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A Concept for a Decision Support System Based on Practical Experiences from a National Disease Emergency
The Dutch Experience

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In 1997-1998, the Netherlands experienced a large epidemic of classical swine fever (CSF). The magnitude of this epidemic stressed the role information systems could play in supporting the management during an eradication campaign. The enforcement of an eradication strategy can become very complicated, especially with large epidemics, due to time pressure and many different procedures that have to be executed at the same time. The application of comprehensive information systems may result in more control over the process and in a relief of the operational management.
After a brief description of the Dutch epidemic the authors provide an overview and the general application of four different types of information systems, classified as decision support systems. The application of these information systems in animal disease control is illustrated by providing concepts for a system architecture for transaction processing, management and executive information support and decision support. The application of a data warehouse as part of this systems architecture is explained.
The eradication of CSF from the Netherlands was complicated by several factors. It is important to notice that information systems cannot prevent these factors. However, information systems can support disease control authorities in controlling these factors.

Classical swine fever, decision support systems, disease control, the Netherlands.

Introduction

Experience during the eradication campaign of the 1997-1998 epidemic of classical swine fever (CSF) in the Netherlands made (again) clear that effective management of large animal health emergencies is a complex and dynamic process which necessitates comprehensive preparation. Although preparation starts with an adequate prevention strategy this gives no guaranty of staying free of contagious diseases such as CSF. If a contagious animal disease is introduced in a free country, decision makers have to face many uncertainties regarding the course of the epidemic, the expected efficacy and efficiency of eradication strategies and the possibility of sanitary measures set by other countries. Despite these uncertainties they have to decide on an eradication strategy or a change in eradication strategy (*Jalvingh et al.* 1999).

Furthermore, managing the enforcement of the eradication strategy can become very complicated, especially with large epidemics, due to time pressure and many different interrelated procedures that have to be executed at the same time.

Therefore, an eradication operation of a contagious animal disease should be prepared in advance and be supported by a high performance technical and administrative organisation. To ensure that work complies with professional standards, procedures have to be designed in sufficient detail.

After brief descriptions of the Dutch pig production and of the 1997-1998 epidemic of CSF, the authors describe the role of different types of information systems in decision support. Finally, the authors present concepts for computerised information systems for both the support of the enforcement of disease control measures and for decision support. Both applications of information systems are considered very important as a basis for effective and efficient management of large animal health emergencies.

The presented concepts are based on existing decision support systems (DSS) for animal diseases. One system is in operation at the Animal Health Service (AHS) in the Netherlands. The other system is EpiMAN, a DSS for the control of a foot-and mouth (FMD) epidemic developed at the Department of Veterinary Clinical Sciences, Massey University, New Zealand, on behalf of the Ministry of Agriculture and Fisheries (EpiMAN-NZ) (Sanson, 1993, Donaldson, 1996, Stark, 1998).

The 1997-1998 epidemic of classical swine fever in the Netherlands

The Dutch pig production

In 1997, the Netherlands contained 21,000 swine herds including 15.2 million pigs. In 9,158 herds approximately 1.2 million breeding sows were present producing approximately 24 million piglets per year.

The Dutch pig production depends heavily on the export of pigs and pig products to other countries, mainly within the European Union (EU). In 1996, 75% of pigs and pig products with a total value of 2.3 billion Euro were exported (Agricultural and Horticultural Data, 1998).

Magnitude of the epidemic

The first outbreak of CSF was detected at 4 February 1997 and the last outbreak at 6 March 1998. The area affected had the highest pig density in the Netherlands with between 2,500 and 2,900 pigs per km^2 and an average of 1,000 pigs per farm (Pluimers et al., 1999).

During the epidemic more than 700,000 pigs in 429 infected herds were destroyed and more than 1.1 million pigs in approximately 1,290 herds were exterminated in preventive depopulation operations. Furthermore, because of welfare issues over 9.2 million pigs from overstocked farms were rendered under a programme supported legally and financially by the European Commission (*Pluimers et al.* 1999).

Almost 48,000 visits were performed to screen controlled areas and more than 9,600 visits were needed to follow up on traces to suspect farms, resulting in approximately 420,000 blood- and tissue samples for laboratory investigation (*Anonymous,* 1998).

In spite of the transportation ban 50,000 transports of live pigs took place, due to the buy out of pigs from overstocked farms. The total workload involved with the disease eradication was almost 400 person-year of which 80 person-year under direct management of the regional crisis centre (*Anonymous,* 1998).

The total sum of direct losses by the farmers caused by the 1997-1998 CSF-epidemic in the Netherlands was more than 1,35 billion Euro. Consequential losses for farmers and related industries (abattoirs, breeding organisations, the transportation industry and feed mills) were 440 million Euro and 621 million Euro, respectively (*Meeuwissen et al.* 1999).

Preparation

From 1986 (start of the non-vaccination policy in the EU) to 1997, only a few CSF outbreaks were discovered in the Netherlands; one outbreak in 1986, two in 1990 and eight in 1992, all of them in areas with a low pig-density (*Elbers et al.* 1999). Although the neighbouring countries Germany and Belgium had experienced recent large epidemics, there was little motivation in the pig sector to take the sanitary precautions needed to keep the disease out of the Netherlands (*Pluimers et al.* 1999).

Although a contingency plan to eradicate CSF existed and despite the fact that veterinary organisations were trained and equipped for disease eradication, these precautions proved to be inadequate for a large epidemic (*Pluimers et al.* 1999). The emphasis of the existing contingency plan was focused on enforcement from a veterinary point of view. Little attention was given to the administrative organisation; the chain of command, the layout of the organisation, the job description of the staff involved and the administrative criteria were not clear. One possible reason for this inadequate precaution was the result of an ongoing reorganisation of the veterinary organisations within the Ministry of Agriculture, Nature management and Fisheries (*Anonymous* 1997).

At the onset of the epidemic there was no computerised system available to support the disease eradication authorities in managing the eradication campaign (*Anonymous* 1997).

Factors that complicated the CSF-eradication campaign

The eradication campaign was complicated by several factors:

– The first outbreak was detected approximately six weeks after introduction of the CSF virus, giving the CSF virus opportunities to spread from one herd to another. Afterwards it became clear by epidemiological analysis that approximately 36 herds were already infected on 4 February 1997, the day the first outbreak was confirmed and a total standstill of pig movements was ordered in a 10 km radius around the infected herd (*Elbers* 1999).
– The response measures initially taken were not effective enough in a herd-dense area. Only upon implementation of additional measures such as rapid preventive depopulation of herds in contact with or located near infected herds, increased sanitary measures, additional screening by practitioners and reduction of animal movements did the epidemic fade out (*Elbers* 1999).
– In early March 1997, CSF was detected in two centres for artificial insemination (AI) (*Elbers et al.* 1999). Three weeks later CSF was detected at a farm outside the then infected area. This infection could only be explained if semen was the cause of the infection. The two AI centres had delivered suspect semen in the infectious period to 1680 pig herds of which a considerable number outside the infected area (*Pluimers et al.* 1999). These herds were officially declared CSF suspect, creating an enormous logistic problem to visit, investigate and decide on a disease status for these herds.
– Insufficient killing and rendering capacity caused problems primarily at the start of preventive depopulation in mid April 1997, resulting in delay of depopulation of contact and neighbouring farms (*Pluimers et al.* 1999).

All these factors contributed to a rapidly increasing epidemic and resulted in an overwhelming amount of information for the departmental and the regional crisis staff. The number of different interrelated eradication procedures accumulated accordingly.

Decision support and the role of information systems

A framework for decision support

Decision-making processes fall along a continuum that range from highly structured (sometimes referred to as programmed) to highly unstructured (nonprogrammed) decisions (*Turban* 1990).

A structured decision process is a process in which the procedures are standardised, the objectives are clear and the input and output are clearly defined. Specific characteristics of a highly structured task include (*Alter* 1996):

– information requirements are known precisely;
– methods to process the information are known precisely;
– desired format of the information is known precisely;
– decisions or steps within the tasks are clearly defined and repetitive;
– criteria to make decisions are understood precisely;
– success in execution of the tasks can be measured precisely.

Unstructured processes are "fuzzy," complex problems for which there are no ready to hand solutions. An unstructured task is so poorly understood that the information to be used, the method of using the information and the criteria for deciding whether the task is being well done cannot be specified. Unstructured decisions tend to be performed based on experience, intuition, trial and error, rules of thumb and vague qualitative information (*Alter* 1996, *Turban* 1990).

Semistructured processes fall between the structured and the unstructured problems, involving a combination of both standard solution procedures and individual judgement. The information requirements and procedures are generally known although some aspects of the task still rely on human judgement (*Alter* 1996, *Turban* 1990).

Successful information systems impose the amount of structure that is appropriate for the activity being supported (*Alter* 1996). Information systems supporting decision making are often classified according to the degree of structure in decision processes they support (*Turban* 1990, *Alter* 1996). However, system categories are not mutually exclusive. Next, four categories of information systems will be briefly discussed. A detailed discussion of different categories of information systems can be found in *Alter* (1996), *Inmon* (1993) and *Turban* (1990).

Transaction processing system (TPS)

A TPS is an information system that collects and stores data about transactions and controls decisions made as part of a transaction (*Alter* 1996). A transaction is an event that generates or modifies data stored in an information system. TPSs control the collection of specific data in specific formats in accordance with rules, policies and goals. It checks each transaction for easily detectable errors such as missing data, data values that are obviously too high or too low, data values that are inconsistent with other data in the database and data in the wrong format. It also may check for required authorisations for the transaction (*Alter* 1996). A TPS can govern transaction processing and automatically trigger follow-up procedures. Automatic transaction processing can have important advantages especially if a great deal of information must be processed or if a time delay is unacceptable (*Alter* 1996). Furthermore, a TPS facilitates structured repetitive decisions and improves consistency, efficiency and quality of decision making by considering all key factors. It dictates what information will be used and how the information will be combined. It also dictates how a task should be done by using a set of rules or procedures to make the decision instead of relying on human judgement (*Alter* 1996).

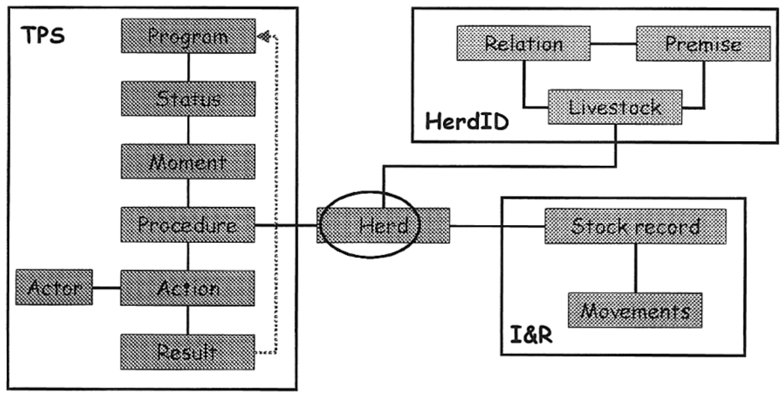

Figure 1. A conceptual model of a transaction processing system and some related sub-systems.

Management information system (MIS)
A MIS is capable of generating management information to monitor performance, maintain co-ordination, and provide background information about the organisation's operations. The information is summarised rather than about details of individual transactions. The information consists of pre-specified reports, mainly on a scheduled basis. Structured management information provides support for general management by identifying important measures of performance (*Alter* 1996). Furthermore, a MIS can maintain co-ordination and planning with respect to conflicting situations, available capacities and moments set by procedures.

Executive information system (EIS)
An EIS is a highly interactive MIS providing managers and executives with flexible access to information in order to monitor operational results and general business conditions. It provides rapid access to timely information and direct access to management reports (*Turban* 1990). The traditional MIS approach to provide pre-specified reports on a scheduled basis is too inflexible for many questions such as understanding problems and new situations, although this approach is sometimes acceptable for the same indicators over time (*Alter* 1996). Through EISs, the executive analyst can pinpoint problems and detect trends that are of vital importance to management. Problem identification is the key to effective decision making. One of the typical uses of EIS is drill-down analysis (*Inmon* 1993). Drilling down refers to the ability to start at a summary number and to break that summary into a successively finer set of summarisations.

Decision support system (DSS)
A DSS is an interactive system providing information, tools or models to help managers or professionals make decisions in semistructured or unstructured situations (*Alter* 1996). DSSs solve part of the problem and help isolate places were judgement and experience is required. DSSs incorporate both data and models, are designed to assist managers with their decision process in semistructured or unstructured tasks and support, rather than replace, managerial judgement. The objective of DSS is to improve the quality of decision making by modelling all alternatives and by forecasting their contributions to the goals.
A DSS is generally composed of 1) a database which contains relevant data for the situation

and is managed by a database management system (DBMS), and 2) models including statistical, economic, spatial, management science or other quantitative models that provide the system's analytical capabilities and 3) a user interface to through which the user can communicate with and command the DSS.

An important characteristic in the definition of DSSs is the incorporation of both data and models. The ability to invoke, run, change, combine and inspect models is a key capability in DSSs. The models in the DSS can be divided into strategic, tactical and operational models (*Turban* 1990). Strategic models are used to support strategic planning responsibilities of the executives. Tactical models are employed mainly by middle managers to assist in allocating and controlling the resources of the organisation. Operational models are used to support the day-tot-day working activities in the organisation.

A concept of a system architecture to support the control of a classical swine fever epidemic

Within the European Union (EU), the criteria to be applied in the preparation of a national contingency plan for a CSF outbreak have been harmonised by EU legislation (directive EU80/217 (*CEC* 1980)). However, member states of the EU are allowed to apply additional measures if deemed necessary. The national contingency plan should form the basis for the design of information systems.

The concept of the system architecture to support animal disease control presented in the following sections mirrors the current system architecture (partly under construction) at the AHS in the Netherlands.

Transaction processing system

The first step in designing the TPS is the translation of the contingency plan in a comprehensive administrative organisation (AO). The AO describes how a disease control programme or a disease eradication programme should be managed. It describes the chain of command, the layout of the organisation, the job description of the staff involved, the procedures that govern the disease control processes, the administrative criteria to judge events or outcomes of procedures and the instructions for field implementation of the strategies. Next, the AO will be worked out in flowcharts expressing the sequence, the timing and logic of procedures. Finally, the procedures as worked out in the flowcharts will be translated in computer instructions to actually computerise the disease control programme.

A disease control activity can be described as a group of related steps or activities that use people, information and resources to reach a specific goal. The steps are related in time and place, have a begin and end and have inputs and outputs. Actions to be undertaken are usually directed towards herds, the objects under investigation. Examples of actions to be undertaken are monitoring, clinical inspections, blood sampling, depopulation followed by cleaning and disinfect ion. Each action has to be performed by skilled individuals, at the right time and at a known place. Follow up has to be well organised; samples requires laboratory testing; results require appropriate interpretation; conclusions require a correct follow up. The cycle has to be closed; the process continues.

In the systems architecture of the TPS of the AHS a procedure control module is designed in which all kind of procedures can be stored by setting parameters. Through a second module, objects under observation are registered according to their specific status. In the case of CSF these objects are herds with pigs. The registered herd disease status (e.g. not suspect, suspect, infected) triggers the procedure(s) that have to be undertaken.

To administer herds in an appropriate manner a specific subsystem (Herd-ID) is required in which herds, personal and non-personal entities and (farm-) sites are kept up to date. To have an accurate actual stock record, different identification and registration systems (I&R-systems) for different farm animal species are kept.

To support the farm visit, inspection protocols derived from the procedure control module and sampling lists with information from the Herd-ID and I&R subsystems are available. Samples are uniquely identified (and tagged in the TPS) when transferred to the laboratory. Results are interpreted using distinct algorithms. The conclusions drawn from the results are interpreted by the procedure control module and trigger new procedures. This obviously depends on the obtained final conclusion: a negative test result induces another routine check; positive results induce immediate action. (Fig. 1).

The system architecture can be seen as a team of co-operating systems, with each a specific task and governed by an intelligent procedure control module. This obviously requires unity in data definition and a common database. At the AHS in the Netherlands, this architecture uses a relational database, managed by an Oracle DBMS.

Management information

In an extensive epidemic a high number of actions have to be undertaken within a distinct period. Some actions can be combined; others exclude one another. This is facilitated by a (tactical) planning module. The inspection capacity (in amount and capacities) is administered. Each inspection team, most fit for the job, is provided with a daily workload.

A separate management information module is incorporated in the system architecture of the TPS providing background information about the organisation's operations using pre-specified reports and graphics on a scheduled basis.

Data warehouse

Analytical processing in disease control focuses on monitoring the progress of the implemented control strategies. It also includes quantitative analysis of the actual and predicted course of the epidemic in relation to the control strategy in force and evaluation of 'what-if' scenarios to select the most effective alternative control strategy. Transaction processing systems are critical for operational support. Any stagnation or disturbance of transaction processing due to analytical processing of operational data is unacceptable. Therefore, as the core of the environment for analytical processing a data warehouse (DW) will be used. A DW is a physical separation of decision support systems from the operational data systems. It collects data from any source, inside or outside the organisation, re-organises that data and places it into a new database. Data is integrated and organised by subject rather then by application. The DW contains only information necessary for analytical processing. The resulting information is accessible to powerful tools for exploitation (EIS) and decision support (DSS).

Furthermore, by using a DW for analytical processing the information analyst does not longer have to (Inmon, 1993):

- search for the definitive source of data;
- create special extraction programs from existing systems;
- worry about data that are not integrated;
- worry about detailed and summary data and the linkage between the two;
- worry about an appropriate time basis of data, and
- worry about unexpected information requests.

The first step in designing the DW is describing the data model of the DW. The data model represents the information needs of the disease control authorities. The second step is to determine the best data available to fulfil the data identified in the data model. Based on these two steps the DW will be designed. Once designed, data in the DW is organised by subject. The third step is to design and build the interfaces between the data sources and the DW to populate the DW on a regular base. Specific characteristics of these interfaces are subject-oriented integration of data, alteration of a time base and condensation of data.

Executive information

To design the data model of the DW, the information needs of the strategic, tactical and operational management must become clear. Factors which are believed to be most critical for a successful disease control will be identified by interviewing senior managers involved in the control of the CSF-epidemic. The AO can be used to identify the measures of performance related to each of these critical success factors. Furthermore, the information requests from each management level during the 1997/1998 epidemic of CSF will be analysed. The identified information needs from both approaches will be used to design the initial data model of the DW.

Standard (commercial available) tools will be connected to the DW to allow users to interactively isolate and model information concerning specific performance indicators or events. Specific characteristics of these tools are the ability to perform drilling down analysis, visualisation techniques (graphics and maps), modelling and forecasting (regression analysis, clustering and trend analysis) and spatial analysis.

Decision support systems

Potential applications of strategic DSS models in the control of CSF include evaluation of (alternative) control or eradication strategies (e.g. monitoring programmes for CSF, preventive depopulation of neighbouring herds, emergency vaccinations with marker vaccines) and economic impact analyses of these strategies. Examples of decision support models which can be used are: deterministic tree models, stochastic simulation models, economic models, spatial models, and mathematical and population-dynamic models. Some decision models will partly be adopted from EpiMAN-NZ, others will be new designed.

To ensure the usefulness of decision models, it is very important that the underlying disease control and disease spread mechanisms are modelled as correct as possible. Therefore, different research projects are in progress in the Netherlands to increase the insight in disease spread mechanisms. The results of these research projects will be used to improve existing models and to design new models.

The decision models will be connected to the DW to give them easy access to the appropriate information.

Concluding remarks

Effective management of large animal health emergencies is a complex and dynamic process, which necessitates a comprehensive preparation. Computerised support of managerial decision making is considered very important as a basis for effective and efficient management of large animal disease emergencies. Once the first outbreak is detected, computerised support should be immediately available for the proper enforcement of the disease eradication measures, for the evaluation of effects of applied eradication measures and for decision making at various levels. However, as can be learned from the Dutch experience, the time between introduction of the CSF virus and the detection of the infection is one of most important parameters that determine the magnitude of an epidemic. In this period the virus can spread freely. It is therefore important that computerised support of decision making spans the whole process of disease control, including prevention and monitoring.

Information systems based on a comprehensive administrative organisation will lead to proper enforcement of a control strategy as it was planned. This is of special importance for disease emergencies as time pressure is high, the amount of data accumulates fast and many interrelated procedures occur simultaneously. An information system based on a comprehensive administrative organisation results in more control over the process and in a relief of the operational management.

The eradication of CSF in the Netherlands was complicated by several factors. It is important to notice that the availability of comprehensive information systems at the time of occurrence of the epidemic could not have prevented these complicating factors. What an information system probably could have done was to identify some of these factors more timely and to make the analysis of these factors easier by providing easier access to the information needed and to provide models to perform these analyses and to evaluate alternative strategies.

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