MULTICRITERIA ANALYSIS OF CONTAGIOUS ANIMAL DISEASE CONTROL STRATEGIES

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ABSTRACT

Decision making in controlling contagious animal diseases is a complex, conflicting process, characterized by a mixture of epidemiological, economic and social-ethical value judgements. An integral evaluation framework is developed to illustrate the potential support of evaluation techniques such as the Multi Criteria Analysis (MCA) in choosing the control strategy that best meets all conflicting judgements.

The presented MCA is based on the average judgement values of the CVO's, as elicited by a survey. Results show a general tendency towards the ranking of control alternatives, which in most of the cases appears to be independent of the evaluated contagious disease (viz. FMD, CSF and AI). In the moderate populated livestock areas, the basic EU control strategy and the protective vaccination strategy are generally appreciated over the other control strategies. In the densely populated livestock areas, preference is mostly given to the pre-emptive slaughter strategy, followed by the protective vaccination strategy as second best option.

The performed analyses illustrate that the MCA technique can support policy makers in choosing the control strategy that best meets all the conflicting epidemiological, economic and social-ethical judgements. The MCA technique provides a balanced approach to ensure that all criteria enter the strategy evaluation, with the result that overall differences between opposing stakeholders turn out to be not as great as they seem in an unstructured, face-to-face meeting.

1. INTRODUCTION

Decision making in controlling animal contagious diseases is a complex, conflicting process, characterized by epidemiological, economic and socio-ethical value judgements. The objective of this paper is the development of an integral evaluation framework to support policy makers in choosing the control strategy that best meets all these conflicting judgements by applying a multi-criteria analysis (MCA).

MCA can be effective in increasing the understanding, acceptability and robustness of a decision problem. Although it is one of the most frequently applied tools within operations research and management science (Dodgson *et al.*, 2000 ; Voogd, 1982), MCA methods are hardly applied in the management of animal disease control even though it generally improves the quality and transparency of the decision making process. The MCA study as described in this paper reflects the application of such a MCA-framework to order the various control strategies according to the preferences of various stakeholders.

2. MATERIAL AND METHODS

2.1 Background described MCA research

The presented MCA research was part of a large EU research project in which the consequences of outbreaks of contagious animal disease were evaluated for various EU member states. Within this EU project, member state specific data were collected comprising demographic and livestock production data, epidemiological and economic data. These data were used as inputs in various modelling modules to obtain insight in the epidemiological and economic impact of outbreaks of contagious animal diseases. The results of these modelling

studies along with the results of a detailed questionnaire to elicit the preferences of various stakeholders served as inputs of the presented MCA-framework (Huirne *et al*, 2005)

2.2 Definition MCA

The general purpose of a MCA is to serve as an aid to thinking and decision making, but not to take the decision. The MCA technique deals with complex problems that are characterized by any mixture of quantitative and qualitative objectives, by breaking the problem into more manageable pieces to allow data and judgements to be brought to bear on the pieces. Then the technique reassembles the pieces to present a coherent overall picture to decision makers (Voogd, 1982).

Multi criteria analysis establishes preferences between alternatives to an explicit set of objectives and measurable criteria to assess the extent to which the objectives have been achieved. A key feature of MCA is its emphasis on the judgement of the stakeholders involved, in establishing objectives and criteria and estimating the relative importance weights of each criterion.

There are many different MCA methods. The principal difference between the main MCA methods is the way in which each alternative's performance across all criteria is aggregated to form an overall assessment of each alternative. Most MCA applications use the simple linear additive evaluation method, which is also the basis of the multi criteria analysis performed. This method combines the alternative's values into one overall value by multiplying the value score on each criterion by the weight of that criterion, followed by a summation of all those weighted scores (Dodgson *et al.*, 2000 ; Voogd, 1982).

2.3 Steps within MCA

The applied MCA involves eight steps, as represented by Table 1 and described below.

Table 1. The 8 steps within the applied Multi Criteria Analysis.

1. Establish the decision context
2. Identify the alternatives to be appraised
3. Identify objectives and criteria
4. 'Scoring'
5. 'Weighting'
6. Calculate overall value
7. Examine the results
8. Sensitivity analysis

2.3.1 Step 1: Establish the decision context

Within this first step the objective of the MCA should be clearly defined along with an identification of the key players or so-called stakeholders; i.e., decision makers as well as people who may be affected by the decision.

MCA is all about multiple conflicting objectives. There are ultimately trade-offs to be made. Nonetheless, in applying MCA it is important to identify a single high level objective for which there will be sub-objectives. The aim of this MCA is to make best use of data currently available to support the decision on controlling contagious animal diseases as FMD, CSF and AI.

A key player or stakeholder is anyone who can make a useful and significant contribution to the MCA. Stakeholders are chosen to represent all the important perspectives on the subject of the analysis. One important perspective in the field of controlling contagious animal diseases is that of the final decision maker and the animal health authority to whom that person is accountable. Within this analysis the Chief Veterinary Officers were approached to express these governmental values by their questionnaire responses. Those responses were given by a written questionnaire, so there was no interaction or exchange of information/experiences between the various participating CVO's.

Beside the group of CVO's, three other groups off stakeholders were questioned for their judgements to reflect the general public opinion (viz. an agricultural interest group, a non-agricultural interest group and a veterinarian group).

2.3.2 *Step 2: Identify the alternatives to be appraised*

The appraised alternatives per contagious animal disease consisted of the default EU measures (viz. stamping out of detected herds and installation of protection and surveillance zones) and one or more of the following additional control measures:

PRE = pre-emptive slaughter of neighbouring farms within a predefined radius around a detected farm.

VAC _kill = suppressive vaccination within a predefined radius around a detected farm. Vaccination is applied as a suppressive measure, all vaccinated animals will therefore be slaughtered as soon as the epidemic is under control.

VAC _live = protective vaccination within a predefined radius around a detected farm. Vaccination is applied as a protective measure, all vaccinated animals will therefore stay on the farm as soon as the epidemic is under control.

2.3.3 *Step 3: Identify objectives and criteria*

Assessing alternatives requires thought about the consequences of the alternatives, for strictly speaking it is the consequences that are being assessed not the alternatives themselves. Criteria and sub-criteria or indicators are the measures of performance by which the alternative control strategies are judged. Criteria are specific, measurable objectives. They are children of higher-level parent objectives, who themselves may be the children of even higher-level parent objectives.

This research is centred on 3 high-level objectives or main criteria, viz. epidemiology, economics, and social-ethics. Each criterion is broken down into lower level objectives or indicators to facilitate the scoring process. These clusters of indicators are as presented in Table 2.

Table 2. Overview main criteria and their indicators, along with the preference weights indicated by the CVOs.

Main Criteria	**CVO weight**	**Cluster of epidemiological indicators**	**CVO weight**
Epidemiology	53	Duration	28
Economics	30	Number infected herds	25
Social-ethics	17	Size affected region	19
		Number destroyed animals	12
Cluster of social-ethical indicators	**CVO weight**	Number destroyed herds	12
		Number destroyed non-farm animals	5
Efficacy	18		
Socio-economic factors	11	**Cluster of economic indicators**	**CVO weight**
Macro-economic factors	7		
Commercially interested parties	8	Direct farm losses	15
Animal health	8	Cons. farm losses affected region	14
Animal welfare	7	Cons. farm losses outside affected region	10
Tourism	4	Losses other participants	11
Non-farm animals	3	Losses non agricultural sectors	9
Human health	11	Organisation costs	11
Governmental policy	8	Export restrictions EU markets	12
Natural life-cycle	6	Export restrictions non-EU markets	9
Food source	9	Tax payer	9

In general, criteria and indicators are defined by help of the stakeholders in an iterative way. However, within the scope of this research, it was not possible to conduct such an extensive, iterative process. The definitions of criteria and indicators are therefore based on 1) the results of a former study in which Dutch stakeholders were interviewed by means of a Group Decision Room session to define the criteria by which animal control strategies should be evaluated (Huirne *et al.*, 2002) and on 2) additional expert consultation.

2.3.4 *Step 4: 'Scoring'*

By determining criterion scores, attention should be paid to the measurement scale. A distinction can be made between a quantitative and a qualitative measurement scale. In case of a quantitative scale the measurement unit is known, i.e. a quantity has been defined as a standard by which the magnitude of differences can be expressed. Examples of measurement units are animals, farms, days, and so forth.

The measurement unit of a qualitative measurement scale is unknown. Three qualitative measurement scales can be distinguished of which the ordinal scale contains most information, since the numbers of this scale give a rank order. Whether a choice-possibility is worse or better than any other choice possibility can be expressed by means of an ordinal scale; no information is available about 'how much' such is the case.

Even if the criterion scores have been determined on a quantitative measurement scale for all criteria, these scores are mutually incomparable since most of the measurement units will differ from each other. One criterion might be expressed in number of farms, whereas another criterion is measured in days. To make the various criterion scores comparable it is necessary to transform them into one common measurement unit, by taking care that for each criterion the scores will get a range from 0 to 1. This kind of transformation is called standardization. The method of standardization used for the scores in this study can be written as:

Standardized score i = (score i / maximum score)

or each score is divided by the highest score of the criterion concerned. An example is given in Table 3.

Table 3. A numerical example of the method of standardization.

Criterion expected length epidemic	Alternative			
	A	B	C	D
Score (days)	76	235	178	156
Standardized score	0.32	1.00	0.76	0.66
Directed standardized score	0.68	0.00	0.24	0.34

Related to standardization is the issue of the direction of the criterion scores. For some criteria a higher score implies a 'better' score, whereas for other criteria higher score implies a 'worse' score. The example criterion 'length epidemic' from Table 3 is an example of the latter. Each standardization should therefore be accompanied by a consideration of the direction of the scores. In this study the worst criterion score is given a standardized value of 0, whereas the best criterion score has a standardized values of 1.

Criterion scores can be derived in many different ways. In this study all quantitative scores are based on the results of modeling studies (Huirne *et al.*, 2005). The presented MCA analyses are directed towards the 95 percentile values, assuming a risk-averse attitude with respect to the contagious animal disease control. The scores of qualitative indicators are obtained by ranking the alternatives per criterion by its expected effectiveness. These effectiveness rankings are based on the insights obtained by the questionnaires, personal interviews and model studies.

2.3.5 *Step 5: 'Weighting'*

A criterion's weight should depend on the range of difference in the criterion scores and on how much the stakeholders care about the difference. For instance, most stakeholders consider length of the epidemic an important decision criterion. However, when alternative strategies would result in an expected duration difference of only a few days, length would not longer be an important decision criterion. In this study, stakeholders were asked to express their judgements (= weights) on grounds of their subjective knowledge on possible ranges of criterion scores.

The weighting factors applied in this study are based on the results of a written questionnaire. By this questionnaire various groups of stakeholders expressed their judgements using comparative. In this paper main emphasize is on the judgements of the CVOs. Their weighting factors for the 3 main criteria and the three clusters of epidemiological, economic and social-ethical indicators are represented in Table 2.

2.3.6 *Step 6: Combine the weights and scores for each alternative to derive an overall value*

The overall weighted scores can be obtained by multiplying an alternative's score on a criterion by the importance weight of the criterion, carried out for all criteria, followed by summing the products to give the overall preference for that alternative.

This procedure is used for the determination of the overall values of the three main criteria, epidemiology, economics and social ethics. In general the higher the overall value, the better the alternative control strategy scores within the concerned criteria.

However, the performed multi criteria evaluation is based on criteria, which are partially assessed on a **quantitative** scale as well as partially on a **qualitative** scale. To account for the specific characteristics of both measurement scales, a mixed data multi criteria technique is applied to determine an overall score per alternative.

In this mixed data evaluation technique differences in alternatives are expressed in a condensed way by means of **paired comparisons.** Standardized scores of each indicator are compared in pairs of the evaluated alternatives, resulting in so-called dominance scores. A positive score implies dominance of one strategy in relation to another while a negative value implies submission. A dominance measure of 0 implies an indifference between the compared strategies. By weighting these dominance scores per criteria, overall dominance scores of the three main criteria are obtained.

To compare the outcomes of the quantitative and qualitative dominance scores, the scores of the individual main criteria are standardized into the same unit. In this way the dominance scores of the quantitative criteria epidemiology and economics are comparable to the dominance score of the qualitative criterion social-ethics. By weighting these standardized dominance measures with the aggregated weights of the constituent criteria the overall dominance score per alternative is calculated, which represents the degree in which an alternative is better (or worse) than another alternative.

2.3.7 Step 7: Examine the results

The aggregation of the dominance scores of the three main criteria (viz. epidemiology, economics and social-ethics) into one overall dominance score per alternative gives an indication of how much an alternative is appreciated over another. These overall dominance scores are also determinative in the overall ordering of the evaluated control strategies.

2.3.8 Step 8: Sensitivity analysis

Sensitivity analysis provides a means of examining the extent to which the relative importance weights of each criterion/indicator makes any difference in the final results. Interest groups often differ in their views of the relative importance of the criteria (or weights) and of some scores, though weights are often the subject of more disagreement than scores. In this study special attention is given to the comparison between the ranking of alternatives based on the preferences expressed by the CVOs and the ranking based on the preferences expressed by the representatives of the general public.

Using the MCA model to examine how ranking of options might change under different weighting systems can show that for instance, two options always come out best, though their order may shift. If the differences between these best options under different weighting systems are rather small, accepting a second best option can be shown to be associated with little loss of overall benefit.

3. RESULTS

This subparagraph illustrates the overall MCA results based on the evaluation of FMD control alternatives for one of the studied EU member states, characterised as a net importing, densely populated livestock area.

3.1 Overall scores main criteria

Table 4 demonstrates the overall weighed scores of the three main criteria. Based on the overall epidemiological score, the Pre strategy is preferred best, followed by the Vac_live strategy. The overall 0 score on the Vac_kill strategy indicates that – compared to the other 2 alternatives – Vac_kill scores worst on all epidemiological indicators. However, the efficiency with which this strategy controls an FMD epidemic is comparable with the

efficiency of the Vac_live strategy. Due to the fact that the vaccinated animals will be killed afterwards, Vac_kill scores worst on all indicators involving number of destroyed herds or animals. These indicators, therefore, do not strictly reflect epidemiological efficiency; they also reflect a social-ethical element.

Table 4. Overall weighed scores of three evaluated FMD control alternatives per main criterion. Bold printed values reflect alternatives with highest scores (= highest rank).

Criterion	Control alternative			Difference second best alternative
	Pre	Vac_live	Vac_kill	
Epidemiological score	**36**	27	0	9
Economic score	58	53	**63**	5
Social/Ethical score	21	**55**	33	22

The ranking of the alternatives based on the economic criterion demonstrates that the Vac_kill strategy is preferred above the others. However differences in overall economic values among the alternatives are rather small, as reflected by the small difference in overall value between the first and second ranked alternatives (viz. 5 points).

The economic ranking based on the MCA may differ from the economic ranking based on the result of adding all the losses to one overall value. By utilizing subjective weighting factors, the MCA ranking is not only accounting for the height of the losses but also for, for instance, value judgements on topics as 'who is bearing the losses'.

From a social-ethical point of view, alternative Vac_live is evaluated to exceed the other 2 alternatives. With a difference of at least 22 points, Vac_kill is evaluated as the second best option.

3.2 Overall strategy value

Standardized scores of all indicators are compared in pairs of the evaluated alternatives, resulting in so-called dominance scores. A positive score implies dominance of a strategy in relation to another while a negative value implies submission. A dominance measure of 0 implies indifference between the compared strategies. By weighting the dominance scores per criterion, overall dominance scores of the three main criteria are obtained.

Table 5 demonstrates the dominance scores of the three main criteria as a result of paired comparisons of the 3 FMD control alternatives. For instance, the fourth column of the table describes the results of the comparison between the Vac_live strategy and the Vac_kill strategy. As reflected by the positive scores, the Vac_live strategy dominates the Vacc_kill strategy on 2 of the 3 main criteria (viz. +5.19 on Epidemiology, +0.73 on Social-Ethics). However, regarding the Economic criterion, the Vac_live strategy is dominated by the Vac_kill strategy (economic dominance score = -0.57).

Table 5. Criteria dominance scores of the paired comparisons of the evaluated FMD control alternatives (e.g. EU/Pre = EU strategy compared to the Preventive culling strategy).

Criterion	Pre/V_live	Pre/V_kill	V_live/Pre	V_live/V_kill	V_kill/Pre	V_kill/V_live
Epidemiology	1.75	6.95	-1.75	5.19	-6.95	-5.19
Economics	0.28	-0.29	-0.28	-0.57	0.29	0.57
Social/Ethics	-1.12	-0.39	1.12	0.73	0.39	-0.73
Total	0.92	6.26	-0.92	5.35	-6.26	-5.35

According to the total dominance scores the Pre strategy is favoured over the other 2 strategies; i.e. all total paired dominance scores are positive. The dominance difference with respect to the Vac_live strategy is,

however, small (0.92). Vac_kill is completely dominated by the other strategies as reflected by its negative total dominance scores.

4. DISCUSSION AND CONCLUSION

Within the EU project various MCAs were conducted to evaluate the ranking of alternative strategies to control the contagious animal diseases as FMD, CSF and AI. All analyses were based on the judgement values of the CVOs. Results show a general tendency towards the ranking of alternatives, which in most of the cases appears to be independent of the evaluated disease (see for detailed information Huirne *et al*, 2005). The general tendency can be described as follows:

- From an epidemiological point of view, the Vac_live strategy is preferred as strategy to control epidemics of CSF or AI. For the control of FMD, the Pre strategy is appreciated over the other alternatives. Vac_live is, however, the second best option.
- From an economic point of view, the EU strategy is ranked as best option for those situations where the EU strategy is evaluated as an effective control strategy. There is no unambiguous ranking of alternatives, which characterises the preference in the other situations (i.e. situations in which the EU strategy has a restricted control efficiency).
- From a social ethical point of view, the Vac_live strongly dominates the other control alternatives.
- From a multi criteria point of view:
    - In the moderate populated livestock areas, the Vac_live and EU strategies are generally preferred over the other control strategies, independent of the specific disease.
    - In the densely populated livestock areas, preference is mostly given to the Pre strategy, followed by the Vac_live strategy as second best option.

Difference in ranking between clusters of countries, comprising regions with comparable density and/or trade characteristics, are possibly underexposed due to the use of 'average' CVO judgements. Disaggregating the panel of CVOs into subgroups conform the density and trade characteristics of the country the CVOs represent, followed by an analysis per cluster would provide better insight into the possible presence of alternative rankings.

Individual CVOs - or in general – individual interest groups often differ in their views of the relative importance of the various criteria. Using the MCA framework to examine how ranking of alternatives might change under different preferences or weighting systems can show that, for instance, two alternatives always come out best. Their order, however, may shift. If the differences between these best alternatives under different weighting systems are rather small, accepting a second best option can be shown to be associated with little loss of overall benefit, as demonstrated by the following illustration.

The results of the conducted questionnaire demonstrate variation in preferences among four studied interest groups or stakeholders (viz. CVO group, agricultural interest group, non-agricultural interest group and veterinarian group). Table 6 summarizes the indicated preference weights for the main criteria per interest group. This overview stresses the contrast in perspectives of the non-agricultural interest group in comparison to the other interest groups.

Table 6. Criterion preference weights (%) per interest group.

Interest group	**Criterion**		
	Epidemiology	Economics	Social-ethics
CVO	53	30	17
Agriculture	49	33	18
Non-Agriculture	51	15	35
Veterinarian	53	26	21

An evaluation of the overall dominance scores based on the preference weights of these individual interest groups makes it possible to examine differences in ranking of alternatives. Table 7 demonstrates - for instance - the interest group specific overall scores of AI control alternatives for an exporting, densely populated EU member state. Based on the preferences of the CVO and the Agricultural interest groups the Pre strategy is ranked first followed by the Vac-live strategy as second best alternative. From the Non-agricultural and Veterinarian point of view, the ranking of these two alternatives is just the opposite. However, differences

between first and second best alternatives are rather small. The loss of overall benefit associated with the acceptance of the second best alternative is highest for the Non-agricultural interest group (difference of 5.8).

Table 7. Overall dominance scores of AI control alternatives based on the criterion weights of the individual interest groups. Bold printed values reflect alternatives with highest scores (= highest rank).

Interest group	**Control alternative**			Difference with second best alternative
	Pre	Vac_live	Vac_kill	
CVO	**8.3**	7.4	-15.6	0.9
Agriculture	**8.2**	6.8	-15.0	1.4
Non-Agriculture	4.2	**10.0**	-14.2	5.8
Veterinarian	7.4	**8.0**	-15.4	0.6

Generally, when opposing stakeholders discuss alternative options, they quickly focus on their differences of opinions, ignoring the effect of many criteria on which there is an agreement. The MCA technique provides a more balanced approach to ensure that all criteria enter the evaluation, with the result that overall differences are not as great as they seem in an unstructured, face-to-face meeting.

The applied integral evaluation framework illustrates the potential use of the MCA technique within the complex decision making process of controlling contagious animal diseases. Nevertheless, people make the decisions, not models. MCA models can assist people in decision making by providing structure to debates, ensuring quality conversations, documenting the process of analysing the decision, separating matters of fact from matters of judgement, making value judgments explicit, bringing judgements about trade-offs between conflicting objectives to the attention of decision makers, creating shared understanding about the issues, generating a sense of common purpose, and, often gaining agreement. MCA can do any or all of these, but it does not give 'the' answer.

5. REFERENCES

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