, potential users should be warned of the dangers of interpreting the results of a single run of the model, as it may by chance, reflect a particularly favourable or unfavourable set of outcomes, which may be unlikely to be encountered in the real world. The growing availability of low-cost computing power has put powerful analytical tools like Monte Carlo simulation models, at the fingertips of decision makers. Using a *Monte Carlo simulation model*, Morris (1976) found that the development of a vaccine for a single pathogen of bovine mastitis could not be justified economically as a practicable alternative to teat dipping and dry cow treatment.

Monte Carlo simulation model was also used by Garner & Lack (1995) to evaluate alternative control strategies in the event that a FMD outbreak occurs in Australia.

CONCLUSIONS

The analytical methods discussed in this work are tools, not inviolate formulae, to assist the decision makers confronted with a mass of information relevant to a large health protection program. The directors must systematically examine the broadest range of knowledge that will enable them to wisely use these tools. No system is successful in the hands of the uninformed or in the absence of essential facts.

The focus of economic studies must be on estimating the benefit of action against a disease rather than just on the economic impact of the presence of a disease. By the judicious and pragmatic use of a large and expanding armoury of techniques, it is possible to quantify the effects of animal disease on productivity, and to represent these effects in economic terms.

It is also necessary, to include an evaluation of the riskness of each of the alternative courses of action. An insight into the impact of various risk attitudes of decision makers, may contribute towards a more considered approach for a successful eradication or control campaign.

The use of models to measure, quantify and evaluate the causal relationships, impacts and effects of decision variable choices, is increasingly becoming necessary to defend grant proposals, input use (e.g., chemicals, feeds, machinery) or management practices with numbers that depict monetary value or some other measure. As demands on control grow, it is desirable to have a modelling environment in which "what if" scenarios can be performed to explore the epidemiological and economic effects of the various diseases and their eradication. Thus, the use of models to optimise the application of herd health programs is on the increase (Korver & Van Arendok, 1987).

Despite the apparent power that simulation modelling gives the experimenter, it is important to bear in mind that a desirable requirement of a simulation model is simplicity in the eyes of the user. Often decision makers will not have confidence in the predictive ability of a model if they do not understand its mechanisms, but clearly it must also be well validated and accurate.

Furthermore, as Dijkhuizen et al. (1995) stated, calculations in animal health economics often suffer from a serious lack of accurate data. Further research in this field is necessary.

For the purpose of this work, the methods discussed have some disadvantages when comparing with CBA (Drummond et al. (1997). First, there has been an overwhelming reluctance to attach money value to benefits. And secondly, costs are largely limited to those that appear in public or private budgets and that are more narrowly defined than social costs. Furthermore, decisions on animal disease control or eradication strategies reach beyond the scope of the individual farmer making it necessary to analyse their economics at the national level.

No algorithm is available, however, to model the indirect losses of export bans. The size and duration of such bans are usually dependent on political decisions, making it too arbitrary to predict the losses within each of the control or eradication strategies. Expected differences in risk for export bans, therefore, have to be included subjectively in the final stage of the decision-making process.

In fact CBA has been the technique most commonly used for the economic analysis of public projects. Part of the reason for its common use is institutional, as CBA modules are usually taught in connection with a public finance course, or as part of a public policy curriculum. Part is historical, as there has been much more discussion of CBA of government activities than of any other activities. And part is substantive, as governments have more complex and varied responsibilities than private decision-makers. Private households can take market prices as given, but governments have an obligation to see if these prices accurately reflect social costs. Private households can analyse problems from their own perspective, but governments should analyse them from the perspective of all groups in a community.

It is strongly emphasised that there is no unique or best decision criterion for quantifying economic costs and benefits. As each criterion has its own limitations, estimates using more than one enable the analyst to gain a better understanding of the probable economic effects of a given control or eradication program. The use of B/C as a sole criterion has declined, and a combination of the B/C, NPV and IRR is preferred.

It is necessary to keep in mind that in the final expression of CBA, benefits either do or do not exceed costs, and this estimate of project alone does not reveal all the information on which the result is based. Anyone who needs the result as part of a decision or policy-making process should not accept the results without reviewing distributional effects, shadow prices, time preferences and other variables, which are difficult to quantify.

Optimising the farmers' overall resource allocation requires quantitative insight into the relationship between veterinary services, animal health status and farm income. Research to specify this relationship has mainly been carried out through systems simulation. More research is necessary to make these modelling results better applicable for actual on-farm decision support. Especially when combined with expert systems features and integrated in management information systems, it is possible to generate results tailored to individual circumstances; to simplify data input and to add relevant heuristic information not yet included in the algorithms.

Developments in hardware and software design over the past two decades have laid the foundations for information management in animal health to move gradually from what can now be seen as relatively primitive beginnings to tightly integrated systems which provide very powerful support for management, in the evaluation of health management options at both the national and farm levels. In many ways these represents the embodiment of the current state of epidemiological thinking in the form of integrated processing and analysis systems which use the techniques of epidemiology and economics within practical management systems.

Economic analysis helps to justify investment in prevention, control and/or eradication programs, but a wide variety of information must be gathered about the impacts of losses in different production systems. The expected losses due to infectious livestock diseases are determined to a large extent by a combination of three factors: the type of disease, the animal species and the economic level involved.

Farmers' decision making is not just based on economic principles, there are other considerations that could explain the benefits when eradicating an animal disease. Personal beliefs about risk and uncertainty, and personal satisfaction should also be considered as they could strongly influence farmers' decision. These considerations can help to provide a more rational basis to understand farmers' decision making.

If the understanding of disease effects is the basis for animal health services to livestock, then the focus of these services needs to be one of health management rather than principally disease treatment. This knowledge may help to explain why the outcome of control or eradication livestock diseases programs often differs so much from their previous calculations.

The literature reviewed suggest a clear course of action, through systematic research into animal health economics focusing on quantifying the financial losses and benefits caused by livestock infectious diseases; analysing the programs' operational infrastructure; and optimising decisions when controlling or eradicating those diseases. It seems that to match these objectives and make economically sound decisions, it becomes necessary to use an integrated modelling approach. Published work in this field is scarce and hardly goes beyond the epidemiological analysis and the analysis of the direct cost of the control or eradication program.

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