Simulation model for the apple chain

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Abstract
Numerous (simulation) models have already been made for all kinds of companies and products. Many of these models deal with the isolated problems of a separate company c.q. a link of a chain. This paper presents a simulation model for the entire apple distribution chain. The model aims to minimize the total distribution costs, taking into account the restrictions set by the final consumers. The model, although it is not ready for implementing in practise yet, can help the strategic decision making in the chain, while it is possible to evaluate strategic alternatives for there impacts. It is the author's hope that this paper can contribute to further exploration of (agri)chain modelling.

Keywords: chain logistics, operations research, simulation model, apple, distribution chain, quality, strategic decision making.

Introduction

Traditionally the logistical production chain is seen as a line of coupled, but separately functioning enterprises. The communication, co-operation and adaptability between organisations in these chains is not always optimal. The organisations are primarily concerned with their own position, profits and interests, which leads to the well-known sub-optimizations. Although all participants in the chain have different interests, they still have the mutual goal to provide the final consumer with an excellent product. Last years, it has become clear that enterprises do not stand alone in merchandising there products, but that they are a part of a greater whole of economical activities in the successive links of the production chain. Therefore, an integral approach of the production chain is necessary (De Vlieger, 1992).

Chain logistics can play an major role in improving the performance of all the organisations in the chain separately and as a whole. Chain-logistics aims at the streamlining of the entire logistical chain and chain management, the improvement of the position of the organisation in the chain and of the position of the chain with respect to competitive chains (Van Ballegooie, 1992). The production chains are not always restricted to the national borderlines of the country, but may also reach over these borderlines. This is especially so for an exporting country as the Netherlands are.

This paper deals with the apple chain. The Netherlands are exporting a great deal of its produced apples. Our main export market is Germany, where we have to compete with apples from all over the world. At the moment, the fruit-market in West-Europe is coping with satiation symptoms, where the Dutch supply is ever more increasing. The supply of high quality apples is probably the only way to market these products (De kleijn, 1992).

This paper presents a method which can help to solve the above mentioned chain problems: a simulation model of the apple distribution chain. The aim was to develop a model which is able to evaluate different distribution chain arrangements with respect to costs and quality-decay. First of all, such a model can give more insight in the functioning of international agricultural chains in order to reach an optimal market supply for the consumer. Furthermore, the model may be helpful to localise logistical handling of which the costs can be reduced, taking into account the quality and environmental demands asked for by the market. Finally, use of this model can improve the insight in the coherence of the elements of the apple chain, the logistical processes that take place during the distribution, the costs of these processes and the quality-decay that occurs during these processes.

In section 2, a description of the apple chain is given. Section 3 presents the simulation model, whereas section 4 discusses the quality(decay) and decision making in the apple chain. The status of the present simulation model is discussed in section 5, and finally the conclusions are presented in section 6.

Description of the appel chain

The research has been restricted to the export of Dutch apples to Germany. In 1992, almost 490.000 tons of apples were picked in the Netherlands. The main apple species are Elstar (143.000 ton) and Jonagold (135.000 ton). From the total amount of apples, about 50% is used for the inland consumption, about 10% is further processed by the industry and about 40% is exported. Half of the amount of exported apples goes to Germany. (ZMP-bilanz, 1990 en PGF, 1992)

But how are the Dutch apples distributed from the Dutch producers to the German consumers? *Figure 1* shows the different possibilities.

The apple chain consists of some successive links starting with the producers and ending with the German consumers. The producers have two possibilities to distribute their products. They can either be a member of an auction and deliver all their products to this auction, or they can sell their products directly to the merchants. When the products are merchandised through an auction (which happens with 75% of the apples), the products are bought by exporters (64%), wholesale dealers and multiple shop organisations (24%), industry (4%) and retailers (7%) (CBT, 1991). In general, the actual purchase is done by so-called commission-agents, who buy the products for the merchants for a certain commission. Most of the apples are distributed to Germany via exporters, who sell these pro-

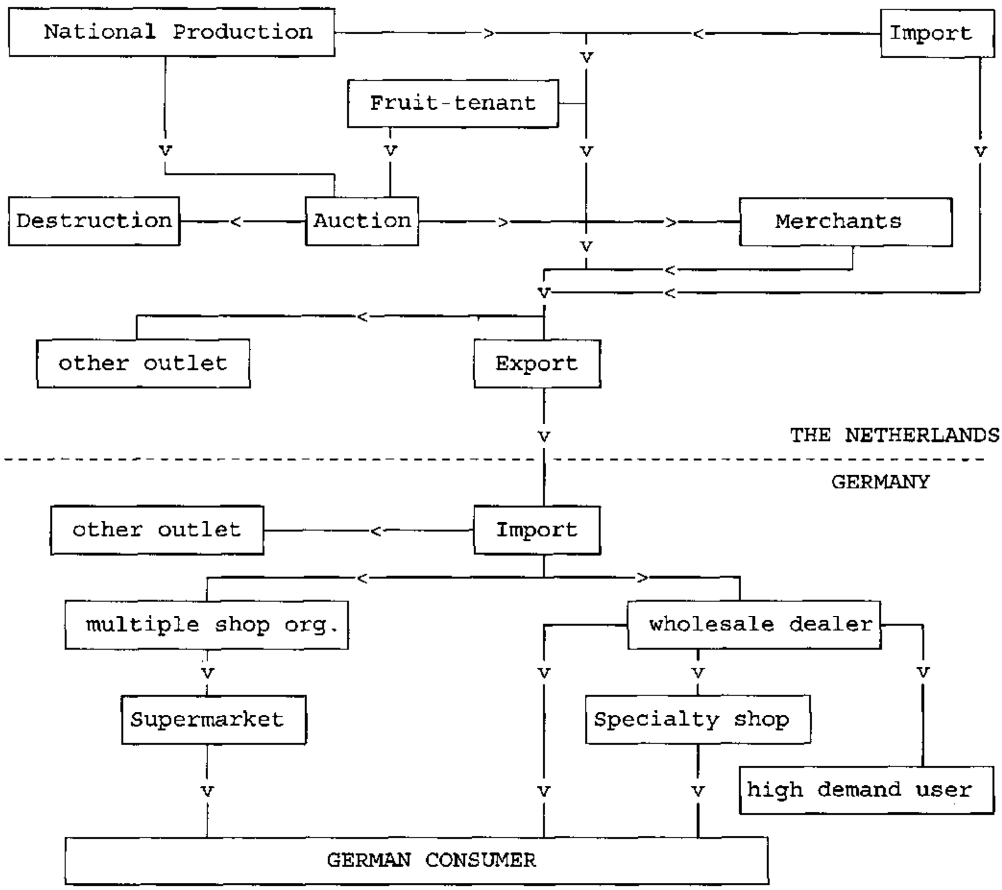

Figure 1. The structure of the apple chain.

ducts to German multiple shop organisations or wholesale dealers. Finally, the apples reach the consumers via supermarkets or specialty shops.

Logistical processes
In order to obtain more insight in the logistical processes that take place in the distribution chain, the activities of the different participants are briefly discussed.

The producers
The picking of the apples starts in August, with the summer species, and ends in October. The apples are usually gathered in boxes of 325 kilograms, sometimes in wooden crates of 20 kilograms. After the harvest, the producer has to decide whether he will store the apples (only for the preservable species) or market them. Apples can be stored at the auction or at the farmer's house, depending on the storage facilities of the producer. In prac-

tise, about 60% of the apples is stored at the producer's farms and 40% at the auction. There are three different storage possibilities (IKC-fruitteelt, 1989):

1. cold storage
   The temperature is dropped by mechanical cooling until 1 à 2 °C. In addition the air humidity is sometimes raised.
2. cold storage with controlled atmosphere (CA-storage)
   Besides the low temperature, the oxygen-percentage is dropped until about 16% and the carbon dioxide percentage until 5%.
3. cold storage with ultra-low-oxygen (ULO-storage)
   This is a form of scrubbed CA-storage were the oxygen-percentage is dropped until about 2%.

The months after the harvest, the stored apples must be merchandised and taken out of the storage cells. In which month this happens depends on the remaining quality and the price setting of the apples. When the apples come out of the storage cells, they have to be sorted and packed. The evacuation of a complete storage-cell takes about two to three weeks. The sorting of the apples (which can take place at the farmer's home or at the auction) is based on the measurements colour, weight, size and quality of the apples. After the sorting the apples can be packed in different packages: the most important packages are the wooden crate (60 x 40 cm, 12 kg) or the cardboard box (60 x 40 cm, 12 kg or 40 x 30 cm, 10 kg). Finally, the apples are transported either to the auction or directly to the buyer (usually the exporter). This transportation can take place in conditioned and in unconditioned vehicles.

Auction
There are several ways to market the apples through the auction. The traditional way is to sell by auction and actually deliver the products at the auction. The apples are then 'blocked' and sold for the clock. Other ways of distributing the apples are all through mediation by the auction. By most of these methods, the buyer of the products is known in advance. The producer prepares the apples (sorting, packaging) by the wishes of the buyer, and delivers them sometimes directly to the buyer.

The apples arrive at the auction in the afternoon or evening the day before auction takes place. After the inspection (which is a control of the sorting) the apples are blocked and positioned in the auction hall. During auction, uniform blocks of apples are being offered. The buyers can take a number of crates of apples out of the blocks for the price set by the clock. After auction, the apples are taken out of the blocks and are grouped at a dockside for each buyer. If the packaging does not satisfy the buyer, he can repack the products (at the auction or at home) and put them in another packaging. Then the wooden crate is mostly replaced by the cardboard box.

Exporters
There are two kinds of exporters, the fruit-exporter and the packet-exporter. The fruit-exporter only deals in fruits, the packet-exporter mainly deals in vegetables with fruit as an addition to the packet. The exporter buys his products at several auctions and/or directly from producers to get the right assortment. In general, all these products are transported

to a central place, where they are regrouped depending on the next buyer. It's also possible that the exporter does not have a buyer yet, but that he wants to speculate with the products, i.e. he stores the products and waits with selling them until the price increases. This cold or unconditioned storage can take place at the exporters company or at the auction.

German buyers
Buyers of the Dutch apples in Germany are the wholesale dealers or the multiple shop organisations. The transportation from the exporter to Germany, which can take place conditioned or unconditioned, is most often done by professional transporters. Over 80% of the amount of apples are distributed by the multiple shop organisations. The remainder of the apples reach the retailers by way of the wholesale trade market (De Kleijn, 1992 and Heisters, 1988). With both ways, the products can (and probably will) be stored, repacked and transported again, before they reach the final buyer, the consumer.

Conclusion
When you closely look at the successive logistical processes that take place during the distribution of the apples, you will notice that these processes consist of a repeating cycle of three handling: storage, (re)packing and transportation. For each of these processes, there are several ways to carry out the process. Storage can take place for several months or weeks and under several conditions, (re)packing can be in several packages and transportation can be over different distances and under several conditions.

Quality in the apple chain
As stated in section 1, delivering products with a high quality standard is a necessity to survive the tough competition in international agricultural markets. Competition is not only based on the price, but also on the quality of the products, especially in a satiated market. 'Quality of the delivered goods' is defined as the degree in which the performance of the supplier satisfies the expectations of the buyer. The performance is primarily evaluated on grounds of specifications of product-quality, quantity and costs (price) and secondly on the delivered service. Based on interviews with participants in the apple distribution chain, several critical moments or aspects are localised with regard to the product quality. They refer to the next points:

1. The picking moment.
   To get a homogeneous group of apples, the producer should have several picking-times for each specie. Each time only those apples should be picked that are sufficiently ripened at that moment (IKC-fruitteelt, 1989). In practise, this is not sufficiently done.
2. Storage.
   Often, the take-in and take-out time of the apples out of the storage cells takes too much time. These periods have to be as short as possible to preserve as much of the quality as possible. Especially, on these moments are the environmental conditions far from optimal. Apples have to be stored under optimal conditions.

3. The auction hall.
   The period in which the fruit is waiting for the auction and for the transportation is often too long and under non optimal conditions.
4. The lead time.
   The lead time of the apples through the chain (and through the separate links of the chain) is often much too high. It can take up to two months after long-time storage before the apples reach the German consumer.
5. Conditions in the chain during distribution.
   To deliver the apples in Germany with an optimal quality, the products should be in a conditioned environment at all times during distribution. There are too many moments in the apple chain in which this condition is not met.
6. The retail store.
   There is hardly any quality control by the wholesale dealers and retailers. While the apples are only a small part of their business, there is often little product knowledge and therefore also more quality-decay.

The simulation model.
It is hardly possible to express all distribution chain dependencies in mathematical relations, as a lot of factors interfere. However, it is not always necessary to formulate all these dependencies; often the modelling of only the most important factors can give a good insight in the problem. Prior to the formulation of the model, some assumptions have to be made. These assumptions are summarised in the next section. Section 3.2 and 3.3 concentrate themselves on the basis resp. the functioning of the model.

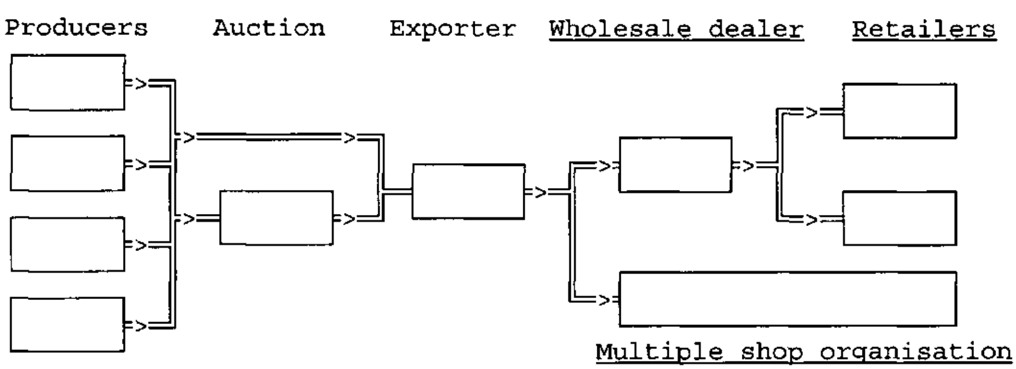

Figure 2. The modelled distribution chain of apples (the German participants are underlined)

Assumptions.
As explained in section 2 there are several distribution paths that lead from producer to consumer. In this explorative research, we have chosen to model the distribution chain, that provides the greatest throughput. Based on interviews with participants in the apple chain (producers, auctions, research institutes) the following chain has been selected:

The modelled chain consists of five participants c.q. actors, namely the producer, auction, exporter, wholesale dealer or multiple shop organisation and retailer. The producers pick the apples and sell them, after a certain storage-period, at the auction or directly to an exporter. The buyers from the exporters are the wholesale dealers or the multiple shop organisations, who distribute the apples further to retailers resp. chain stores. This last link in the distribution chain aims to represent the wishes of the consumers with regard to quality, quantity and packaging.

Assumptions

1. Number of actors per link.
   The model has been formulated for only one possible behaviour per link. Decisions that have to be made in a link (for example, when are we going to pick the apples?) are taken the same way for all the apples. You could say that each link has only one actor: there is only one producer, who sells his products to one exporter, etc.
2. Logistical processes.
   We concluded section 2.1 with the statement that the logistical processes which take place in the apple distribution chain consist of a repeating cycle of three handling, namely storage, (re)packing and transportation. In section 2.2, we concluded that especially the *moments between* two successive handling influence the quality-decay. For example, the time in which the apples are standing in the unconditioned auction hall. We assume that these moments always take equal time, and therefore result in the same quality-decay. This quality-decay is added by the handling the moment belongs to.
3. Distribution.
   First of all, we assume that all apples are picked at the same time. Furthermore, we assume that the long-term storage cells (cooling cells, CA- or ULO-cells) can only be opened at the beginning of each month, where short-term storage (not conditioned or cooled) during distribution can take place for zero, one or two weeks. The exporter can store for zero or one week, the wholesale dealer for zero, one or two weeks. This means that the apples, which come out of the storage cells at the beginning of a month (with an, for the stored apple specie, optimal temperature), are distributed during the four weeks of that month. The simulation c.q. optimization also takes place per month. As the smallest time-unit is one week, we assume that packing (in wooden crate or cardboard box) and transportation (conditioned or not conditioned), both a matter of hours, cost no time at all.
4. Capacities.
   We assume that there are no capacity-restrictions. All apples can be stored, transported and packed at all times and in all links.
5. Quality.
   We assume that all apples have the same quality at the time of the picking. In practise, quality-variations in a parcel of apples appears during the distribution of the apples. We assume that there are no variations in quality in a parcel which has followed the same successive logistical processes.

6. Costs.
   The total chain costs are minimized in the model. These are not the actual chain costs, because we are only looking at those costs which are decisive for the selection of a possible logistical handling. Costs as profits, production costs, etc. are not taken into account while we assume that these costs are equal for all possible distribution chains. Therefore, the total chain costs should be considered as an indicator of the differences between possible distribution chain arrangements and not as actual chain costs.

The basis of the model.
The simulation model is based on a decision tree. This tree is a graphical reproduction of all the successive decisions that have to be made within the distribution chain. A decision consists out a choice out of a number of possibilities, whereby each possibility affects the state of the products. In our case, the decisions reflect the logistical processes in the apple chain. *Table 1* summarizes the successive logistical processes being modelled.

As can be seen, the first decision reflects the long-term storage at either the producers farm or at the auction. The second decision reflects the sorting and packing of the apples, etc. Each decision contains a number of possible ways to carry out the logistical process. For example, long-term storage can take place in unconditioned, cooling, CA- or ULO-

Table 1. The logistical processes which have been taken along in the model.

Decision	Logistical process.
1	long-term storage at the producers farm or the auction.
2	sorting and packing of the apples at the producer's farm.
3	transport of the apples to the auction or to the exporter.
4	short storage by the exporter.
5	repacking by the exporter.
6	transport to the wholesale dealer or the multiple shop organisation (MSO)
7	short storage by the wholesale dealer or MSO.
8	repacking by the wholesale dealer or MSO.
9	transport to the retail trader or chain store.

Table 2. Different possibilities for the logistical processes.

	logistical process	possibility 1	possibility 2	possibility 3	possibility 4	possibility 5
1	long-term storage	unconditioned	cooling cell	CA-cell	ULO-cell	
2	sorting and packing	wooden crate	cardboard box			
3	transport to exporter	unconditioned	isotherm			
4	short storage exporter	none	1 wk uncond.	1 wk cooled	2 wk uncond.	2 wk cooled
5	repacking exporter	none	cardboard box	small packaging		
6	transport exporter	isotherm	cooled			
7	short storage wh.dea-ler none	1 wk uncond.	1 wk cooled			
8	repacking wh. dealer	none	cardboard box	small packaging		
9	transport wh. dealer	isotherm	cooled			

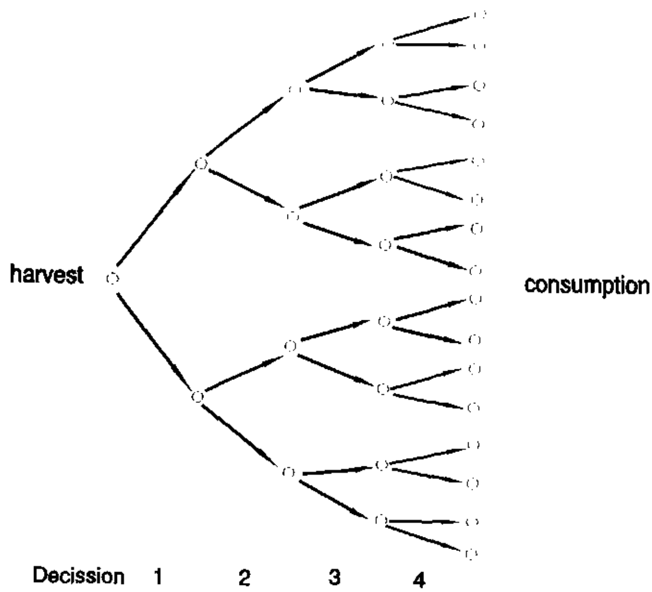

Figure 3. A decision tree with 4 successive decisions, each having 2 possibilities

cells. In *table 2*, the different possibilities for the nine logistical processes are summarized.

With Table 2 we can set up the decision tree for the apple chain. This tree consists of nine successive decisions with each at the most 5 possibilities. *Figure 3* gives an example of a decision tree with 4 successive decisions, each having two possibilities.

This tree represents the apple chain, through which the apples float from the producers (on the left side) to the consumers (right side). There are numerous ways for a parcel of apples to be distributed from the producer to the consumer. The chain starts with a certain state in which all the apples occur. The state of a parcel of apples at any moment during distribution is determined by quantity, quality, packaging and time. After each decision, the state of the parcel is changed. For example, if 50% of the apples are stored in a cooled cell for one week, the quality decreases, the quantity halves and the time increases with one week. The original 100% picked apples is divided over several parcels of apples which float in different ways through the decision tree (from the left to the right) and are therefore submitted to different logistical handling. At the end of the chain, also the right side of the tree, the state of the different parcels of apples has to satisfy the demands of the consumers. At a certain time there has to flow a certain quantity of apples, which posses a certain quality and packaging, out of the tree.

The functioning of the model.

Each 'path' through the decision tree results in different states and costs. In the mathematical notation of this problem, it is possible to formulate these product flows with flow-variables and equality equations. In each one of these equations, the balance is made up

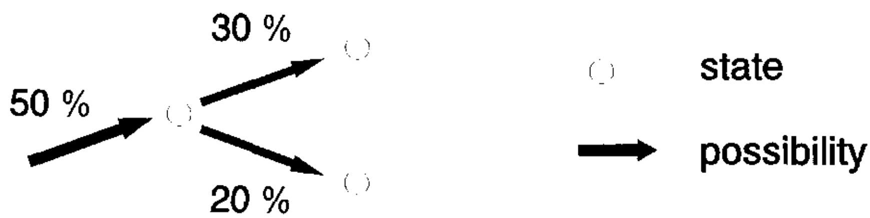

Figure 4. Graphical presentation of a decision with two possibilities of a certain logistical process; 30% of the original 50% of apples are submitted to possibility 1 and 20% to possibility 2

for the logistical process the decision reflects; the total quantity of apples that is submitted to one logistical handling (also a decision) is divided over the several possibilities of this handling (*Figure 4*).

When a possibility is chosen for a certain quantity of apples, the state changes according to the given influence of the handling. In addition to these balance equations, there are demand equations. In these equations, the states of the apples at the retailers have to be equal to the demanded quality, quantity and packaging by the consumers. In order to formulate the problem mathematically all the branches in the tree (i.e. each possibility of each successive decision) are numbered. In this way, it is possible to formulate all the balance and demand equations in an uniform way.

The mathematical notation of the model is implemented in Sciconic. The program consists of a main program, a subroutine, several data-files and a report-writer. When the model is activated by a user, following algorithm is executed:

1. The user of the model can select his own distribution month, distribution country (Germany or the Netherlands) and long-term storage place (auction or the producers farm). Different input-dates are taken, dependent on the choices the user has made.
2. Because the influence of each logistical process (each branch in the tree) on the state of a parcel of apples is known in advance, we can calculate the state of the parcel for any branch in the tree. This is done in the subroutine. Now, we can compare the final state of the apples, at the right side of the tree, with the demanded states by the consumers. If these states for a certain 'distribution path' do not harmonize with each other, this path is excluded for the optimization.
3. Finally, a linear optimization takes place for the remaining 'distribution paths' where the total distribution costs are being minimised. This results in an optimal 'distribution path' for each week of the selected month and for each demanded state of the apples.

With this model, alternative distribution routes can be compared for their costs and appearing quality-decay. It is possible to measure the influence of the different logistical processes on the distribution costs and the states of the apples.

In the research a case-study has been carried out, using estimated data. In this study, the quality of the apple was reproduced by the constipation of the apple, as most data with regard to the quality concerned this apple characteristic (Cramwinckel, 1991 and De Jager, 1993). Therefore, we can present some possible outcomes of the model:

- When the apples are longer stored, the total distribution costs are higher. This is, besides the higher storage costs, due to the higher quality-decay. During the remaining distribution period, higher costs (more cooling) must be made to preserve enough quality. For example, all the transportation has to be under conditioned circumstances. The longer the storage period is, the better a total cooled distribution chain has to be reached.
- When the apples are stored at the auction instead of at the producer's farm, more quality-decay takes place. This is so, because most of the times the sorting is done at the producers farm and therefore the apples remain more time in an unconditioned environment. Therefore, the sorting should take place near the storage-cells.
- The total distribution costs depend on the total allowed quality-decay. If more quality-decay is allowed, less costs have to be made during the distribution to satisfy the customer's demand. For example, the apples can be transported in unconditioned vehicles.

The present model shows, that modelling of a distribution chain is possible and can give additional insight in the arrangements of the distribution chain. However, there are still some shortcomings in the model. The most important ones are discussed in the next section.

Quality and decision making in the apple chain

The presented simulation model forms the bases for a larger model which could support the strategic decision making in the apple chain. This model will allow us to evaluate strategic alternatives on their effects. First, the presented model should be expanded. Considering the assumptions (section 3), we choose to concentrate on the quality(decay) and on the situation with several active actors per link in the chain. Section 4.2 discusses the quality and quality-decay during distribution and section 4.2 discusses the decision making in the various links of the chain.

Quality and quality-decay.

We have defined 'Quality of the delivered goods' as the degree in which the logistical performance of the supplier satisfies the expectations of the buyer. Focusing on the product-quality, we can define the product-quality as the degree in which the characteristics of the product satisfy the user. All of these characteristics have to satisfy a certain minimum demand; a satisfying quality at a certain moment means that the whole of quality characteristics satisfies the whole of quality demands at that moment in the chain (Saedt, 1989).

The question, however, is which of the apple characteristics determine 'quality'? Therefore, several participants of the apple chain have been interviewed and asked for their definitions. This resulted in the following apple quality characteristics: colour, ground-colour, constipation, size and purity of the apple. The colour and the size are not affected during distribution, whereas the other characteristics are. During the interviews, it turned out that the successive participants in the chain do not have the same demands for all of these characteristics. For example, the producer is more concerned about the colour, largeness and the constipation, whereas the retailers give priority to the purity of the apple.

During the distribution, not all the apples are exposed to the same environmental conditions. For example, apples on the outside of the tree are exposed to more sunlight then the ones in the middle. Also storage-cells contain a certain dispersion in temperature and gas-composition. Because of these dispersions in environmental conditions that occur at all logistical handling, an ever greater variation in quality occurs when the apples are distributed (Meffert, 1991).

In the present model, the quality parameter is expressed by one of the above mentioned quality characteristics. In order to catch the real quality-life during distribution in the model, it should be possible to take more quality-characteristics and the occurring quality-variation along. In the model, both expansions can easily be made applying probabilities.

Decision making in the various links of the apple chain

The quality of the produced products and of the finally consumed products are affected by the decisions taken in the successive links of the chain. Therefore, we have to give some attention to these decision making-processes. In practise, there are three factors which play an important role in the decision process; quality, quantity (availability) and costs (price) (Van den Berg, 1991: 197). During the distribution, a number of decisions are taken that are decisive for the progress of the product stream. These decisions based on the three mentioned factors affect the state of the apples. Each actor bases his decisions on the available information. Because the available information can vary for different persons (due to different information sources) and because every person interprets the available information in his own way (due to different backgrounds, educations, etc.), differences can occur in the decisions taken by different persons (Steenkamp, 1986). The present simulation model incorporates only one possible behaviour (decision making) per link (see section 3). In reality, there are many possible behaviours per link. Each different combination of these behaviours results in a different product stream, i.e. a different distribution chain, and different lead times within its chains. Our model, which encloses the greatest product stream, allows to simulate these different behaviours in the distribution chain. Probably, it is also possible to model these different behaviours per link applying probabilities.

Status of the present simulation model

The present model optimizes the total distribution costs for a chosen month, taking into account the restrictions set by the final consumers on quantity, quality and packaging. The model can be used to compare and evaluate various ways to carry out logistical processes (storage, packing and transportation) in the distribution chain, with respect to their impact on quality and costs. The result of the model is a distribution chain for which the best way to carry out each logistical process is presented.

However, there are still some shortcomings in the model. For example, only the largest product stream is modelled, only one participant per link is taken along and the model operates with fixed storage periods. Furthermore, the quality-life of the apples is not taken along conform the reality and the model does not give any indications about profits (which are often decisive for a certain decision). But these shortcomings do not decrease the applicability of such a model. With some expansions of the model, it will be a close description of the reality. The main problem of the functioning of the model at the moment is the availability of reliable input data. A lot of data concerning the costs of logistical handling and of the quality-decay that occurs are not available yet. Even a sophisticated model can not replace the lack of reliable input data.

Conclusions

In this paper a model is described which can help the strategic decision making in the apple chain. With the model strategic alternatives can be evaluated on their (positive and negative) effects. The present model calculates the optimal way to distribute the Dutch apples to Germany, i.e. with minimal costs and satisfaction to demands concerning quality, quantity and packaging. Although this model does not completely reflect the complex reality, it shows that such models can give insight in complex situations and in the effects of different strategic alternatives.

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