Decision Analysis in Bovine Practice

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Introduction

Decision and analysis has been described as "A systematic articulation of common sense"[1]. It represents a quantitative approach to the decision-making process and, as such, it is simply a means of enhancing, not replacing, clinical judgment. In bovine practice, decisions have to be made regularly and these decisions are often made under conditions of uncertainty. Decision analysis is a tool to help insure that appropriate decisions are made.

The technique is widely used in the business community and is rapidly gaining acceptance in the medical profession but has only recently started to find favour in veterinary medicine. One of the first examples of its use in veterinary medicine was the analysis of the use of heat mount detectors in dairy herds[2]. Subsequently it has been used in bovine practice to evaluate time for treatment of ovarian cysts in dairy cattle[3] and the use of metabolic and cellular profiles in beef feed lots [4].

Example

In order to demonstrate the use of decision analysis in a herd disease situation, a hypothetical example is presented. The problem involves a 100 cow dairy herd housed in a free stall barn and milking 80 cows in a parlour. Production for the herd is 7,000 Kg/cow/year (15,432 lbs.) and milk has been assigned a value of $40.00/hl (approximately $15.00 per cwt). The owner does not teat dip but uses dry cow therapy on an irregular basis and the dairyman's veterinarian has recenly convinced him to enroll on a DHI somatic cell counting program in order to evaluate his mastitis situation. Based on the somatic cell counts, it is estimated that the losses due to subclinical mastitis are as follows:

1. Cow infection rate equals 25%
2. Average loss is 10% of production per infected cow
3. Total subclinical loss equals:
   100 x 25% x 10% x 7,000 kg/yr x $0.40/kg = $7,000

The herd also experiences approximately 50 cases of clinical mastitis per year with the following losses:

1. $20.00 for drugs and labour
2. $40.00 for discarded milk
3. Total clinical loss equals 50 x $60 = $3,000 per year.

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Consequently, current mastitis losses are $10,000 per year.

The dairyman has become convinced that he has a mastitis "problem" and since he is bedding on shavings, he assumes that his problem is primarily coliform in nature and wants to switch to straw bedding. It is estimated that the switch to straw would cost an extra $2,000 per year and the veterinarian points out that the $2,000 could alternatively be used to cover the cost of teat dipping the herd for the year. In order to further evaluate the problem, the veterinarian recommends culturing a number of clinical and subclinical cases of mastitis at a total cost of approximatley $200.00. These results will be used to determine whether the herd problem is primarily coliform (over 75% of cultures are coliforms), or if it is a mixed problem (25% to 75% of cultures yield coliforms) or if the problem is primarily staphylococci and streptococci (less than 25% of cultures yielding coliforms) in nature. It is assumed that for various types of infection and remedial actions the losses will be as follows:

Type of Infection	Switch to Straf	Teat Dip	Do Nothing
Coliform	7,000	10,000	10,000
Mixed	9,000	7,000	10,000
Staph/Strep	10,000	5,000	10,000

The dairyman decides that he does not want to go to the trouble and expense of obtaining the cultures. Consequently, in order to graphically portray the problem and to determine the expected economic benefit of culturing, the veterinarian decides to carry out a decision analysis.

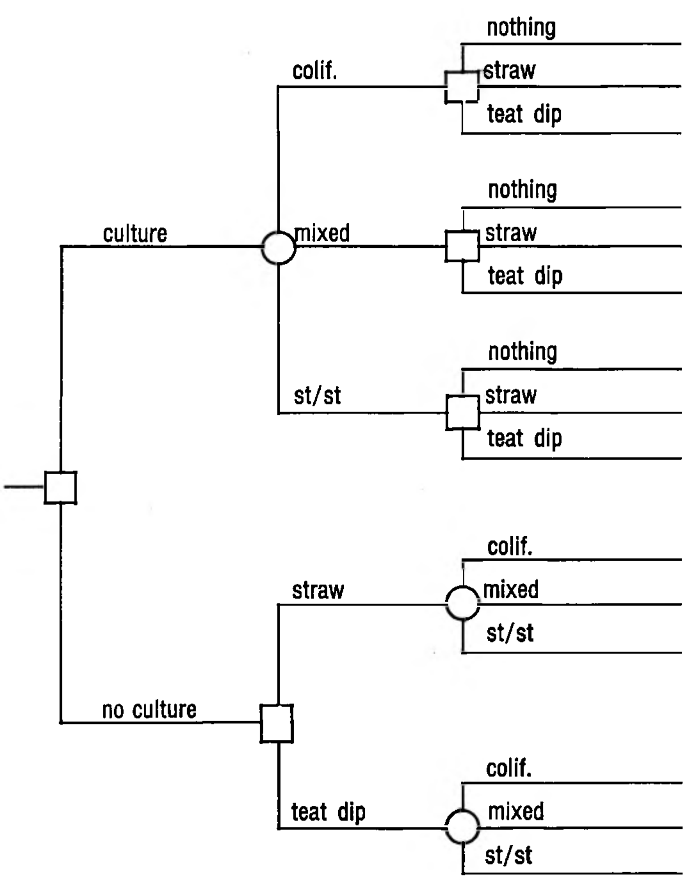
Steps Involved in a Decision Analysis

There are four steps in carrying out a decision analysis. The first is to adequately define the problem at hand. The decision to be made may involve whether or not to carry out additional diagnostic test procedures or it may be directly related to making environmental or management changes within a herd. Once the decision to be made is clearly defined, all possible alternative courses of action must be identified.

The second step is the construction of the "decision tree". This involves structuring the problem over time, starting with the initial decision to be made. Each possible alternative course of action represents one branch of this decision tree. Each of these branches then rebranches as the problem is followed through time. Each location where the tree branches is referred to as a "node". The node may be a decision node if the operator (veterinarian or herd manager) is able to select one of the subsequent branches. Decision nodes are, by convention, represented by square boxes. For example, in Figure 1 the decision as to whether or not to culture part of the herd is the main problem and is represented by a decision node. Alternatively, a node is described as a chance node if the outcome is determined by fate. Chance nodes are generally represented by circles. In Figure 1, whether or not the herd has primarily a "coliform", "mixed", or "staph/strep" infection is represented by a chance node.

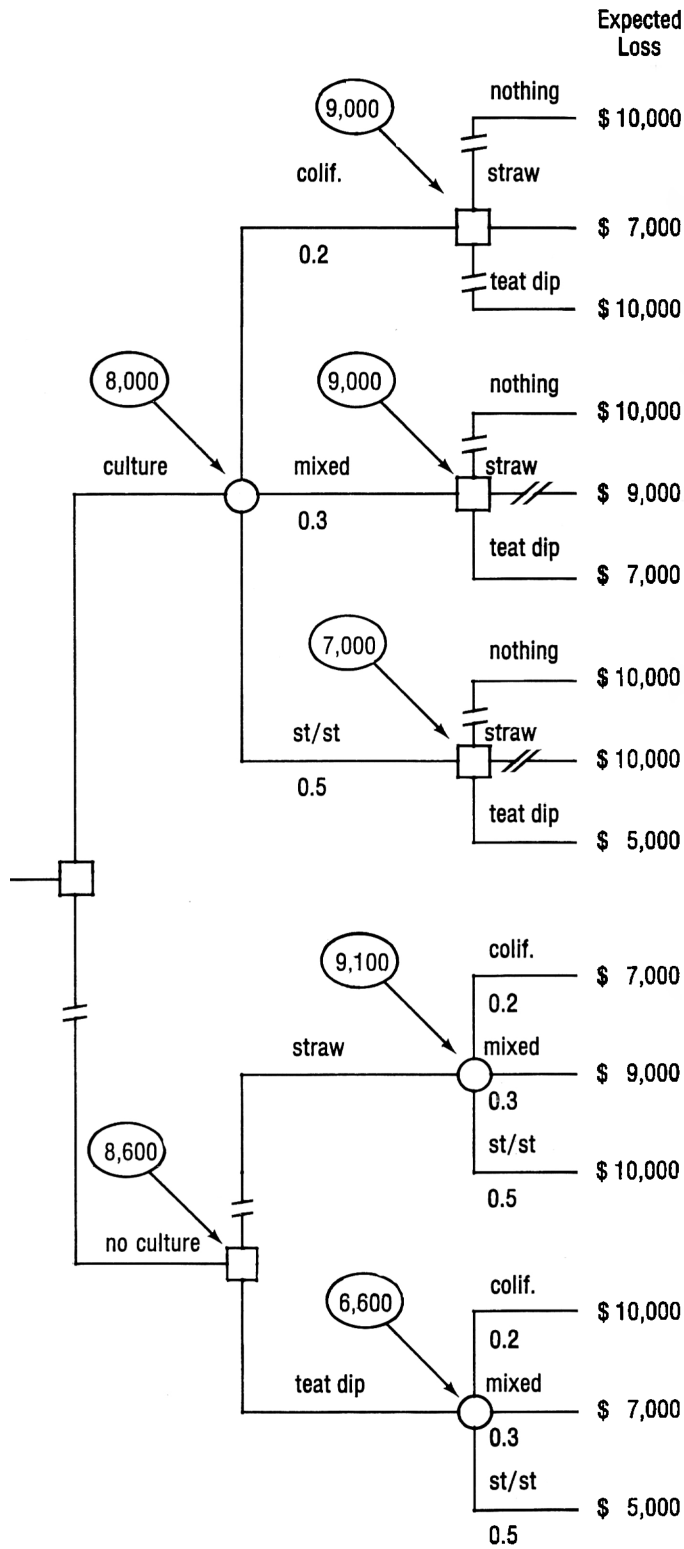
It is essential that the sequence of nodes and branches on the tree represent the probable sequence of events in time. It is important to note that if the cultures are carried out, the knowledge of whether the infection is "coliform" or "mixed" or "staph/strep" appears on the tree before (to the left of) the decision as to whether to do nothing, to switch to straw bedding or to start teat dipping. If however, cultures are not performed then the decision as to whether to switch to straw or to start teat dipping has to be taken before the type of infection is determined.

FIGURE 1. Decision tree for culturing decision.



The third step in the construction of a decision tree is the identification of the probabilities associated with each branch arising from a chance node. The sum of the probabilities assigned to the branches must equal 1.0.

FIGURE 2. Decision analysis of culturing problem.



Objective estimates of these probabilities may be available from research studies or from a veterinarian's own personal records or it may be necessary to use subjective estimates. Probabilities have been included in the tree shown in Figure 2 and it can be seen that the probability of the herd being classified as "coliform" has been estimated at 0.2 while the probabilities of "mixed" and "staph/strep" have been estimated at 0.3 and 0.5 respectively.

The fourth step in the decision analysis process is the assignation of values to the ends of each of the branches (the final outcomes). In veterinary medicine, assigning values to the ends of the branches usually means assigning a dollar value according to the outcome of the herd. Outcomes (values) have been assigned to the ends of all branches in Figure 2. The values used are the ones given above in the description of the problem.

Once values have been assigned, it is simply a matter of determining the expected value at each node in the tree. At each decision node the value of the branch with the highest expected value is chosen and that becomes the expeced value for that node. In this example (dealing with losses due to a disease) the highest expected value is equivalent to the minimum expected loss (i.e. losing $5,000 is better than losing $8,000). By convention, two parallel lines are drawn through branches not chosen and the expected value at the decision node is enclosed in an oval. If any costs are involved with any branches (for example treatment or diagnostic costs) these costs are subtracted from the value assigned to the node. For example, if cultures are performed and the herd is classified as "coliform" then the appropriate decision would be to switch to straw since it would result in the lowest expected loss ($7,000 loss + $2,000 for straw = $9,000 compared to $10,000 for doing nothing and $12,000 for switching to straw).

At a chance node the value of each branch is multiplied by the probability of that branch and these products are summed to give the expected value at the chance node. For example, in Figure 2 the expected value at the chance node following the completion of cultures has an expected value of $8,000:

(($9,000 x .2) + ($9,000 x .3) + ($7,000 x .5) = $8,000)

The expected values of all nodes on the tree are calculated by working from right to left until the values for the branches arising from the initial decision are determined. Selection of the appropriate course of action is then simply a matter of choosing the branch with the highest expected value (lowest expected loss). For this herd a decision to culture would be made since the expected loss of the "culture" branch is $600 less than the expected loss of the "no culture" branch and the cost of culturing amounted to only $200.

Sensitivity and Threshold Analyses

One of the difficulties of decision analysis is that objective estimates of probabilities and values of outcomes may not be readily available. Consequently, an investigator may wish to determine what effect adjusting the probabilities or outcome values has on the initial decision. Two methods of evaluating this effect are sensitivity and threshold analysis.

Sensitivity analysis involves simply altering the various probabilities within the decision tree and determining what effect they have on the initial decision. Table 1 shows a variety of probabilities for each of the three "types of infection" in the herd and the expected loss if cultures are performed and the expected loss if they are not. It can be seen that for all probability combinations listed, it is advantageous to culture because the "culture" branch always has an expected loss of more than $200 less than the "no culture" branch.

TABLE 1. Sensitivity anaylsis of decision to culture.

Probability for Each Type of Infection			**Expected Loss**		
"Colif."	"Mixed"	"St/St"	"Culture"	"No Culture"	Difference
.1	.1	.8	$7400	$7700	$300
.1	.4	.5	8000	8300	300
.1	.8	.1	8800	9100	300
.2	.3	.5	8000	8600	600
.2	.5	.3	8400	9000	600
.2	.7	.1	8800	9400	600
.4	.1	.5	8000	9200	1200
.4	.4	.2	8600	9800	1200
.6	.1	.3	8400	10100	1700
.6	.3	.1	8800	9900	1100
.8	.1	.1	8800	9500	700

Threshold analysis is simply a special form of sensitivity analysis which identifies the point in the spectrum of probabilities at which the initial decision is reversed. Table 2 shows a threshold analysis in which the probability of a "mixed infection" is held constant at 0.3 and the probabilities of coliform and staph/strep infections are varied accordingly. It can be seen that it is only advantageous to not culture if the probability of the infection being "colif." is less than 0.067.

TABLE 2. Threshold analysis of decision to culture.

Probability for Each Type of Infection			**Expected Loss**		
"Colif."	"Mixed"	"St/St"	"Culture"	"No Culture"	Difference
0	.3	.7	$7600	$6600	—$1,000
.05	.3	.65	7700	7850	150
.067	.3	.633	7735	7935	200
.1	.3	.6	7800	8100	300
.2	.3	.5	8000	8600	600
.3	.3	.4	8200	9100	700

Advantages of Decision Analysis

The use of decision analysis when tackling a formidable problem has a number of advantages. Firstly, structuring the problem over time identifies the logical sequence in which tests or interventions should be carried out. The process of constructing the tree also serves to break a complex problem down into a number of simpler components. The tree also aids in the identification and examination of all possible outcomes to various courses of action.

Completing the "tree" by the incorporation of probabilities and values may serve to point out areas where knowledge is limited. This can aid in the examination of the problem by clearly indicating what additional information is required. This information may then be obtained from published literature or personal records. If subjective estimates of probabilities have to be used, then sensitivity and/or threshold analyses should be conducted to determine the effect of changing those probabilities.

An additional advantage is that a decision analysis forces the investigator to define outcomes in dollar terms. In bovine practice, where the financial health of the herd under investigation is of prime importance, this is essential. Finally, decision analysis can be used to improve communications amongst veterinarians and between veterinarians and dairymen. If two veterinarians disagree on which decision should be made, the creation of a "decision tree" will clearly identify specifically where the disagreement lies.

Construction of a formal decision analysis tree takes time and may require additional research to obtain reasonable estimates of the probabilities and outcomes required for the tree. However, the time spent may well save time in the long run through the identification of a logical sequence of steps to be taken in tackling the problem. It should also result in a more optimal allocation of funds available for health management in the herd.

References

1. Weinstein M.C., Fineberg H.V., Elstein A.S., Frazier H.S., Neuhauser D., Neutra R.R., McNeil B.J., Clinical Decision Analysis. Philadelphia: W.B. Saunders, 1980; 351 pp. 2. Williamson N.B., The use of decision analysis to evaluate the economic effects of heat mount detectors in two dairy herds. Aust Vet J 1975; 51:114-121. 3. White M.E., Erb H. Treatment of ovarian cysts in dairy cattle. A decision analysis. Corn vet 1980; 70:247-257. 4. Carpenter T.E., Norman B.B. An economic evaluation of metabolic and cellular profile testing in calves to be raised in a feedlot. J Am Vet Med Assoc 1983; 183:72-75.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