CHAPTER 19

APPLICATION OF RISK ANALYSIS IN CONTAGIOUS DISEASE CONTROL

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Summary

An application of risk analysis to two Identification and Recording systems for the Belgian pig industry is described. The systems considered are the revised Belgian system and a system based on electronic identification. Emphasis is placed on the major application of these systems, *i.e.*, the use in the control of Classical Swine Fever.

The results show differences in preferred choice between (assumed risk-neutral) decision makers at the (supra-) national level and farmers with various degrees of risk aversion. Within the group of farmers, the degree of risk aversion does not cause any significant preference shifts.

It is concluded that inclusion of risk analysis in decision making on contagious disease control is a valuable extension of current simulation modelling. Currently, the most hampering issue is, however, the scarcity of usable information on preference and risk attitude of decision makers.

1 Introduction

Decision making in contagious disease control is subject to many uncertainties. The occurrence of outbreaks and the frequency of epidemics are almost impossible to predict. Furthermore, the epidemiological and economic impact of outbreaks and of various disease control measures is hard to estimate beforehand. One thing is sure, however: the economic losses due to contagious disease outbreaks can be very high. For example, total direct losses due to three epidemics of Classical Swine Fever (CSF) in Belgium in 1990, 1993 and 1994 were estimated at BFr 12,300m (approximately US$ 350m).

In recent years, simulation modelling has proved to be a valuable instrument in supporting decisions with respect to contagious disease control. Examples have been described for, among other things, Foot-and-Mouth disease (Miller, 1979; Berentsen *et al.*, 1992; Garner and Lack, 1995) and Aujeszky's disease (Houben *et al.*, 1993; Buijtels *et al.*, 1997). However, no account was taken of the aspects of uncertainty and risk attitude of the decision makers, *i.e.*, a risk analysis was not included. Nevertheless, inclusion of these aspects is important, for instance, to indicate preference shifts between decision makers with differences in risk attitude, as was demonstrated by Dijkhuizen *et al.* (1994).

The aim in this paper is to show how risk attitude and uncertainty can be taken into account in studying contagious disease control. As an example, a study will be presented which was directed towards the role of Identification and Recording (I&R) systems in the control of Classical Swine Fever (CSF) in Belgium. A detailed description of this study is provided by Saatkamp *et al.* (1997).

2 The decision problem

The decision alternatives

National I&R systems aim at recording all relevant data regarding movements and inventory mutations to, from and within a particular animal population (*e.g.*, births, deaths, removals, purchases, sales, imports and exports). It is obvious that information on these aspects can be valuable for contagious disease control, in particular if animal and personal contacts are important factors in the disease spread (Saatkamp *et al.*, 1995a). This is so in the case of CSF. Currently, in Belgium, I&R systems are mainly used for CSF control.

The decision problem dealt with is the choice between the following two I&R systems:

EMDC: *E*artags with in most cases *M*anual recording, user-friendly *D*ocuments and *C*omputerized data storage, the revised Belgian system which has recently been introduced; and

TEC: *T*ransponders with *E*lectronic recording and data transfer and *C*omputerized data storage, an I&R system based on electronic identification, which is in its final stage of development.

The TEC system is more sophisticated than the EMDC system. In disease control, utilization of the TEC system would most likely result in less severe epidemics in most circumstances, accompanied by a reduction in economic losses due to the disease (Saatkamp *et al.*, 1995c, 1996). Furthermore, it has more possibilities for additional applications, which would enable spread of operational costs (Saatkamp *et al.*, 1995a). On the other hand, the estimated operational costs of the TEC system are considerable, *i.e.*, BFr 922m/year. This is about four times higher than BFr 218m/year, the figure for the EMDC system.

The nature of the decision problem

With regard to large-scale investment projects (as, for example, replacement of the EMDC by the TEC system), two extreme situations are imaginable when considering risk. First, such projects can be considered to be entirely a public issue. Both the costs of the project are borne by and the possible revenues accrue to the public sector. Since, at this level, risks associated with various different projects are assumed to be pooled (Arrow and Lind, 1970), a risk-neutral attitude is advocated (Little and Mirrlees, 1974). This implies that decisions should be based on expected monetary values or average outcomes. At the other extreme, the investment decision may be seen as relevant to only a particular group of society, for example, the pig sector. The investments are at the (collective) expense of the group members, and the revenues also accrue to them. However, various members can have different risk attitudes, depending on, for example, their economic backgrounds (large farms versus small ones). In such cases, inclusion of risk attitude, *i.e.*, degree of risk aversion, in the decision-making process is clearly desirable.

With respect to the current decision problem on I&R systems, ultimate decisions are made at the (supra-) national level, while the costs are borne by the sector, *i.e.*, the farmers. Furthermore, the possible revenues from improved I&R systems with respect to CSF control (*i.e.*, reduced losses due to CSF epidemics) are currently not evenly distributed. From the total losses of a CSF epidemic, the farmers collectively account for about 20-25%, the national Belgian government about 5%, the European Union about 40-45% and Trade and Industry about 30-35% (Saatkamp *et al.*, 1996). Therefore, the decision problem has been evaluated from two perspectives: the (supra-) national level and the farm level.

3 Material and methods

The evaluation included the above-mentioned I&R systems, *i.e.*, the EMDC and the TEC systems. Two categories of application of the systems were considered: CSF control (currently the most important one) and others, so-called attributable co-use of the system. It was assumed that the current control practices were applied with both systems. Only regarding the transport restrictions in the 10-km Surveillance zone, two options were considered: (1) the current policy (10^+), *i.e.*, a general transport standstill in the entire zone and for the full duration of the epidemic, and (2) a less rigid policy (10^-) which allows fattened pigs originating from the surveillance zone to be slaughtered and marketed. A consequence of the current policy is that considerable numbers of slaughter pigs and piglets have to be confiscated and rendered, which considerably increases the losses due to the disease.

The evaluation criterion used was the total losses due to CSF and the total costs of I&R attributed to CSF control on a yearly basis (YLC_{CSF}). Hence, $YLC_{CSF,n}$ was used for evaluation at the (supra-) national level, whereas $YLC_{CSF,f}$ refers to the evaluation at the farm level.

The evaluation procedure included three subsequent steps (see Figure 1):

1. Stochastic simulation of the losses due to single CSF epidemics.
   For every combination of basic inputs with respect to I&R system (EMDC and TEC), region (high-, medium- and low-density) and Surveillance zone policy (10^+ and 10^-), a CDF (cumulative distribution function) was calculated for the direct losses per single CSF epidemic (L_{CSF}). Hence, CDFs were calculated for 2*3*2=12 combinations. The random elements used were related to the disease spread: the number of weeks between disease introduction and notification (the so-called pre-period) and the dissemination rates of the disease. These calculations were carried out, using two adapted and inter-linked epidemiological and economic simulation models described by Saatkamp *et al.* (1995b, 1996).
2. Stochastic simulation of YLC_{CSF}.
   The yearly direct losses due to CSF (YL_{CSF}) were calculated using stochastic simulation with the random elements frequency of CSF epidemics in Belgium and in the respective regions. Calculated losses were further treated in two ways. First, YL_{CSF} were added to the total yearly operational costs of the I&R system attributed to CSF control (YOC_{CSF}; this figure is made up of the yearly operational costs of the I&R system ($YOC_{I\&R}$) and the percentage of attributable co-use). Hence, $YLC_{CSF,n}$ to the national pig sector was obtained. Because five levels of attributable co-use were considered (0, 25, 50, 75 and 100% respectively), a total of 2*2*5=20 CDFs for $YLC_{CSF,n}$ were obtained. Second, average

YL_{CSF} were calculated per farm. These were added to the $YOC_{CSF,f}$ for an average farm, calculated from the actual $YOC_{I\&R,f}$ to the farmers and the percentage of these costs a farm attributed to the control of CSF. Again, five levels of attribution were distinguished. This resulted in 2*2*5=20 CDFs for the yearly losses and costs for an average farm, $YLC_{CSF,f}$.

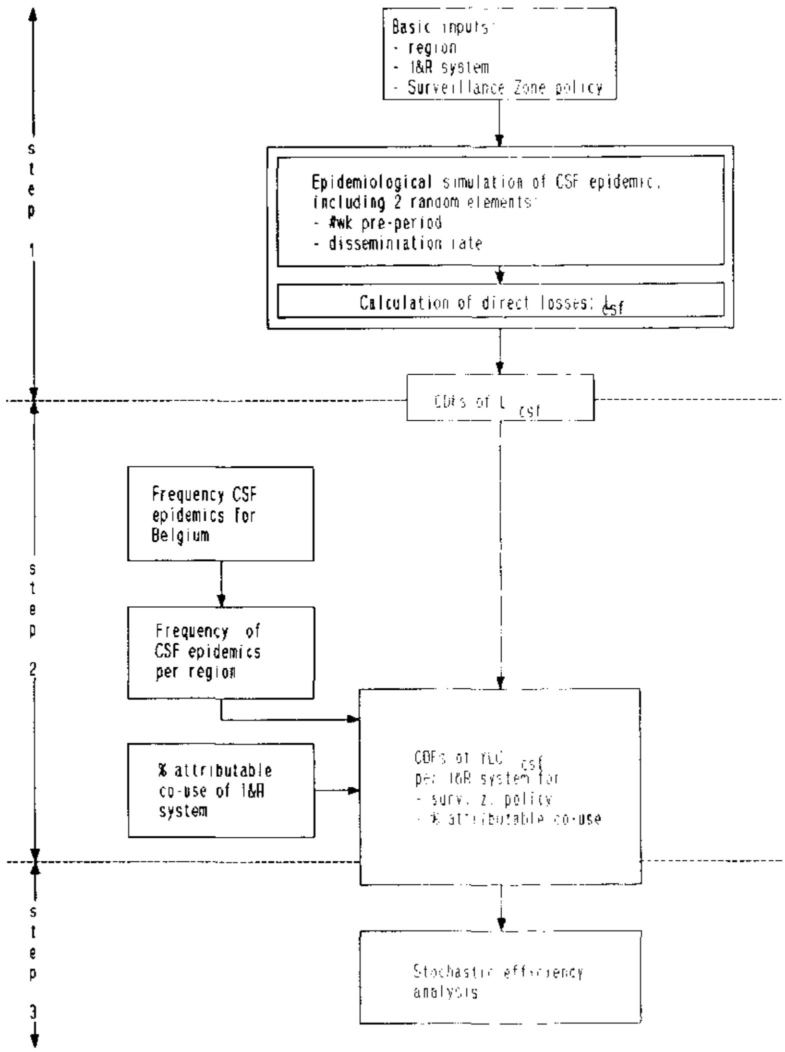

Figure 1. Overview of the analysis procedure

3. Stochastic efficiency analysis of the CDFs for $YLC_{CSF,f}$.
   A pairwise analysis of Stochastic Dominance with Respect to a Function (SDRF) was carried out between the comparative CDFs for the EMDC and the TEC systems. This was done using the program developed by Goh *et al.* (1989), in which the bounds of the absolute risk aversion coefficient (RAC) were set. RAC bounds were found by assuming the following relative risk aversion coefficient ($r'(y)$) intervals for risk attitude (Anderson and Dillon, 1991): –0.5 to 0, 0 to 0.5, 0.5 to 1.5, 1.5 to 3.5 and 3.5 to 8 for normal risk-preferring, risk-neutral, somewhat risk-averse, fairly risk-averse and extremely risk-averse decision makers respectively. Division of these bounds of $r'(y)$ by BFr 800,000, *i.e.*, the average return to labour and management of a typical Belgian pig farmer (Buyle, 1993), provided the following bounds of the RAC[1]: –0.0000006, 0, +0.0000006, +0.000002, +0.000004 and +0.00001.

4 Results

The descriptive statistics regarding the $YLC_{CSF,n}$ are presented in Table 1. Comparison of the mean values for $YLC_{CSF,n}$ between I&R systems shows that, with the current 10^+ Surveillance zone policy, the TEC system is favourable when at least 50% of co-use can be obtained. With the alternative 10^- policy, the degree of co-use should be at least 75% for a decision in favour of the TEC system. Comparing the EMDC system with the 10^- and the TEC system with the 10^+ Surveillance zone policy shows that the EMDC system is most favourable in all cases except when 100% of co-use for the TEC system and 0% for the EMDC system is presumed.

Table 2 presents the results of the SDRF-analysis for $YLC_{CSF,f}$. Three main comparisons between the EMDC and TEC systems were made: (1) both systems with the current 10^+ Surveillance zone policy (left part), (2) both systems with the alternative 10^- policy (middle part), and (3) the EMDC system with the 10^- and the TEC system with the 10^+ policy (right part). Furthermore, also two levels of losses due to CSF attributed to the farmers collectively ($YL_{CSF,f}$) were taken into account: (1) a default percentage of 20% and 25% of the total losses with Surveillance zone policies 10^+ and 10^- respectively (upper part) and 65% (lower part); the latter figure includes all losses due to CSF except those to Trade and Industry. Within each comparison, five levels of $YOC_{CSF,f}$ to farmers were distinguished: 100, 75, 50, 25 and 0% (100% means that all $YOC_{I\&R,f}$ are paid by the farmers and attributed to CSF, whereas with 0%, all these costs are either paid by others (for example, through subsidies) and/or are attributed to other applications). Only results below the diagonal are presented, assuming that the level with respect to the EMDC system is always equal to or less than that of the TEC system. Finally, these comparisons were made for different intervals for RAC.

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[1] Stricktly speaking, this is not correct. Theory prescribes that total wealth should be used instead of return, although examples are described in which the latter was used (see: Raskin and Cochran, 1986). A reliable estimation of total wealth, however, is sometimes even harder than the estimation of return. Moreover, the immediate availability of such wealth in case of calamities is questionable. Therefore, it was decided to use returns.

Table 1. Descriptive statistics of $YLC_{CSF,n}$ (yearly losses due to CSF and costs of I&R in mBFr[1]) for different combinations of I&R systems, percentage attributable co-use and Surveillance Zone policy

I&R system	Surveillance Zone policy	% attributable co-use	Minimum	Mean ± standard error	Maximum
EMDC	10^+	0	218	1,279 ± 23	4,072
		25	164	1,225 ± 22	3,891
		50	109	1,169 ± 22	3,827
		75	55	1,113 ± 22	4,732
		100	0	1,069 ± 22	4,115
TEC	10^+	0	922	1,607 ± 13	3,692
		25	692	1,370 ± 13	3,004
		50	461	1,145 ± 13	2,952
		75	231	911 ± 13	2,248
		100	0	688 ± 13	2,127
EMDC	10^-	0	218	726 ± 12	2,912
		25	164	685 ± 13	3,294
		50	109	622 ± 13	2,763
		75	55	581 ± 13	2,424
		100	0	510 ± 12	2,569
TEC	10^-	0	922	1,221 ± 7	1,962
		25	692	994 ± 7	2,166
		50	461	769 ± 7	1,779
		75	231	538 ± 7	1,359
		100	0	310 ± 7	1,344

[1] 1 US$ equals approximately 35 BFr.

The most striking result was that no significant preference shifts were observed when changing the RAC within the range from −0.0000006 to +0.00001. Therefore, separate results per RAC interval are not presented. A general picture that emerges is that, for a decision in favour of the TEC system, it is required that a maximum of only about 25% of the $YOC_{I\&R,f}$ could be spent on CSF control. If these $YOC_{CSF,f}$ to the farmers are higher, then the EMDC system should be preferred. This figure is even less when a 10^- Surveillance zone policy is considered. When a choice has to be made between the EMDC system with a 10^- Surveillance zone policy and the TEC system with the current 10^+ policy, all the $YOC_{I\&R,f}$ should come from other sources for a choice in favour of the TEC system, *i.e.*, the $YOC_{\&R,f}$ would be zero.

Table 2. Results of SDRF-analysis on $YLC_{CSF,f}$ (yearly losses due to CSF plus costs of I&R to farmers) using fixed bounds of RAC. The composition of the table is explained in the text. Dominance of the TEC system is denoted by +, dominance of the EMDC system by –

	Comparison of default percentages of $YL_{CSF,f}$														
TEC	EMDC/10^{+}/20%[1] versus TEC/10^{+}/20%					EMDC/10^{-}/25% versus TEC/10^{-}/25%					EMDC/10^{-}/25% versus TEC/10^{+}/20%				
	100	75	50	25	0	100	75	50	25	0	100	75	50	25	0
100	–					–					–				
75	–	–				–	–				–	–			
50	–	–	–			–	–	–			–	–	–		
25	+	+	–	–		+	–	–	–		–	–	–	–	
0	+	+	+	+	+	+	+	+	+	+	+	+	+	+	–
	Comparison of situations with 65% $YL_{CSF,f}$														
TEC	EMDC/10^{+}/65% versus TEC/10^{+}/65%					EMDC/10^{-}/65% versus TEC/10^{-}/65%					EMDC/10^{-}/65% versus TEC/10^{+}/65%				
	100	75	50	25	0	100	75	50	25	0	100	75	50	25	0
100	–					–					–				
75	–	–				–	–				–	–			
50	+	–[2]	–			–	–	–			–	–	–		
25	+	+	+	+		+	+	+	–		–	–	–	–	
0	+	+	+	+	+	+	+	+	+	+	+	+	+	–	–

[1] this notion means: EMDC system, 10^{+} Surveillance zone policy, 20% of YL_{CSF} are borne collectively by farmers

[2] with RACs (absolute risk aversion coefficients) between +0.000004 and +0.00001, no dominance occurred

5 Discussion

From the (supra-) national point of view, the results indicated that, for Belgium, with the current 10^{+} Surveillance zone policy, an attributable co-use level of at least 50% would be sufficient for a preference for the TEC system. Such a percentage seems likely in the near future, given the additional application possibilities of the TEC system (see: Aarts *et al.*, 1989). With the 10^{-} Surveillance zone policy, this percentage should increase to about 75%. Although this percentage seems questionable, cost reductions, subsidies and new technical developments could alter the direction towards a preference for the TEC system. In contrast, comparing the EMDC system with the 10^{-} and the TEC system with the 10^{+} Surveillance zone policy shows an undeniable preference for the EMDC system. Only if the $YOC_{I\&R}$ are fully attributable to other applications, should the TEC system be chosen.

From the perspective of the average Belgian farmer, replacement of the EMDC by the TEC system is hardly feasible since at least 75% of the $YOC_{I\&R,f}$ should be accrued to others and/or other applications. This holds even if the farmers collectively were required to meet the majority of the losses due to CSF. This conclusion is not affected by the degree of risk aversion of the farmers. This might be explained by the fact that, except in dramatic situations (*i.e.*, if an epidemic is extremely severe), the average losses due to CSF are only a relatively small part of the average labour income (Note: this does not overlook the fact that, if a particular farm is affected by CSF, the losses can be dramatic; however, the probability of such an event is very low).

These results imply that, for Belgium with respect to CSF control, replacement of the EMDC by the TEC system merely for CSF control is not economically feasible. Furthermore, results suggest that the best way to proceed is to improve CSF control in such a way that less expensive Surveillance zone policies become possible, *i.e.*, that the transport standstill and intervention measures can be mitigated without affecting the disease control. This would have a considerable impact on the $YLC_{CSF,n}$. Currently, such measures are being discussed (Dijkhuizen and Davies, 1995) and advocated (Roberts, 1995). With such a policy, the TEC system would only be feasible if the costs attributed to CSF could be reduced to less than 25%. This holds for the (supra-)national level, and to a lesser extent for the farm level. Such a reduction could be achieved through cost reduction and the use of additional applications. Although it remains questionable whether or not this could be achieved, it should be kept in mind that large-scale introduction of a TEC system could release new impulses to the pig sector, in particular because of its possibilities for automation. Additional benefits associated with this could justify the large investments for the TEC system.

6 Concluding remarks

The present example shows that in decision making with respect to large and complex issues, such as contagious disease control, differences in preferences can occur between parties involved (*i.e.*, decision makers at the (supra-) national level and farmers). These differences can result from differences in risk attitude on the one hand and economic impact of the decision alternatives (costs and benefits) on the other. Therefore, inclusion of a risk analysis which considers all parties involved is recommended in studying contagious disease control. This could contribute to a comprehensive insight into the consequences of various decision alternatives for the parties involved.

Inclusion of risk analysis in simulation studies on contagious disease control can be done without serious problems. Application of software for SDRF-analysis on CDFs appeared to be rather easy. An alternative SDRF-approach, involving direct calculation of the so-called break-even risk aversion coefficients (BRAC), was proposed by McCarl (1988; 1990). Experience with this approach regarding the present study provided similar results.

Different risk efficiency models have been described in the literature, varying from the First-Degree Stochastic Dominance technique, with limited discriminating power, to Convex Stochastic Dominance and SDRF, which have more discriminating power (see *e.g.*: Anderson *et al.*, 1977; King and Robison, 1984). The major source of difference is the trade-off between the discriminatory power of the model on the one hand and the applicability on the other. The former is strongly determined by the availability of information on preference and risk attitude of the decision maker. In the agricultural area in general, and in the field of contagious disease control in particular, information on risk attitude and preference is rather scarce or absent. SDRF models can be applied if the analyst defines the various classes of decision makers according to risk attitude by estimating RACs, or by calculating BRACs. The outcomes, however, apply only to the class of decision makers defined by the analyst. To improve the use of risk efficiency models in contagious disease control, therefore, more information on preferences and risk attitudes of various people involved is a prerequisite. Research in this field should be stimulated.

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