COMBINING EXPERT OPINIONS: A COMPARISON OF DIFFERENT APPROACHES

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Expert opinion can be used in risk assessments to provide input data when no other data are available. Typically, experts are interviewed or asked to fill in a questionnaire in order to provide their estimates for certain variables that are needed for a quantitative risk model. As these values can be difficult to estimate and as there can be biological variability of the values, the level of the uncertainty of the estimate is sometimes also collected. This can be achieved by asking the expert to provide a probability distribution or – as many experts are not familiar with probability distributions – by asking for the most likely value plus a minimum and maximum value. Using these three numbers, a probability distribution (e.g. BetaPert distribution[1]) of the variable is obtained.

In the case where more than one expert is consulted, there now remains the question on how to best combine the distributions provided by the experts. Clemen and Winkler[2] provided a review of mathematical and behavioral approaches to this problem. Behavioral approaches are used during the expert interview with the objective to have the experts define a single probability distribution representing their consensus. Among the mathematical methods, there are a series of possible approaches. The objective of this paper is to demonstrate some selected mathematical methods and to compare the results in order to make some general recommendations.

Material and Methods

At the 3rd International Symposium on the Epidemiology and Control of Salmonella in Pork (Washington, August 1999), an expert workshop was conducted to obtain expert opinion on the frequency of salmonella infection states. Seventeen experts provided complete information on the relative frequency of six mutually exclusive and exhaustive salmonella infection states of pigs at the point of shipment for slaughter. The experts provided most likely values as well as minimum-maximum values. As the experts came from a number of different countries with variable levels of salmonella control programs, only opinions from experts from the same country were combined to avoid bias. In this paper, the results of six Danish experts are presented regarding one output parameter, namely the probability of pigs coming from an endemically infected herd to shed salmonella and to be contaminated with salmonella on the skin at the time of loading for slaughter.

The following approaches for combining the 6 probability distributions were applied:

1) The minimum, median and maximum value of the most likely figures provided by the experts are used to construct a new BetaPert distribution (Method *Median 1*).

2) The median value of the provided minimum, most likely and maximum values, respectively, is calculated and used to construct a new BetaPert distribution (Method *Median 2*).
3) Six BetaPert distributions are constructed from the figures provided by the experts and used to construct a discrete distribution with equal weights as described by Vose[1] (Method *Discrete equal*).
4) Same as above, but the self-assessment of the knowledge of the experts ranging from 1=low to 5=high is used to assign weighting factors (Method *Discrete non-equal*).
5) Six BetaPert distributions are constructed from the figures provided by the experts. The mean is claculated from the percentiles (stepsize: 5%) of the cumulative distributions and used to construct a new, combined cumulative distribution as suggested by Vose[1] (Method *Cumulative*).

All simulations were performed using @RISK software (Version 4.0, Palisade Corp., Newfield, NY) and running 5000 iterations.

Results

The distributions provided by the six experts were highly variable as displayed in Table 1.

Table 1: Parameters defining BetaPert distributions describing the probability of pigs being infected and contaminated with salmonella if coming from an endemically infected farm at point of loading for slaughter as estimated by six experts.

Expert ID	Minimum value	Most likely value	Maximum value
1	0.000	0.080	0.100
2	0.000	0.001	0.003
3	0.000	0.050	0.400
4	0.000	0.080	0.300
5	0.000	0.010	0.020
6	0.010	0.020	0.100

The combined distributions resulting after using the five combination methods are displayed in Figure 2. This figure shows that the methods *Median 1* and *Median 2* provided comparatively narrow distributions while the two methods using discrete distributions provided very broad distributions with extremely long right-hand tails. The method *Cumulative* provided an intermediate distribution.

Discussion

This exercise demonstrated that, depending on the method used for combining probability distributions, the resulting synthesis can be very different in shape and range.

If only the most likely value of an input parameter is elicited, the distribution of this mode need to be used to generate the probability distribution as in method *Median 1*. However, this distribution does not truly reflect the full range of possible values but only the uncertainty regarding the most likely value. It is therefore desirable to elicit the full range of values. Then, these distributions may be combined by using a simple approach as in method *Median 2* or using discrete distributions where each opinion of an expert is an observation and the probabilities express the weight that is assigned to this opinion. The results of these two approaches are very different in that only the discrete distribution approach reflects the true variability between experts. However, the method *Discrete* is highly sensitive to extreme values from individual experts. Also the issue of how to assign weights has not been resolved[2].

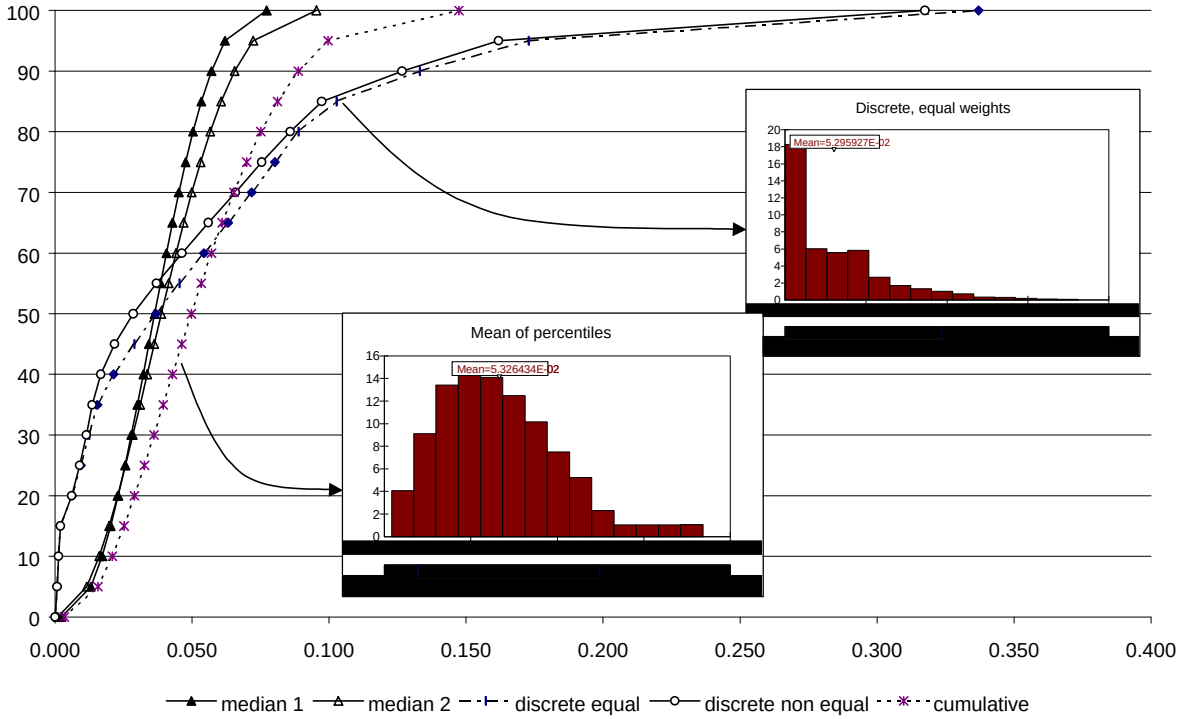

Figure 2: Cumulative combined distributions constructed from six BetaPert distributions provided by six experts and using five different methods.

An intermediate and practical approach is the method *Cumulative* which allows the use of the full available information from all distributions and yet provides a robust result. Using a step interval of 5% for the percentiles, this method is not too laborious to conduct using appropriate software. Bayesian updating methods and multilevel modeling have also been suggested[2,3] as alternative methods for combining probability distributions and will be evaluated in a next phase of this project.

In order to avoid the issue of how to combine probability distributions provided by experts in the first place, behavioral approaches should be considered. These methods allow the elicitation of a single distribution using the information provided by all experts[4]. As an additional advantage of this technique, empirical studies suggested that knowledge acquisition from groups may be of better quality than knowledge acquisition from individuals if eliciting quantities that require an understanding of Bayes' Theorem[5].

Reference

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