A Framework for the Development of Computerized Management and Control Systems in Dairy Farming

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Introduction

Decision making on dairy farms has become more complex due to factors such as an increase in herd size and in knowledge about dairy cow nutrition and health. The decision-making process is further complicated by the increasing volume of available information, for example from sensors on the farm or from external sources such as the milk recording agencies and feed companies. Computerized information systems, such as decision-support systems (DSS) and record keeping systems, can be developed to support the dairy producer in dealing with this increased complexity of decision making and availability of information. However, these information systems, which can be created for various areas in dairy farming such as breeding, nutrition, and finance, need to be developed in an integrated fashion to ensure a coordinated execution of all dairy-farming activities.

Dairy farming consist of both management type of activities (which are mainly related to the planning and organization of the farm), and process control type of activities (which are closely related to the regulation of physical processes, such as the control of the climate in the barn and the daily feeding and milking of the cows). Both types of activities can be supported or automated with computerized information systems, but also need to be integrated with each other.

Objectives

The objective of this study was to develop a framework to guide the long-term creation of computerized management and control systems in dairy farming. This framework describes the virtual part of dairy farming, i.e., the information processing activities and the flows of information, while the physical implementation of decisions made, for example how the feeding of the cows physically takes place, was considered outside the scope of the analyses.

Experimental procedures

Dairy farm Management and Control Activities

In this framework, the information processing activities involved in dairy farming are defined as Management and Control Activities (MCA). These MCAs are interconnected and form together what is defined as a Management and Control System (MCS) (Figure 1). The MCS can thus be seen as a network of MCAs, within which information is being exchanged and processed. On a specific dairy farm, distinct levels of management and control were considered: strategic, tactical, operational, and regulatory, although in reality a continuous range of levels exists. At the strategic level, MCAs tend to focus on the whole farm and the long-term. Tactical MCAs are performed within the scope of the strategic plan and focus on the medium-term. Operational, or short-term, MCAs are influenced by the actual day-to-day situation on the

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farm. The regulatory level concerns MCAs in the very short term which tend to be continuous, and take place in real time. The implementation of strategic decisions tends to be mainly virtual, since it usually involves additional decision-making activities at the tactical and lower levels, while towards the regulatory level, implementation tends to become more of a physical nature.

In addition to the level, MCAs can also be classified according to the area or sphere of dairy farming of which they are part. The following eight spheres of activity were recognized: breeding, health, nutrition, environment, milk production, fixed assets, labor, and finance. Table 1 gives examples of MCAs in different spheres and levels.

**Flow of information**

In addition to the information processing perspective, the MCS can also be analyzed in terms of the flows of information between the MCS and its environment, and within and among the MCAs (Figure 1). In this framework, the term information is interpreted in a broad sense, including signals, data, information, and knowledge.

Dairy producers have to deal with a large amount of information exchange with various external agents, such as the milk-recording agency, breed associations, artificial insemination units, veterinarians, feed companies, and the milk processing industry. Information not only flows from the external agent to the producer but also vice versa; in order to generate farm specific recommendations, external agents need information about the local farm conditions.

With the present day level of technology, some of the dairy farm MCAs can be automated, leading to MCSs in which MCAs can be performed either by humans or by automated systems. Some MCAs can also be carried out by both human and automated components, as in the case of DSSs. Complete automation at the operational, tactical, and strategic level, and leads to regulatory level implementation (Figure 2). However, a substantial amount of interaction and information exchange also exists among spheres. Decisions in the nutrition sphere, for example, influence and depend on the milk production and health of cows (Figure 2). This high level of inter-relationships among both spheres and levels needs to be accounted for in the development of computerized information systems.

**Processing of Management and Control Activities**

The MCS describes dairy farming in terms of a network of MCAs. However, where and how these MCAs take place can vary considerably. The most appropriate location to perform MCAs (on-farm versus external) depends on many factors, such as the skills and interest of the farmer and the level of the MCA. MCAs at the regulatory or operational level (for which decisions have to be made immediately and on a routine basis), are performed most efficiently on the farm, as in the case of the detection of estrus or mastitis. Higher level MCAs, that require specific knowledge, may be performed by external agents. For example the formulation of feed rations is often performed externally, by the DHIA, a feed company, or an external consultant. This external processing of MCAs increases the amount of information that needs to be exchanged between the farm and external agents.
automated with a computer or regulation device. Automated MCAs are required in monitoring systems to perform the data acquisition with sensors and to control the automated physical implementation of decisions as in the case of climate control and the daily feeding and milking of cows. Decision making at higher levels tends to be more complex and ill structured. In these cases, complete automation is often not possible. DSS can however be developed to help the human decision-maker by automating parts of the decision-making process.

**Impact**

This MCS framework provides a description and categorization of the various kinds of information processing activities and information flows involved in dairy farming. As such it constitutes a starting point for the creation of computerized management and control systems (CMCSs). The actual development of these CMCSs or their components requires more detailed analyses of the MCAs involved and the information exchange among them. The framework allows for the development of integrated CMCSs in a modular fashion, within the overall structure of a global model of the dairy farm. In addition, the framework can act as a reference base for the analysis of existing dairy farm information systems.

<table>
<thead>
<tr>
<th>Sphere of activity</th>
<th>Strategic</th>
<th>Tactical</th>
<th>Operational</th>
<th>Regulatory</th>
</tr>
</thead>
<tbody>
<tr>
<td>Breeding</td>
<td>develop long term breeding goals</td>
<td>planning of calving pattern</td>
<td>selection of sire per cow</td>
<td>measurement of mounting activity</td>
</tr>
<tr>
<td>Health</td>
<td>develop disease prevention strategies</td>
<td>develop of treatment procedures</td>
<td>diagnosis and treatment of disease</td>
<td>measurement of body temperature</td>
</tr>
<tr>
<td>Nutrition</td>
<td>choice of feeding system</td>
<td>seasonal ration formulation based on available feeds</td>
<td>ration formulation per cow</td>
<td>allocation and transportation of feed to cow</td>
</tr>
<tr>
<td>Environment</td>
<td>choice of ventilation or manure system</td>
<td>choice of bedding material</td>
<td>adjustment of climate set points</td>
<td>climate control</td>
</tr>
<tr>
<td>Milking production</td>
<td>develop long term milk production goals</td>
<td>development of milking procedures</td>
<td>identification of cows with abnormal milk</td>
<td>milk cluster detachment</td>
</tr>
<tr>
<td>Labor</td>
<td>hiring permanent labor</td>
<td>hiring seasonal labor</td>
<td>scheduling labor</td>
<td>timing of tasks</td>
</tr>
<tr>
<td>Fixed assets</td>
<td>investment in housing and equipment</td>
<td>development of a maintenance schedule</td>
<td>maintenance of fixed assets</td>
<td>lubrication of vacuum pump</td>
</tr>
<tr>
<td>Finance</td>
<td>long term financial planning</td>
<td>acquisition, investment, and repayment of funds</td>
<td>cash flow management</td>
<td>automatic payment</td>
</tr>
</tbody>
</table>
Figure 1. The Management and Control System (MCS) as a network of Management and Control Activities (MCA). The arrows indicate information flows.

Figure 2. Management and Control Activities (MCA) and their information flows involved in ration formulation and feeding, at the regulatory (reg.), operational (oper.), and tactical (tact.) level.