Multi Criteria Analysis Of Alternative Strategies To Control Contagious Animal Diseases

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Abstract

Decision making in controlling contagious animal diseases involves complex trade-offs between multiple objectives. An integral evaluation was performed to illustrate the potential support of evaluation techniques such as Multi Criteria Analysis (MCA) in choosing the control strategy that serves the general interest best.

The performed MCA research was part of a large European Union (EU) research project. EU 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 FMD, CSF and AI. 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 developed MCA-framework.

The MCA was centred on the 3 high-level objectives of epidemiology, economics and social-ethics. The appraised control alternatives consisted of the basic EU strategy, a pre-emptive slaughter strategy, a protective vaccination strategy and a suppressive vaccination strategy. The approached stakeholders reflected the judgements of the European Chief Veterinary Officers, 'agricultural concerned' Europeans, and 'non –agricultural concerned' Europeans.

The preferences of the elicited stakeholder groups resulted in a surprisingly similar final ranking of control alternatives. Due to the balanced evaluation technique of the MCA overall differences between opposing stakeholders turned out to be not as great as they seemed in an unstructured, face to face meeting.

Introduction

Decision making in controlling contagious animal diseases is a complex, conflicting process, characterized by a mixture of epidemiological, economic and social-ethical value judgements. Different stakeholders will have different ideas about which strategy to choose. Their views may, for instance, represent the interests of the farming community, the commercially related industry, the animals, the consumer or the general citizen. This may create a situation of conflicting interests, as economic motives may prevail in the views of some, while animal or human welfare motives may be prominent in the view of others.

Application of a Multi Criteria Analysis (MCA) could support policy makers in choosing the control strategy that best meets all of these conflicting interests. A 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 a MCA-framework to order the various contagious-animal-diseases control strategies according to the preferences of various stakeholders.

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Methods

General

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).

There are many different MCA methods (Nijkamp et al., 1990). The applied approach in this paper is based on the Multi Attribute Utility Theory (MAUT). MAUT approaches try to determine a real-value function, i.e. a utility function for a finite set of alternative systems x^1, x^2,.., x^m such that

$$U\left[Z_1(x^j), Z_2(x^j)..,Z_k(x^j)\right] \phi\, U\left[Z_1(x^i),.Z_2(x^i,..,Z_k(x^i)\right]$$
$$x^j \ \phi \ x^i$$

where ϕ indicates preference of system x^j with respect to system x^i. A key assumption in the MAUT approaches is the assumption of preferential independence of objectives, meaning that the trade-off between objectives $Z_i(x)$ *and* $Z_j(x)$ is not affected by the level of $Z_k(x)$ and $k \bullet i, j$. In many situations, this preferential independence is too strong; this is particularly obvious in the case where interactions between objectives are apparent. MAUT approaches are generally used in situations where the number of alternatives is small and where the assumption of preferential independence is not problematic.

Background presented MCA

The presented MCA research was part of a large EU research project in which the consequences of outbreaks of contagious animal diseases 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)

The applied MCA involved the following eight steps: 1) establish the decision context, 2) identify the alternatives to be appraised, 3) identify objectives and criteria, 4) score, 5) weight, 6) calculate overall value, 7) examine the results, and 8) sensitivity analysis

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.

The objective of this MCA was to make best use of data currently available to support the decision on controlling contagious animal diseases as FMD, CSF and AI.

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 European Chief Veterinary Officers (CVO) were approached to express these governmental values. Those responses were given by a written questionnaire, so there was no interaction or exchange of information/experiences between the various participating CVOs. Beside

the group of CVOs, two other groups of European stakeholders were questioned for their judgements to reflect the general public opinion (viz. an agricultural interest group and a non-agricultural interest group).

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. This measure results in a regaining of the disease free status (or removal of export bans) 3 months after culling the last detected animal.
- 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. This measure results in a regaining of the disease free status 3 months after culling the last detected or vaccinated animal.
- 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 after the epidemic is under control. This measure results in a regaining of the disease free status 6 months after culling the last detected animal.

Step 3: Identify objectives and criteria

This research is centred on three high-level objectives or main criteria, viz. epidemiology, economics, and social-ethics. Each criterion is broken down into lower level criteria or indicators to facilitate the scoring process. Six epidemiological indicators were used: 1) duration, 2) total number of infected herds, 3) size of the affected region, 4) total number of destroyed animals, 5) total number of destroyed herds, and 6) total number of destroyed non-farm animals (backyard animals)

The cluster of economic indicators consisted of 9 indicators: 1) direct farm losses, 2) consequential farm losses within affected region, 3) consequential farm losses outside affected region, 4)losses other agricultural sectors, 5) losses non agricultural sectors, 6) organisation costs, 7) export restrictions EU markets, 8) export restrictions non- EU markets, and 9) the amount tax payer had to contribute.

To score the alternatives on their social-ethical achievements 12 indicators were defined, reflecting the consequences with respect to 1) efficacy, 2) socio-economic factors, 3) macro-economic factors, 4) commercially interested parties, 5) animal health, 6) animal welfare, 7) tourism, 8) non-farm animals, 9) human health, 10) governmental policy, 11) natural life-cycle, and 12) food sources.

Step 4: Score

By determining criterion scores, attention should be paid to the measurement scale (viz. quantitative or qualitative). 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 standardize them into one common measurement unit, by taking care that for each criterion the scores will get a range from 0 to 1. 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.

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. Each standardization should therefore be accompanied by a consideration of the direction of the

scores. In this study the worst criterion score was given a standardized value of 0, whereas the best criterion score had a standardized value of 1.

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

Step 5: Weight

The weighting factors applied in this study were based on the results of a written questionnaire. By this questionnaire the various groups of stakeholders expressed their judgements with respect to the defined main criteria and clusters of indicators, using comparative rating scales. Stakeholders had to make judgments of each indicator with direct reference to their judgments of the remaining indicators (Churchill, 1995), by dividing 100 points per cluster. This paper emphasizes the judgements of the CVOs. See for a further description of the questionnaire and its results Huirne et al., 2005.

Step 6: Calculate overall value

By means of the simple linear additive evaluation method, the overall weighted scores of the three main criteria, epidemiology, economics and social ethics were obtained. In general the higher the overall value, the better the alternative control strategy scored within the concerned criterion.

However, the performed multi criteria evaluation was based on criteria, which were 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 was applied to determine an overall score per alternative. In this mixed data evaluation technique, which was a generalised form of the concordance analysis technique, differences in alternatives were expressed in a condensed way by means of paired comparisons. Standardized scores of each indicator were 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 were obtained.

To compare the outcomes of the quantitative and qualitative dominance scores, the scores of the individual main criteria were standardized into the same unit. In this way the dominance scores of the quantitative criteria epidemiology and economics were 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 was calculated, which represented the degree in which an alternative was better (or worse) than another alternative.

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 was preferred over another. These overall dominance scores are also determinative in the overall ordering of the evaluated control strategies.

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 was 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.

Results

Weighting factors reflecting preferences of the CVOs

The response rate of the 25 CVOs on the written questionnaire was about 80% (i.e. 20 questionnaires). With respect to the main criteria, the CVOs preferred the epidemiological criterion with an average relative weight of 53%. Corresponding average weights for the economic and social-ethical main criteria were 30% and 17%.

Duration of the epidemic (28%) and the number of infected herds (25%) were regarded as the two most important epidemiological indicators. Differences between the relative weights of economic indicators were not as profound as the epidemiological indicators. Direct farm losses (15%) and consequential farm losses in affected region (14%) were regarded as the two most important economic indicators. Efficacy (18%) and social-economic factors (12%) were considered as the most important social ethical indicators.

MCA application to evaluate three FMD control alternatives

Subsequent paragraphs illustrate the overall MCA results based on the evaluation of three FMD control alternatives for an area within one of the studied EU member states, characterised as a net importing, densely populated livestock area.

- Overall weighed scores per main criteria

By means of the simple linear additive evaluation method, the overall weighted scores of the three main criteria, epidemiology, economics and social ethics were obtained as demonstrated by Table 1.

Table 1. Overall weighed scores per main criterion and FMD control alternative. Bold printed values reflect alternative with highest criterion score (=highest rank).

Criterion	Control alternative		
	Pre	Vac_live	Vac_kill
Epidemiology	**36**	27	0
Economics	58	53	**63**
Social-ethics	21	**55**	33

Based on the overall epidemiological score, the Pre strategy was 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 scored 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 are killed afterwards, Vac_kill scored 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.

The ranking of the alternatives based on the economic criterion demonstrates that the Vac_kill strategy was preferred above the others. However differences in overall economic values among the

alternatives were 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 economic value. By utilizing subjective weighting factors, the MCA ranking is not only accounting for the magnitude 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 was evaluated to exceed the other 2 alternatives. With a difference of at least 22 points, Vac_kill was evaluated as the second best option.

- Overall strategy value

Table 2 demonstrates the dominance scores of the three main criteria as a result of paired comparisons of the three FMD control alternatives. For instance, the fifth 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 dominated the Vacc_kill strategy on two of the three main criteria (viz. +5.19 on Epidemiology, +0.73 on Social-Ethics). However, regarding the Economic criterion, the Vac_live strategy was dominated by the Vac_kill strategy (economic dominance score = -0.57).

Table 2. Criteria dominance scores by paired comparisons of the evaluated FMD control alternatives (e.g. Pre/V_live = Pre strategy compared to the Vac_live strategy).

Criterion	Paired comparisions					
	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

By aggregating the weighted dominance scores per criterion, the overall dominance scores of the three control alternatives were obtained According to these total dominance scores the Pre strategy was favoured over the other strategies; i.e. all total paired dominance scores were positive. The dominance difference with respect to the Vac_live strategy was, however, small (0.92). Vac_kill was completely dominated by the other strategies as reflected by its negative total dominance scores.

Ranking under different preferences or weighting systems

Beside the group of CVOs, an 'Agricultural concerned' interest group and a 'Non-agricultural concerned' interest group were questioned for their preferences. Table 3 summarizes the indicated preference weights for the main criteria among the three interest groups. This overview stresses the contrast in perspectives of the Non-agricultural interest group in comparison to the other interest groups.

An evaluation of the overall dominance scores based on the preference weights of these three interest groups makes it possible to examine differences in ranking of alternatives. Table 4 demonstrates - for instance - the interest group specific overall scores of AI control alternatives for an exporting, densely populated livestock area. Based on the preferences of the CVO and the Agricultural interest groups the Pre strategy was ranked first followed by the Vac-live strategy as second best alternative. From the Non-agricultural point of view, the ranking of these two

alternatives was just the opposite. However, differences between first and second best alternatives were 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 3. Criterion preference weights (%) per interest group

Interest group	Criterion		
	Epidemiology	Economics	Social-ethics
CVO	53	30	17
Agriculture	49	33	18
Non-Agriculture	50	15	35

Table 4. Overall dominance scores of AI control alternatives based on the criterion weights of the individual interest groups. Bold printed values reflect alternatives with highest rank.

Interest group	Control alternative		
	Pre	Vac_live	Vac_kill
CVO	**8.3**	7.4	-15.6
Agriculture	**8.2**	6.8	-15.0
Non-Agriculture	4.2	**10.0**	-14.2

Discussion

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.

The criterion preferences of the 'Non-agricultural concerned' interest group differed from the other 2 elicited stakeholder groups (Table 3). Nevertheless, the final ranking of the AI control alternatives appeared surprisingly similar (Table 4). 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.

Based on the findings within the described study it can be concluded that the MCA technique is a suitable tool to assist the complex decision making process of controlling contagious animal diseases 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, gaining agreement.

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