Information systems research for chain management

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Abstract

There has been a growing interest for issues regarding product chains lately, because optimization of the processes of businesses involved results in increased efficiency and new opportunities for the product environment. Six departments of Wageningen Agricultural University are participating in a research programme on technical and organizational management of product chains. This paper provides an introduction to this research programme and focuses on the essential role of information systems. This role is illustrated for the perspectives of the disciplines agricultural engineering, computer science, management studies and mathematics. In four cases it is depicted how these disciplines contribute to the research regarding optimization of product chains.

Keywords: agricultural product chains, simulation models, business engineering, computer aided logistics, decision support.

Introduction

Currently, many organizational changes are taking place and new strategic directions are emerging in the field of agricultural production, processing and distribution. Some of the main issues are higher quality demands of products, shorter product life cycles and broader assortments of products. Combined with typical characteristics of the agricultural production process: e.g. perishability of products, varying quality of products, seasonal supply of raw materials and the diverging product flow, this makes new demands on businesses in the production of food (Trienekens, 1993). Also societal constraints and requirements are imposed on economic activities to ensure minimal waste, to restrict pollution and to economize on the use of resources.

An agricultural product chain is a chain of businesses involved in the production of agri-products: from the production of primary raw materials via the processing of (one or more) semi-finished products towards the production and distribution of products for the end-consumer. Figure 1 represents the most important processes, the divergence of the product range and information systems for the collaborating actors. It should be noted that the information may flow in two directions, thus emphasizing that information from consumers may give feedback to the lower units of the chain. Both the animal and the vegetable production is included.

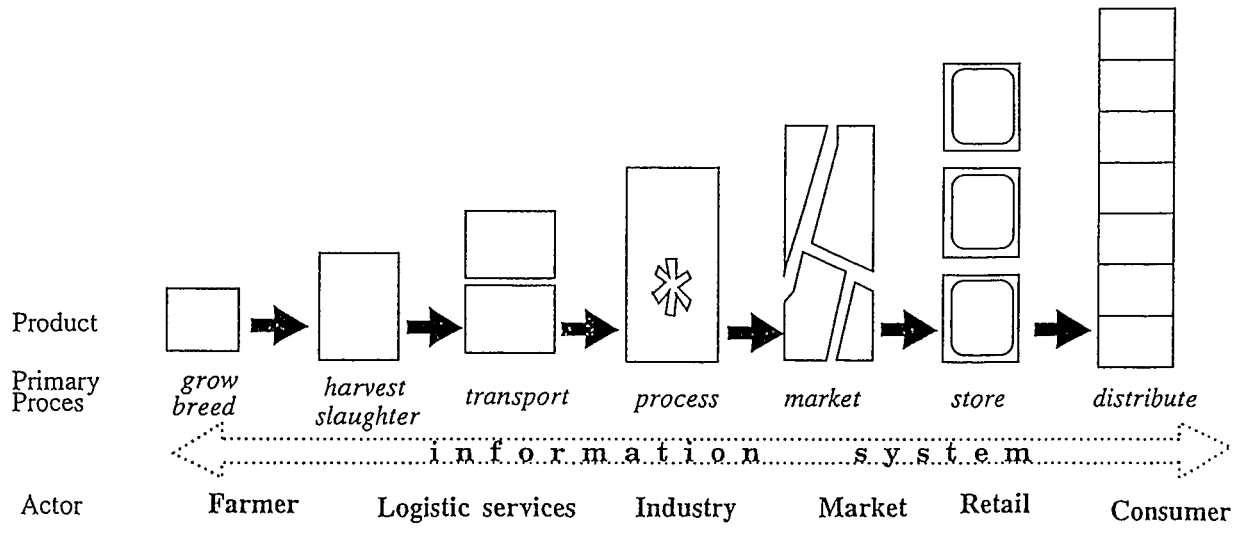
Wageningen Agricultural University concentrates its activities on the Life- and Environmental sciences, but does so in an integrated and broad way. The term agriculture has always been interpreted very broadly, it includes the whole chain of activities involved in obtaining sufficient food of good quality.

Developments as described above require an integral approach with respect to vertical integration in function areas such as management, production technology, information systems and logistics. In addition, this asks for integral management and control of the product chain. The research approach is necessarily interdisciplinary as well as disciplinary. From the interdisciplinary point of view the aim of the research is to contribute to the development of practical solutions to management and/or control problems of organizations in the chain. This requires the synthesis of applicable disciplinary contributions with respect to methods, tools and techniques (Meijs 1994a). From the disciplinary point of view, therefore, the aim is at the development of applicable methods, tools and techniques that are required to solve the practical problems.

Information systems and product chain models

With the rapid evolution of information technology new challenges and new opportunities arise. The traditional internal focus of information systems has expanded with the proliferation of data- and telecommunication technologies. Organi-

Figure 1 - The agricultural product chain



zations are now integrating applications and expanding the systems, thereby connecting them to entities beyond the boundaries of the organization.

A major field of our research programme is related to the development of models to describe and analyse information systems in agricultural product chains. In this paper the development of these models is the key issue. We can distinguish two goals for product chain models:

- Models for analysis: the purpose of the analysis is to increase understanding of the chain, based on analysis of problems and opportunities in the current business/chain situation, followed by the identification of changes to business/chain activities;
- Models for design: the models contain normative elements, suggesting that in the future new business functions are required. Design activities are the opposite of analysis activities, because the farmer should ultimately introduce systems to be realized. (Re)design of an entire chain is rather ambitious, therefore design usually means design of part of the chain.

Chains in the production of biomass crops

Introduction

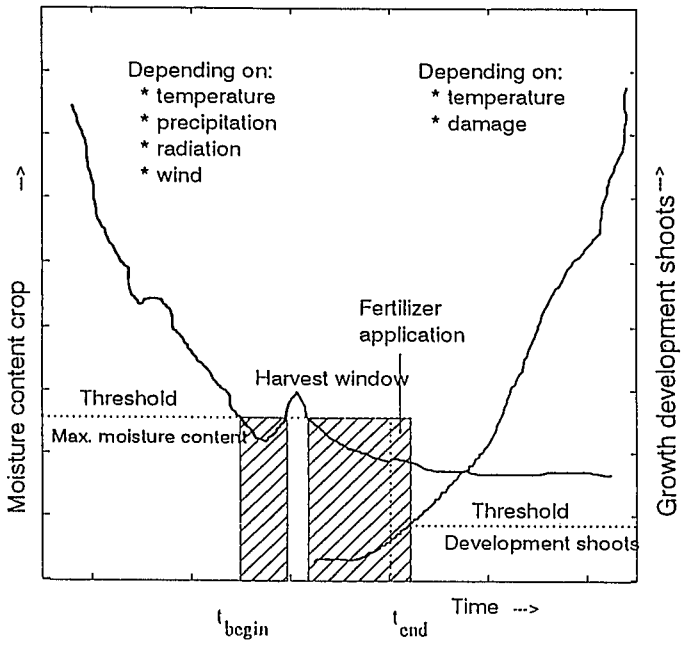
In order to achieve optimization of production systems in primary production there is a need for information that is to the point and quantitatively correct. The information has to be made easily available through Management Information Systems.

In Europe much research on biomass crops has recently been started. Biomass crops are, high-yielding crops that can be used for production of energy, building materials, as pulp for paper and packaging materials and for other bulk, non-food products. In general, the research is concerned with new crops such as Miscanthus, Arundo donax, but also very old crops such as hemp are again investigated. The production chains of these crops have to be developed from scratch. A Dutch research programme on hemp for fibres has just been finished and with the support of two EU projects now research on Miscanthus has been started by the Department of Agricultural Engineering and Physics. This crop will serve here as an example.

Miscanthus is a perennial C_4-grass which originates in East Asia. In Denmark a clone with a high productivity (10 - 20 ton dry matter per ha) was recognized, called *Miscanthus sinensis* 'Giganteus' hort. The crop can reach a length of 3 metres and looks like reed and bamboo (Huisman, 1994).

The optimization of the production chain is complex because there is a large number of relevant production chains as defined by the application of the product. In addition, there is a large number of parameters that have to be taken into account such as: cost, capacity, energy consumption, time-dependant losses, quality and density of the product. All of these parameters depend largely on the weather conditions during harvesting time in spring. This dependence has to be known quantitatively. Because of the variation in weather conditions over the years, calculations based upon conditions of one year are not sufficient, but field research over many years takes too much time. An attractive method to solve this problem is to define the relations in models which have meterological data as inputs and to calculate the above-mentioned parameter values by simulation using input data from many years. The me-

Figure 2 - Dependence of harvest window on crop moisture content and shoot development of Miscanthus



teorological data may be obtained from different locations.

The objective of this research was to develop a general method for calculating costs of harvesting, storage and transport as parts of the production chain, taking into account the application of the product, crop and soil characteristics and historical, local meteorological data. The method is developed and applied here for Miscanthus but is set up in a general way so that it can be applied to other (biomass) crops, the data of which are not available.

Method

Harvesting Miscanthus takes place between January and May because in that period moisture content in the crop has decreased to such a level that the crop can be stored. For long storage the moisture content needs to be about 15 %, but for a shorter period preceding drying, it may be higher. The rate of decrease depends on weather conditions (temperature, precipitation, radiation and wind). When a specific moisture content (threshold), as defined by the requirements of a specific production chain, is reached, harvesting can be started (t_{begin}) and continued until the threshold is crossed again (see Fig 2).

The threshold level depends on the harvesting, storage and processing method. Also other criteria will effect the start and end of the workable period. {Criterium (n,m), n=1,2,3; m=1,..,n}. (Portiek, 1977)

The period of harvesting between t_{begin} and t_{end} is called the 'harvest window'. It shows the workability for the harvest. The smaller the workability, the higher the machine costs because of the need for larger machine capacity to finish in time. Drying costs depend on the moisture content of harvested material which depends on the chosen threshold but also on the harvested new shoots.

Fig. 3 shows the overall model needed for the calculation of the costs of logistics of harvesting, storage and transport of Miscanthus. Bij using historical weather data, the models can calculate historical crop or soil characteristics. With these data the workability and thus costs can be calculated for the various local weather conditions. Under the assumption that there is no climate change, the future workability can be statistically described. The model for drying in storage is needed to predict the possibilities of drying by natural ventilation and the costs of artificial drying.

The output is entered into a database from which the statistics related to the simulated years of the criteria for selection of production chain can be calculated.

Information Architectures for Electronic Markets

Introduction

Nowadays we see that the client-server architecture is increasingly being incorporated into information systems as it moves toward the support of distribution. But we can also notice some hurdles for decentralized information systems:

- lack of policies and procedures;
- difficulty in integrating supposedly open systems;
- increase of the complexity to delevop decentralized systems.

An auction is an important part of the product chain, collecting the supply of fruit, vegetables, plants and flowers from the growers. Every day the fresh products are sold at the auction to commission merchants, exporters and retailers. The auction follows the dropping price pattern. The auctioneer starts with a high order price. He then calls hypothetical prices on a downward scale. This is mostly done electronically by using the so-called Dutch clocks. It is the task of the auctioneer to open at an adequate price level. Fig. 4 depicts the essential components of the computer infrastructure:

- Electronic auction clocks connected to a real-time computer and to the press buttons of the buyers at the stands of the auction room. In the middle of the clocks in the auction room for fruit and vegetables, you can see an electronic display, indicating the essential information of the present transaction (number of the supplier, product code, quality, quantity, price);
- Network (ethernet) for the transport of the clock-transactions to the computersystems for the business administration;
- Databases for storing actual and historical data;

- Workstations and personal computers are available for on-line information for the administrators and managers at the different departments.

It is the potential speed of the Dutch auction that allows numerous items to be sold in a short time. This is an important aspect if the goods to be sold are perishable.

In connection with a newly formulated business plan, where more responsibility for the workprocesses was delegated to the operational personnel, an information planning study was conducted at an auction with a turnover of Dfl 100 million and with 200 employees and more than 1000 business relations. The construction of an information architecture for an auction of fruit and vegetable is described in the next section.

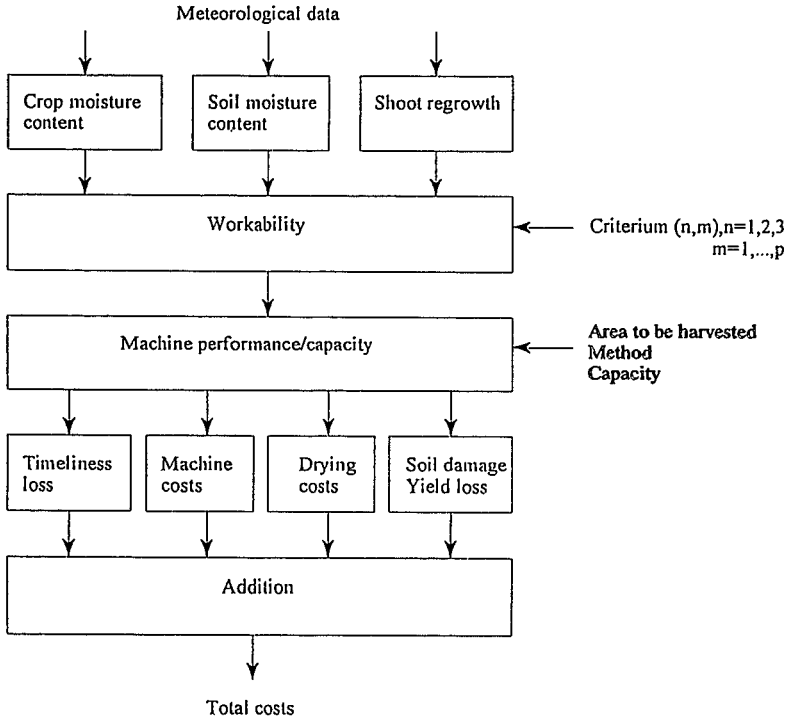
Method: building information architectures

Information planning is a decision-making process, in which management of the auction and representatives of growers and trade give direction to the development of the information systems. This concerns the formulation of an information strategy and information plan, the latter containing information architectures with priority lists for the implementation of information systems. The planning of information systems takes place within the context of other forms of planning practised within the auction. If business functions, data and decisions or other aspects can be defined in a stable manner for a given line of business, this will lead to the definition of information architectures. The resulting information architectures are represented by means of natural language descriptions, charts, matrices and various other diagrams. The systems architecture included:

- relation information systems;
- market systems including subsystems for cash and carry, mediation.

In the coming years the distribution of electronic information over multiple sites that are interconnected via a communication network will continue.

Figure 3 - Model for calculation of total costs



Especially the introduction of decentralized database systems offers new possibilities. Some prerequisites for the DBMS software that enables the construction of decentralized database applications are:

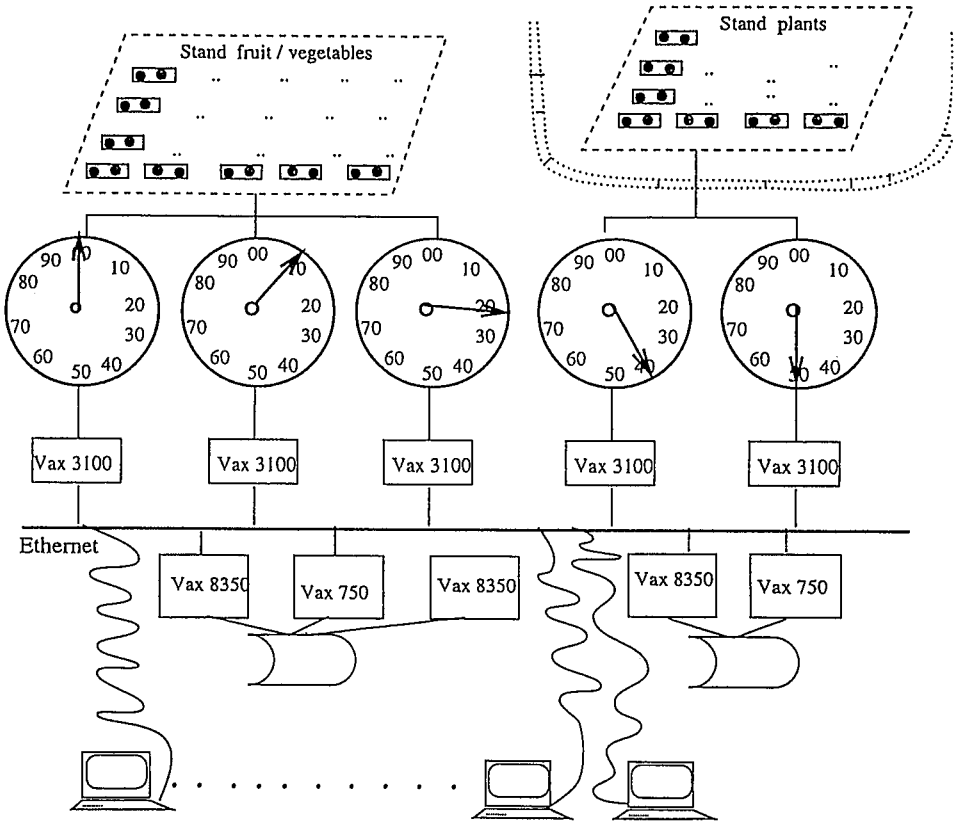
- the ability to access remote sites and transmit transactions to various sites via the communication network;
- to keep track of the data distribution and replication;
- the ability to maintain the consistency of copies of replicated data items;
- the ability to develop execution strategies for transactions that access data from more than one site.

Results

As is often the case with planning in general, the most critical part of the process is putting the plan into practice. To avoid that costly information plans stay on the shelf (and gather dust), special attention should be paid to implementation via specific system development projects (Uijttenbroek, 1992). The payoff for creating information architectures is in the system development process. Potential advantage of applying these decentralized database systems, practising at e.g. an auction includes the following:

- Supporting the decentralized nature of applications, e.g. data concerning the cold-storage space is stored in the micro-processor controlling the temperature of the spaces and products, while the results of financial transactions for the stored products will be kept at the grower's office. Other examples may refer to the tracking and tracing of processed food products along the product chain;
- Increased reliability. The failure of one single site does not mean that the whole system goes down (as is the case in a centralized system);
- Improving the availability of data and software. Replication of data and to allow the growers to access data at remote sites in the auctionhall, increases the availability and capacity to process;
- Decentralized systems enable a flexible evolution of systems, also by adding and removing data processing capacity in accordance with expansion or reduction of the domain.

Figure 4 - Computer infrastructure of the auction



It is becoming accepted that a key to successful strategy lies in the alignment of the various architectures (Meijs, 1994b). Information systems enable the business to be more competitive. Therefore, re-engineering of the processes is necessary (Meijs 1994c).

Models for Logistics and Information systems in food product chains

Introduction

The field of management studies approaches problems in businesses from several interrelated perspectives, e.g. information systems, logistics, business economics, quality assurance, etc. The perspective of management studies on product chains therefore is an interdisciplinary one. In this case we will look into the research fields of logistics and information systems. As shown in the introduction of this paper, optimization of the logistic and informational infrastructures of enterprises in chains is crucial for being competitive on the changing market of the industry.

Related to this objective, our research aims at the development of models that describe, analyse and improve the interrelated flows of goods and information throughout product chains.

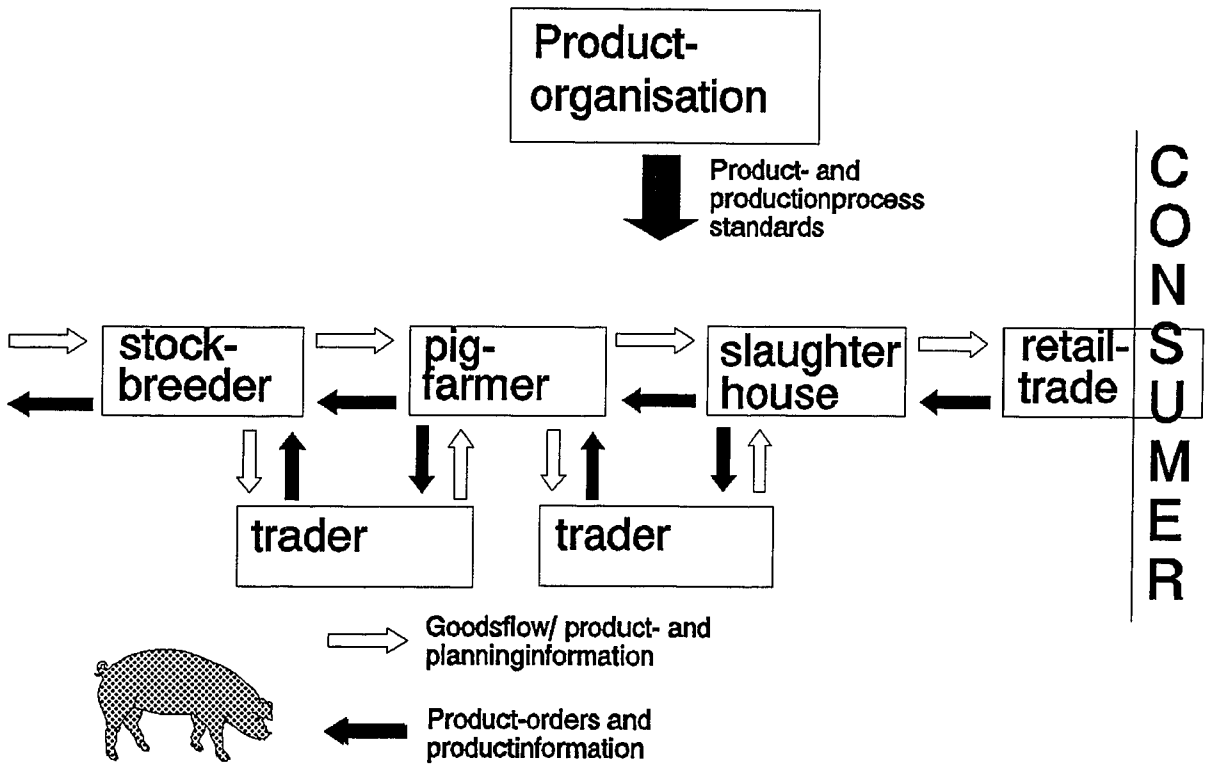
Method

Our research project consists of several interrelated sub-projects which are described below.

One of the main areas for attention is analysis of the research field: agro-industry and product chains. This research has led, until now, to some specific characteristics of agricultural product chains. Especially uncertainty in supply, dynamics in both the production materials and the production process and the divergent structure of the product flow (see Figure 1) make agricultural product chains different from other product chains. In projects concerning chain analysis or chain (re)design special attention has to be paid to the dynamics and uncertainty within the flow of goods.

Analysis of the goods of (companies in) different types of product chains is a second area for attention. Companies in distinct chains often vary in their objectives of collaboration. Mostly these are aimed at lower costs, better (unique) product quality and/or better delivery conditions. These goals determine in fact the way businesses work together. An example is the Dutch pork chain in which the search for a new and unique product has led to collaboration in the field of guaranteed product characteristics (including some process characteristics) and the exchange of product and process data. Also a chain organization has been established to develop standards and to control the intercompany agreements. Until now more than 12% of all Dutch pigs have entered/fall under a collaboration programme which covers the biggest part of the chain; in the near future this is expected to be more than 50%. Figure 5 presents an impression of the pork chain.

Figure 5 - The pork chain



In this figure we see a key role for the consumer, the chain participants (stockbreeder, pigfarmer, slaughterhouse, traders and retail trade), the flow of goods and information upstream and downstream and the chain organization. The chain organization covers all participants in the chain except the retail trade and the consumer. For the sake of clarity the production processes and production capacities of the chain participants are not included in the figure.

Given certain goals of (companies in) the agricultural product chain we have to distinguish between products, production processes, production capacities on the one hand and relevant management processes on the other; these processes are of importance for explaining the behaviour of the flow of goods and information in agricultural product chains. Research (Beers, 1994) indicates that primary (product-oriented) processes in the chain are the most important ones with regard to chain collaboration. Other processes are, with respect to product chain research, only relevant in the way they contribute directly to the production processes.

Another research project aims at developing methods for describing and modelling product chains. We search for an integration of methods regarding the flow of goods in product chains and methods regarding information systems. For the information systems component we are looking for methods that describe and model data, processes and communication networks. For the logistics component we look for methods that describe and model the production processes in the chain, the structure of the transactions between chain participants, management of capacities (aggregate planning and control) and management of the flow of goods (detail planning and control) in the chain, and relations between enterprise and chain management. These different perspectives must be studied in an interrelated way. This is in fact the central part of the research, which must lead to a method that describes and models the flows of goods and information in the chain.

When we succeed in developing models for analysing agricultural product chains, projects can be started to improve the flows of goods and information in chains in practice. In fact these will be chain (re)designing projects.

The several research projects as described above are in progress.

Recycling of slaughter by-products

Introduction

Any type of industrial processing creates waste (by-products and pollution). Meat production and processing is no exception to this general rule. The main objective of meat production is to produce food for the consumer and anything else leaving the slaughterhouse or meat-packaging plant may be qualified as by-products or waste. If these are not dealt with and disposed of properly they may create pollution problems (Urlings, 1992).

In this section the outlines are sketched of a prototype-mathematical-model to trace the optimal processing configuration of these slaughter by-products for animal nutrition. The model focuses on optimization of economic and technological factors within environmental restrictions and veterinary assumptions and legislation. The current processing strategies are compared with alternative innovative ways of processing. The model includes both process-integrated and end-of-pipe measures to meet environmental objectives. Investments, operational costs, quality development, product values and environmental loads are dealt with in a so-called mixed integer linear programming model, a common way of modelling in Operations Research. This model has been developed in cooperation with the Faculty of Veterinary Sciences of the University of Utrecht.

Modeling

With vertical integration it is possible to improve the efficiency and effectivity in the chain of slaughter by-products. The total efficiency and effectivity can be improved by certain efforts that will give higher product quality and reduced environmental costs.

A mathematical model (of so-called mixed integer linear programming model) was built. In this model the disposal and upgrading of slaughter by-products can be optimized. Costs of energy, environmental costs and restrictions, durable investments, and labour are incorporated in the model. Also the product quality and value have been taken into account.

The model aimes at being a tool that represents the slaughter by-product business, and that finds and evaluates optimal processing strategies for these products. Main goal was to compare the current central large-scale rendering with decentral processing at the source (of a relatively small scale), at the slaughterhouse, at different ways of sorting the by-products, and different storage methods.

If the by-products are treated immediately after slaughtering, then the highest nutritional value can be preserved, with a lower disintegration of the best amino and fatty acids. This means some logistical flexibility, fewer environmental costs, a more valuable product, a different energy consumption, changes in processing costs, and shifts of the processing costs within the chain. The modelling of these cost- and benefit identifiers can result in valuable management support for future strategic decisions concerning chain structure.

It is expected that in the future a full chain analysis to optimize all aspects of disposal and upgrading of slaughter by-products is necessary to take strategic decisions regarding this subject.

Conclusions and further research

In this paper an overview of the research programme on chain management was presented. The essential role of information systems research for the optimization of the product chains was shown by 4 cases from the broad research field of the six disciplines involved in the research programme. The importance of research on product chain is underlined by the fact that also at other universities in the Netherlands research projects regarding product chains have recently been started.

However, still some important questions remain:

- Definition questions: with regard to the definition of product chains as related to e.g. (large) businesses, networks of businesses; the definition of chain participants; etc;
- Questions with regard to the integral development of models for purpose of chain analyses and chain (re)design;
- Questions with regard to the development of a framework for product chain modelling; a framework which could form a basis for the different disciplines participating in the research programme.

Further research has to deal with these questions.

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