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A conceptual framework for economic optimization of single hazard surveillance in livestock production chains

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ABSTRACT

Economic analysis of hazard surveillance in livestock production chains is essential for surveillance organizations (such as food safety authorities) when making scientifically based decisions on optimization of resource allocation. To enable this, quantitative decision support tools are required at two levels of analysis: (1) single-hazard surveillance system and (2) surveillance portfolio. This paper addresses the first level by presenting a conceptual approach for the economic analysis of single-hazard surveillance systems. The concept includes objective and subjective aspects of single-hazard surveillance system analysis: (1) a simulation part to derive an efficient set of surveillance setups based on the technical surveillance performance parameters (TSPPs) and the corresponding surveillance costs, i.e., objective analysis, and (2) a multi-criteria decision making model to evaluate the impacts of the hazard surveillance, i.e., subjective analysis. The conceptual approach was checked for (1) conceptual validity and (2) data validity. Issues regarding the practical use of the approach, particularly the data requirement, were discussed. We concluded that the conceptual approach is scientifically credible for economic analysis of single-hazard surveillance systems and that the practicability of the approach depends on data availability.

1. Introduction[1]

During the last decades, the European Union (EU) has regularly faced major crises in the fields of livestock production and food safety. Examples include classical swine fever (CSF) during the 1990s in the Netherlands, Belgium and Germany; bovine spongiform encephalopathy (BSE) in the 1990s in the United Kingdom; dioxins in 1999 in Belgium; and highly pathogenic avian influenza (HPAI) in the 2000s in several EU countries. Such crises not only caused enormous socio-economic impacts (see, e.g., Anonymous, 2002; Asseldonk et al., 2005; Longworth et al., 2012a,b), but they also resulted in reduced public confidence in food production and products (Jonge et al., 2004).

One of the EU's responses to improve the quality of both food production and products was the introduction of new standards to improve surveillance to guarantee the safety in food production chains, ranging from visual inspection and blood sampling to second-line supervision of surveillance by others, e.g., slaughterhouses. Surveillance[2] is commonly defined as: the systematic collection of data

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[1] A list of abbreviations is included in Appendix A.

[2] Salman (2003) discussed the difference between monitoring and surveillance and used the term 'MOSS' (monitoring and surveillance

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on the occurrence of specific hazards, the analysis and interpretation of these data, and the dissemination of consolidated and processed information to contributors to the program and other interested persons (Raska, 1966; Langmuir, 1971; Kelsey et al., 1986; Dufour and Audige, 1997). According to the World Animal Health Organization (OIE), a surveillance system is "a method of surveillance that may include one or more component activities that generates information on the health, disease or zoonosis status of animal populations". In agreement with these general definitions, and also to avoid terminology ambiguity, subsequent aspects were defined as follows:

- A single-hazard surveillance system (SHSS) is a surveillance system that aims to detect a single microbiological or chemical hazard in a livestock production chain, such as CSF or salmonella surveillance.
- A surveillance system component (SSC) is a specific surveillance activity within a SHSS; for example, clinical diagnosis and routine serological tests in slaughterhouses. Hence, each SHSS consists of one or more SSCs.
- A surveillance setup of a SHSS is the combination of SSCs with their respective levels of intensity, e.g., sampling frequency and size.
- A surveillance portfolio (SP): the collection of a group of SHSSs operated by one single organization, e.g., a Food Safety Authority or a private slaughterhouse.

The overall optimization problem of any surveillance organization is to maximize surveillance performance within given or expected budget constraints. This economic surveillance optimization problem can be dealt with at two levels: (1) the SHSS, and (2) the surveillance portfolio. This paper focuses on the first level.

Surveillance is an important tool to manage complex system to avoid unfavorable damages. In the early stage, many studies on surveillance systems were conducted in military area (e.g., Cutrona et al., 1961; Easton and Fleming, 1960; Kaufman, 1964). Later, surveillance systems were extensively studied in the fields of engineering (e.g., Kuno et al., 1996; Haritaoglu et al., 2000; Muller-Schneiders et al., 2005), human health (e.g., German et al., 2001; Chou et al., 2004) as well as animal health (e.g., De Vos et al., 2007; Häsler et al., 2012). With regard to the studies on surveillance system in livestock product chains, a considerable amount of literature is available on technical evaluation of SHSSs (Paisley and Corso, 2011; Willeberg et al., 2011). Drewe et al. (2012) performed a systematic review of evaluations of SHSSs, observing that there is a distinct lack of standardization with regard to such evaluation and only a few of these studies included some kind of economic aspect. Drewe et al. (2012) concluded that economic evaluation should be an integral part of the evaluation process of surveillance systems. Häsler et al. (2011) developed a practical framework for the economic evaluation of national SHSSs, with the main objective of guiding decision makers (DMs) in planning, designing, and conducting economic evaluations. They made a distinction between situations with and without legal or other constraints, and recommended cost-effectiveness analysis (CEA) for the former and cost–benefit analysis (CBA) for the latter. The framework presented by Häsler et al. (2011) provides important steps toward improvement and standardization of economic evaluation of SHSSs. However, it focuses primarily on financial evaluations and does not account for non-financial impacts such as social unrest and public health or the subjective valuation of these impacts. Moreover, the framework appears to be rather 'open'; that is, it leaves ample room for non-harmonization.

The aim of this article is to build further on the above-mentioned studies and present a new conceptual approach for SHSS analysis. This provides a consistent conceptual basis for the development of quantitative tools for decision support, aimed at producing an economic evaluation of alternative surveillance options for a SHSS that explicitly emphasizes the benefits of hazard surveillance as well as the subjective evaluation by the stakeholders.

The remainder of this article is organized as follows. The SHSS analysis framework is elaborated in Section 2, followed by a numerical example for illustration purpose in Section 3 and a discussion in Section 4.

2. A conceptual framework for economic evaluation of single-hazard surveillance systems

In this section, a three-step evaluation framework for SHSS evaluation is presented (Fig. 1).

Step 1 aims to obtain, from a variety of surveillance setups regarding a particular SHSS, the most efficient set of setups; that is, those that are not outperformed simultaneously by others on the two main criteria: technical surveillance performance parameters (TSPPs) and costs. To enable this, the hazard is subject to two distinct processes.

Firstly, the dynamics of the hazard within the population must be analyzed,[3] taking the following two main features into account: the hazard characteristics, particular those influencing spread and expression of symptoms, and the population characteristics such as production chain structure. Such an analysis can be performed using dynamic stochastic simulation modeling (see, e.g., CSF (Klinkenberg et al., 2005), BSE (Yamamoto et al., 2008) and salmonella (Van der Gaag et al., 2005)). The model should include two main aspects: (1) the dynamics of the hazard as such, namely the spread of the disease, and (2) the development of symptoms within individual animals. For the latter, a generic list of symptoms presented in Table 1 is proposed.

The expressions are categorized into non-specific clinical symptoms, suspicious clinical symptoms, and pathological findings in blood and organs. After infection, expression of these symptoms occurs stochastically and time-dependent (see Appendix B). The symptom development, including "viraemia", together with the within- and between-farm transmissions, should aim to provide a population matrix that includes the following three levels:

system). For convenience reasons, we use the term "surveillance" interchangeably for both monitoring and surveillance.

[3] *Note*: For zero-prevalence hazards, hazard introduction must be assumed.