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A framework for animal health management

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Summary — In modern production systems, the most economically limiting diseases are multifactorial enzootic health disorders. Relevant decisions in health management have to be based on rational procedures. A first-level approach implies the use of quantitative information on the economic impact of the disease. A more relevant approach of decisions regarding health problems consists of evaluating the economic worth of the interventions in terms of cost-effectiveness. Decision analysis and decision support are of interest today, particularly for herd health control schemes regarding enzootic disorders.

animal health / economics / management

Résumé — Bases conceptuelles et méthodologiques de la gestion de la santé animale. Dans les systèmes de production modernes, le premier facteur d'ordre sanitaire qui s'avère limitant au plan économique est la pathologie enzootique d'origine multifactorielle. La gestion de la santé dans ce contexte réclame des bases et procédures rationnelles. Un premier niveau d'abord s'appuie sur la quantification des coûts liés à la maladie. Une approche plus adaptée est permise par les méthodes d'évaluation économique des actions de maîtrise de la santé. Enfin, spécialement pour la gestion des problèmes posés par les troubles enzootiques, les méthodes d'analyse de décision et d'aide à la décision sont pertinentes.

santé animale / économie / gestion

INTRODUCTION

Management deals with decision making. To decide is to make the choice to solve a problem or to take advantage of a change in the use of resources. The final decision cannot be separated from the whole decision-making process involving several steps of reflexion, analysis and negotiation (Roy, 1985).

In modern production systems and from an economic point of view, enzootic health disorders are presently the primary limiting factor related to health. These disorders are present at variable levels in most herds. Their prevalence is influenced by factors belonging to the farming system itself (Madec and Tillon, 1988; Landais, 1991). Their consequence is primarily a decrease in the productive efficiency of the herd (Mar-

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tin *et al*, 1987). Farmers can underestimate this aspect of the disease (Dijkhuizen, 1988). Moreover, the economic significance of such disorders might be high because of the financial vulnerability of most intensive production systems. Management of health in this context has to be undertaken on rational procedures according to both economic factors (Howe, 1985; Madec *et al*, 1992) and farmers preferences regarding health management decisions (Ngategize *et al*, 1986).

The purpose of this paper is to discuss the basic concepts and methods used (i) to assess the economic impact of a disease; (ii) to provide an evaluation of the economic worth of a health program or a single intervention; and (iii) to make rationally grounded health management decisions.

ECONOMIC IMPACT OF A DISEASE

Quantifying the economic impact of a disease or a disease complex is used to determine priorities between target diseases for intervention in health schemes or for allocating research resources. It allows also the measurement of the losses at the initial and final stages of a control program.

Level of assessment

Measurement of the economic impact of disease can be performed at several levels: a single animal; a single farm or herd; the whole sector of the producers involved in a production; the related agro-supply and/or processing industry; and the consumer. At the national economy level, the aggregated losses are generally lower than those at the production level because of the positive effect of the activities generated in veterinary services, drugs trade and laboratory analyses. The impact of an outbreak of a contagious disease which leads in many cases to trade restrictions differs in nature

from the impact of a multifactorial enzootic disorder (Renkema, 1980).

Components of the economic impact of health disorders at farm level

Categories gathering direct or indirect consequences of a disease were defined (Renkema, 1980; Dijkhuizen, 1983; Jactel, 1986). A descriptive approach consists of ranking the components, which decrease in the following order according to the sensitivity and awareness of the farmer: (i) mortality and abortions, cost of treatments, regulatory cullings; (ii) discarded products and slaughter refusals, penalties on selling prices, emergency cullings, trade restrictions; (iii) costs of preventive interventions; (iv) reduction in milk or meat productivity, decrease in selling prices, increase in culling rate; and (v) decrease in genetic improvement, additional labor costs.

These components can be aggregated in economic terms to obtain the whole cost of disease. However, it is relevant (McInerney, 1987; Schepers, 1990) to separate: (i) the *losses* that are calculated as monetary values to express the decrease in output of the production process considering a reference level; and (ii) the *expenditures* associated with treatments and preventive interventions that are directly measured amounts of inputs. The relative importance of the 2 categories generally varies inversely (McInerney *et al*, 1992). High levels of global impact of disease may result (fig 1) from a

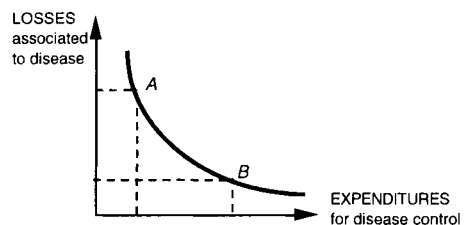


Fig 1. Relationships between losses and expenditures related to disease.

high level of losses (A) or from a high level of expenditures (B). Prevention at the herd level is not always the most relevant attitude compared with treatment of the incident cases, as illustrated by Joosten *et al* (1988) for retained placenta in the dairy cow.

Steps and methods for assessment of the economic impact of a disease

The general scheme that should be implemented to measure the economic impact of a disease includes several steps:

(1) Determination of reduction of outputs of the process (Renkema, 1980; Dijkhuizen, 1983):

(a) Identification of the different forms of the disease that occur, especially if the study deals with a disease complex.

(b) Measurement of the incidence and prevalence of each of the identified forms. These 2 first steps are usually performed with descriptive epidemiological methods using observational study designs. In some cases, relevant information is obtained from national or local monitoring systems (*eg* NAHMS, Gardner *et al*, 1990).

(c) For each form of the disorder, evaluation of the related mortality and culling cases and of the effects on the production process in physical units and technical terms. Basic methods are also descriptive observational approaches. A complementary modelling step is often performed to express the quantitative deviation of performances of the herd (Bartlett *et al*, 1991; Luquet, 1991; Houben *et al*, 1993, for mastitis in dairy cow). Moreover, some contributions are experimental studies using experimental reproduction of the disease in order to avoid confounding effects (*eg* Rainard and Poutrel, 1982, also for mastitis in dairy cow).

(d) Conversion of these effects for the whole herd and the study period in economic or

financial terms. Calculations can be made using prices and values in each farm recorded (*eg* Jansen *et al*, 1987) or more often using reference or average data as default values. Other approaches are exclusively theoretical and based on programming and simulation methods using existing knowledge (Boichard, 1990; Hurd and Kaneene, 1993). Vagsholm *et al* (1991) suggested the use of total revenues and expenditures instead of unit prices and quantities without performing the step defined in (c).

(2) Measurement of specific inputs (expenditures related to interventions) in observational studies. Information can also be obtained from monitoring systems.

Limits of the available studies on the economic impact of enzootic health disorders in livestock can be put forward:

(1) The external validity of the results is generally low; both technical characteristics and economic vectors differ between the production systems.

(2) The components taken into account differ in studies dealing with a same health disorder. Studies on mastitis costs illustrate this point (Scheepers and Dijkhuizen, 1991).

(3) Economic transpositions with averages often lead to an underestimation of the between-farms variability.

(4) The assessed impact is frequently a measure for a given (but not described) level of intervention whereas no assessment is available for the situation without any intervention.

(5) Associations between diseases and carry-over effects are scarcely considered (Fetrow *et al*, 1991; Beaudeau *et al*, 1993; Houben, *et al*, 1993).

Quantitative information about losses and expenditures related to a given occurrence level of a disease and under a given control scheme is not really sufficient to decide to change anything. Information about the marginal relationships between losses and

expenditures related to an intervention or a change is needed to assess the relevancy of a choice (McInerney, 1988; Seegers *et al*, 1991).

ECONOMIC WORTH OF INTERVENTIONS TO CONTROL DISEASE

The consequences of enzootic health disorders affect only the considered farm. The level of present risk factors varies highly between farms. Farmers' perception of risk and attitude towards risk in health problems can differ (Pardon and Denis, 1982). They have important margins of choices and their strategies might differ in an equivalent situation (Enevoldsen *et al*, 1992). Objectives of intervention could be: (i) elimination of disease; (ii) limitation of disease occurrence by reducing the exposure to risk factors (suppression or reduction of their action); and (iii) limitation of the consequences of disease by treatments. Choice of strategies and related interventions and programs should be first grounded on their economic worth.

The economic worth of a program or a single intervention is established using 2 categories of approaches (Dijkhuizen, 1988):

- (1) Positive (or observational) studies: 'with vs without'-designs ('after vs before' or 'program vs control') are mostly used in field experiments to evaluate the economic worth of intervention (eg Sol *et al* 1984; Erskine and Eberhart, 1990). Such studies are often time-consuming and/or expensive and provide only ex-post information. Economic transpositions may be difficult and have to include discounting.
- (2) Theoretical (or normative) studies (Ngategize and Kaneene, 1985): methods mostly used to study intervention on enzootic diseases are decision trees (Madec *et al*, 1992), partial budgeting (Ellis and James, 1979), and systems simulation mod-

els (Sorensen, 1990; Hurt and Kaneene, 1993). These approaches provide relevant ex-ante information when sufficient previous knowledge exists. Sensitivity analysis can partially offset imperfect knowledge.

Additional observations can be stated regarding limits of the performed assessments of economic worth of intervention on enzootic health disorders:

- (1) Important lacks and defaults might exist in availability, reliability and resolution of information provided by observational studies. Theoretical approaches are therefore often of low reliability. Economic modelling reveals these gaps and can therefore help to set priorities in epidemiological research (Dijkhuizen, 1988).
- (2) Risk is only scarcely taken into account. Exceptions can be considered in probabilized decision-tree approaches (Galligan *et al*, 1987) and stochastic simulations (eg Marsh *et al*, 1987).
- (3) The evaluation criterion used is usually the expected monetary return of the outcome of a choice. In some cases, the decision maker will prefer other utility functions (see below).

More emphasis should therefore be given to decision analysis and decision support.

DECISION ANALYSIS AND DECISION SUPPORT IN ANIMAL HEALTH

Several steps are included in a decision-making process (Davis, 1988; Anderson *et al*, 1992):

- (0) Identification of the problem or the opportunity to change. This step is not necessarily obvious when dealing with an enzootic health and productivity disorder at the farm level (Schukken *et al*, 1991).
- (1) Identification and formulation of exclusive alternatives. These should include the 'no change' option (baseline alternative). A

decision tree is a common representation scheme of the structured problem if it is not too complex or deals with the all the parameters of the whole production system.

(2) Integration of the environment of the decision (*eg*, resource limitations, organizational factors, legal constraints, or market fluctuations). Steps 2 and 3 structure the problem but might also require time and investigation.

(3) Evaluation and analysis of each alternative. This step is performed using the above-described methods to obtain a basic pay-off table (Dijkhuizen *et al*, 1992).

(4) Comparison and ranking of the alternatives and choice. This step must deal with risk and uncertainty and with the decision-maker's attitude towards risk (see below).

Additional steps in a comprehensive 'problem solving' process are (Noordhuizen *et al*, 1987; Anderson *et al*, 1992):

(5) Implementation of the decision.

(6) Evaluation of the results.

Uncertainty and risk

The expected outcome after an intervention is usually not known with certainty. An intervention can be followed by different events resulting in different 'states-of-nature'. Different ways of accounting for risk can be proposed. Some do not take into account the chance in determining which decision should be made. Others consider the probabilities of getting the different possible outcomes. Such probabilities may be obtained from specific studies. If they are not available in a given situation, they may sometimes be extrapolated from the literature. Another approach is to consider the belief of the decision-maker in expected outcome. Subjective probabilities then measure his belief in the chance of getting the different outcomes (Hardaker, 1982). If further information is available for a particular

decision, then probabilities can be revised with the use of Bayes theorem. A new set of probabilities better fitting the given situation is then used to compare possible actions.

When 'true' probabilities are not known, and subjective probabilities are not considered relevant, sensitivity analysis can be of high interest. Different sets of probabilities are used and the ranges of probabilities giving identical recommendations for decision-making are established (Dijkhuizen *et al*, 1992).

Attitude of the decision-maker towards risk ('preference')

The consequence of an action and the occurrence of a 'state-of-nature' result is an outcome measured in monetary value. If the objective of the decision-maker is only to maximize profit, monetary value measures his preferences. This supposes that the decision-maker is indifferent to the uncertainty of the outcome or 'risk neutral'.

In fact, attitudes of decision-makers towards risk vary a great deal between risk aversion and risk preference. Studies performed in the field of agriculture mainly show that farmers are rather risk averse (Hardaker, 1982). Very few data are available for decisions in animal health. To measure preferences of decision-makers accounting for their attitude towards risk, the concept of utility was proposed by Von Neumann and Morgenstern in 1947. Utility is a measure of the total worth of an outcome reflecting a decision-maker's attitude towards profit, loss and risk (Fourgeaud and Perrot, 1990; Anderson *et al*, 1992). It is assessed through certainty equivalent (CE). The CE of a risky choice is the value of the (theoretical) certain outcome the decision-maker just accepts instead of the risky prospect (fig 2). A risk-neutral decision-maker assigns the expected monetary value (EMV) of the outcome to the CE. For a 'risk

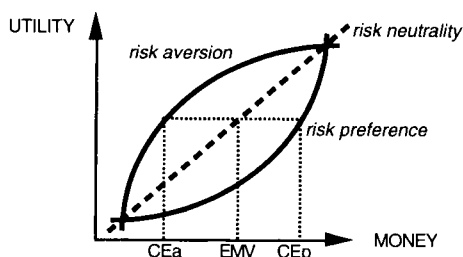


Fig 2. Utility functions: certainty equivalent in situation of risk aversion (CEa) and risk preference (CEp) versus expected monetary value (EMV).

avoider' the CE is lower (CEa) than the EMV whereas for a 'risk taker' it is higher (CEp). The utility function is defined for each decision-maker.

Instead of utility, Galligan *et al* (1987) proposed the use of a combination of expected value and variance of an outcome to allow for accounting for risk in measuring preferences for decision-making in veterinary interventions.

Four assumptions must be fulfilled to define and use utility functions: ordering (the decision-maker is able to rank all possible consequences of an action); transitivity; continuity; and independence (preferences between 2 actions does not depend on the existence of other actions). In many real-life situations these assumptions are violated. Instead of using utility, definition of preferences can rely on dominance relationships between actions (Roy, 1985).

Choice of action

Making the choice of action can rely on methods of comparison of possible alternatives that differ in their degree of consideration of risk and attitude towards risk.

Game theory proposes criteria for choices that do not consider probabilities of getting the possible outcomes (Officer and

Anderson, 1968; Anderson *et al*, 1992). Examples are 'maximin criterion' (choice of the action with the best minimum outcome) or 'minimax regret criterion' (choice of the action with the smallest maximum regret defined as the difference between the outcome of an action and the most favorable outcome in that situation).

Choice of the action with the highest expected monetary value is an approach which considers probabilities but does not take into account the attitude of the decision-maker towards risk. It is not relevant for situations where decision-makers are not risk-neutral.

Both risk and attitude towards risk are considered in the expected utility approach. The expected utility of each alternative is calculated with probabilities of the states-of-nature and utility function of a decision-maker. The action with the highest expected utility is chosen.

For a program based on the combination of different elementary interventions, portfolio theory can be used to determine efficient sets of intervention combinations. Efficient combinations minimize the risk for a given level of return on investment and are therefore preferred by risk-averse decision-makers (Galligan and Marsh, 1988).

Multicriterion models accounting for both risk and attitude towards risk are proposed to make choices on the basis of multiple dominance relationships when utility cannot be defined (Roy, 1985).

There are few decision support systems developed for animal health management. Decision analysis methods have been proposed for some choices of intervention on the basis of expected monetary value (Ngategize *et al*, 1986). Expected utility has almost never been used except by Elder and Morris (1986) to compare cattle tick control strategies.

Moreover, but just as important, decision analysis approaches demand accurate and

reliable information to allow for relevant comparisons. Design and implementation of information systems providing necessary data to decision-makers are needed. Existing off-farm data bases containing health and productivity information can be more extensively used to improve animal health management (Dohoo, 1991). Additional on-farm data can be recorded. Farmers are cooperative in building reliable data bases as long as they can retrieve useful information from them (Noordhuizen *et al*, 1987).

CONCLUSION

Management of enzootic health disorders has to deal with complexity, economic aspects and farmers' attitude towards risk. There is a need for improvement of general knowledge (research needs), and for provision of specific additional and more accurate information to solve particular problems. There is also a need to make a more relevant use of that information especially when it is feasible to take into account risk and attitude towards risk. This concerns both research contributions to establish the databases and also more operational aspects as reliable on-farm-information-and-decision-support systems.

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Modelling the dynamics and economics of health in individual dairy herds: future tasks for the veterinarian in practice and in research

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Summary — Collaboration with practicing veterinarians was established in a research project and has resulted in several epidemiologic tools to assist them in their work. Simultaneously, the research group obtained continuous access to valid and precise data and obtained first-hand knowledge about real-life problems for the dairy farmer and the practicing veterinarian. The veterinarian was able to supply detailed information concerning managerial routines applied on the farm. Epidemiologic analyses of the collected data produced input for herd-specific modelling of herd dynamics and economic effects of relevant production alternatives by means of a dynamic, stochastic, and mechanistic simulation model. The relevance of this approach as a research methodology is discussed.

herd health / health economics / epidemiology / simulation / meta-analysis

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