Logistic control concepts in chain perspective
- a framework to structure logistic control -

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Introduction

Supply chain management is a growing concept in current logistics literature (Evans *et.al.*[1]; Hakansson[2]; Harland[3]). Supply chain management is defined here as an integrative approach to dealing with the planning and control of the flow of materials from agricultural producers to end-users. Several factors such as globalisation, pressure to reduce time to market, and an increased customer service focus, have spurred on interest in supply chain management. To retain customers in increasingly competitive markets, firms have focused on improved customer service as an important means of competitive differentiation. Given the dependence of a company on its supply chain partners to provide many of the key customer service elements, from sales and delivery to post-sale support, supply chain relations and supply chain management are receiving increased attention and recognition (Ellram[4]).

The agribusiness has some characteristics that distinguish it from other industries. The most prominent ones are the perishability of the products (shelf-life constraints), inhomogeneousness of product quality, unpredictability of supply lead times due to seasonal influences, uncertainty in product availability, and variable production yield (e.g. Van Rijn[5]). A traditional way of coping with uncertainties is to build inventories. Other ways are providing additional capacity or creating slack in time. These anticipations of uncertainties lead to increased logistic costs and a reduction in the flexibility of the production organisation (Durlinger[6]). Because of the shelf-life constraints and the high utilization of the available capacities in agribusiness, it is difficult to anticipate supply irregularities using traditional methods. Since only little slack is available, the logistic performance of the company is closely related to the supplier's performance. If companies in agribusiness want to play a prominent role in the changing environment, the supply control of successive links in the chain needs to be coordinated.

This paper advocates that the logistic control of companies has to be analysed and reconsidered in chain perspective in order to deal with supply, process and demand uncertainties successfully. We believe that increased coordination and an open exchange of information between supply chain partners, can considerably improve the logistic performance of participants in the supply chain. Many of the possible enhancements will require changes that cut across organisational boundaries. A framework will be presented which can be used to develop different logistic control concepts in chain perspective, and judge them by the levels of uncertainty and possible improvements of the logistic performance. The practical applicability of the framework is briefly displayed in a case study.

Developments in agri-chains

Recently, a lot of developments in the food industry and retail markets have taken place which have had a great impact on the total chain management. Customers demand products customized to their individual needs forcing companies to go for 'mass customization'. Product-life cycles are shortening (Bhattacharya *et al.*[7]). Modern consumers display a whimsical purchasing pattern with respect to food products. Retailers demand high quality, highly frequent JIT delivery of an ever greater product assortment. For example Albert Heijn, one of the leading retail chains in the Netherlands, will triple their product assortment in the next few years. Lead times will decrease from 2 days to several hours and the delivery frequency will increase from once a day to perhaps two or three times a day (Damman[8]). We are going from a sellers to a buyers market in which an integral approach is necessary to anticipate the changing performance criteria.

These developments imply a certain challenge for the performance of logistic control in the food industry. Cooperation in the supply chain seems necessary to meet these challenges. Not only the food industry itself is confronted with higher performance criteria, also their suppliers and even their second-tier suppliers have to perform according to the new standards. Because of the typical characteristics of the agribusiness, all chain participants from agricultural producer to end-user have to be attuned in order to fulfil customer demands effectively. It can be estimated that by using responsive customer-driven supply chains the profitability of these chains could be improved drastically. This potential for improvement is based on the reduction of inventory-carrying costs, reduction of indirect and direct labour costs and the increase of sales and sales margins via better delivery performance at the operative level and a reduction in time-to-market at the tactical and strategic level (Eloranta *et al.*[9]).

Research focus

In this research we concentrate on the improvement of customer service by adjusting the supply management of food-producing companies in agri-chains. The basic assumption is that in order to create a competitive logistic performance, the reliability of supply and the compatibility of supply and process management are crucial. Because

of increasing logistic performance demands (frequent JIT delivery, high quality) producing companies have to be as flexible as possible. This means that e.g. stocks, setup-times and production batches have to be reduced. The supply of materials becomes increasingly important. In this research we analyse which form of logistic control is applied by food producing companies and their suppliers with inherent supply, process and demand uncertainties and try to improve these concepts by chain analysis. The following research questions have been formulated:
(1) How can we characterise supply and process uncertainties?
(2) How can we characterise logistic control (concepts) in agri-chains?
(3) What is the relation between uncertainty, logistic control and the logistic performance?
(4) What are the benefits of a total chain approach for the logistic performance?
In this paper only the first two research questions are addressed. The other two will be briefly discussed in the case-study and are the subject of further research.

We have to emphasize that we are mainly interested in the simultaneous control of the materials and information flows. It is not our intention to alter the physical infrastructure. The goal of this study is to improve the logistic performance of the food producer by influencing/controlling the environment or adjusting the logistic control concept to the new environmental demands. The organisational objectives and the current logistic infrastructure i.e. production capacities, production routes, suppliers and customers are left unchanged.

Theoretical framework

The control paradigm formulated by De Leeuw [10] is used to describe the control situation. It consists of three aspects: the controlled system, the controlling system and the information system in an environment (figure 1).

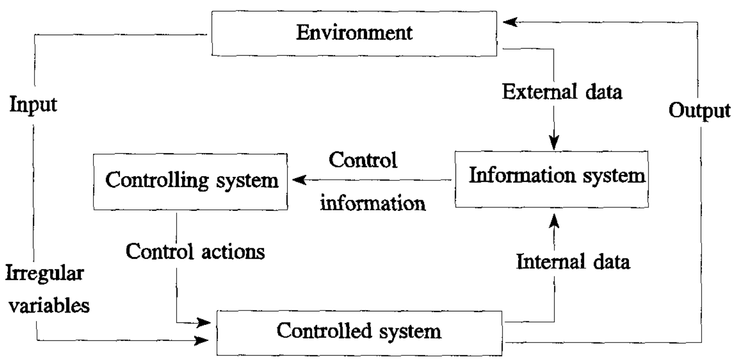

Figure 1 The control paradigm.

According to Bemelmans [11] the primary transformation process determines the structure of control needed to satisfy the logistic goals. The chosen form of control determines in its turn under which constraints what information needs to be produced. In this study, this bottom-up approach is also followed. Also Bertrand *et al.*[12]

advocate a systems approach to define the problem studied. When applying a chain approach, the production system considered becomes much larger. The subject of study consists of several production systems coupled to each other in a supply chain (figure 2).

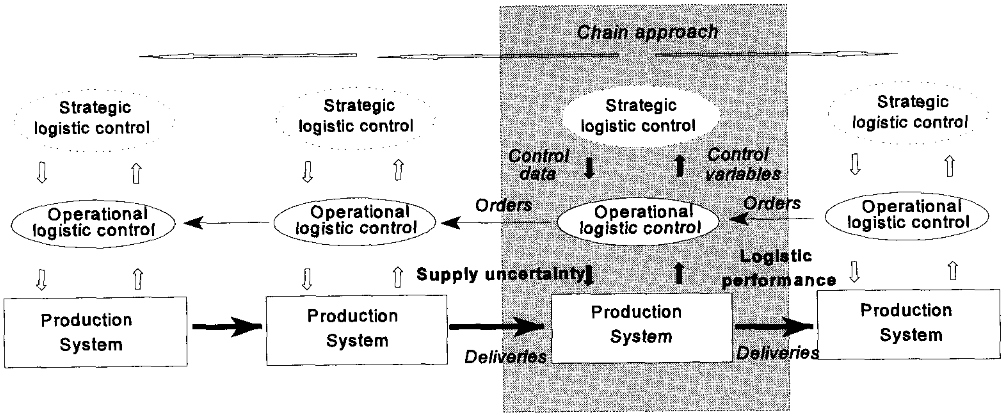

Figure 2 Research model of the supply chain (the food producing company is shaded).

Supply uncertainties 'enter' the (sub)system where they influence the control of the production system. By defining and tuning the operational and strategic logistic control variables and information system, control actions can be taken which will lead to a certain logistic performance. We hope to improve the customer service by reducing the supply uncertainties and/or improving the compatibility of supply and production management.

Decision-making under uncertainty

Uncertainty and dynamics

According to Bertrand *et al.* uncertainty and dynamics are closely related phenomena in a production environment. A situation is more dynamic when one has to react to increased changes in the environment. A situation is more uncertain when these changes come more unexpectedly. Uncertainty creates dynamics since anticipation to changes becomes more difficult. An organisation has to be flexible (in quantity and time) in order to react to these changes. (Bertrand *et al.*[12])

Managers and other employees make decisions based on the amount and the accuracy of information available to them. Decisions involve future actions and their expected consequences, which can not always be foreseen. Management levels are classified by the nature of the decisions made during planning and control. Decisions may differ in aspects like planning horizon, frequency of decision-making, level of detail, and level of uncertainty (Anthony[13]). Eilon[14] makes a theoretical distinction between risk and uncertainty. *Risk* refers to a situation in which all possible outcomes are known as well as their associated objective probabilities; *uncertainty* refers to a situation in which only a limited number of possible outcomes is known and in which objective probabilities are not available (Leutscher[15]). In practice, however, the boundary between risk and uncertainty is largely a matter of degree. Generally, the manager is able to determine the most likely and relevant possible outcomes and associate (objective or subjective) probabilities with these outcomes. Thus, decision-making under risk or uncertainty is somewhere in between decision-making under deterministic conditions and decision-making under ambiguity (Eilon[14]). In accordance with Leutscher[15], we will apply risk and uncertainty interchangeably to refer to decision-making situations in which the decision-maker has imperfect information about future events.

Supply uncertainty

Supply uncertainty refers to the degree to which raw or packing materials are not delivered in time, in the right amount or according to the right specifications (quality or price). The food industry obtains their raw materials from agricultural businesses. These raw materials usually have natural variations in quality which often lead to variations in the quantities of materials used for manufacturing a product (Rutten[16]). Raw materials have a potency or yield which is usually not known in detail until the materials arrive at the factory. Furthermore, adjustments in production planning (because of interruptions in the production process) or recipes can cause differences in material requirements. In short, supply uncertainty refers to the degree of congruence of the material availability with the material requirements for the production system and the extent to which this is known in advance (in quantity and time). Note that uncertainty can be the consequence of actions by suppliers (e.g. delivery unreliability), of characteristics of the production process (e.g. production yield), characteristics of the product (e.g. perishability), situational factors (e.g. the weather) or control actions of the production organisation. The uncertainty can be defined at two levels i.e. uncertainty in planning and control and uncertainty in the physical production system.

Remedies for supply uncertainty

Operational management is required as a form of adaptive behaviour in a context of bounded rationality. Based on Galbraith[17] two main strategies for an organisation faced with greater uncertainty can be formulated:

(1) An increase and a full utilization in the flexibility of the production system in order to deal with the uncertainty. The planning and control system will be made more flexible if e.g. a more efficient planning of critical capacities is made, information is more frequently gathered or new process technologies are installed.

(2) An increase in the reliability of the production environment in order to reduce the uncertainty. The planning and control system will be made more reliable if e.g. more or better (chain) information is used, planning of chain participants is better coordinated or procedures are improved and communication errors are avoided.

Both strategies are concerned with the design and layout of the production process and the planning and control structure (including the information system). The first strategy focuses on the planning and control of the individual company in the chain, the second on planning and control in chain perspective. The latter has our main interest.

Logistic control

Logistic control is concerned with the planning, control and coordination of supply, production, stock-holding and distribution of goods. In any organisation or organisational unit where several activities are performed simultaneously or consecutively, coordination of these activities is necessary to ensure that they lead towards the same objectives. We will apply the term control to indicate the planning activities as well as the controlling and coordination activities of goods flows and information flows. As we are focused on agribusiness, product quality has to be taken into account. In accordance with Bertrand *et al.*[12] the next definition of logistic control is formulated:

> *Logistic control is the function of management, which plans, directs, controls and coordinates the material supply and production activities in production systems to achieve a specific delivery flexibility and delivery reliability at minimum costs and with a specified product quality.*

The *logistic control concept* is a model of the way the organisation controls its flows of goods and information. It represents the logistic control over its main elements. There is no general accepted definition available. However, several authors do agree on the characterising elements. According to Hoeken and Van der Mark[18] the control concept consists of three aspects: the concept of working, the logistic organisation and the provision of information. Bertrand *et al.*[12] emphasize the position of the Customer Order Decoupling Point, the nature of the interface between the production and marketing organisation, capacity management versus materials coordination and the way planning takes place. Derived from these authors, we emphasize four elements in the logistic control concept which together give body to the logistic control structure:

A. Hierarchical levels of production planning with a rolling horizon
B. Logistic control variables
C. Information control
D. Level of coordination

The strategic decision of an organisation which logistic control concept to implement, depends on the strategy of the organisation and the characteristics of the market, product and process (Hoekstra and Romme[19]; Ballegooie and De Jong[20]). The choice depends on situational characteristics and it includes a choice of the level of coordination within the chain. In agribusiness supply, uncertainties play a central role in the decision process concerning which concept to choose. Hence, specific logistic control concepts can arise. The distinguishable elements will be briefly discussed in the next subsections. Thereby, the emphasis is laid on the decision process of semi-structured decisions taken from a rational perspective.

A. Hierarchical production planning with a rolling horizon

This paper advocates a *hierarchical approach* to logistic control; the complete control problem should be decomposed into a number of (partly) hierarchically ordered sub-problems. The hierarchical approach towards production planning and control is advocated by many authors (e.g. McKay[21]; Meal[22]; Anthony[13]). In accordance with Ziggers[23] we distinguish two levels of management: <u>structural optimization</u> involving strategic and tactical planning, and <u>process optimization</u>, which relates to the implementation of strategic and tactical plans and involves operational and task management as a way of control. Higher-level decisions have longer lead times, longer planning horizons, and are concerned with aggregates such as total manpower requirements and total product-line demand. The lowest level decisions are concerned with individual items, machines and workers (Meal[22]). The hierarchy is natural in the sense that long lead-time decisions necessarily constrain short lead-time choices. The higher the decision level, the longer the planning horizon, and the greater the uncertainty under which decisions have to be made.

Next to hierarchical production planning, we adhere to a *rolling planning horizon*. Due to the occurrence of supply and process uncertainties in agribusiness, a shortage of information in decision-making processes arises. Since relevant information can be gathered in certain time-intervals, planning should be adjusted at each period. The greater the uncertainty, the more replanning occurs.

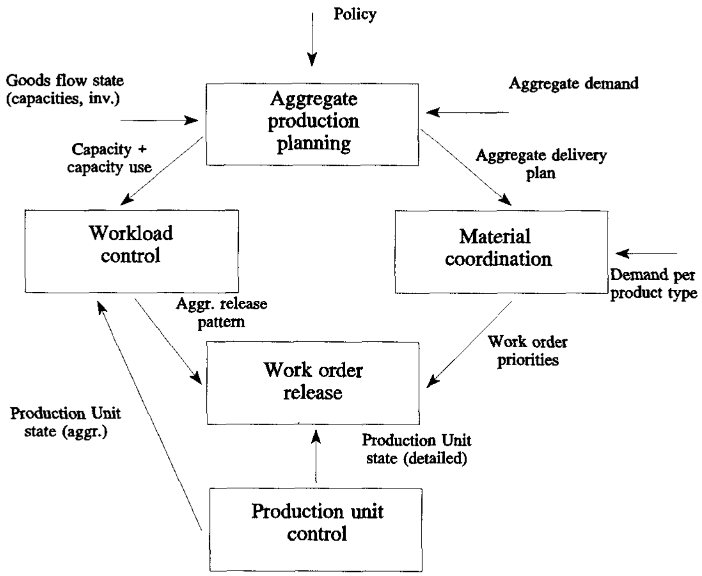

Figure 3 Global goods flow control structure (Bertrand *et al.*[12,p.58])

Bertrand *et al.*[12] separate the production control problem into the production unit-control problem (how to achieve the agreed performance, given specific environmental restrictions) and the goods flow control problem (how to realize for each production unit the agreed environmental conditions and to realize the overall production control objectives at the same time?). Goods flow control is decomposed into two control levels: *aggregate production planning* and *material coordination* (figure 3). The aggregate production planning level forms the connection with the higher levels of control in the production organisations, where integration of the various control aspects of the organisation (logistics, quality, and so on) takes place. In material coordination, priorities are determined for the release of work orders for production-items. These priorities are based on detailed demand information and on the work order throughput times of the various stages. The release possibilities can be restricted by other (finer) operational constraints of the production unit and by material availability. *Work load control* and *work order release* constitute the interface of goods flow control and production unit control.

The level of management that concentrates on structural optimization is concerned with the aggregate production planning in chain perspective, whereas process optimization refers to workload control and material coordination. In this research these three planning elements take a central position when discussing logistic control.

B. Logistic control variables

Logistic control variables are the decision variables, which are responsible for the steering and control of supply, production and distribution. They represent the basis on which the different decisions are taken. The actual steering points are deducted from the logistic goals formulated by top management. Durlinger[16] makes a distinction in dependent and independent variables. When the value of an independent variable is changed, the values of other independent variables do not change whereas the values of dependent variables do change. For example, if the setup-time can be reduced this will influence the capacity utilization degree but it will not affect the used batch quantity. Durlinger calls these independent variables *control variables*. As examples Durlinger mentions set-up times, batch progress times, machine and labour capacities, batch sizes, demand, routings, and scheduling. Bertrand *et al.* [12] distinguishes several levels of decision functions. At the higher levels the decision variables are mostly aggregate variables which do not directly refer to specific work orders or customer orders. The function of the higher level decisions is to create the conditions for flexible, fast, and accurate processing of the orders. Periodically, say once a year, standards for batch sizes, capacity utilization degrees, manufacturing lead times and stock levels are simultaneously set by top management.

In this research, we distinguish three main control variables; the *capacity utilization degree*, the *average batch throughput time* of the product package and the *stock level* in total numbers or periods of demand. The position of the Customer Order Decoupling Point indicates the importance of stocks and time. Market demands indicate the importance of production flexibility, and so on. If, for example, a decision has to be made concerning the batch size, one can aim at a certain stock-level, degree of capacity utilization and/or lead time. Probably, all three variables play a role in the decision. Because of the perishability of the goods in the agribusiness, importance of lead time is great. From each variable, the desired norm and priority of the variable have to be determined in order to know how the decision is taken.

C. The information control

The control paradigm depicted in figure 1 refers to the information system as one of the distinguishable elements. The information system's task is to register the relevant internal and external data and convert it to control information. The controlling system takes decisions on the basis of this information and processes control actions. Different logistic control systems require different information systems, just as different production situations require different control systems. The general architecture of software for the support of logistic control consists of four elements: systems software (the application-independent software-packages which should be available before application programmes can run), state-independent processing systems (which allow the recording of recipes, routings, capacity types, standard lead times, and so on), application software which monitors the state and state-transitions of materials and orders, and finally the decision-support systems which should aid a human decision maker (Bertrand *et al.*[12]).

Currently, the vast majority of companies uses standard software packages which are in some way extended, modified or completed by the user. When a company applies a chain approach, demands on information systems change. New information exchanges will take place and decisions will be taken differently. Because of that, the content of the four levels of the architecture of information systems already mentioned will alter. In this paper, we are focused on two elements i.e. the application software and the decision-support systems. These represent the content of information flows within organisations and between organisations in the supply chain. The decision support systems will support different decisions at different control levels and therefore require different information.

D. The level of coordination

The fourth element that characterises the logistic control concept is the level of coordination or degree of integration between decisions taken (1) at different hierarchical levels within the organisation, (2) at different functional units in the organisation, and (3) in different organisations in the supply chain. Ballegooie[20] distinguishes three levels of integration within the organisation evolving from separate control systems for the functional units, materials management (integration of purchasing and production control) to internal logistics management (integration of materials management and physical distribution). Since our focus is on supply chain management, external integration is the central issue here.

In Boorsma and Van Noord[24] four different levels of chain integration are distinguished evolving from physical integration (e.g. by using packaging standards), information integration (tuning of information flows, e.g. EDI), integration at control level (cooperation by the systematic use of control information by chain partners) and organisational integration (positioning control activities in another link of the chain). In this study we are mainly focused on control integration. The aim is to reduce costs and to improve customer service. By linking the control information of several successive chain partners, the chain as a whole can react quicker and more effectively to market developments. The level of chain approach is defined by *the degree to which activities of separate links in the chain are attuned in order to plan, control and execute logistic processes*. The higher the level of information provision and coordination of plans between different participants in the chain, the higher the level of chain approach. Of course, the kind of information exchanged and the intensity of the information interaction have to be taken into account.

A framework to structure logistic control

Now that we have discussed the four constituent elements of the logistic control concept a framework can be presented, which can be used to structure logistic control and help in formulating hierarchical levels of chain approach for an individual organisation. When this framework is also applied to its the preceding and following links in the chain, a clear picture arises of the possible benefits of the different levels of chain approach for each link.

It is obvious that management does not just start by selecting a logistic control concept. As already stated, the choice of this concept depends on the strategy of the organisation and the characteristics of the market, product and process. Market demands of logistic performances have to be determined in terms of factors like lead times and flexibility. Product characteristics such as quality decay, recipes, and process characteristics such as product routings and -times, capacities and setup times have to be registered in terms of complexity, uncertainty and flexibility. Furthermore, decisions have to be made about the logistic goals, product-assortment, product market combinations, etc. All these factors have to be taken as input for the strategic decision concerning which logistic control concept to implement, including the level of chain approach the organisation wants to execute. The choice of a chain approach is a choice between alternatives with consequences for the layout and functioning of operational logistic control.

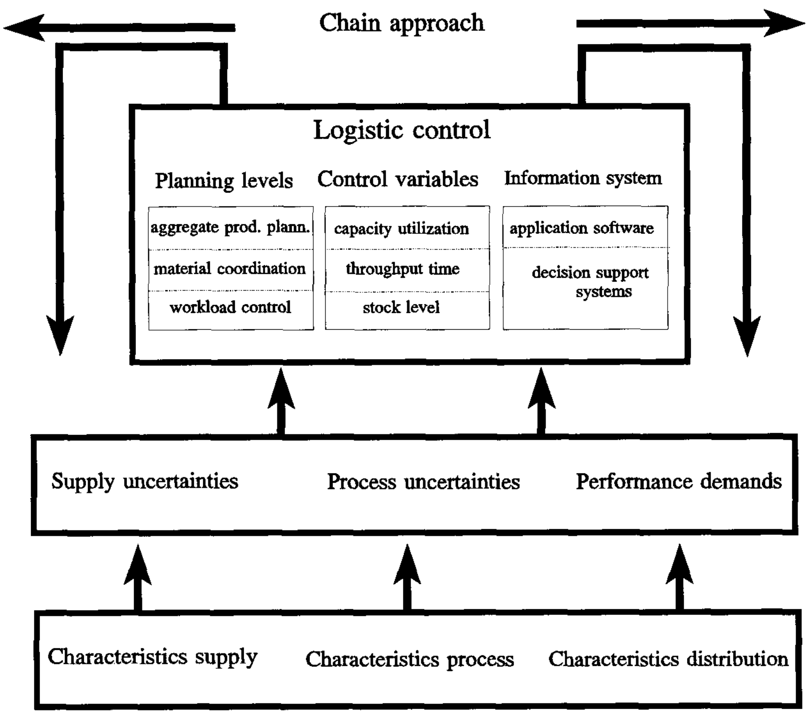

Figure 4 A framework for logistic control.

The framework consists of four layers each representing a phase of analysis. The first two layers form the basis on which the logistic control concept is designed. The fourth layer entails the formulation of hierarchical levels of logistic control in chain perspective. The four layers are:

1. characteristics of the primary production process, including the environment;
2. level of uncertainty in supply and process management;
3. layout of logistic control;
4. level of chain approach.

The layout of logistic control is characterised by the existing planning levels, control variables and information systems. The levels of chain approach that arise can be expressed in levels of coordination between decisions taken by different organisations in the chain. This framework is used in a case-study of the vegetable chain which is presented in the next section.

Case-study of the vegetable chain

The network considered involves growers, auctions, an export firm specialized in vegetables and fruits and retailers. A particular chain, consisting of one grower, an export firm and a retailer, is analysed according to the four distinguished phases of the framework. The emphasis is put on the logistic control function of the export firm as centre of the chain.

Applying the framework

1. *Characteristics of the primary production process*

The market can be characterised by multiple suppliers and customers in different countries. Every day, the highly perishable products can be bought at different locations at different costs and with different quality and lead-times. Customers want the products delivered in 24 hours and want them to be of an acceptable quality and at a low price. Usually, a great variety of products is ordered at one time. There is a seasonality in the supply of products. The firm has the possibility of repacking and storing the products. The products have a low unit-price and take up little space.

2. *Level of uncertainty in supply and process management*

Since we are dealing here with daily merchandising of perishable products, the mismatch between the necessary supply of products and the demand for products is relatively large. The export firm deals with a high level of uncertainty in supply and demand, both in quality and lead time. Additionally, the product price influences the purchasing quantity and thereby causes uncertainty in supply quantities. Every day claims are received concerning customer dissatisfaction about the delivered quality, quantity or time of delivery.

3. *Layout of logistic control*

Annually, agreements are made with major customers about quantities and prices and with contracted suppliers about quantities and specifications. The planning of procurement takes place on the basis of customer orders, available stock and expected customer orders. Approximately 75% of the products have to be purchased before customer orders are received. Customer orders are always accepted, independent of stock levels, and lead times are then fixed. Logistic control is a derivative of commercial sales, and has to fulfil the promises made by sales. Every day a new distribution schedule is produced based on actual customer orders. Supply control and process/distribution control are uncoupled. In other words, supply lead times are not tuned to distribution departing times.

The firm purchases its products mainly on expectations and consecutively delivers the products out of stock. Customer orders are not coupled with purchasing orders. Repacking can occur on customer order. The control variable time is one of the key performance indicators of the export firm. Because of the short lead times, production activities must start long before actual customer orders are received. Capacity utilization together with the costs are restrictions to the logistic system. Purchasing, supply, packing and distribution are all activities that have to be fulfilled within the limits of certain time-windows in order to achieve a high delivery reliability.

The export firm uses a central information system with several central databases. Personnel with different functions use different working fields and are not informed about the actions of co-workers. Few records of historical information are kept. Stock control takes place in batch mode; every evening stock mutations on the total of the day are registered. Procedures for activities are not formally written down.

4. *Level of chain approach*
The level of coordination between decisions in the export firm can be characterised by separate control systems for purchasing, production and distribution. This is depicted in the goals formulated for the different control systems; purchasing is judged on purchasing costs, sales on customer satisfaction and revenues and logistics on total logistic costs. These goals show an incompatibility since the purchasing department can buy his products at a low cost at an auction far away resulting in high transport costs and long supply lead times. Coordination in chain perspective hardly occurs; cooperation only takes place in the field of packaging.

Formulation of chain approaches
By applying the framework to the export firm a clear picture arises of the control structure. The next step was to analyse these four elements for the other chain participants in order to get insight into chain-improvement options. Having done this for a grower and a retailer, four levels of chain-integration for the export firm were formulated:

Level 0: Separate control systems for the links in the chain
This embraces the current situation in which internal improvements are obtained e.g. the provision of real time stock information together with an order acceptance procedure and the integration of supply, production and distribution planning.

Level 1: Dyadic information exchange in advance between links in the chain
Information is exchanged in advance concerning e.g. expected orders, current stock-levels, ATP (available to promise) in time and quantity. In that way supply uncertainties of chain partners will be reduced.

Level 2: Dyadic coordination of logistic control between links in the chain
At this level it is possible to influence the logistic control of suppliers or customers in order to obtain a higher logistic performance. For example, the grower coordinates his capacity plan with the exporter and the retailer gives Point-of-Sale and stock information. The exporter adjusts his control system and that of suppliers in order to fulfil the (agreed) demands of retailers.

Level 3: Coordination and information exchange over links in the chain

At this level direct coordination takes place between for example the grower and the retailer. The exporter functions as chain mentor and adjusts the applied logistic concepts of the different chain participants to each other. We are dealing here with a fixed chain in which the information exchange and coordination is optimal.

Starting from level 1, the layout of the chain is fixed; the export firm has selected specific suppliers and contracts with specific retailers. When the level increases more coordination takes place between the links in the chain. Since the logistic control of the different chain participants is better attuned, a reduction in logistic costs can be established (e.g. decreased stock levels, throughput times) and the logistic chain performance can be improved. However, the lack of decision freedom for each participant may decrease.

From the viewpoint of the export firm the levels are evaluated on their implications for the logistic performance. The results of the analysis gave the managers insight into the firm's logistic control structure in chain perspective. In this particular case level 1 was selected as the first objective.

Research perspectives

Current developments have led to a need for higher reliability and flexibility within the production system and the planning and control system. Hence, supply and process uncertainties will have to be evaluated and reduced. In this paper a framework is presented which can be used to structure logistic control and help in formulating hierarchical levels of the chain approach for the individual organisation. When this framework is also applied to the preceding and following links in the chain, a clear picture arises as to the possible benefits of the different levels of chain approach for each link. The practical value of the framework is briefly displayed in the case study.

In further research the framework will be elaborated upon. General levels of chain approach will be formulated and the distinguished elements of logistic control will be filled-in in detail. By means of simulation, changes in logistic control will be evaluated on their impact on logistic processes and the logistic performance. In this way the relationships between the four layers of the framework will be quantified. Finally, the compatibility of logistic control concepts applied by successive companies in agri-chains will be evaluated.

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