Effective Food Supply Chains

Generating, modelling and evaluating supply chain scenarios

Jack G.A.J. van der Vorst

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Abstract
The research described in this thesis aimed at ① obtaining insight into the applicability of the concept Supply Chain Management (SCM) in food supply chains (SCs) from a logistical point of view, and ② finding an efficient and effective method to analyse and redesign the SC to improve SC performance. Via a multidisciplinary literature research the concept of SCM was defined and a generic list of SCM redesign principles was generated. Three case studies were used to devise a research method on the generation, modelling and evaluation of SC scenarios. Central elements in this method are ① the focus on the identification and management of the sources of uncertainties in SC decision making processes, and ② the use of simulation and field tests to evaluate SC scenarios. A modelling framework was developed in this research that captures the relevant concepts of the SC system needed to adequately model and simulate the dynamic behaviour of food SCs. In each case study a new SC scenario could be identified that performed considerably better than the current scenario.

Preface

This thesis presents a step-by-step approach to generate, model and evaluate supply chain scenarios in food supply chains. By applying the approach in actual supply chains the competitiveness, that is the effectiveness, of those chains can be improved, thereby explaining the title of this thesis. It is the result of a multi-disciplinary research on which I look back with great pleasure. Many people have contributed to the completion of this thesis. This seems the ideal place to express some words of thank.

I started this research in 1994 with only a project-title: *Logistic control in chain perspective – planning in uncertainty*. Although the words are closely related to the current contents of this thesis, the intended outcome of the research was very unclear at the start. Especially in that first year I experienced the necessity of having a clear and scientific founded research proposal. I was very fortunate to have two members of my supervisory board to ‘pick up’ and help focus the research after some ‘start-up problems’. Also becoming an Assistant Professor in 1996, with all associated educational activities, helped me in finding my way. Chapter three, for example, is for a great deal the result of preparing lectures for the IGB-course.
I would like to express my gratitude to Adrie Beulens and Paul van Beek for taking the effort and having the enthusiasm to guide me through the PhD-research and making the ‘end of the tunnel’ visible for me. Adrie, thanks for the elaborate and fruitful discussions (amongst others on ‘ontology’ issues), the many laughs, and the interesting experiences in doing the ECR-project together. Paul, thanks for the contributions you made in shaping my thoughts during the past twelve years and the constant interest in my personal and professional well-being. You both have become more than just thesis advisors to me.

Many thanks to all organisations involved in the case studies without whose co-operation this thesis would not have been possible. A special word of thanks to Henk and Erwin; the enervating discussions resulted in useful outcomes (also in follow-up student projects) and inspired me to find solutions which could help you do your business even better! Related to the ECR-project I would like to thank Wim de Wit for the pleasant co-operation; you were always at ease and never a question was left unanswered. I really enjoyed working with you all. I would also like to thank the students, whose work contributed in one way or another to the completion of this thesis. Fred, Niels, Geert, Hilbert, Eva, Maarten and, especially, Stephan .. many thanks. Will Bertrand, thanks for the interesting discussions and useful suggestions on several draft versions of this thesis.

One of the main factors that made me start this research in the first place, were the colleagues of the Management Studies Group. I must say that I really enjoy(ed) working with you all; especially the lunches, diners and trips with many good laughs stimulated me to keep on

going. Thanks for keeping the educational work load at an appropriate level. Also the co-operation with all enthusiastic lecturers in IGB was very motivating as well as the co-operation with Frans Ruffini, with many interesting ‘walks and talks’ at international conferences in Padova, Dublin, and Venice.

A lot of thanks to my father and mother for supporting me all those years in many ways and for giving me the opportunity to study. Furthermore I would like to thank my family and friends (especially the ‘Pistols’) for their interest in my research.

Last, but definitely not least, … Sascha … many thanks for being there all the time, for your confidence and understanding (especially in the last year) and for reminding me every now and then what life’s all about.

Wageningen, July 2000 Jack van der Vorst

Summary

The overall objectives of the research described in this thesis were to obtain insight into the applicability of the concept Supply Chain Management (SCM) in food supply chains (SCs) from a logistical point of view, and to find an efficient and effective method to analyse and redesign the SC to improve SC performance.

Background
The background and rationale of this thesis are discussed in Chapter 1. Interest in SCM has been spurred by recent socio-economic developments. Because of demographic and socio-economic developments (e.g. strong increase of the ageing population, more double-income families) there is a growing demand for fresher products and products with higher added values. Furthermore, the effects of globalisation, the market entrance of new competitors, and stricter governmental requirements for food safety and environment-friendly production place increasing demands on management. These developments have resulted in a change in performance requirements for food SCs as a whole and, consequently, for all stages in the SC. Managers realised that sub-optimisation occurs if each organisation in a SC attempts to optimise its own results rather than to integrate its goals and activities with other organisations to optimise the results of the entire chain. This holds true especially in food SCs where particular actors in the SC can damage all the efforts taken in another stage to preserve high product quality. There has been growing recognition that it is through logistics and SCM that the twin goals of cost reduction and service enhancement can be achieved. The recent developments in Information and Communication Technology facilitate this process.

Research objective and questions
The main questions food companies face are *whether, how,* and *with whom* they should start SCM activities. They should be able to analyse what SCM can do for them and find out what the consequences might be if a SC view is taken together with one or more supplier(s) and/or customer(s). An extensive literature research did not reveal any integral method to generate, analyse and evaluate SC redesigns, i.e. SC scenarios (Chapters 2 and 4).

Our *research objective* was therefore to contribute to the body of knowledge on SCM by developing a step-by-step approach that could generate, model and evaluate SC scenarios in specific food SCs. That is, we aimed to develop:

① a research method to analyse a food SC and to generate a number of SC scenarios that are estimated to improve the current SC performance;

② a research method to assess the impact of different SC scenarios for a particular food SC on SC performance and to identify a 'best practice' SC scenario.

A 'best practice' SC scenario refers to a feasible SC scenario that achieves the best possible outcome for the whole system with respect to predefined SC performance indicators. Both methods should assist managers of food companies in evaluating their current position in a food SC and in deciding whether and how they should redesign the SC.

In Chapter 1 we developed a *proposition* to guide our research. Because of rapid changes in markets, products, technology, and competitors, managers must make decisions on shorter notice, with less information, and with higher penalty costs than in the past. Decision making uncertainty has increased regarding what developments managers should react to and what impact possible actions may have. By breaking down the walls that are present between successive SC stages, decision making uncertainties may decline, since more information and control possibilities will become available to the decision-makers in each stage. This led us to the following proposition:

To identify effective SC scenarios one should focus on the identification and management of the sources of uncertainties in SC decision making processes.

On the basis of this proposition the following three *research questions* were formulated:
① What is the relationship between uncertainty in SC decision making processes and SC performance in food SCs?
② How can we identify potentially effective SC scenarios for a particular food SC? (validation of the proposition)
③ How can SC scenarios be assessed with regard to SC performance and the individual performance of the SC participants?

Research design
Considering the research objectives and type of research questions to be answered, we used the multiple-embedded case study design. This research followed the inductive/deductive research cycle, in which literature and case studies were used to devise a research method on the generation, modelling and evaluation of SC scenarios. Three case studies were selected. Case I was conducted in a fresh food SC, comprising growers, auctions, an exporter of vegetables and fruits, and foreign retailers. Case II comprised a salad producer and a retail organisation (made up of a retail distribution centre and retail outlets). Finally, case III comprised two suppliers of desserts, a cheese producer and a retail organisation. We used the chosen case studies in two ways:
- All three exploratory case studies were used for theory building, addressing ① the relationship between uncertainty and performance and ② the identification of potentially effective SC scenarios.

- The two latter case studies were further elaborated upon to explore the area of ③ assessing the impact of SC scenarios on SC performance, in order to identify a 'best practice' SC scenario for that particular food SC.

Main definitions

Chapter 2 showed that there is no generally accepted definition of a SC and SCM. The dispute mainly focuses on the level of analysis. Based on the findings in literature, we defined a supply chain as the series of (physical and decision making) activities connected by material and information flows that cross organisational boundaries. SCM was defined as follows:

Supply Chain Management is the integrated planning, co-ordination and control of all logistical business processes and activities in the SC to deliver superior consumer value at less cost to the SC as a whole whilst satisfying the requirements of other stakeholders in the SC.

Our system and process view on SCs was presented in Chapter 3, resulting in a definition of a SC scenario:

A SC scenario is an internally consistent view of the settings of all SC redesign variables concerning the managed, managing, and information systems and organisation structure in the SC.

The four descriptive system elements comprising a SC scenario were described in detail in Chapter 3. A *SC redesign variable* is defined as a management decision variable at strategic, tactical or operational level that determines the setting of one aspect of the SC configuration or management and control. Furthermore, we identified *Key Performance Indicators* (KPIs) for food SCs that are needed to assess the effectiveness of SC scenarios, i.e. the degree to which the SC objectives are fulfilled. Finally, Chapter 3 concluded with a conceptual model that can be used to describe, analyse and typify a SC in detail to facilitate the SC redesign process.

Approach for SC analysis and redesign

In Chapter 4 we developed a preliminary research method for generating potentially effective SC scenarios. First, a review of literature in several areas (SCM, Logistics Management, Business Process Re-engineering and Operational Research) led us to a generic list of 22 SCM redesign principles that are thought to be able to improve performance on one or more SC KPIs. Each redesign principle refers to alternative settings for one or more of the SC redesign variables, thereby representing various SC scenarios. Second, by linking the list of redesign principles to potential sources of SC uncertainty in a SC, we found a means of identifying potentially effective SC redesign variables for that SC. Those sources of SC uncertainty that impact the SC KPIs are the first candidates for the redesign process. This approach was tested and further elaborated in Chapter 5, in which we discussed the findings of three exploratory case studies.

We concluded that sources of SC uncertainty refer to inherent characteristics of the SC and characteristics of the managed system, managing system, information system and/or organisation structure that are present at a certain point in time and that generate SC uncertainty. Our definition of SC uncertainty is based on the general requirements for effective control presented by De Leeuw (1988):

SC uncertainty refers to decision making situations in the SC in which the decision-maker lacks effective control actions or is unable to accurately predict the impact of possible control actions on system behaviour because of a lack of:

- *information (or understanding) of the environment or current SC state;*
- *a consistent model of the SC presenting the relationships between SC redesign variables and SC performance indicators.*

Generating SC scenarios in food supply chains

By applying the framework for SC analysis and redesign developed in Chapter 3 to the three case studies (Chapter 5), a detailed picture emerged of the configuration and operational control of activities in the SC. In this process, Organisation Description Language (ODL) and Event Process Chain (EPC) mapping techniques provided a powerful basis to redesign the SC, because it made the total process transparent and it made it possible for us to illustrate the opportunities for eliminating non-value-adding processes to managers. These techniques facilitated discussions with key employees in the SC and helped in identifying SC uncertainties and, more important, sources of SC uncertainty.

In all three cases the identification of SC uncertainties and especially their sources led to the recognition of potentially effective SC redesign variables. In this process the generic list of SCM redesign principles helped in identifying a complete overview of possible SC redesign strategies. By estimating the impact of each strategy on the SC KPIs, potentially effective SC redesign variables were identified.

In all three case studies an extended list of sources of SC uncertainty was identified. This allowed us to create a generic list of sources of SC uncertainty that may be found in food SCs. By linking this list to the generic list of SCM redesign principles developed in Chapter 4, we generated a valuable tool for SC redesign projects. It lists potential improvement areas in the SC when certain types of SC uncertainty are encountered in an investigated SC.

Modelling and evaluating SC scenarios

After SC scenarios are identified, we need an approach to model and evaluate these scenarios to determine the best practice SC scenario. In Chapter 6 we concluded that the combination of two methods is most effective:

- First, a *mathematical model* of the SC has to be built that allows for the quantitative assessment of the impact of SC scenarios on the SC KPIs. Because of multiple performance- and time-related process aspects that need to be taken into account when modelling SCs we focussed in our research on simulation instead of analytical modelling.

- Second, a *field test experiment* has to be conducted in the SC comprising one of the most promising SC scenarios, to provide practical and organisational restrictions and to thus reveal the feasibility of alternative SC designs.

In Chapter 6 we also developed a modelling framework for modelling the dynamic behaviour of food SCs. We believe the modelling framework captures all relevant concepts of the SC system needed to adequately model and simulate SC scenarios. The main modelling components are business processes, business entities, databases, resources, performance indicators and redesign variables. To model the dynamic behaviour of SCs some general assumptions are used as a starting point. For example, we assume system hierarchy, and we view the SC as a network of business processes with precedence relationships that use resources, and as a dynamic system with changing performance characteristics (especially when the time frames considered change). Two simulation tools, ExSpect and Arena, are introduced that were used in the two case studies in Chapter 7 for evaluating SC scenarios.

The case studies showed the applicability of the modelling approach. Simulation results, validated by managers of the participating companies (expert validation), showed the trends and order of magnitude of changes in SC performances of different SC scenarios. Both ExSpect and Arena proved to be promising tools for modelling SC scenarios, although each of them had some disadvantages.

The case studies also showed the complementarity of the field test to a simulation study; in one case study the best performing scenario in the simulation study was exchanged for a feasible scenario Y because of the field test results. By using this evaluation approach, SC managers can be supported in deciding whether or not to implement a new SC scenario. In both case studies, SC scenarios were suggested that perform considerably better than the current design.

Finally, an analytical approach was suggested for model validation purposes. It showed that analytical models can be used very successfully for smaller SC problems.

A step-by-step approach to generate, model and evaluate supply chain scenarios
Chapter 8 summarised our complete step-by-step approach for the analysis and redesign of food SCs which aims at identifying a best practice SC scenario for a particular food SC (Figure 1).

The approach starts with the joint definition of the boundaries of the SC to be investigated and the SC objectives (*step 1*). From these objectives the SC KPIs are identified. By describing the SC processes in detail SC uncertainties and their sources are identified (*step 2*). Effective SC scenarios are identified by linking the main sources of uncertainty found in the SC (*step 3*) with the list of SCM redesign principles (*step 4*). The potential SC scenarios are evaluated quantitatively and qualitatively by, respectively, a model study (*step 5*) and a field test experiment (*step 6*). Finally, a ‘best practice’ scenario can be identified and implemented in practice (*step 7*).

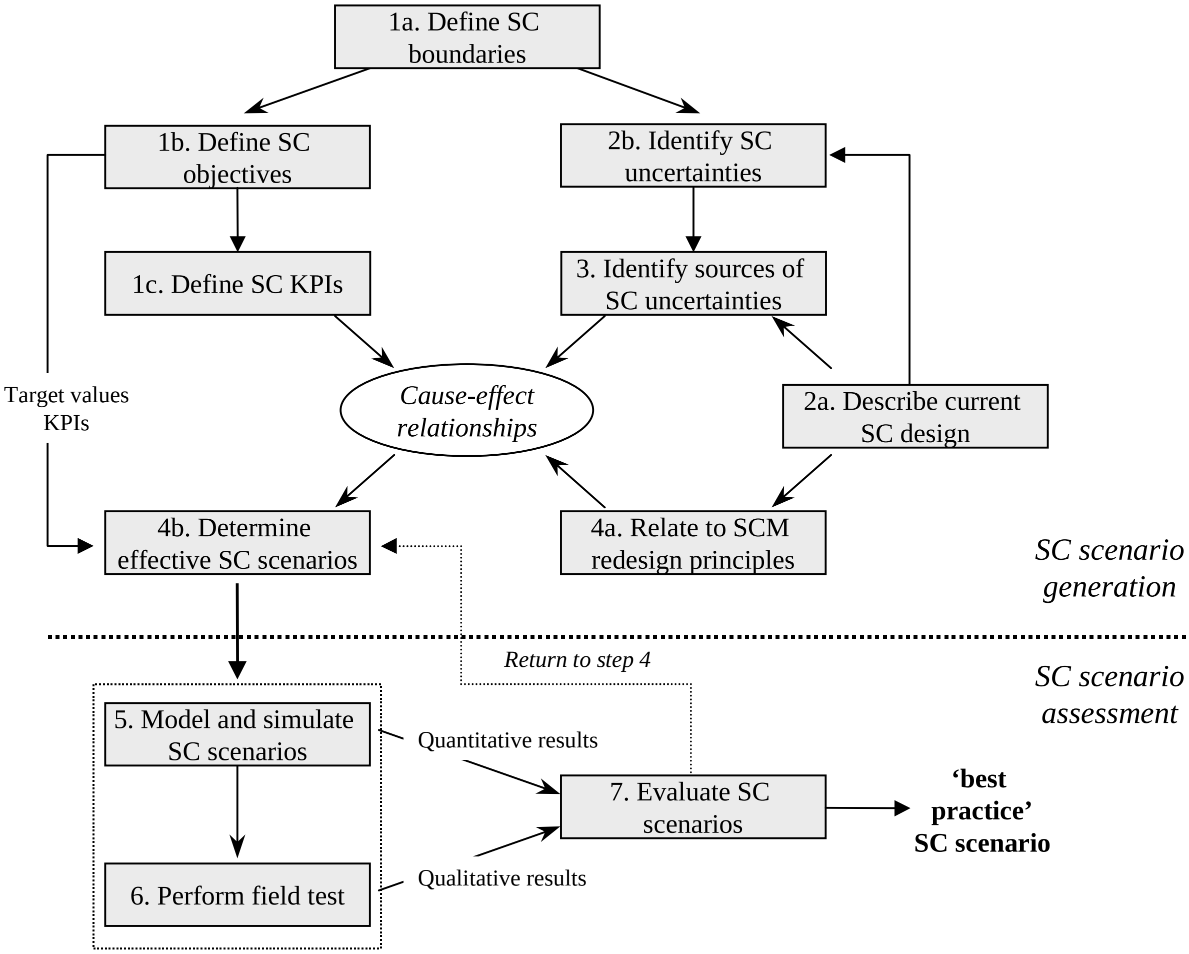

Figure 1. A step-by-step approach to generate, model and evaluate SC scenarios.

Main conclusions

Finally, Chapter 9 summarised the main findings and answered the three research questions as follows:

① *What is the relationship between uncertainty in SC decision making processes and the SC performance in food SCs?*

The presence of uncertainties in SC decision making situations results in the establishment of safety buffers in time, capacity and/or inventory to prevent a poor SC performance. These safety buffers initiate the existence of several non-value-adding activities that reduce the profitability of the SC. Reducing or even eliminating the SC uncertainties will improve SC performance.

② *How can we identify potentially effective SC scenarios for a particular food SC?*

The use of our step-by-step approach for generating effective SC scenarios will result in a number of important SC redesign variables. The combination of different settings for these SC redesign variables establishes a number of potentially effective SC scenarios. The degree of effectiveness has to be determined in the evaluation phase (research question 3).

③ *How can SC scenarios be assessed with regard to SC performance and the individual performance of the SC participants?*

The impact of a SC scenario on SC performance should preferably be evaluated by using both a modelling (simulation) study and a field test experiment. In this way the new SC scenario is evaluated both qualitatively (i.e. considering the behavioural and organisational aspects) and quantitatively. The modelling framework developed in this research provides a good means for capturing the dynamic behaviour of a food SC. The final decision of which SC scenario to implement depends on the trade-off between multiple SC performance indicators for each SC participant and the SC as a whole, and the feasibility of each SC scenario.

We are confident that we have been successful in contributing to the body of knowledge on SCM. Our step-by-step approach (including the suggested tools and techniques) can be used to analyse, redesign and evaluate food SCs more effectively and efficiently, which enhances the competitive advantage of the SCs. It enables managers to assess the impact of SC scenarios on SC performance; it provides insight into SC functioning; and it works as a facilitator to allow managers to rethink current SC business processes.

Opportunities for further research

In our view SCM research should focus on the construction of a toolbox comprising theories, methods and techniques, and working applications to analyse and improve the management of the SC. We acknowledge that our step-by-step approach to generate, model and evaluate SC scenarios should be considered as a first step towards a generic toolbox that can be used to improve SC performances. This thesis concluded by suggesting some interesting areas for further research. The most important, in no particular order, are the following:

- Refinement of the lists of SCM redesign principles and sources of SC uncertainty (by reviewing other literature and doing case studies in other industries).
- Adoption of a SC network perspective within SCM research emphasising the investigation of SC interactions.
- Definition of unique and integrated SC performance measures.
- Further research into the applicability of different types of quantitative methods combined with a typology of SC decision situations.
- Elaboration and refinement of the SC modelling framework and the construction of a library of generic building blocks on the level of individual business processes to facilitate efficient and effective modelling of SCs.
- The construction of a Decision Support System for SC analysis and redesign, using our step-by-step approach and the case study results, which generates SC scenarios automatically.
- Incorporation of requirements of other stakeholders in the SC analysis, such as the government, environmental protection groups, and trade-unions.

Abbreviations

'How many a dispute could have been deflated into a single paragraph if the disputants had dared to define their terms'
(Aristotle)

ABC	Activity Based Costing
APS	Advanced Planning and Scheduling
ATP	Available to Promise
BBD	Best-Before-Date
BPR	Business Process Redesign
CAO	Computer Assisted Ordering
CLM	Council of Logistics Management
CODP	Customer Order Decoupling Point
CPFR	Collaborative Planning, Forecasting and Replenishment
CRP	Continuous Replenishment (Programs)
CSF	Critical Success Factors
DPP	Direct Product Profitability
DRP	Distribution Requirements Planning (DRP-I) or Distribution Resource Planning (DRP-II)
EAN	European Article Numbering
ECR	Efficient Consumer Response
EDI	Electronic Data Interchange
EFT	Electronic Funds Transfer
ER	Efficient Replenishment
ERP	Enterprise Resource Planning
DRP	Distribution Requirements Planning
DSS	Decision Support System
ICT	Information and Communication Technology
IT	Information Technology
JIT	Just in Time
KPI	Key Performance Indicator
MPS	Master Production Schedule
MRP	Material Requirements Planning (MRP-I) or Manufacturing Resource Planning (MRP-II)
OR	Operational Research
POS	Point of Sale
QR	Quick Response

RDC	Retailer Distribution Centre
SC	Supply Chain
SCC	Supply Chain Council
SCM	Supply Chain Management
SCOR	Supply Chain Operations Reference (-model)
SCP	Supply Chain Planning
SKU	Stock Keeping Unit
TCO	Total Cost of Ownership
TOC	Theory of Constraints
UPC	Unique Product Code
VAP	Value Adding Partnership
VMI	Vendor Managed Inventory

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Chapter 1

Problem Definition

'The best way to manage the future
is to create it' (Peter Drucker)

1.1 Introduction to the research problem

The objectives of the research described in this thesis are to obtain insight into the applicability of the concept Supply Chain Management[1] (SCM) in food supply chains (SCs) from a logistical point of view, and to find an efficient and effective method to analyse and, if beneficial, redesign the SC to improve SC performance.

Since the 1980s, literature on SCM stresses the need for collaboration among successive actors, from primary producer to final consumers, to better satisfy consumer demand at lower costs (see, for example, Ellram, 1991; Towill, 1996; Bechtel and Jayaram, 1997; Cooper et al., 1997a). SCM deals with total business process excellence and represents a new way of managing the business within each link and the relationships with other members of the SC (Lambert et al. 1998). A driving force behind SCM is the recognition that sub-optimisation occurs if each organisation in a SC attempts to optimise its own results rather than to integrate its goals and activities with other organisations to optimise the results of the chain (Cooper et al., 1997a). Stevens (1989) refers to the interdependency of activities in the SC; 'If one activity fails, the chain is disrupted, creating poor performance and destabilising the workload in other areas, thereby jeopardising the effectiveness of the SC'. This was first recognised by Forrester in 1961 when he modelled a factory – distributor – retailer system and showed that small disturbances in one part of the system can very quickly become magnified as the effect spreads through the SC[2].

Firms are increasingly thinking in terms of competing as part of a SC against other SCs, rather than as a single firm against other individual firms (Christopher, 1992). This holds true especially in food SCs because of the shelf life constraints of food products and increased consumer attention for safe and environment/animal-friendly production methods (Boehlje et al., 1995). Recent events have increased interest in SCM as a means of improving the strength of the SC. Examples are the BSE crisis in the United Kingdom and the Classical Swine fever

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[1] In the remainder of this thesis we will use the abbreviation SCM for Supply Chain Management and the abbreviation SC for supply chain.
[2] Later on this has been called 'the Forrester effect'; we elaborate on this in Chapter 4.

in the Netherlands, which made producers aware of the necessity of SC control and intensified SC co-operation (see also Box 1.1). Furthermore, the increased interest in SCM has been spurred by intensified competition (due to open EU-markets), demographic and market developments combined with developments in Information and Communication Technology (ICT) that enable the frequent exchange of huge amounts of information for co-ordination purposes (see also Box 1.2).

Box 1.1 Classical swine fever in the Netherlands
On February 4, 1997 classical swine fever was diagnosed on a farm in Venhorst in the Netherlands. To prevent the spreading this disease, all hogs on that farm were destroyed and transportation of all livestock was prohibited in the area near the farm. Also, hogs on nearby farms were removed. Nonetheless, more farms were infected and soon a large part of the Netherlands was subjected to a breeding and transportation ban of livestock. In December 1997 classical swine fever was diagnosed at over 400 farms. In the evaluation project the tracking and tracing of the whereabouts of the animals and the activities undertaken in the whole SC proved to be essential in preventing the spreading of diseases and gaining consumer trust. Experience had shown that incorrect actions at one stage in the SC could result in a disaster for the whole sector.
(source: www.minlnv.nl/varkenspest/evaluatie/eind)

At the start of this research in 1994, limited knowledge on SCM and its potential for SC performance improvement was available. Since then a lot of research has been done (see Bechtel and Jayaram (1997) for an extended overview). Nevertheless, most gaps identified in 1994 are still present. A literature review on SCM by Beamon (1998) identified a number of issues that have not yet been adequately addressed in literature. She suggests the following research agenda for SC design and analysis:

- evaluation and development of SC performance measures;
- development of models and procedures to relate SC decision variables to performance measures;
- consideration of issues affecting SC modelling;
- classification of SC systems to allow for the development of rules-of-thumb or general techniques to aid in the design and analysis of manufacturing SCs.

This gap is confirmed by Lambert et al. (1998), who state that there is a need for building theory and developing normative tools and methods for successful SCM practice. Amongst many others, they identify research opportunities such as:

- How should a firm decide which internal process to link with which supplier(s) and customer(s)?
- What decision criteria determine whose internal business processes prevail across all or part of the SC?
- How should the existing SC be mapped?
- How should a firm analyse the network to determine if there is a better configuration?
- What measurements should be used to evaluate the performance of the entire SC, individual members or subsets of members?
- What are the potential barriers to implementation and how should they be overcome?

This thesis aims to fill in some of these gaps concerning the redesign process of SCM. The main questions individual food companies face are *whether, how* and *with whom* they should start SCM activities. Food companies should be able to analyse what SCM can do for them and find out what the consequences might be if a SC view is taken together with one or more supplier(s) and/or customer(s). We focus here on the logistical elements of SCM, i.e. the SC configuration and the operational management of SC activities and their relationships with SC performance. An extensive literature research did not reveal any integral method to generate, analyse and evaluate SC redesigns. Lambert et al. (1998) and Beamon (1998) support this.

This thesis reports the findings of research into a tool for decision support, which supports organisations in a food SC in identifying a ‘best practice’ SC scenario[3]. The tool consists of:

1. A research method for analysing a SC network to identify effective SC redesigns;
2. A research method for assessing the impact of SC redesigns on SC performance.

Since the research object of this thesis is the food SC, Section 1.2 will discuss the typical characteristics of food SCs. Furthermore specific developments in these SCs that have increased interest in SCM are discussed. Section 1.3 focuses on the key element of SCM, which will be described as the possibility to reduce decision making uncertainties in the SC that used to be treated as ‘givens’ (Silver et al. 1998) in the traditional management view. Section 1.4 will present the research design and, finally, Section 1.5 will give an outline of this thesis.

Box 1.2 Home replenishment

Streamline, Inc. in the USA provides Internet-based ordering of a wide range of goods and services and delivery of these items directly to customers' homes (including fresh produce, general household items, flowers, postage stamps, dry cleaning, video and video game rental, and so on). Customers are provided with a (secured) service box in their garage so they don't even need to be home to receive deliveries. Orders can be placed by shopping online, faxing or phoning in at any time and any day of the week up until the night before the assigned delivery day. Orders are filled from Streamline's 56,000 square foot fulfilment centre in Westwood, Massachusetts. Industrial producers look at Streamline as an alternative distribution channel for the powerful retailers. Facilitating this ‘home-replenishment’ concept requires a new logistical and information technical infrastructure. But what should it look like?

(source: www.getstreamlined.com)

1.2 SCM in Food supply chains

1.2.1 Food supply chains

Food SCs comprise organisations that are responsible for the production and distribution of vegetable or animal-based products (Zuurbier et al., 1996). In general, we distinguish two main types of food SCs:

[3] A definition of a ‘best practice’ SC scenario will be given in Section 1.4, and will be further elaborated in Chapter 3. All definitions are provided in the Glossary.

1. *SCs for fresh agricultural products* (such as fresh vegetables, flowers, fruit). In general, these SCs may comprise growers, auctions, wholesalers, importers and exporters, retailers and speciality shops. Basically, all of these SC stages leave the intrinsic characteristics of the product grown or produced in the countryside untouched. The main processes are the handling, storing, packing, transportation, and especially trading of these goods.
2. *SCs for processed food products* (such as snacks, desserts, canned food products). In these SCs agricultural products are used as raw materials for producing consumer products with higher added value. In most cases, conservation and conditioning processes extend the shelf life of agricultural products.

Actors in both types of SCs realise that original good quality products can easily deteriorate because of an inconsiderate action of another actor, for example storing a unit load of milk on a dockside in the burning sun. Van Rijn and Schijns (1993), Rutten (1995) and Den Ouden et al. (1996) sum up a list of specific process and product characteristics of agricultural food SCs. These, including some enhancements, are summarised in Table 1.1 and categorised by (potential) stage in the SC.

Table 1.1 Overview of the main product and process characteristics of food SCs

SC stage	*Product and process characteristics*
Overall	• Shelf life constraints for raw materials, intermediates and finished products and changes in product quality level while progressing the SC (decay) • Recycling of materials required
Growers cq. Producers	• Long production throughput times (producing new or additional products takes a lot of time) • Seasonality in production
Auctions / Wholesalers / Retailers	• Variability of quality and quantity of supply of farm-based inputs • Seasonal supply of products requires global (year-round) sourcing • Requirements for conditioned transportation and storage means
Food industry	• Variability of quality and quantity of supply of farm-based inputs • High volume, low variety (although the variety is increasing) production systems • Highly sophisticated capital-intensive machinery focusing on capacity utilisation • Variable process yield in quantity and quality due to biological variations, seasonality, random factors connected with weather, pests, other biological hazards • A possible necessity to wait for the results of quality tests (quarantine) • Alternative installations, alternative recipes, and product-dependent cleaning and processing times • Necessity to value all parts because of complementarity of agricultural inputs (for example, beef cannot be produced without the co-product hides) • Necessity for lot[4] traceability of work in process due to quality and environmental requirements and product responsibility • Storage buffer capacity is restricted, when material, intermediates or finished products can only be kept in special tanks or containers

Because of the specific characteristics of food products, the partnership thoughts of SCM have already received a lot of attention over the years in food SCs. In agribusiness in general about 70% of the production value is accounted for by the costs of raw materials (Van Weele, 1988). It is vital for industrial producers to contract suppliers to guarantee the supply of (the right) raw materials. Furthermore, they co-ordinate the timing of the supply of goods with suppliers

[4] A lot or a batch is a quantity produced together sharing the same identifying characteristics such as production date and process parameters.

to match capacity availability. The increased attention of consumers for food safety and environmental issues increases the necessity for tracking and tracing of goods in the SC (see Box 1.1). One example, is a soft drink producer who recalled soft drinks after glass splinters where detected in the bottles. Such occurrences have led to the introduction of integral quality control systems and increased attention for SCM and associated tracking and tracing in food SCs.

1.2.2 Developments increase interest in SCM

We can distinguish three main categories of developments that have stimulated interest in SCM: socio-economic, market structure and technological developments. Table 1.2 gives an overview of these developments for the different stages in food SCs.

Table 1.2 Developments in food SCs

Stage in the SC	*Developments*
Growers / producers	• Increasing production costs due to governmental rules concerning environmental and consumer-related issues • Lower prices due to liberalisation of markets • Reducing number of and scaling-up of farms in the EU
Wholesalers	• Scaling-up and concentration • Global sourcing
Food industry	• World-wide concentration of food producers • Increasing power of retailers • Differentiation by A-brands • Advanced processing and Information and Communication Technologies
Retailers	• World-wide concentration of retailers • Growing strength of supermarket own-label products • More consumer knowledge through new Information Technologies • Growing relative importance of supermarkets for grocery purchase • New ways of distributing food to consumers
Consumer market	• Saturated markets • Mass customisation

Socio-economic developments

Recent socio-economic developments have resulted in a change in performance requirements for food SCs as a whole and, consequently, for all stages in the SC. Because of demographic developments (e.g. strong increase of the ageing population, more double-income families and smaller households) and changing social concerns there is a demand for fresher products and products with higher added values. The buying behaviour of consumers is changing constantly, is unpredictable and differs per individual. This is referred to as *mass-individualisation* and has the following characteristics (Hughes, 1994):

- a need to simplify the preparation of food and increase the convenience of eating (more snacks, chilled and ready-made meals);
- increased demand for refined foods and for foreign, cosmopolitan and ethnic foods (for example, Italian pasta dishes and Asian curries);
- greater emphasis on physical and mental well-being, resulting in a shift towards lighter and healthier meals (less fat, sugar, meat), greater diversity in the choice of foods, and an increase in vegetarian dishes (c.f. functional foods). Furthermore, consumers want natural

and fresh foods and they have doubts about food products produced with the help of bio-technology and conserved by means of controlled atmospheres;

- a desire for greater conviviality attached to food, i.e. more eating outdoors and more preparation of meals at home for friends.

These trends in consumer demand have led to a growing fragmentation of markets, especially with respect to safety, healthiness, environment, animal-welfare, naturalness, convenience and variety (NRLO, 1995). The term ‘neighbourhood retailing’ has emerged to indicate that local needs may differ because of demographic developments (e.g. specific suburbs with more Chinese or Italians). Stern et al. (1996) call this ‘micromarketing’. Despite the apparent benefits to consumers, proliferating product assortments are making it more difficult for manufacturers and retailers to predict which of their goods will sell and to plan production and orders in response to customer demand. As a result, the inaccuracy of forecasts increases along with the costs related to forecast errors, such as extensive inventory and stock out costs (Fisher et al., 1994). Therefore, companies should be more demand-driven than forecast-driven.

Market structure developments

The second category refers to changes in market structure. Cohen and Huchzermeier (1999) mention the world-wide reduction of trade barriers and the development of regional, multi-country economic zones (*globalisation*). The installation of the European Union has led to open markets. This has increased the number of competitors, but it has also made it easier to purchase raw materials all over the world. Lubbers (1997) refers to the term *glocalisation*, meaning the global sourcing of raw materials combined with local marketing. These developments coincide with the adoption of a new competitive strategy by leading multinational companies. The effects of globalisation (i.e. open markets), the market entrance of new competitors, and stricter governmental requirements for food safety and environment-friendly production place increasing demands on management. The request for top quality ingredients in food products and reliable, standardised products has led to economies of scale in production and distribution.

Box. 1.3 Agribusiness in the Netherlands under pressure

A 1994 A.T. Kearney study (initiated by the Ministry of Agriculture, Nature Management and Fisheries) concluded that the competitive position of Dutch Agribusiness was in danger (Kearney, 1994). Producers of Dutch meat, dairy and vegetable products, in particular, had become bulk producers with little product variety and they had missed market developments. European markets had become saturated and fragmented and co-ordination and co-operation between the different participants in the SC had become necessary to meet consumer expectations. The efficiency and effectiveness of agri-chains has to change dramatically in order to cope with market developments. This catalysed the thoughts and projects on SCM in food SCs in the Netherlands to change from a supply oriented (push) to a demand oriented (pull) strategy where only those products are produced and supplied that are asked for on the market place.

Technological developments

The third category refers to advances in technology. These can be divided into two areas: developments in process technology and developments in information technology.

Developments in process technology refer to new cooking, processing, packing, conditioning and transportation techniques, such as the microwave oven, and more sophisticated chilling technology. Other developments are new bio-technological breakthroughs that are beginning to change the nature of food products. Genetic manipulation can build disease resistance into plants and seems to reduce the requirements for herbicides and pesticides – a critical factor for assuaging consumer concerns about food safety and the environment. Furthermore, better seeds and production methods have led to a substantial increase in agricultural production yields.

Information technology (IT) has been important for the development of logistical marketing activities. Increased information enables a facility to co-ordinate activities and to opt for 'control by information' rather than 'control by doing' (Gattorna and Walters, 1996). The introduction of bar coding and scanning technologies, in particular, has resulted in huge amounts of Point-of-Sale information, which are transported and processed by Electronic Data Interchange (EDI) and Enterprise Resource Planning (ERP) systems. The growing importance and market-power of the large retailers makes it necessary for processors to deliver products that fit the retailers` image and their service. This means the producer needs detailed information about consumer demands and preferences.

Box 1.4 Supplier contracting

HAK BV is market leader in the Netherlands in processed vegetables. One of the key enablers for this market leadership is tight chain partnerships with key suppliers concerning the whole process of growing, harvesting, and processing of the vegetables. The aim is to process high-quality products that can be traced accurately through the whole SC and to co-ordinate the supply of raw materials with the availability of restricted production capacities.

1.2.3 Implications for food supply chains

The turbulent, uncertain and highly competitive environment forces organisations to be more efficient and effective. This results in a need for SC redesign.

Attention to consumer value

The socio-economic developments described above have led to increased emphasis on the creation of *value* for consumers. The creation of customer value has implications for all stages in the SC: retailers have to reshuffle their assortments and delivery strategy, food industries and distributors have to improve logistical performances, and agricultural producers have to use more environment and animal-friendly production methods. Food producing companies are forced to change over from push (supply) oriented production to pull (demand) oriented production (Hughes, 1994). Furthermore, expanding product assortments require a need for changes in logistics to make smaller supplies in stores and more deliveries per day possible.

Increase of decision making uncertainty

Change in markets, products, technology, and competitors are occurring at an increasingly rapid pace. As a result, managers must make decisions on shorter notice, with less information, and with higher penalty costs. There is increasing uncertainty in SC decision making as to what developments to react to, and what action to take. The increase of uncertainty has led to a need for higher reliability and flexibility within the production systems and the planning and control systems in the SC (Handfield and Nichols, 1999).

Box 1.5 Agility in the food supply chain
Albert Heijn (AH), one of the leading retailers in the Netherlands, has to provide over 650 stores with the right products at the right time depending on the needs of the consumers. In the past, each AH-store received fresh products (vegetables, dairy, meat products, etc.) by individual deliveries resulting in up to 25 deliveries per week. By combining these shipments in a composite distribution centre this number is reduced to less than 10. Furthermore, outlet inventories have decreased since each fresh food product is now delivered every day. To facilitate this distribution system direct supplier deliveries to AH-stores are forbidden, and one national and four regional distribution centres have been built in the Netherlands. Nowadays, store-orders are delivered within 18 hours and AH hopes to decrease this to 4 hours in the near future.

(source: Jansen and Radstaak, 1997)

The need to redesign food supply chains

The keys to long-term competitive advantage in today's marketplace are flexibility and customer response (e.g. Stalk and Hout, 1990; Christopher, 1992; Hewitt, 1994). To maximise a competitive advantage, all members within the SC should 'seamlessly' work together to serve the end consumer (Towill, 1997). It is no longer possible to cope with uncertainties by building inventories, creating slack in time or by providing additional capacity (Newman et al., 1993). These anticipations of uncertainties lead to increased logistic costs and a reduction in the flexibility of the production organisation (Durlinger, 1995). The huge importance of high-quality product supply to consumers combined with the knowledge that other actors in the SC can damage all the efforts taken to preserve high product quality, leads to a thorough understanding of the necessity to perform well as a total SC.

It can be estimated that by creating responsive customer-driven SCs, the profitability of these SCs could be improved drastically. The potential for improvement is based on the reduction of inventory-carrying costs, the 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 of time-to-market at the tactical and strategic level (Eloranta et al., 1995). The recent developments in Information and Communication Technology (ICT) facilitate this process. Many companies are re-engineering and rationalising their logistical networks to take advantage of the reduction in, or elimination of, numerous artificial barriers that have previously affected all logistical decisions.

1.3 Key element of SCM is uncertainty reduction in SC decision making

Logistical performance often does not conform to logistical objectives due to the presence of uncertainties in SC decision making. The only market information a producer receives is customer orders. But these are subject to rapid changes, especially in the food sector, where, for example, weather conditions can have a huge impact on consumer demand. In literature, uncertainties in supply and demand are recognised to have a major impact on the manufacturing function (Wilding, 1998). Tom McGuffog (1997), director of planning and logistics at Nestlé UK, concluded that the complex statistical forecasting packages employed by the organisation do not substantially assist the interpretation of demand. Forecasts may work very well for a while, but forecasters need to be aware of the variables, which could suddenly break the relationship with the past and create a new trend (Van der Heijden, 1996). Harrison (1996) found that demand uncertainty leads to higher inventories, longer lead times and hence slower responsiveness. His study showed that the supplier was critically dependent on the material planning and control systems used by the assembler, and seemed to mirror the accuracy of those systems. Manufacturing firms are continually bombarded with unpredictable and uncertain events both from outside and from inside their organisations (Newman et al., 1993).

We agree with Davis (1993) who states that the real problem with complex networks is 'the uncertainty that plagues them'. This uncertainty is expressed in questions such as: what will my customers order, how many products should I have in stock, will our critical machine break down, and will the supplier deliver his goods on time? Uncertainty propagates throughout the network and leads to inefficient processing and non-value adding activities (see Box 1.6). Because of the specific product and process characteristics in food SCs (see Section 1.2.1), these SCs are even more vulnerable to the presence of SC uncertainties.

Box 1.6 Uncertainty propagates throughout the supply chain

A supplier of raw silicon delivers a bad lot to an integrated circuit (IC) manufacturer. Without properly sized safety stocks to buffer the production line against such an event, the IC manufacturer in turn delays its deliveries to one of its customers, a computer manufacturer. The shortage of parts shuts down the computer line, and shipments to computer dealers across the country are late. A customer walking into his neighbourhood computer store discovers the machine he wants is out of stock. However, the opportunistic salesperson sells him a competing machine available then and there. For want of an on-time silicon delivery, a sale is lost.

(source: Davis, 1993)

SCM provides the opportunity to reduce decision making uncertainty in the SC, which management has considered as unchangeable 'givens' (Silver et al., 1998) up to now. SCM can eliminate 'broken SCs', as Davis (1993) calls them, which have substantial stock held at one point to enable another actor in the SC to operate with minimal stock. Partnerships with key suppliers and customers will reduce uncertainty and complexity in an ever-changing global environment and minimise risk while maintaining flexibility (Handsfield and Nichols, 1999). This is confirmed by Sheombar (1995) who concludes that co-ordination in dyadic partnerships leads to a reduction in *task uncertainty*[5], which ultimately results in improved performance. It is also in accordance with Mason-Jones and Towill (1998), who state that 'those companies which cope best with uncertainty are most likely to produce internationally competitive bottom-line performances'.

By breaking down the walls that are present between successive SC stages, decision making uncertainties may decline since more information and control possibilities will become

[5] The concept of task uncertainty will be elaborated upon in Chapter 4.

available to the decision-makers in each stage. In turn, this will allow them to estimate the impact of alternative management actions on the SC performance. Hence, they will be able to manage the system in the direction of the organisational and/or SC objectives. For example, by gaining insight in actual consumer demand production peaks can be detected earlier, providing the producer with enough time to adjust production plans.

1.4 Research design

1.4.1 Research objective and questions

SCM literature provides little knowledge about methodologies that give guidelines on how to redesign your SC and evaluate these redesigns qualitatively and quantitatively (we refer to Beamon (1998) and Lambert et al. (1998)). On the other hand agribusiness, food industries and retailers are clearly very interested in the achievements of SCM and in implementing a 'best practice' SC scenario. For this research project, we defined such a SC scenario as follows:

Definition 1.1
A 'best practice' SC scenario refers to a feasible SC configuration and operational management and control of all SC stages that achieves the best outcome for the whole system.

We will elaborate on this definition in Chapter 3 when we discuss the constituting elements of a SC scenario. Our **research objective** was to contribute to the body of knowledge on SCM by developing a step-by-step approach that could generate, model and evaluate SC scenarios in food SCs. That is, we aimed to develop:

1. a research method to analyse a food SC and to generate a number of potentially effective SC scenarios that are estimated to improve the current SC performance.
2. a research method to assess the impact of different SC scenarios for a particular food SC on SC performance and identify a 'best practice' SC scenario.

These methods should assist food companies in evaluating their current position in a food SC and in deciding whether and how they should redesign the SC. First, they refer to a choice of included variables, the way they are organised, the interactions among variables and the way in which alternative patterns of variables and company choices affect outcomes, i.e. SC performance (Porter, 1991). Furthermore, the methods refer to an action plan (list of steps to be taken) including tools and techniques for collecting and processing data (we refer to Van der Zwaan and Van Engelen, 1994) to evaluate SC scenarios.

The SCM literature discusses a lot of different SCM redesign strategies that can be used to improve SC performance. However, it is unclear which strategy should be used in what particular situation and, furthermore, a complete list of these redesign strategies has not been reported in literature up to now. To operationalise the SC redesign process we aimed to develop a generic list of SCM redesign principles from literature and practice, that focus on SC performance improvement. The use of one or several of these SCM redesign principles in a food SC will alter the SC configuration and/or operational management and control. That is, according to definition 1.1, it changes the SC scenario.

In accordance with Davis (1993) and Lee and Billington (1992) we believe that the identification of decision making uncertainties in SC decision making, and especially the identification of system characteristics that cause these uncertainties, can help in effectively redesigning such a SC. Reducing uncertainty is achieved by understanding the root causes and how they interact with each other (Mason-Jones and Towill, 1998). Therefore, to guide our research (Yin, 1994), the next proposition is adhered to:

Proposition 1.1

To identify effective SC scenarios one should focus on the identification and management of the sources of uncertainties in SC decision making processes.

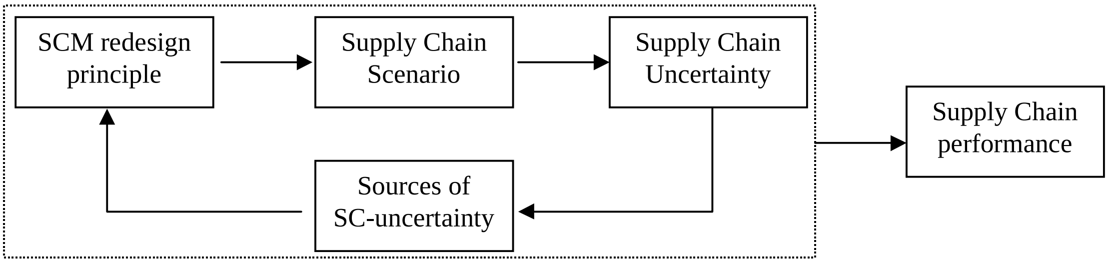

Figure 1.1 Research model

According to this proposition, potentially effective SCM redesign principles can be recognised via the analysis and identification of sources of decision making uncertainties in the SC. Subsequently, a potentially effective SC scenario can be established by selecting one or more of these SCM redesign principles. Therefore, we are interested in the relationship between sources of SC uncertainty and effective SCM redesign principles. When an effective SC scenario is implemented in the SC, this will reduce SC uncertainties and, as a result, improve SC performance. These relationships are depicted in our research model (Figure 1.1). This leads us to the following scientific research questions and sub-questions:

Research question 1

What is the relationship between uncertainty in SC decision making processes and SC performance in food SCs?

1.1 What is a supply chain?
1.2 What is Supply Chain Management?
1.3 How do we define SC performance?
1.4 What are uncertainties in SC decision making processes?

Research question 2

How can we identify potentially effective SC scenarios for a particular food SC?

2.1 What are effective SC scenarios?
2.2 What SCM redesign principles can be identified in literature and practice?
2.3 What sources of uncertainty can be identified in food SCs?
2.4 What are the relationships between SC uncertainties, SCM redesign principles, SC scenarios and SC performance?

Research question 3

How can SC scenarios be assessed with regard to SC performance and the individual performance of the SC participants?

3.1 How can we evaluate SC scenarios with regard to SC performance?

3.2 What modelling approach of SCs to evaluate SC scenarios is appropriate?

1.4.2 Research method

Yin (1994) defines research design as follows. 'It is an action plan for getting from the initial set of questions to be answered to some set of conclusions about these questions. It guides the investigator in the process of collecting, analysing, and interpreting observations. It is a logical model of proof that allows the researcher to draw inferences concerning causal relations among the variables under investigation. The research design also defines the domain of generalisability, that is, whether the obtained interpretations can be generalised to a larger population or to different situations.'

Yin (1994) introduces three criteria to determine the appropriate research method given a particular research setting. According to Yin, *case studies* are the preferred strategy in our exploratory research since:

- 'how' questions are being posed that deal with operational links needing to be traced over time, rather than mere frequencies or incidence;
- the investigator has little control over events (unlike in an experiment);
- the focus is on a contemporary phenomenon within some real-life context.

Case studies add direct observation and systematic interviewing (Yin, 1994). They allow for analysing and organising social data so as to preserve the unitary character of the social object being studied (Hutjes, 1992). In our research we tried to explain the causal links in real-life interventions that are too complex for the survey method or experimental strategies.

Yin (1994) discusses four types of case studies. A primary distinction is made between one and multiple case studies. A second distinction refers to the unit of analysis; a case study may involve one (holistic case study) or more than one (embedded case study) unit of analysis. In the embedded case study attention is also given to a subunit or subunits. Miles and Huberman (1994) note: 'One aim of studying multiple cases is to increase generalisability, reassuring yourself that the events and processes in one well-described setting are not wholly idiosyncratic. At a deeper level, the aim is to see processes and outcomes across many cases, to understand how they are quantified by local conditions, and thus to develop more sophisticated descriptions and more powerful explanations.' Since we were focusing on a general step-by-step approach to SC analysis and redesign, which considers the SC as a whole as well as the individual organisations within the SC, we used the *multiple-embedded case study*.

This research followed the *inductive/deductive research cycle* (Figure 1.2), in which literature and case studies are used to devise a research method on the generation of effective SC scenarios. Van Aken (1994) calls this the 'reflective cycle'. Induction refers to the generalisation of observed relationships in case studies into theoretical relationships between research variables.

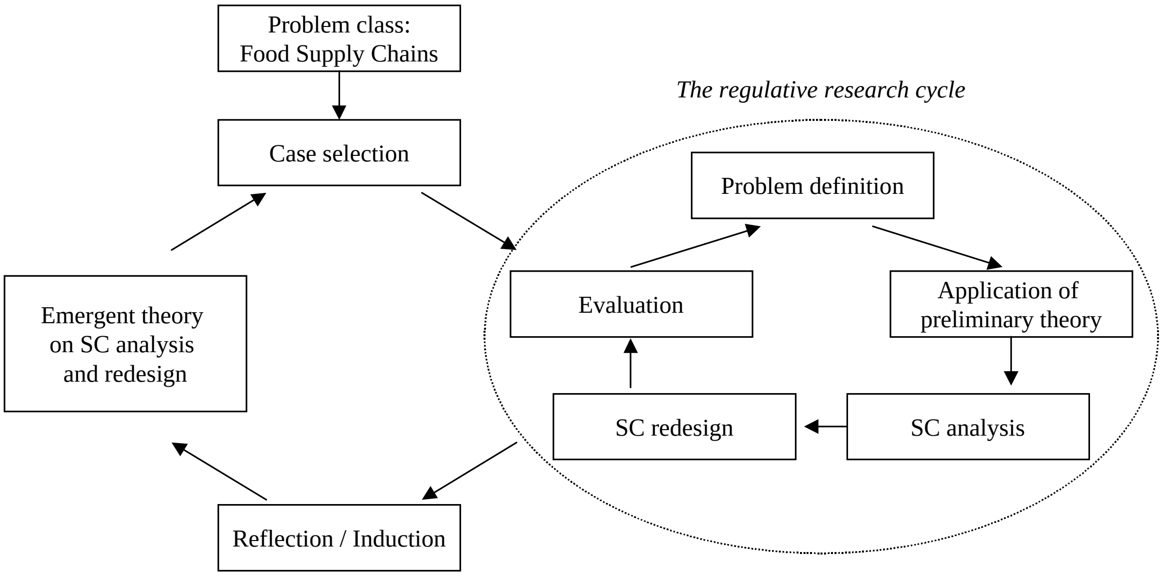

Figure 1.2 The reflective research cycle.

Given the limited number of cases that can usually be studied, it makes sense to choose cases such as the extreme situations in which the process of interest is 'transparently observable'. In contrast to hypothesis-testing research (which relies on statistical sampling), this theory building from case study research relies on *theoretical sampling* (i.e. cases are chosen for theoretical, not statistical, reasons) (Eisenhardt, 1989). Yin (1994) adds that case studies are generalisable to theoretical propositions and not to populations or universes.

In 1994 the Foundation for Agri-Chain Competence, a governmental subsidised organisation, was established in the Netherlands to facilitate public-private partnerships. In the period 1994-1998 over 60 SC projects were conducted. The three case studies used in our research originated from two of these projects. The first project was conducted in 1995 in a *fresh food SC* - comprising growers, auctions, an exporter of vegetables and fruits, and foreign retailers. The second project was conducted from the end of 1995 to mid-1997. Within this project several Efficient Consumer Response (ECR) improvement concepts (see Chapter 2 for an elaboration on ECR) were tested in *multiple food SCs for processed products*. Both projects aimed at identifying a logistical 'best practice' SC scenario. Methods developed in these projects were further tested and evaluated in several graduate student thesis projects from 1997 to 1999. We used the chosen case studies, which cover both types of food SCs, and various SC designs, in two ways (Figure 1.3 gives an overview of the complete research design):

- All three exploratory case studies were used for *theory building*, addressing the research approach for identifying effective SC scenarios. One extensive case study was conducted in a SC for fresh products and two case studies were conducted in SCs for processed products.
- The two latter case studies were further elaborated upon to explore the area of *assessing the impact of SC scenarios on SC performance*. The objective was to identify a 'best practice' SC scenario for that particular food SC.

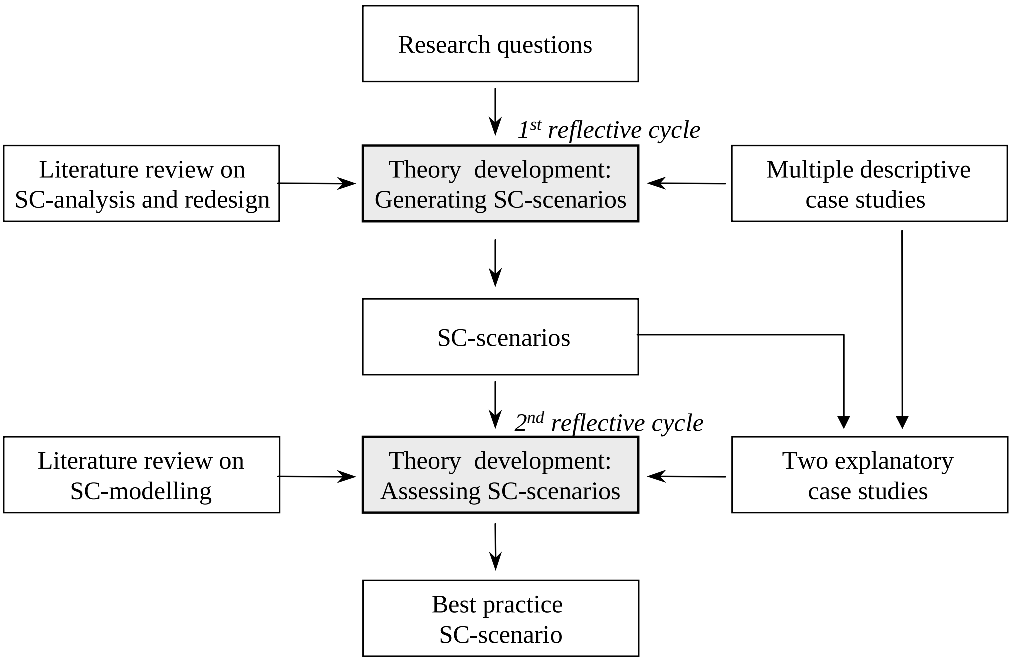

Figure 1.3 Overview of the research design.

Literature reviews were conducted in several areas: SCM, Logistical Management, Business Process Re-engineering and Operational Research. Furthermore, some literature on Marketing and Strategy were consulted. The results of this research were validated/verified by expert testing, in discussions with key practitioners in the field and researchers from the international scientific community (Van der Vorst et al., 1996, 1997$_{ab}$, 1998$_{abcdef}$, 1999$_{abc}$, 2000 $_{abc}$).

1.4.3 Research demarcation

Lambert et al. (1998) distinguish three key decisions that have to be made in SCM: 1) who are the key SC members with whom to integrate processes; 2) what are the SC processes that can be used to integrate these key members; and 3) what type/level of integration should be applied to each of these process links (Figure 1.4). We will use these key decision areas to demarcate our research.

SC Network Structure

One of the first steps in building SCs is partner selection. This research focussed on the improvement of established SCs within a network structure, hence partner selection is not the issue. We assume that multiple SC participants have jointly agreed upon the SC objectives. The goal of this study is to improve the SC performance by influencing/controlling the environment or adjusting the SC scenario to new environmental demands. Our level of analysis is first of all the individual SC functioning in a SC network.

SC Business Processes

Central in SCM is the integration of business processes. A *business process* can be defined as a process that produces a specific output or value to a customer (Chapter 3 discusses business processes in more detail). The members of the Global Supply Chain Forum have identified seven key business processes that could be integrated in the SC: customer relationship management, customer service management, demand management, order fulfilment, manufacturing flow management, procurement, product development and commercialisation, and returns process (Lambert et al., 1998). In this research project, we focused on order fulfilment, procurement and manufacturing flow management. Depending on the objectives of the SC research (and the stakeholders), different aspect systems can be considered, such as economic, legal, logistical, and information systems. We focused on the logistical business processes and left out political and governmental aspects of SCM. We also disregarded financial flows.

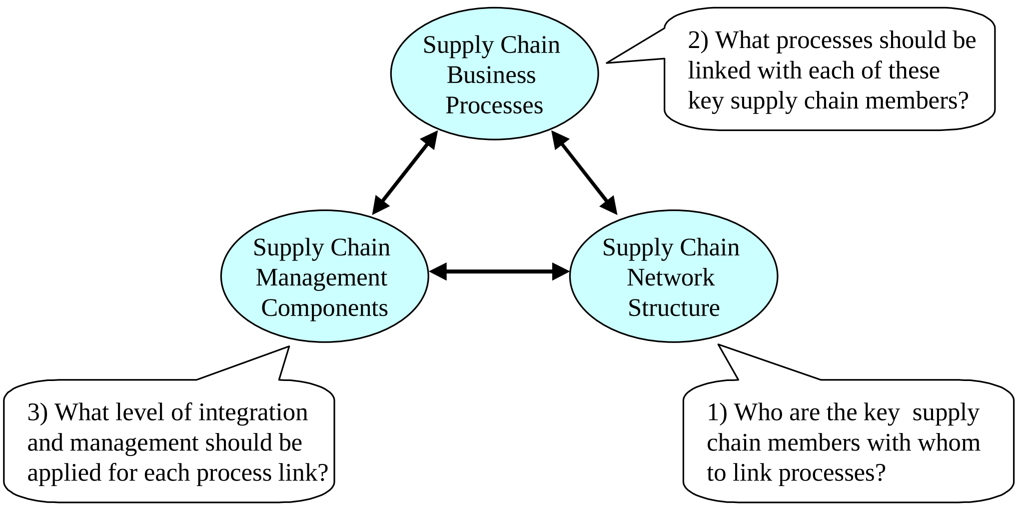

Figure 1.4 SC Management Framework: elements and key decisions to be made (Lambert et al., 1998)

SC Management Components

Lambert et al. (1998) distinguish two groups of management components. The first is the *physical and technical group,* which includes the most visible, tangible, measurable and easy-to-change components: planning and control methods, work flow/activity structure, organisation structure, communication and information flow facility structure, and product flow facility structure. The second group comprises the *managerial and behavioural components*: management methods, power and leadership structure, risk and reward structure and culture and attitude. Literature on change management (Hammer and Champy, 1993 and Hewitt, 1994) shows that if the second group is left out, managing the SC will most likely be doomed to fail. Therefore, in the assessment of SC scenarios both groups are considered.

1.5 Outline of this thesis

Figure 1.5 presents the outline of this thesis. Chapter 2 presents an overview of SCM research from different fields, i.e. Management studies, Business Process Redesign and Operational Research. Furthermore. It also presents definitions of a SC and SCM. Chapter 3 presents our view on SCs from a system and process approach. A definition of SC performance is given and key performance indicators for food SCs are identified. This chapter concludes with a framework for SC analysis and redesign and a definition of an effective SC scenario. Chapter

4 develops a preliminary research method for generating potentially effective SC scenarios. It starts with a discussion of SC uncertainty and derives a list of generic SCM redesign principles from literature. The question that remains is what SCM redesign principle best fits a particular situation? Therefore, Chapter 5 discusses three exploratory case studies, in which the preliminary method was used. This resulted in a general list of sources of uncertainty in food SCs that link the presence of certain types of SC uncertainty to effective SCM redesign principles, thereby further developing our research method. Chapter 6 develops a method for evaluating SC scenarios in food SCs. The primary focus is on the development of a framework for modelling SC scenarios in order to assess the impact of SC scenarios on SC performance. Chapter 7 describes and evaluates the findings of two case studies in which the evaluation method was applied. Chapter 8 summarises our step-by-step approach for the analysis and redesign of food SCs, which aims at identifying a best practice SC scenario for a particular food SC. Chapter 9 presents the general conclusions of this thesis, a discussion of its implications and indications for further research.

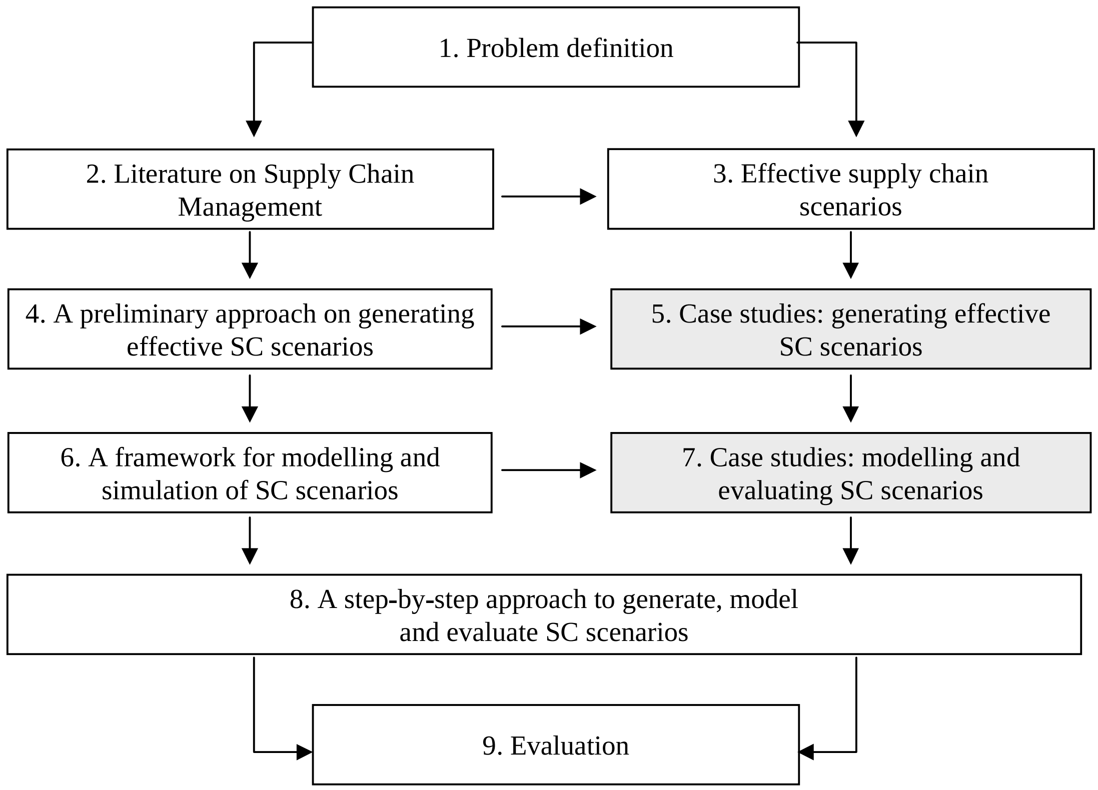

Figure 1.5 Outline of the thesis

Chapter 2

Literature on Supply Chain Management

'The only constants in the current business environment are turbulence and change'
(Kees van der Heijden)

2.1 Introduction

Before we elaborate on the elements of the research questions (Chapter 3) and focus on SC redesign (Chapter 4) a literature review of SCM will be presented. The main contributions of this chapter will be:

- a discussion of the background of SCM and the main findings in Operations Management, Business Process Redesign, and Operations Research literature related to SCM;
- definitions of a SC and SCM;
- a discussion of the Critical Success Factors for SCM;
- taxonomies of SCM-research and SC models.

Section 2.2 describes the emergence of SCM from the integration process of logistical activities. Our working definitions of a SC and SCM are given in Section 2.3. The next two sections discuss related concepts. Section 2.4 discusses Business Process Redesign and Section 2.5 Efficient Consumer Response. Findings on SCM in Operations Research literature are presented in Section 2.6. Section 2.7 focuses on vertical partnering and criteria for successful partnerships. We conclude this chapter with a taxonomy of SCM literature and some concluding remarks.

2.2 Integration of logistical activities

In 1986, the American Council of Logistics Management defined logistics management as follows:

Definition 2.1

Logistics Management is 'the process of planning, implementing and controling the efficient, cost-effective flow and storage of raw materials, in-process inventory, finished goods, and related information from point-of-origin to point-of-consumption for the purpose of conforming to customer requirements' (Lambert and Stock, 1993).

Included within this definition are aspects such as customer service, transportation, storage, plant site selection, inventory control, order processing, distribution, procurement, materials handling, return goods handling, and demand forecasting. Historically, logistics has been considered an issue deserving modest priority in each organisation. Nowadays logistics is seen as a value-adding process that directly supports the primary goal of the organisation, which is to be competitive in terms of a high level of customer service, competitive price and quality and in terms of flexibility in responding to market demands. For an extensive historical overview of the development of logistics we refer to the thesis of Ruffini (1999).

Until recently logistical activities (such as order administration, transport, ordering and inventory control) were often separate functions or activities involving individual managers with their own tasks and objectives. Consequently each function sought to maximise its own objectives: for example, order administration and information activities might attempt to process an increasing number of orders. This might occur at the cost of accuracy, and accordingly credit checks might be overlooked and order progressing enquiries serviced ineffectively (Daugherty et al., 1996). Table 2.1 gives an example of cross-functional concerns identified by Gattorna and Walters (1996) presenting advantages and disadvantages for functions when the delivery frequency is increased.

Table 2.1 Impact of more frequent deliveries on the logistic-mix functions

	Order administration and information	*Transport*	*Facilities*	*Order size / quantity*	*Inventory control*
Advantages			Reduces space and cube requirements		Lowers inventory holding costs
Disadvantages	Increases processing costs	Increases costs, lowers utilisation	Increases labour costs + inventory movements	Possibility of uneconomic unit loads	Increases OOS probability

During the early 1970s the notion of trade-off analysis was proposed. Problems of sub-optimal performance could be overcome if sub-optimal performance in one, or even two, of the distribution activities was accepted, such that the economies obtained from the other activities lowered the overall costs of the distribution function (Gattorna and Walters, 1996). For example, inventory holding costs and warehouse costs (storing inventory) were reduced considerably when faster but more expensive transportation modes replaced slower traditional modes (the substitution of sea freight by air freight). The route to SCM was thus evolutionary, rather than revolutionary (Ellram and Cooper, 1993). Stevens (1989) describes an often-cited, four-stage evolutionary path from functional control to SCM:

Stage 1. *Baseline*: Functional islands

Responsibility for different activities in the organisation is vested in different, almost independent, departments. Characteristics of this stage are staged inventory caused by failure to integrate and synchronise activities, independent and often-incompatible control systems and procedures, and organisational boundaries and functional islands.

Stage 2. *Functional integration*: Materials Management and Physical Distribution

This level of integration is characterised by an emphasis on cost reduction rather than performance improvement; discrete business units, each of which is buffered by inventory; reactive customer service (whoever shouts the loudest, gets the goods); and poor visibility of final consumer demand (using only MRP-II[1]).

Stage 3. *Internal integration*: Logistics Management

This stage involves the integration of those aspects of the SC directly under the control of the company. It embraces outward goods management, integrating supply and demand along the company's own chain. Characteristics are a comprehensive integrated planning and control system (MRP-II combined with DRP), full systems visibility, an emphasis on efficiency rather than effectiveness, extensive use of EDI, and reacting to customer demand rather than managing the customer.

Stage 4. *External integration*: SCM

Finally, full chain integration is achieved. This stage embodies a change of focus from being product-orientated to being customer-orientated, i.e. penetrating deep into the customer organisation to understand its products, culture, market and organisation. Integration upstream the SC to include suppliers also represents more than just a change of scope – it represents a change in attitude, away from the adversarial attitude of conflict to one of mutual support and co-operation.

Based on the principles of Business Process Redesign, Hewitt (1994) expanded Stevens' model by suggesting an emerging new fifth stage, which embodies integrated intra-company and inter-company SC process management. The objective of optimisation initiatives in this stage is total business process efficiency and effectiveness maximisation (Cooper et al., 1997a). According to Stevens (1990), the objective of managing the SC is to synchronise the requirements of the customer with the flow of material from suppliers in order to effect a balance between what are often seen as the conflicting goals of high customer service, low inventory investment and low unit cost as illustrated in Figure 2.1.

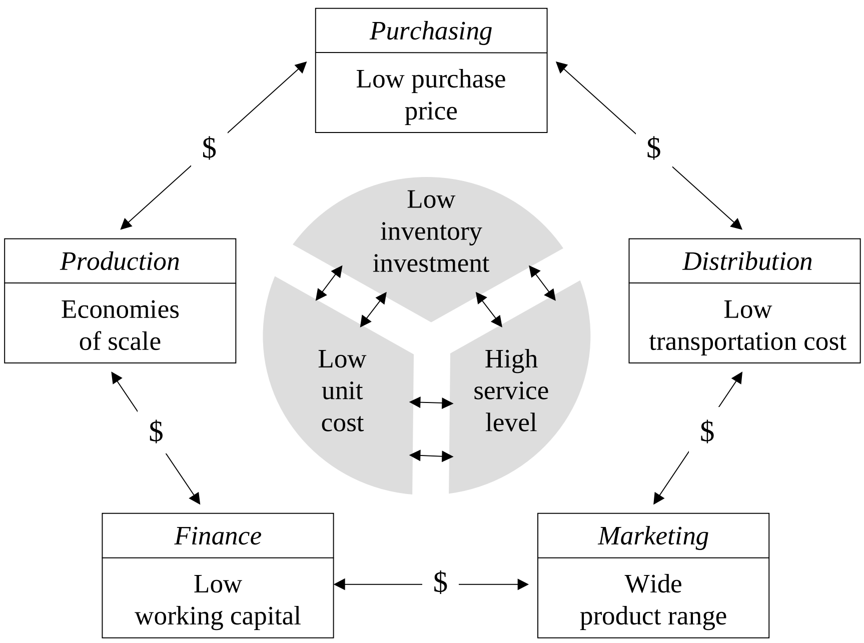

Figure 2.1 Balanced SC involves functional trade-offs (Stevens, 1989).

[1] For an elaboration on MRP, DRP and EDI we refer to Slack et al. (1998) and Silver et al. (1998).

To provide higher service levels, without incurring an undue burden of cost, all the activities along the SC must be in balance with the SC objectives, and that the right investments have to have been deployed. Achieving the necessary balance between cost and services involves trade-offs throughout the chain.

A lot has been written about SCM since the 1980s. The next section will discuss the findings of a literature review on the concepts of SC and SCM.

2.3 Definition of Supply Chain and Supply Chain Management

The term 'Supply Chain Management' is relatively new. It first appeared in logistics literature in 1982 as an inventory management approach with an emphasis on the supply of raw materials (Oliver and Webber, 1982). Oliver and Webber discuss four characteristics of SCM:

1. SCM views the SC as a *single entity*. Therefore, it does not delegate fragmented responsibility for various segments in the SC to functional areas such as purchasing, manufacturing, distribution and sales.
2. Supply is a *shared objective* of practically every function in the chain. It is of particular strategic significance because of its impact on overall costs and market share.
3. SCM provides a *different perspective on inventories,* which are used as a balancing mechanism of last, not first, resort.
4. SCM requires a new approach to systems: *integration*, not simply interface, is the key.

Houlihan (1985) and Jones and Riley (1985) elaborate on the concept emphasising a reduction in inventory both within and across firms. Jones and Riley (1985) claim that SCM should fulfil final customer service requirements, define where to position inventories along the SC and how much to stock at each point, and it should develop appropriate policies and procedures for managing a SC as a single entity. Lee and Billington (1992) state that SC analysis is much *more than just inventory modelling*. It can be extended to distribution strategy analysis and to other types of SC problems (Lee and Billington, 1995).

Around 1990, academics first described SCM from a theoretical standpoint to clarify how it differed from more traditional approaches to managing the flow of materials and the associated flow of information (Ellram and Cooper, 1990). Initially, according to Bechtel and Jayaram (1997), the emphasis was on facilitating product movement and co-ordinating supply and demand between a supplier and buyer. Logistics managers in retail, grocery, and other high inventory industries began to see that a significant competitive advantage could be derived through the management of materials through inbound and outbound channels. Purchasing literature states that SCM evolved from an upgrade of the purchasing function to an integral part of the corporate planning process. Since its introduction in the retail industry, the SC concept has spread to other industries such as computers (Davis, 1993) and copiers (Hewitt, 1994). Other terms are also used for SCM activities:

- Tan et al. (1998) refer to comparable labels used in purchasing literature, including integrated purchasing, supplier integration, buyer-supplier partnerships, supply base management, and strategic supplier alliances.
- Womack and Jones (1994) refer to the *lean enterprise* as a group of individuals, functions, and legally separate but operationally synchronised companies.

- Lambert and Stock (1993) introduced the concept of *Integrated Channel Management*, and described it as 'the co-ordination of all activities, beyond just the traditional logistics activities, between channel members that result in a high level of customer satisfaction for end-users'.
- Boorsma and Van Noord (1992) define *SC integration* as 'he co-ordination of logistical activities between separate links in the chain in order to plan, control and execute the logistic processes as one integrated system supported by an integrated information system, with the aim of improving the logistic performance of the complete system'.
- The concept of *Demand Chain Management* (Vermunt, 1996; Christopher, 1998) has also been proposed to distinguish it from the type of management in which 'supply' begins and drives the chain of activities.

Although at the beginning SCM was mainly discussed in purchasing literature (see the labels for SCM presented by Tan et al. (1998)), the emphasis now lies on the process of supplying goods to consumers to fulfil their needs. Comparable initiatives have been undertaken at the industry level. Various concepts have been presented, such as *the extended enterprise,* which is characterised by a dominating company who extends its view and scope of operation, takes the lead and sets the pace. The *virtual enterprise* is characterised by complementary contributions from a number of different companies, where one company plays the role of a broker (Hayfron et al., 1998). From a marketing perspective, Stern et al. (1996) define a *marketing channel* as 'an orchestrated network of interdependent organisations that creates value for end-customers by generating form, possession, time and place utilities'. However, Johnson and Wood (1996) view the SC as an extension of the marketing (or distribution) channel. First of all, suppliers of the manufacturer are included. Furthermore, SCs consider the re-engineering of products and processes and place particular emphasis on inventory management, communication and co-ordination issues. Whilst SCs aim at long-term agreements between parties, a marketing channel functions with daily market transactions.

2.3.1 What is a Supply Chain?

Bechtel and Jayaram (1997) provide an extensive review of the literature and research on SCM. Their findings show that the term SCM is often misused and that no agreement exists about its definition. Table 2.2 presents an overview of SC definitions found in literature to illustrate this divergence in views. Particular attention should be paid to differences in the scope of SC analysis in these definitions. Hoogewegen (1997) distinguishes between five possible levels of analysis:

1. single organisation; for example, a manufacturer;
2. dyad, referring to the relationship between two organisations, a seller and a buyer;
3. entire SC; incorporating the seller's supplier and/or the buyer's customer;
4. industry level (for example manufacturers);
5. total network of organisations that participate in a specific part of the economy.

These different views are all represented in literature. Whereas some authors refer to SCM in the context of an individual organisation or dyad (for example, Davis or Stevens), others refer to the SC level (for example, Jones and Riley or Lee and Billington) or the network level of analysis (for example, Beers et al., Ellram or Christopher). In this thesis, the SC level of analysis is chosen, taking account of the other participants in the SC network. Our logistical working definition of a SC is based on the definitions in Table 2.2 and is defined as follows:

Definition 2.2

A supply chain is a network of (physical and decision making) activities connected by material and information flows that cross organisational boundaries.

The aim of the supply chain is to produce value for the ultimate consumer whilst satisfying other stakeholders in the SC.

Table 2.2 Definitions of a supply chain.

Author(s)	*Definition of a supply chain*
Jones and Riley, 1985	The planning and control of total materials flow from suppliers through manufacturing and distribution chain to the end-users.
Stevens, 1989	The connected series of activities which is concerned with planning, co-ordinating and controlling material, parts and finished goods from suppliers to the end customer
Scott and Westbrook, 1991	The chain linking each element of the production and supply process from raw materials through to the end consumer. Typically such a chain will cross several organisational boundaries.
Ellram, 1991	A network of firms interacting to deliver a product or service to the end customer, linking flows from raw material supply to final delivery.
Towill et al., 1992	A system whose constituent parts include suppliers of materials, production facilities, distribution services and customers, all linked together via the feed forward flow of materials and the feedback flow of information.
Christopher, 1992	The network of organisations that are involved, through upstream and downstream linkages, in the different processes and activities that produce value in the form of products and services in the hands of the ultimate consumer.
Davis, 1993	A network of processing cells with the following characteristics: supply, transformation and demand.
Lee and Billington, 1995	A network of facilities that procure raw materials, transform them into intermediate goods and then final products, and deliver the products to customers through a distribution system. It spans procurement, manufacturing and distribution.
Thomas and Griffin, 1996	Material and information flows both in and between facilities, such as vendors, manufacturing and assembly plants and distribution centres ... there are three traditional stages in the SC: procurement, production and distribution.
Cooper et al., 1997a	The integration of business processes from end-user through original suppliers that provides products, services and information that add value for customers.
Christopher, 1998	The network of connected and interdependent organisations mutually and co-operatively working together to control, manage, and improve the flow of materials and information from suppliers to end users.
Beers et al., 1998	A network of connected organisations aimed at the fulfilment of consumer needs … in conjunction with the fulfilment of needs of other stakeholders of such an entity.
Trienekens, 1999	A network of processes with precedence relationships that are linked by the flow of products, information and/or money.
Handfield and Nichols, 1999	It encompasses all activities associated with the flow and transformation of goods from the raw materials stage, through to the end user, as well as the associated information flow. Materials and information flow up and down the SC.

The concept 'value-added activity' originates from Porter's '*value chain'* framework. In 1985 Porter introduced the value chain framework to describe the activities of an individual organisation (see Figure 2.2). The value created by these activities minus the costs of executing them represents the margin the organisation makes. *Value* is the amount buyers are willing to pay for what a company provides and it is measured by total revenue. The total set of ‘value-adding activities’ is divided into primary and support activities. Porter defines primary activities as ‘... the activities involved in the physical creation of the product and its sales and transfer to the buyer as well as after-sale assistance’. Support activities are defined as those that ‘... support the primary activities and each other by providing purchased inputs, technology, human resources, and various firm-wide functions’ (Porter, 1985). The value chain of an organisation is the system of dependent activities; the execution of an activity impacts the costs or effectiveness of other activities. Porter’s argument is that the value chain may be used to identify and understand the specific sources of competitive advantage and how they relate to creating added value for customers.

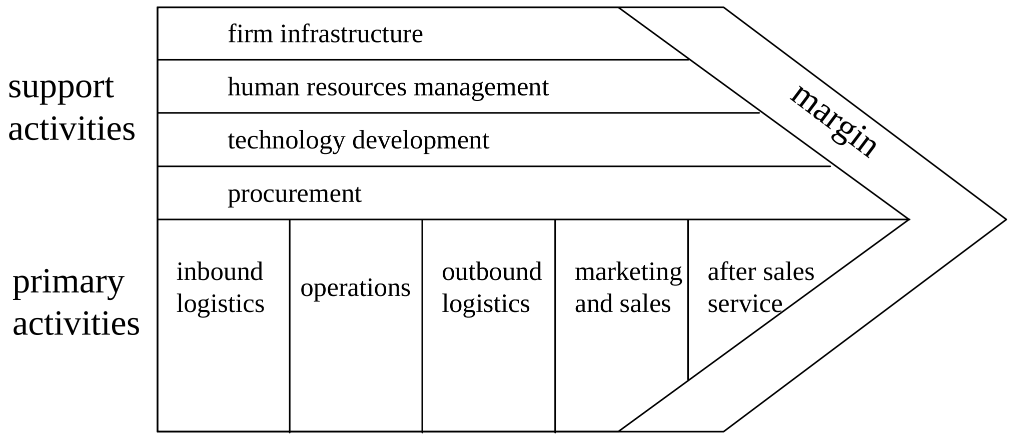

Figure 2.2 The value chain (Porter, 1985)

The value chain provides a systematic way of examining the activities of not only one individual company, but also the activities of component companies within a SC. Porter calls this the *value system*; it comprises the value chains of suppliers, customers and the organisation itself (cf. the marketing channel of Stern et al. (1996)). The value system is not a collection of independent activities, but a system of interdependent activities. Suppliers do not only deliver a product, but they can also influence a firm’s performance in many other ways. Many products pass through the value chains of suppliers and their suppliers (Porter 1985). Downey (1996) prefers the term ‘system’ since this suggests an interactive and dynamic set of relationships acting in concert with one another. These relationships may not be linear, but interrelated in a complex web that interacts dynamically to accomplish the end objective. In his view, the word ‘chain’ seems to connote distinctly different elements that are linked together, end to end in a linear fashion.

Figure 2.3 depicts a generic food SC within the context of the total network. Each firm belongs to at least one SC: i.e. it has at least one supplier and one customer. A SC starts with the end-consumer and works it way upstream via one actor in each industry level. The other actors in the network influence the performance of the SC. As Hakansson and Snehota (1995) state: ‘what happens between two companies does not solely depend on the two parties involved, but on what is going on in a number of other relationships’. Wilding (1998) calls this ‘parallel interaction’. Therefore, the analysis of a SC should preferably take place or be evaluated within the context of the total network.

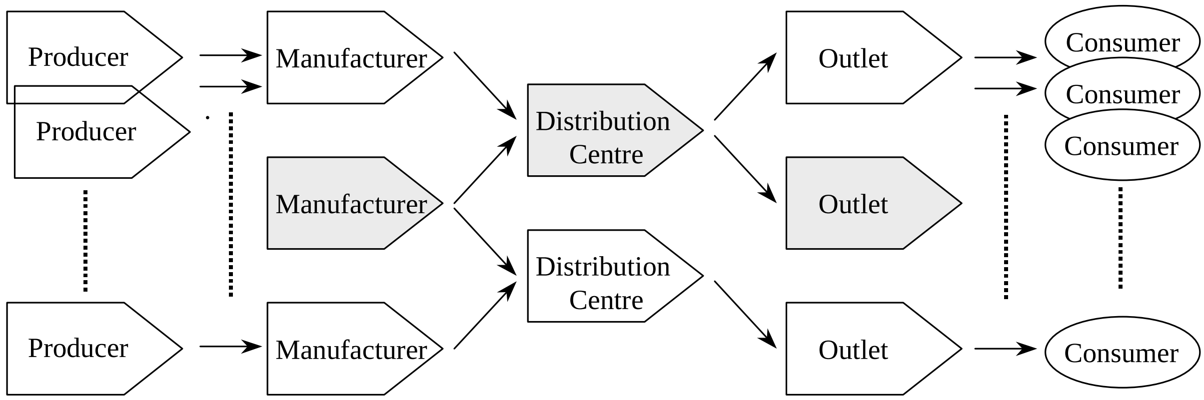

Figure 2.3 Schematic diagram of a generic food SC (shaded) in the total supply network

2.3.2 What is Supply Chain Management?

Ellram and Cooper (1993) state that SCM is an approach whereby the entire network, from suppliers through to the ultimate customers, is analysed and managed in order to achieve the 'best' outcome for the whole system. It includes analysing the level and location of SC inventories, managing information flows throughout the channel, and co-ordinating efforts to best meet the customer's needs (Ellram and Cooper, 1993). The findings of Cooper et al. (1997a) correspond with our definition of the SC. They found some commonalties in literature in terms of what SCM actually is:

- It evolves through several stages of increasing intra- and inter-organisational integration and co-ordination; and, in its broadest sense and implementation, it spans the entire chain from initial source (supplier's supplier, etc.) to ultimate consumer.
- It potentially involves many independent organisations. Thus, managing intra- and inter-organisational relationships is of essential importance.
- It includes the bi-directional flow of products (materials and services) and information, and the associated managerial and operational activities.
- It seeks to fulfil the goals of providing high customer value with an appropriate use of resources, and building competitive chain advantages.

Box 2.1 SC research in the food industry.

Mennega (1993) reported the findings of one of the first SC research project in the Dutch food industry aimed at identifying the possibility of improving customer service (lead time, delivery reliability, flexibility) by establishing throughput-time reduction in the meat chain (comprising cattle-breeders, cattle-raisers, stock farmers, cattle-traders, a slaughterhouse, distributors and retailers). The researchers found major obstacles in the meat chain to reducing SC throughput time. Long biologically determined breeding times result in low volume flexibility of this SC. Because of the nature of the product (living animals and fresh meat products) stock keeping is hardly possible. Furthermore, illness of animals could damage delivery reliability. Research in other chains (electronic, construction and household products) showed much more readily obtainable and higher benefits (for example, a reduction of over 50% in SC throughput time). Finally, they found that four factors were especially required to realise these potential benefits: mutual trust, openness, equal partnerships and the sharing of costs and benefits.

(source: Mennega, 1993)

This definition indicates that SCM is about the co-ordination of managerial and operational activities of organisations connected in a SC to provide high customer value with an appropriate use of resources. SCM focuses on the management of relationships. Cooper and Ellram (1993) make a distinction between traditional management and SCM (Table 2.3). In general we agree with their description. However, we doubt whether a channel leader is needed to establish the required SC co-ordination. We will come back to this in Chapter 3.

Trying to assess the actual scope of SCM is much more difficult than simply defining a SC. Towill (1997) argues that the definition needs to be flexible because it ‘applies right across the business spectrum ranging from international SCs down to a number of related sequential activities undertaken under one roof but covering a number of independent cost centres’. International SCs place great obstacles in the path of information transfer; local autonomy, local system standards and incompatible operating procedures make integration of international systems difficult (Houlihan, 1985).

Table 2.3 Characteristics of SCM according to Cooper and Ellram (1993)

Element	*Traditional Management*	*Supply Chain Management*
Inventory management approach	Independent efforts	Joint reduction in channel inventories
Total cost approach	Minimise firm costs	Channel-wide cost efficiencies
Time horizon	Short term	Long term
Amount of information sharing and monitoring	Limited to needs of current transactions	As required for planning and monitoring purposes
Amount of co-ordination of multiple levels in the channel	Single contact for the transaction between channel pairs	Multiple contacts between levels in firms and levels of channel
Joint planning	Transaction-based	On-going
Compatibility of corporate philosophies	Not relevant	Compatible at least for key relationships
Breadth of supplier base	Large to increase competition and spread risk	Small to increase co-ordination
Channel leadership	Not needed	Needed for co-ordination focus
Amount of sharing of risks and rewards	Each on its own	Risks and rewards shared over the longer term
Speed of operations, information and inventory flows	‘Warehouse’ orientation (storage, safety stock). Interrupted by barriers to flows. Localised to channel pairs	‘DC’ orientation (turnover speed). Interconnecting flows; JIT, Quick Response across the channel

Some researchers also include the carriers in the SC (Gentry, 1996). Still others include governments as part of the chain, since, as a global concept, managing the SC would also include all of the issues associated with government regulations and customs (Beers et al., 1998; Ganeshan et al., 1999). How widely or narrowly the chain is managed is an indicator of the extent to which SCM is being practised (Ganeshan et al., 1999). SCs can be managed as a single entity through the dominant member (referred to as the ‘predator’ by Towill (1997)), or, alternatively, through a system of partnerships requiring well-developed co-operation and co-ordination (Chapter 3 will elaborate on this). Cooper et al. (1997b) suggest that the span of management control should be determined by the added value of any relationship to the firm.

According to Tan et al. (1998) SCM focuses on how firms utilise their suppliers’ processes, technology, and capability to enhance competitive advantage. It focuses on supplier base reduction, concurrent engineering, reduced cycle time and customer satisfaction. The transportation/logistics perspective on SCM focuses on improved visibility and reduced demand uncertainty, consolidation of distribution centres, reduction of transportation costs and, when coupled with state-of-the-art information systems, with the replacement of inventory with information (the transportation system becomes the warehouse) (Tan et al. 1998).

Cooper et al. (1997a) extend SCM beyond logistics. Based on a review of the literature and management practice the authors conclude that there is a need for some level of co-ordination of activities and processes within and between organisations in the SC. Not only logistical processes, but also other business processes are required to operate under internal and external co-ordination. An example is designing products for SCM (Lee et al., 1993; Lee and Sasser, 1995). Based on this emerging distinction between SCM and logistics, the Council of Logistics Management modified its definition of logistics management in 1998. '*Logistics is that part of the supply chain process* that plans, implements and controls the efficient, effective flow and storage of goods, services and related information from the point-of-origin to the point-of-consumption in order to meet customer requirements' (Lambert et al., 1998).

DuPont's director of logistics (Clifford Sayre) defined SCM as a closed loop: 'It starts with the customer and it ends with the customer. Through the loop flows all materials and finished goods, information, even all transactions. It requires looking at your business as one continuous process' (Gattorna and Walters, 1996). The Global Supply Chain Forum defines SCM as the integration of business processes from end user through original suppliers; it provides products, services and information that add value for customers and stakeholders (Lambert et al., 1998). The editor of a new publication devoted to SCM (*Supply Chain Management Review*) defined SCM as 'successful co-ordination and integration of all those activities associated with moving goods from the raw materials stage through to the end user, for sustainable competitive advantage. This includes activities like systems management, sourcing and procurement, production scheduling, order processing, inventory management, transportation, warehousing, and customer service' (Cooke, 1997). Cox (1999) defines SCM as '...a way of thinking that is devoted to discovering *tools and techniques* that provide for increased operational effectiveness and efficiency throughout the delivery channels that must be created internally and externally to support and supply existing corporate product and service offerings to customers'. This leads us to our definition of SCM we shall adopt and use through this study:

Definition 2.3

> *SCM is the integrated planning, co-ordination and control of all logistical business processes and activities in the SC to deliver superior consumer value at less cost to the SC as a whole whilst satisfying requirements of other stakeholders in the SC.*

Finally, one must not forget that SCM is rooted in strategic-level decision making. Of course, SCM includes implementation and operational aspects in which day-to-day operations are managed below the senior management level (Ganeshan et al., 1999). Cox (1999) identifies two dimensions in a SC. The first can be referred to as the operational SC, the second as the entrepreneurial SC. The operational SC refers to the series of primary and support SCs that have to be constructed to provide the inputs and outputs that deliver products and services to the customers of any company. The entrepreneurial SC refers to the notion of companies positioning themselves strategically within a primary SC. Houlihan (1985) states that the differentiating factor is the strategic decision making aspect of SCM. SCM reaches out beyond the boundaries of cost containment and links operating decisions to strategic considerations within and beyond the firm.

Box 2.2 Integrated logistics
A survey amongst 127 logistics executives in varying-sized US firms concerning their perceptions regarding integrated logistics (or SCM) revealed a relationship between integration and logistical performance improvements. Nearly one half of the respondent firms could be considered non-integrated. Logistics executives at integrated firms reported significantly better performance with respect to customer service, productivity, costs, strategic focus, cycle time, and quality. Daugherty et al. conclude that integrated firms believed their competitive position had improved to a greater degree than non-integrated firms. Furthermore, the survey revealed the most important ingredients for successful implementation of integrated logistics: 48% believed top management support is critical, 27% emphasised corporate-wide commitment, and 26% intra-organisational communication/training. Other items mentioned were realistic planning, availability of good information and system flexibility.
(source: Daugherty et al., 1996)

In this section a discussion and definition was given of a SC and SCM. The discussion concentrated on the strategic level, i.e. most of the discussed literature focused on the scope of the SC and the possible benefits of SCM. It is also interesting to focus on the operational level. Section 2.4 will discuss the concept of Business Process Redesign. Efficient Consumer Response is discussed in Section 2.5 and Section 2.6 presents an overview of findings on SCM in Operational Research literature.

2.4 Business Process Redesign

Some of the roots of SCM were provided by Business Process Redesign (BPR). BPR aims at drastic improvement of the performance of organisations through fundamental redesign of business processes (Hammer, 1990). Hammer and Champy (1993) define BPR as 'the fundamental rethinking and radical redesign of business processes to achieve dramatic improvements in critical, contemporary measures of performance, such as cost, quality, service and speed'. It is a revolutionary, rather than an evolutionary process. According to Österle (1995), BPR (or Business Re-engineering as he calls it) first requires an innovative project (revolution) and then refinement (evolution) through process management, such as adjustments to the process or alterations in business conditions. Gunn (1994) defines BPR as follows. 'In BPR we must first understand the current business processes, especially through the eyes of the customer, as the product flows through the business process, with regard to four factors:

- cost and value-added build-up;
- elapsed time;
- quality or yield - the converse of process loss; and
- the flow of data or information that is required or generated by the business process.

Once the current process is understood in this context, it can then be simplified and the waste eliminated from it.'

In general, the redesign literature stresses the importance of focusing on cross-functional customer-driven processes, instead of focussing on functional activities. According to Gunn (1994), the focus of the reengineering activity should be to answer the following three questions:

1. Is this work necessary?
2. Does this work add value for the customer?
3. If we were to start with a clean sheet of paper, would we do it this way again?

To position BPR we refer to Venkatraman (1994), who distinguishes five levels of Information Technology (IT) integration (see Figure 2.4). The framework illustrates that the higher the degree of business transformation, the higher the range of potential benefits. The bottom two levels, i.e. using IT to automate local information processing activities within departments (level 1) and to integrate all automating activities at different departments into one infrastructure (level 2), do not require fundamental changes in the current ways of working. The third level refers to traditional BPR, while the fourth level takes the redesign across the boundaries of a single organisation to include the entire network or chain involved in delivering a product or service. Beers et al. (1998) refer to this as Chain Process Redesign. The fifth level has the largest strategic implications and pertains to redefining the firm's mission and scope as a consequence of new IT-capabilities.

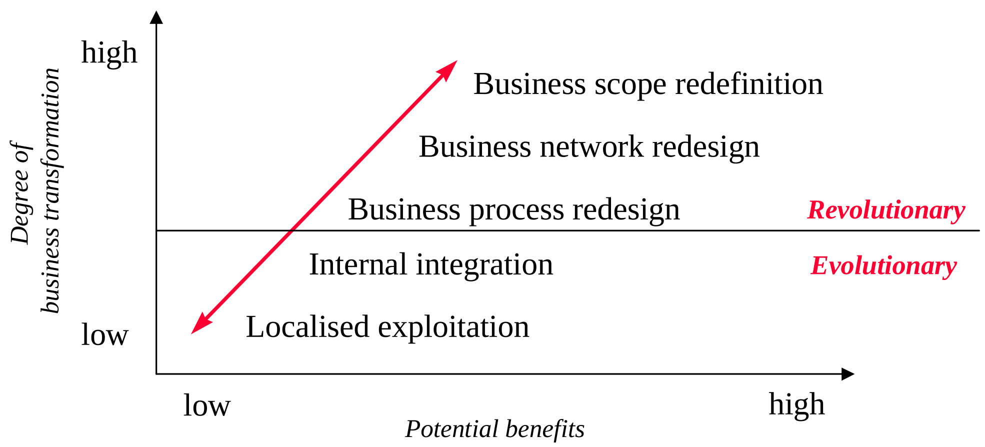

Figure 2.4 From localised exploitation to business scope redefinition (Venkatraman, 1994)

Evans et al. (1995) compare BPR with SCM and conclude that they are two complementary philosophies. Both philosophies recognise that the pressure of change, competition and customers can no longer be ignored and business structures must change. In both cases fundamental changes occur in the business processes, jobs, organisational structures, management systems and beliefs. Also, the objectives and the way they are implemented show many common areas. Straightforward automation of existing processes has long been known to produce marginal improvements (if any at all) and has been a strong example of 'what not to do' in BPR and SCM (Evans et al., 1995). However, BPR requires fundamental rethinking of core business processes, while SCM works to optimise the whole SC.

2.5 Efficient Consumer Response

Related to the concept of SCM, the concept of Efficient Consumer Response (ECR) emerged in food SCs (van der Vorst et al. 1999b). ECR has become the code word for how the consumer packaged-goods channel will operate in the future.

At the end of the 1980s the *Quick Response* strategy was developed for general merchandise retailers and their suppliers as a response to very low overall efficiency of these SCs (Kurt Salmon, 1993). In essence it is an outgrowth of the Just-in-Time philosophy to provide 'the right product in the right place at the right time'. Quick Response (QR) is a partnership strategy in which retailer and supplier work together to respond more quickly to consumer needs by sharing information on Point-of-Sale activity in order to jointly forecast future demand for replenishable items and continually monitor trends to detect opportunities for new items (Fisher, 1997; Iyer and Bergen, 1997). Operationally, both parties use Electronic Data Interchange (EDI) to speed the flow of information, and activities are jointly reorganised to minimise lead times and costs. EDI enabled retailers to automatically generate and transmit orders directly from POS data, increase their reorder frequency and substantially reduce both safety stocks and sales lost to stock outs. QR is a classic case of the substitution of information for inventory (Christopher, 1998).

The principles of this QR strategy were transferred to the grocery SC, which led to the grocery-industry strategy *Efficient Consumer Response* (ECR), in which distributors and suppliers work closely together to offer better value to the grocery consumer. By jointly focusing on the efficiency of the total grocery supply system, rather than the efficiency of individual components, they reduce total system costs, inventories, and physical assets while improving the consumer's choice of high-quality, fresh grocery products. In accordance with SCM the ultimate goal of ECR is to achieve a responsive, consumer-driven system in which distributors and suppliers work together as business allies to maximise consumer satisfaction and minimise system cost (Figure 2.5). Accurate information and high-quality products flow through a paperless system between manufacturing line and check-out counter with minimum degradation or interruption both within and between trading partners (Kurt Salmon, 1993).

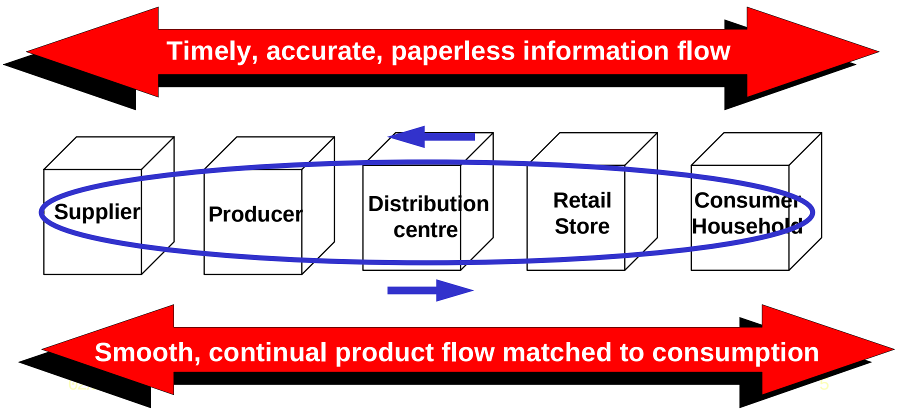

Figure 2.5 The ECR system (adapted from Kurt Salmon, 1993).

Kurt Salmon Associates (1993) were the first to publish on ECR. Their publication reports the findings of an ECR working group comprising a group of industry leaders in the United States (such as Coca-Cola, Kraft General Foods, Procter & Gamble, Campbell and Safeway). This task force was charged with examining the grocery SC and its trade practices to identify potential opportunities for changes in practices or in technology that would make the SC more competitive. The ECR working group developed five guiding principles that concisely articulate the ECR strategy (Kurt Salmon Associates, 1993):

1. Constantly focus on *providing better value* to the grocery consumer: better product, better quality, better assortment, better in-stock service, better convenience with less cost throughout the total SC.
2. ECR must be driven by *committed business leaders* who are determined to replace the old paradigms of win/lose trading relationships with win/win mutually profitable business alliances.
3. *Accurate and timely information* must be used to support effective marketing, production and logistic decisions. This information will flow externally between partners through EDI and will internally effect the most productive and efficient use of information in a computer-based system.
4. Product must flow with a maximisation of value-adding processes from the end of production/packing to the consumer's basket so as to *ensure the right product is available* at the right time.
5. A *common and consistent performance measurement and reward system* must be used that focuses on the effectiveness of the total system (i.e. better value through reduced costs, lower inventory and better asset utilisation), clearly identifies the potential rewards (i.e. increased revenue and profit), and promotes equitable sharing of those rewards.

Coopers and Lybrand (1996) translated these guiding principles into a family of 14 ECR improvement practices categorised into three clusters concerning marketing, logistics and Information Technology (Figure 2.6).

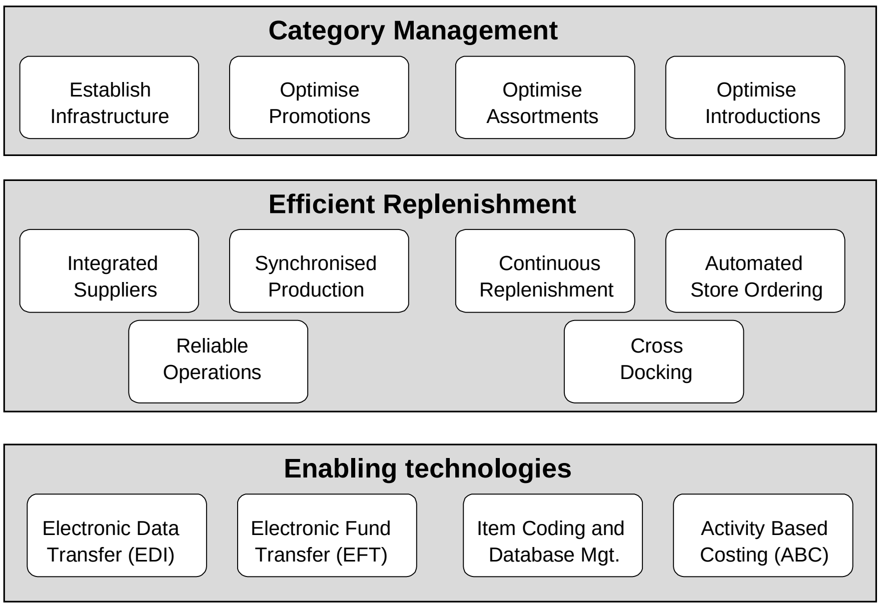

Figure 2.6 ECR performance improvement concepts (Coopers and Lybrand, 1996)

Category Management focuses on product categories for the optimisation of assortments, product introductions and promotions. A product category is defined as a group of products recognisable as such to a particular group of customers (e.g. pet product category or baby product category). Food industries and retailers jointly work on providing consumers with the right product that has the right specifications, resulting in the purchase of the product. The partners in the SC formulate a consumer-oriented strategy for each product category. They start with the assumption that establishing chain partnerships can reduce the costs of these activities. For example, costs of forward buying, brand switching, extra production runs, advertisement, etc. By calculating the total costs and benefits per product (Direct Product Profitability), a better evaluation of assortments can take place. In the food sector, perishability and conditioning are especially important criteria in forming logistics categories. Important distinctions are made between daily fresh products (vegetables and fruits), chilled products (salads, dairy products, etc.), frozen products (fish, ice, etc.) and non-perishables as sugar and coffee.

The objective of *Efficient Replenishment* (ER) here is to ensure an optimised product flow through the SC. Optimised in the sense that one is able to respond to changing consumer demands, ensure low inventories, freshness, quality and long shelf life, required service levels, and so on. Partners in the SC can achieve these objectives by changing the method of operational co-operation in the chain. This is supported by a free flow of accurate and timely information, integrated with the flow of product, throughout the grocery SC. ER consists of secondary improvement concepts, which, when implemented together, should result in responsive, flexible, customer-order-driven SCs (Coopers & Lybrand, 1996):

- Automated store ordering: Store orders are generated automatically based on actual scanning-data, in-house inventory and sales forecast.
- Continuous replenishment: The inventory of the retailer is managed by more frequent and smaller deliveries from the producer, based on actual sales and forecasted demand.
- Cross docking: Eliminating the storage of products at the retailer distribution centre by transferring, re-consolidating and distributing products within 24 hours to the stores.
- Synchronised production: Synchronising production to consumer demand by only producing those products that are actually required, by consumer demand.
- Reliable operations**:** Improving process reliability (reducing manufacturing down time) and improving delivery reliability.
- Integrated suppliers*:* Implementing continuous replenishment, reliable operations and synchronised production upstream the SC.

Box 2.3 Continuous Replenishment at Campbell Soup

In real-life tests with four retailers, Campbell Soup found that Continuous Replenishment reduced inventories in retailer DCs by 50%, while increasing service slightly from 98.7 to 99.5%. Cachon and Fisher (1997a) developed forecasting and inventory management rules to improve the operation of CR, and tested these rules with a simulation using actual demand data provided by Campbell Soup. In this sample their algorithm reduced inventories by 66% relative to what the retailers had been carrying and by 33% relative to what Campbell Soup had achieved, while maintaining or increasing average fill rates.

(source: Cachon and Fisher, 1997a)

Finally, we need *Enabling Technologies* to facilitate the presented ECR concepts. Huge amounts of data have to be collected, exchanged and processed for ECR. Therefore, we need a mutual infrastructure, which provides standard techniques:

- Item coding and database maintenance aids in collecting and processing (point-of-sale) data. The European Article Numbering (EAN)-code system offers the opportunity to register each product uniquely, which is a prerequisite for tracking and tracing.
- Electronic Data Interchange (EDI) facilitates the standardised exchange of data between companies.
- Electronic Funds Transfer is the electronic exchange of account and invoice information between trading partners.
- Activity Based Costing provides insight in the costs of activities within the SC. This facilitates the calculation of financial consequences of changes per individual activity and chain partner.

ECR thus comprises 14 concepts that can be used (together) to improve SC performance. ECR in itself is not a new phenomenon, but it offers a total package of concepts that can analyse and optimise SCs. However, like SCM, ECR does not provide decision makers in the SC with guidelines to help them decide which concept to implement and according to what specifications. We view ECR as a sub-concept of SCM, since it focuses on some elements of SCM that are specific to the food industry (Figure 2.7). SCM is much broader than ECR: for now ECR ignores the political, governmental and environmental issues of SCM. The Efficient Replenishment cluster within ECR represents the research area of this thesis: it focuses on the logistical aspects of SCM.

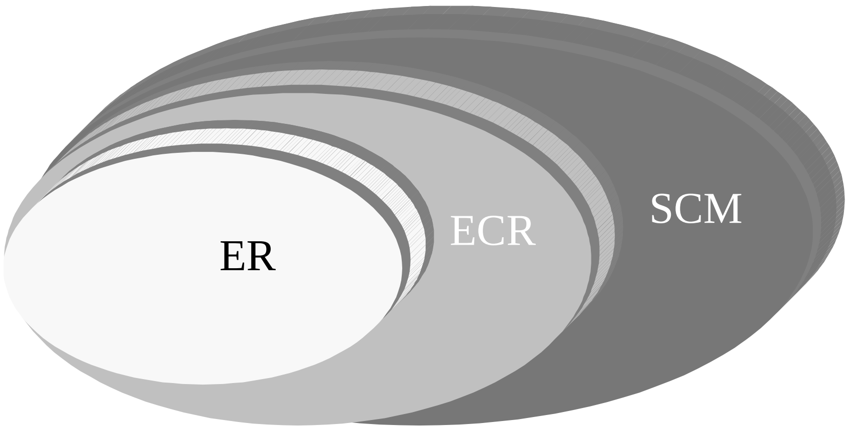

Figure 2.7 View on the relationship between ER, ECR and SCM.

One of the latest developments in this area is called Collaborative Planning, Forecasting and Replenishment (CPFR). CPFR takes a holistic approach to SCM among a network of trading partners. This model can be seen as the integration of Category Management and Efficient Replenishment principles, since it places the SC partner trading relations at the centre of the replenishment decision making process. It focuses on joint planning of the marketing of products, which can be adjusted by all partners within established parameters. Consecutively, the logistics system is optimised according to these plans. For more information on CPFR we refer to www.cpfr.com or www.ascet.com.

2.6 Review of Operational Research literature on SCM

During the last decade, Operational Researchers have put more emphasis on modelling and analysis of multi-echelon systems. The complexity of the SC makes global formulation of the SC problem very difficult. Not surprisingly, the research community has spent more energy modelling smaller sections of the SC. Although simplified, much can be learned from these simplified models.

Though SCM is relatively new, the idea of co-ordinated planning in multi-echelon inventory/distribution systems is not. These systems were first studied nearly 40 years ago (Clark and Scarf, 1960). A key aspect of the Clark-Scarf studies is the use of *echelon inventory* in the control policies for the multi-echelon system. The echelon stock for a component is defined as the inventory of the component plus the entire inventory of downstream items that use or require the component (e.g. subassemblies or end items). This differs from the *installation stock*, which is just the inventory of the component neglecting all downstream inventories (De Bodt and Graves, 1985). Clark and Scarf (1960) demonstrated that order-up-to policies based on echelon stock are optimal for *serial inventory systems* (in which each firm has only one customer) *with periodic review* and set-up costs only at the highest echelon. De Bodt and Graves (1985) found a good order policy for serial systems with stochastic demand and *continuous review*. According to Chen and Zheng (1994b), they were the first to study simple and easily implemented echelon stock policies in multi-stage inventory systems with set-up costs at all stages.

Installation stock (R,Q) policies have been more extensively studied in the context of one-warehouse multi-retailer systems (e.g. Svoronos and Zipkin, 1988; Äxsater and Rosling, 1993; Chen and Zheng, 1994a). Another set of two-echelon models with stochastic consumer demand assumes the supplier receives replenishments at *fixed intervals*, retailer replenishments can occur in any period, and *order batch size* generally equals one (e.g. Jackson, 1988; Nahmias and Smith, 1994). These papers focus on how the supplier should allocate inventory among retailers, and not on how retailer ordering restrictions influence system costs. Van Houtum et al. (1996) review stochastic multi-echelon planning and control systems for production and distribution-to-stock environments. Diks et al. (1996) state that one of the main difficulties in cost-efficient and effective SCM is to determine the target service levels (associated with the service measures selected), so that pre-specified external service targets are met at lowest cost. They give an extended review of contributions in controlling divergent multi-echelon systems with *service level constraints*, considering costs of holding inventory, order costs and the cost of running out of stock.

A major body of the literature on production and inventory control in the last two decades has been devoted to modelling the impact of various uncertainties such as demand patterns, supplier and production lead times, imperfect process quality, process yield, etc. (for an overview see Moinzadeh and Aggerwal, 1997).

Thomas and Griffin (1996) give an extensive review, addressing co-ordinated planning between two or more stages of the SC and placing particular emphasis on models appropriate for modelling the chain. According to them, it is difficult to find algorithms and models for inventory policies in multi-echelon systems with stochastic demand and batch or periodic ordering. Many authors consider a *two-echelon distribution system* with identical retail sites and Poisson demand, and then develop an approximate model of system costs or performance as a function of inventory levels; simulation is used to evaluate the model (Graves, 1996). Jackson (1988) and Schwarz (1989) provide excellent reviews of this literature. Feigin (1999) proposes a SC model that focuses on the management challenge of deciding where and in what quantities to hold safety stock in a *network* to protect against variability and to ensure that target customer service levels are met.

Silver et al. (1998) distinguish two dimensions of information management: local versus global information, and centralised versus decentralised control (Table 2.4). *Local information* implies that each location sees demand only in the form of orders that arrive from the locations it directly supplies. *Global information* implies that the decision-maker has visibility of the demand, costs, and inventory status of all the locations in the system. Hence, this goes a bit further than the concept of echelon stock. *Centralised control* implies that attempts are made to jointly optimise the entire system, usually by the decision of one individual or group (pushing stock to locations where it is needed). Decisions on how much and when to produce are made centrally, based on material and demand status of the entire system. Fransoo and Wouters (1999) refer to a 'SC cockpit' that can manage the SC that consists of different companies as if it were a single company. *Decentralised control*, on the other hand, refers to cases in which each individual unit in the SC makes decisions based on local information (Lee and Billington, 1993). The literature on Supply Chain Inventory Management mostly assumes policies are set by a central decision-maker to optimise total SC performance.

Table 2.4 Different dimensions of information management (after Silver et al. 1998)

	Centralised control	Decentralised control
Global information	• Vendor Managed Inventory • Global Planning Systems	• Base Stock Control • DRP
Local information	*Makes no sense*	• Basic Inventory Control mechanisms

According to Silver et al. (1998), the best solutions are obtained by using global information and centralised control, because the decisions are made with visibility of the entire system using information from all locations. This is questioned by Cachon and Fisher (1997b), whose results suggest that vendor/supplier management of retail inventories will provide little additional value in a one-supplier (holding inventory), single slow-moving product, N retailer model of a SC with stationary stochastic consumer demand. Cachon and Fisher (1997b) explain the relatively low value of demand and inventory information sharing on the ordering and allocation functions of the supplier in their model as follows:

'When the retailer is flush with inventory, its demand information provides little value to the supplier because the retailer has no short term need for an additional batch. The retailer's demand information is most valuable when the retailer's inventory approaches a level that should trigger the supplier to order additional inventory. But this is also precisely when the retailer is likely to submit an order. Hence, just as the retailer's demand information becomes most valuable to the supplier, the retailer is likely to submit an order, thereby conveying the necessary information without explicitly sharing demand data.' (Cachon and Fisher, 1997b).

There is substantial literature on 'ship-all' policies, referring to *cross docking* situations, in which bulk shipments of the supplier are immediately transhipped to the retail sites in order of their need (e.g. Jackson, 1988; McGavin et al., 1993). The multi-echelon literature (e.g. Schwarz, 1989) identifies two reasons for the central warehouse: to pool risk over the replenishment time for the outside supplier and to pool risk over the retail sites by periodically rebalancing the retail inventories.

Bloemhof-Ruwaard et al. (1995) discuss the application of Operational Research (OR) models to *environmental management issues*. They argue that the shift in focus from end-of-pipe control to waste prevention at the source suggests an integrated modelling approach, similar to SCM. The authors review early research efforts that attempt to combine environmental management and OR, citing references from both environmental and OR journals. They conclude that in the near future, the OR community must integrate with related sciences to adequately address environmental issues. Research efforts to efficiently reuse products and/or materials in a SC are discussed by Van der Laan et al. (1999); they refer to *Reverse Logistics Management*.

Cohen and Mallik (1997) give a literature review of *global SCs*. The global SC strategy is characterised by the linkage of decision making at all levels of the firm's SC, i.e. across regional, functional and even inter-firm boundaries. They give a general criticism of the majority of reported models, which is that they lack practicality and would be difficult to implement. Few of the models, for example, incorporate the underlying complexity of a global SC network, and most ignore price and demand uncertainties in international markets. Cohen and Huchzermeier (1999) review the state-of-the-art of modelling approaches to support the design and management of global SC networks under different types of risk (due to fluctuations in market demand, market prices and foreign exchange rates).

More specific for food SCs, Federgruen et al. (1986) present an allocation model for a *perishable product* (with a fixed lifetime), distributed from a regional centre to a given set of locations with random demand. Silver et al. (1998; Chapter 10) present a brief literature overview of literature concerned with perishable items from an organisation perspective.

Table 2.5 Typology of OR multi-echelon inventory/distribution systems

Model elements	*Model choices to be made*
Scope of SC	Dyad, serial (chain) or network
Aspects considered	Environmental issues, global SCs, perishable goods
Demand process	Variable or constant consumer demand
Information availability	Global or local information (echelon or installation stock policies)
Type of SC control	Centralised or decentralised SC control
Type of replenishment	Fixed or periodic inventory replenishment cycles Ship-all or variable size
Objective(s) of model	Minimising SC cost (inventory holding, ordering, out of stock, transportation, etc.) or optimising service levels (out of stock, lead-time, delivery frequency, etc.)
Methodology applied	Optimisation (LP, MILP), simulation (discrete, continuous) or heuristic

To conclude this review of OR-literature, Table 2.5 presents a typology of OR SC models that gives us a good departure point for Chapter 7 when we try to develop a research methodology for the assessment of SC scenarios. The main conclusion that can be drawn from this literature overview is that no mathematical model could be found that incorporates all relevant aspects of SCM. Usually, a restricted scope of the SC is taken or only few performance indicators or management variables are included.

2.7 Strategic partnering

There are two aspects that deserve more attention at this moment. The first is the trade-off between vertical integration and strategic partnering. The second is pitfalls to SC partnerships.

2.7.1 Vertical integration or strategic partnering

Vertical integration can be viewed as an alternative to SCM, in that it attempts to manage and control channel efficiency through ownership. Ellram (1991) groups the advantages, and respectively the disadvantages of vertical integration into three broad categories (Table 2.6).

According to Ellram (1991), the literature does not agree on when vertical integration will occur. Williamson (1985) developed a framework of three critical dimensions; these dimensions determine the way an organisation should be structured in order to be most effective in bringing the firm's products to market. These are 1) the uncertainty associated with the transaction (cost, timing and so on); 2) the degree to which specialised assets or investments are involved in the transaction; and 3) the frequency of the transactions. Williamson argues that as assets become more specific to a single user, there is no advantage to purchasing outside. Vertical integration is most likely for recurrent transactions, which require very specialised assets.

Table 2.6 Advantages and disadvantages of vertical integration (Ellram, 1991)

Advantages	***Disadvantages***
Improves control: • Reduction of uncertainty • Convergent expectations • Reduced probability of opportunism and externalities (e.g. dependency on monopoly suppliers) • Ease of conflict resolution	*Limits competition:* • More difficult for non-integrated firms to enter business • Weakens non-integrated competitors • Inability to replicate market incentives • Internal information distortion
Improves communication: • Improved co-ordination of processes • Greater goal congruence	*Increases risk:* • Asset concentration • Perpetuates obsolete processes • Exaggerates synergies
Improves cost structure: • Economies of scale through avoidance of intermediaries • Process integration (improved asset utilisation) • Avoids switching/transaction costs	*Diseconomies of scale:* • Balancing scale economies • Inability of management to control large organisation efficiently • Limits on span of control • Increased difficulty in communication

Argyrus (1996) elaborates on the capabilities approach to the firm, which postulates that firms vertically integrate activities for which they possess capabilities that are superior to those of the potential suppliers. He found that firms outsource when suppliers possess superior capabilities, except when higher costs are accepted in the short run while capabilities are being developed in-house.

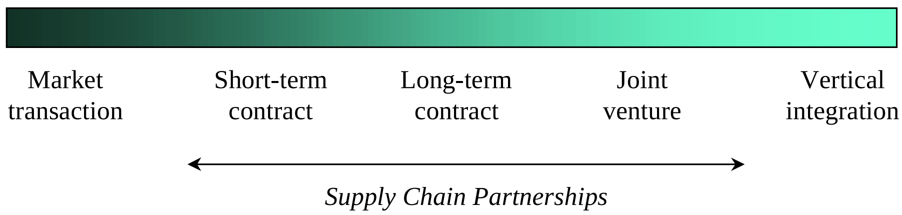

Figure 2.8 Typology of SC partnerships

Within the SC, relationships may take on a variety of legal forms, including vertical integration, long-term contracts, and market transactions. Cooper and Ellram (1993) view SCM as lying between fully vertically, integrated systems and those in which each channel member operates completely independently (Figure 2.8). Broersma (1991) gives some examples of these forms when he describes four types of (logistics) partnering:

1. Price buying: suppliers obtain incidental orders depending on the offerings.
2. Regular supplier: supplier has inventory buffers and receives orders on a regular basis.
3. Contracted supplier: supply is based on contracts (call-offs).
4. Co-makership: coupled systems, EDI and no inventory buffers at both parties.

Ellram (1991) defines partnering as ‘an ongoing relationship between two organisations which involves a commitment over an extended time period, and a mutual sharing of the risks and rewards of the relationship’. This corresponds to the definition of LaLonde and Cooper (1989): ‘partnering is a relationship between two entities in the logistics channel that entails a sharing of benefits and burden over some agreed upon time horizon’. Johnston and Lawrence (1988) refer to Value Added Partnership (VAP) and define it as ‘a set of independent companies that work closely together to manage the flow of goods and services along the entire value-added chain’. In strategic partnerships the emphasis is on co-operation and partnership between the parties, not competition and conflict, as the basis upon which a joint competitive advantage is developed. Partnership refers to a relationship that attempts to build interdependence, enhance co-ordination, improve market position focus (by broadening or deepening), or to achieve other shared goals; and that entails sharing benefits and burdens over some agreed time horizon (Cooper and Gardner, 1993). Partnership is a tailored business relationship featuring mutual trust, openness, and shared risk and reward that yields strategic competitive advantage (Handsfield and Nichols, 1999).

Current social-economic, technological and market developments demanding more specialist knowledge result in companies focussing on their core competencies (see Chapter 1). SCM and vertical integration share similar goals in terms of channel control (Ellram, 1991). SCM positions each firm to do what it does best, while spreading the risk of asset ownership, and reducing market risk through improved co-ordination and communication. Building on the participant’s strengths, SCM attempts to overcome some of the disadvantages of vertical integration.

Box 2.4 SCM at Ford

At the end of 1930s, Ford was a completely integrated car-producing company that produced low-priced cars, due to the introduction of the conveyer belt. The company owned wood plantations for the production of wooden car bodies. When steel found its way into car manufacturing, Ford had some problems because they had to transfer to these new production methods and find new suppliers. Furthermore, Ford had to get rid of the wood plantations because they were no longer of use to them. Such examples show that partnerships might be more interesting than owning all required assets.

(source: Zuurbier et al., 1996)

Debo et al. (1998) describe the ideal partnership. 'Once a partnership is established, both partners do not consider other potential partners anymore. Partners exchange all relevant information with each other and take decisions that are in the interest of both. Decisions taken on a partnership level are implemented locally without problems.' Lamming (1993) showed that these ideal partnerships are not common. He found that 46% of Nissan's existing and potential suppliers in the UK think that it is reasonable to hide cost savings, despite the 'very close' partner relationship.

2.7.2 Criteria for successful partnerships

Not all authors believe that partnerships are beneficial to SCM (Bechtel and Jayaram, 1997). Research performed by A.T. Kearney as reported by Anscombe (1994) questions whether the use of partnerships is useful in SCM. The results of this study suggest that firms misinterpret the partnership idea and strive to create partnerships in all of their relationships, which may not be desirable or reasonable. An empirical study performed by Lambert et al. (1996) supports this conclusion.

Organisations often try to weaken a supplier or customer to ensure their own control of profits (Johnston and Lawrence, 1988). This is understandable, given that the widely followed competitive model suggests that companies will lose bargaining power - and therefore the ability to control profits - as suppliers or customers gain strength. Naturally, such companies tend to share as little information as possible, and consequently managers often lack knowledge of the activities elsewhere along the value-added chain. The conventional solution for ending such destructive games and for controlling resources is vertical integration. But this causes the problem of focus, since tasks require distinctly different orientations and values.

According to Ellram and Cooper (1993), successful SCM relies on forming strategic partnerships with trading partners who play a key role in co-ordinating and overseeing the whole SC, similar to what is called a channel captain in the marketing literature. Zuurbier et al. (1996) identify two basic qualifiers for partner selection: strategic complementarity and cultural congruence (trust and commitment). *Strategic complementarity* refers to the degree of compatibility of the partners' assets and competencies and goals and strategies. *Cultural congruence* refers to the degree of congruence of the partners' beliefs, value systems and norms. Similarly, Tan et al. (1998) suggest that effective SCM rests on the twin pillars of trust and communication. Several authors believe that the most important barrier to re-engineering is people and not systems or technology (Hewitt, 1994; Lee and Billington, 1993).

Table 2.6 combines the findings of literature on partnerships in marketing, contract law, economics and logistics (Cooper and Gardner, 1993; Zuurbier et al., 1996; Simpson and Long, 1998; and Lambert et al., 1998). It provides an overview of aspects mentioned in literature that are relevant in determining if a partnership is appropriate. Because each relationship has its own set of motivating factors driving its development as well as its own unique operating environment, the duration, breadth, strength and closeness of the partnership will vary from case to case and from time to time.

Table 2.6 Critical Success Factors for partnerships

Drivers for partnerships	Main partnership facilitators	Successful partnership characteristics
• Asset-cost efficiencies (cost reduction) • Customer service (e.g. shorter cycle times) • Marketing advantage (e.g. entrance into new markets) • Profit stability/growth	• Strategic complementarity • Corporate compatibility (culture and business goals) • Compatibility of managerial philosophy and techniques • Mutuality (joint objectives, share sensitive information) • Symmetry in power	• Joint planning • Global SC operating controls • Systematic operational information exchange (rapid and accurate transfer) • Sharing of benefits / burdens • Trust and commitment • Extendedness (the relationship will continue into the future) • Corporate culture bridge-building.

Deloitte Consulting (1999) conducted a survey amongst more than 200 companies representing a cross section of industries throughout the United States and Canada. This survey revealed the following obstacles to achieving breakthrough SC performances:

- Few companies have established a management environment (including information systems) that supports the integration required for effective SCM. Instead, they remain functionally oriented with limited cross-functional teamwork and a lack of trust and credibility among the SC organisations.
- Very few organisations take a value-based management perspective of SC performance that assesses the impact of initiatives on revenues, costs, investments, and cost flows to ultimately drive shareholder value.
- The need for a better way to measure SC performance. In a significant percentage of companies, performance metrics are not aligned with corporate objectives. Furthermore, companies are not using the most dynamic tools available for planning and controlling activities along the SC.

Most firms simply do not know how much it costs to operate the channel. Firms need to know the true cost of doing business in the traditional paper-intensive manner compared with the potential costs/savings of being seamlessly electronically connected (Ellram and Cooper, 1993). Lee and Billington (1992), along with 13 other factors, found this to be a critical success factor. They describe fourteen pitfalls of Supply Chain *Inventory* Management and some corresponding opportunities, drawing upon knowledge and experience of SCM at electronics, computer, and automobile companies (Appendix A).

2.8 Taxonomies of SCM literature

We found an interesting taxonomy of SCM literature in Ganeshan et al. (1999). They classified the SCM literature from many different disciplines (including Marketing, Economics/Systems Dynamics, Operational Research / Management Science, and Operations Management) according to three broad perspectives: 1) competitive strategy issues, which have a long-range impact on the firm; 2) firm-focused tactics operating in a shorter time frame (days, weeks or months); and 3) operational efficiencies involving day-to-day decisions that can be altered quickly (Table 2.7). For each category some relevant articles are given below.

Table 2.7 A taxonomy of SCM research (based on Ganeshan et al. 1999).

Category	***Some relevant articles***
1. Competitive strategy issues: - Development of objectives and policies for the entire SC and the analysis of how these support the needs of the firm - Determination of the shape of the SC in terms of design - Discussions on how SCM can enhance the competitiveness of the firm	Oliver and Webber (1982); Jones and Riley (1985); Ellram (1991); Scott and Westbrook (1991); Towill et al. (1992); Davis (1993); Bloemhof-Ruwaard et al. (1995); Cohen and Mallik (1997)
2. Firm-focused tactics: - Implementation of strategic decision (involves developing upstream and downstream relationships) - May deal with only a few players of the overall SC - May involve information systems (MRP, DRP, JIT, etc.) necessary to manage the SC	Cohen and Lee (1988; 1989); Geoffrion and Powers (1995); Verwijmeren et al. (1996)
3. Operational efficiencies: - Concerned with the efficient operation of the company within the SC (focus on inventory management and control, production planning, and information sharing) - Focuses on controls and performance measures	Clark and Scarf (1960); Lee and Billington (1993); Van Dam (1995); Slats et al. (1995); Lee et al. (1997); Moinzadeh and Aggerwal (1997); Cachon and Fisher (1997b)

Furthermore, Ganeshan et al. (1999) categorises SCM research according to the solution methodology used (Table 2.8). We refer to Ganeshan et al. (1999) for a complete taxonomy and list of corresponding authors. Beamon (1998) distinguishes four categories of multi-stage models for SC design and analysis: deterministic analytical models (in which the variables are known and specified); stochastic analytical models (in which at least one of the variables is unknown, and is assumed to follow a particular probability distribution); economic models; and simulation models.

Table 2.8 Taxonomy of SCM research by solution methodology (after Ganeshan et al. 1999)

Solution methodology	Description	Some relevant articles
Concepts and non-quantitative models	Research that analyses the SC in an attempt to define, describe and develop methods for SCM without using quantitative models.	Lee et al. (1997); Scott and Westbrook (1991); Van der Vorst and Beulens (1999).
Case-oriented and empirical study	Research that works with specific firms or industries and uses data collected by the researcher to aid in SCM.	Cachon and Fisher (1997b); Davis (1993); Lee and Billington (1995); Van der Vorst et al. (1998)
Frameworks, taxonomies and literature reviews	Research that categorises or explains concepts in SCM as an effort in the understanding of the breadth and depth of the concept.	Bloemhof-Ruwaard et al. (1995); Cohen and Mallik (1997); Fisher (1997); Thomas and Griffin (1996)
Quantitative models	Research that attempts to develop methods for SCM using quantitative models	See Section 2.6; Van der Vorst et al. (2000)

As will be seen in Table 2.8 several solution methodologies cross our research; we use quantitative and qualitative methods combined with case study research to develop methods for SCM. Furthermore, we aim to assist managers in improving SC performance. This is especially related to the operational efficiency (particularly the quantitative part) but it is also related to the SC configuration. We will go further into this in the next two chapters.

Box 2.5 Resistance to change biggest obstacle for SCM
Research conducted by Arthur D. Little amongst 245 European companies revealed that many companies had problems implementing SCM, even though 48% had appointed a special 'supply chain manager'. The most important complaints were resistance to change (52%), complexity of the SC (49%), an incompatible internal organisation (41%), not co-ordinated objectives (39%), and lack of co-ordination between different disciplines (34%).

(source: Logistiek krant, 1999)

2.9 Concluding remark

This chapter discussed the research environment of SCM. Definitions of a SC and SCM were given and the concepts of BPR and ECR were discussed. Although a lot has been written on the scope and definitions of SCM, literature does not provide us with an operational tool to select effective SC scenarios that improve SC performance. Chapter 4 will go further into this.

This thesis aims to assist decision-makers in the SC in evaluating the benefits of SC partnerships by developing a step-by-step approach to SC analysis and redesign. We aim at finding a 'best practice' SC scenario for a particular food SC that can be implemented. But our approach starts with SC stages that are willing to co-operate. We are not doing research into, for example, the strategic complementarity of the companies. Hence the result of the application of our approach should finally be evaluated together with the other critical success factors for SC partnerships summarised in Table 2.6.

The following chapter will focus on the definition of an effective SC scenario.

Chapter 3

Effective Supply Chain Scenarios

'If performance is not measured, performance is unknown and what is unknown cannot be controlled' (Anders Ljungberg)

3.1 Introduction

Following from our research questions and Proposition 1.1, effective SC scenarios should be established that maximise SC performance. The main contributions of this chapter will be:

- a presentation of our system and process view on supply chains resulting in a definition of an effective supply chain scenario;
- a discussion of supply chain performance resulting in a number of SC Key Performance Indicators that are required to evaluate the effectiveness of a SC scenario;
- a conceptual framework that can be used to describe, analyse and typify a supply chain in detail in order to facilitate the SC redesign process.

Section 3.2 will elaborate on our systems view on SCs and give a definition of a SC scenario. The SC performance is discussed in Section 3.3, where definitions are given and performance indicators are presented. The elements that can describe and typify a SC are discussed in Sections 3.4 to 3.7. As a result, a conceptual framework for SC analysis is presented in Section 3.8. We will conclude this chapter with a summary of the main findings and some additional remarks.

3.2 A Systems View on Supply Chains

3.2.1 Systems Approach

Systems thinking originated in the biological sciences in the 1950s and 1960s and was adapted by the social sciences as a method for understanding real-world phenomena (Jackson, 1993). Biologist Ludwig von Bertalanffy (1968) is recognised as the founder of general systems theory. Systems science looks at organisations as systems that fulfil a certain function in the environment. In system thinking, reality is considered to be a construct of systems and their environments (Trienekens, 1999).

Definition 3.1

A system is a structured set of objects and/or attributes together with the relationships between them (Wilson, 1993) *in its environment*.

These objects are related to each other and to other objects outside the system. In order for the system to fulfil its function, a process takes place that transforms inputs with respect to place, form, size, function, time, or some other characteristic. The element of *synergy* is very important. Or, as Checkland and Scholes (1990) put it, ‘the whole is more than the sum of its parts’. According to the systems approach, analysis is intended to maintain the totality, understand the component’s relations to this totality and the totality's relation to its surrounding world (Ljungberg, 1998). In other words, the components (i.e. the processes) are explained by the totality.

The *boundary of the system* chosen places the system at a particular level within a series of levels. Thus a system is at the same time a subsystem of some wider system and is itself a wider system to its subsystems. What we define to be a 'system' is a choice of resolution level or the choice of level of detail at which we wish to describe the activities. It is a choice; there is no absolute definition of what a system or a subsystem is (Wilson, 1993). Bertrand et al. (1990) define the system boundary as the ‘part of the world’ that is considered as opposed to the part that is out of scope. The system boundary should be established operationally by specifying the inflows and outflows from the environment into the system considered and visa versa.

Not all (sub) systems, or processes, are relevant. A *black box* is defined as a system whose internal structure is not known or not interesting, but whose relationships with the environment are known. That is, the transformation of input into output is known, but the activities within the transformation process itself are not known. Output variables are chosen based on research objectives.

De Leeuw (1988) uses a systems approach to structure organisation theory. His management paradigm can be used to describe an arbitrary control situation. He states that organisations consist of three aspects: the *managed system*, the *managing system* and the *information system* in an environment (Figure 3.1). The managed system refers to the primary transformation processes. The information system’s task is to register the relevant internal and external data and convert it to control information. The managing system aims at realising a certain system output by adjusting *control variables*, whilst dealing with non-manageable inputs (irregular variables such as demand, strikes, illness of staff). It takes decisions on the basis of available information. Control variables are decision variables of the managing system, for example, the location of a factory or the customer order lead time. Finally, output refers to end products delivered to the system’s customers.

Bemelmans (1994) suggests that the managed system determines the form of control needed (i.e. the managing system) to satisfy the logistic goals. The chosen form of control determines in turn under which constraints what information needs to be produced (the information system). This bottom-up approach is also followed in this research.

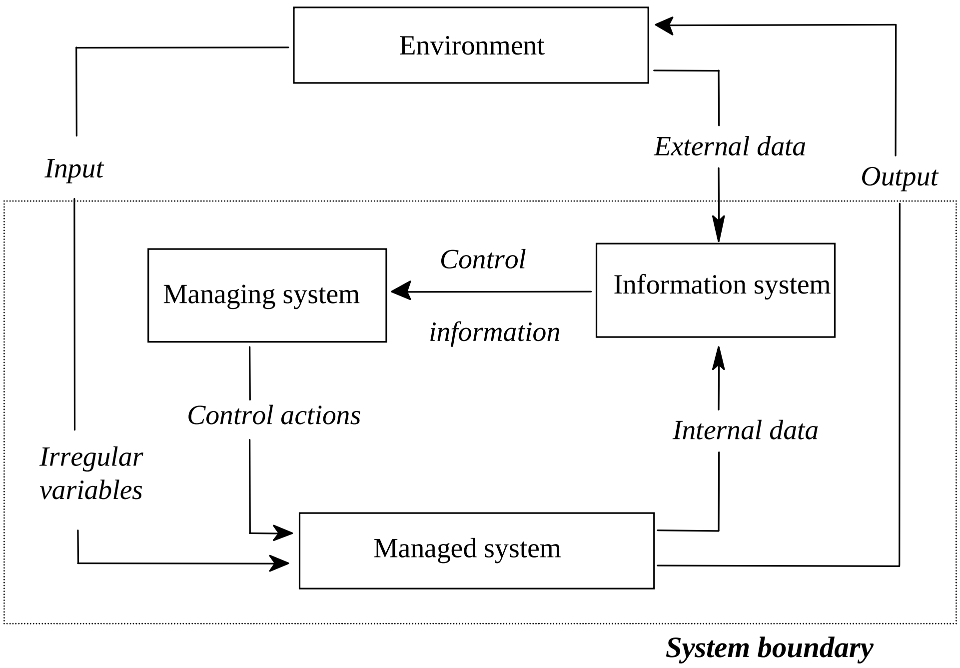

Figure 3.1 The management paradigm adapted from De Leeuw (1988).

Next to the managed system, the managing system and the information system, a fourth element is crucial in describing a SC; the *organisation structure* (Mintzberg, 1979). According to Ribbers and Verstegen (1992) process redesign should focus on each of the four elements of – what they call - the '*logistical concept*': physical design (i.e. the managed system), control concept (i.e. the managing system), information systems and organisation. Note that sometimes the elements that comprise the organisation structure are incorporated in the managing system. For clarity, we have chosen to discuss them separately.

Proposition 2

A SC can be seen as a large system comprising several subsystems (organisations) together with the relationships between them (Figure 3.2). Each subsystem, and therefore the system, can be described by the four elements of the 'logistical SC concept': managed system, managing system, information system and organisation structure.

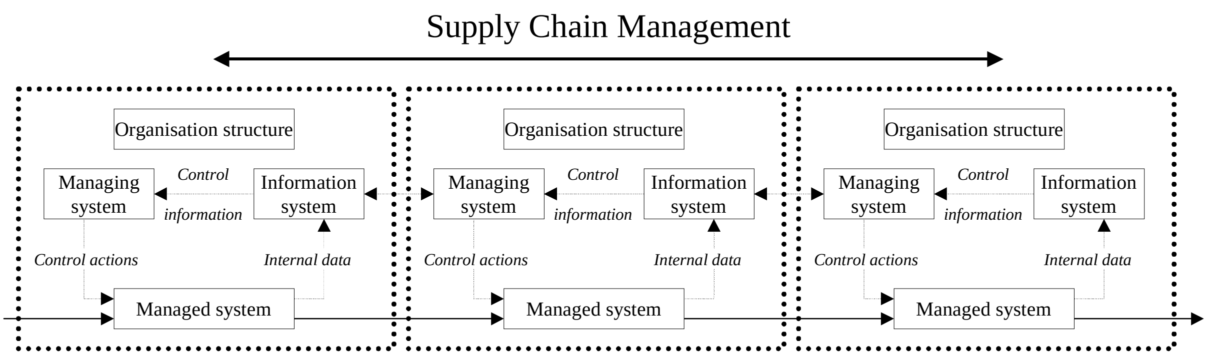

Figure 3.2 Systems view on SCs.

The *behaviour of a system* is goal oriented and is defined as changes of characteristics of (for the researcher) relevant system variables in time. When systems are analysed in the course of time, one can distinguish processes related by precedence relationships (De Leeuw, 1988). Also Ansoff (1969) prefers the word process over (sub) system since this emphasises the dynamism in an organisation. According to Persson (1995) any business can be described as a series of processes, involving the transformation of inputs into outputs in the form of transactions (of goods, information or cash flows) between suppliers and customers. The process approach is closely related to systems thinking. Systems thinking involves movement away from functional department sub-optimisation in the SC to a holistic optimisation of the entire system. The focus is on how decisions made at a particular point in the SC affect the upstream and downstream points in the SC (Davis, 1993).

3.2.2 Process Approach

In recent years a shift has been made from a more functional approach of logistical problems to a process approach (Christopher, 1992). Key differences between the traditional functional approach and the process approach are that, in the latter, the focus of every process is on meeting final customer requirements and the firm is organised around these processes. Hence, the identification of value-adding-processes in the SC (focusing on the final customer service requirements) and their mutual relationships is crucial.

Furthermore, there is a need to shift from output orientation to process orientation (Ellram & Cooper, 1993). Western management tends to be very focused on the end result of a system such as increased sales, reduced defects, or improved profitability. A marketing department may create special deals and promotions to achieve this quarter’s sales by ‘borrowing’ from next quarter’s sales, essentially ‘filling the pipeline’ rather than by creating new demand. In doing so, the results are achieved in the short term. However, the solution or goal will not be achieved for the long term, because the process that created the shortfall from the goal has not been changed (Ellram and Cooper, 1993).

According to Christopher (1992,1998) logistics must be managed as a process rather than as a series of individual activities if one wants to achieve superior performance for the customer. Taking a process approach implies *adopting the customer's point of view*. As Davenport puts it: ‘Processes are the structure by which an organisation does what is necessary to produce value for its customers. … A process is a specific ordering of work activities across time and place, with a beginning, an end, and clearly identified inputs and outputs: a structure for action’ (Davenport, 1993). Consequently, an important measure of a process is customer satisfaction with the output of the process. (Note that the next process can also be defined as the customer.) Österle (1995) elaborates on this definition from an IT-perspective when he states:

‘A process is a set of activities, which are to be undertaken in a specified sequence and which are supported by information technology applications. Its value creation consists of the outputs to process customers. The process has its own management, which steers and designs the process in line with the business strategy using performance indicators derived from it. A company concentrates on those few processes that determine its competitiveness.’ (Österle, 1995, p.62).

Definition 3.2

A process is a structured measured set of activities designed to produce a specified output for a particular customer or market. (Davenport, 1993)

A process orientation implies a strong emphasis on HOW work is done within an organisation, in contrast to a product focus's emphasis on WHAT is done. Processes that involve order management and service cross the external boundaries of organisations, extending into suppliers and customers. Consequently, viewing the organisation in terms of processes and adopting process innovations inevitably entails cross-functional and cross-organisational change. Based on a review of SCM literature, Trienekens (1999) concludes that SC business processes have six general characteristics. Business processes:

- transform input into output;
- are output/customer oriented;
- are cross-functional (and may cross organisational borders);
- are considered to be units with resources;
- are influenced by human resources in process management;
- possess internal management mechanisms tuned to external management mechanisms.

3.2.3 Definition of a Supply Chain Scenario

According to Van der Heijden (1996), scenarios are the best available language for the strategic conversation. They allow differentiation in views, but they also bring people together towards a shared understanding of the situation, making decision making possible when the time has arrived to take action. Porter (1985) defines a scenario as ‘an internally consistent view of what the future might turn out to be’. This view refers to changes in the environment but also to the system itself.

We view the SC as a system consisting of successive stages. And each stage comprises a gathering of interrelated logistical business processes that may cross organisational boundaries aiming to fulfil end consumer wishes. In Chapter 1 we discussed several developments resulting in a need for SC redesign. We define a SC scenario as follows.

Definition 3.3

A SC scenario is an internally consistent view of a possible instance of the logistical SC concept, i.e. the managed, managing, and information systems and organisation structures in the SC.

In Chapter 1 we already defined a ‘best practice’ SC scenario as ‘a feasible SC configuration and operational management and control for all SC stages that achieves the best outcome for the whole system’ (Definition 1.1). *Best practice* is widely considered to be about doing things in the most effective manner, usually focusing upon a specific activity or operation (a critical success factor) such as inventory management, customer service, and so on (Gattorna and Walters, 1996). Effective is defined as ‘the degree to which the objectives are realised’ (Caplice and Sheffi, 1994).

In the remainder of this chapter we will discuss the descriptive elements of a SC and conclude with a conceptual research framework for SC analysis. We will start with a discussion of system output, i.e. SC performance, and elaborate on the effectiveness of a SC scenario. Section 3.4 describes the elements of the managed system, since structural decisions about the SC network should be made prior to sommitting to infrastructure regarding the management of systems and processes within the SC network structure. Subsequently, the elements of the managing system (Section 3.5), the information system (Section 3.6) and the organisation structure (Section 3.7) are described.

3.3 System Output

We believe system redesign requires a notion of current system performance and objectives. In order to assess the SC performance and its related processes accurately, it is necessary to have objective performance information. Therefore, we will first discuss the definition of SC performance. Section 3.3.2 discusses relevant performance indicators and we conclude this section with an elaboration of the assessment of SC performance.

3.3.1 Definition of Supply Chain Performance

According to Bowersox and Closs (1996) the objectives of performance measurement and controlling activities in logistics are to track performance against operating plans and to identify opportunities for enhanced efficiency and effectiveness. Performance measurement is the process of quantifying action, since the performance of the operation is assumed to be derived from actions taken by its management (Neely et al., 1995). The SC performance is an overall performance measure that depends on the performances of the SC stages. The performance element in the definition of SCM is to *deliver superior consumer value at less cost to the SC as a whole*. As discussed in Chapter 2, value is the amount buyers are willing to pay for what a company provides, and it is measured by total revenue. A distinction must be made between a *customer* and *end user.* A customer is the next functional area or party that will use a part or service. The end user is the final user of a product, which in our case, refers to the consumer. Based on Slack et al. (1995) we define SC performance as follows.

Definition 3.4

> *SC performance is the degree to which a SC fulfils end user requirements concerning the relevant performance indicators at any point in time, and at what total SC cost.*

A well-defined set of SC *performance indicators* will help establish benchmarks and assess changes over time. Caplice and Sheffi (1995) refer to Mock and Grove (1979), who define a performance metric as an ‘assignment process where numbers are assigned to represent some attribute of an object or event of interest’ for the decision-maker. Based on Österle (1995) and Fortuin (1988), we define performance indicators as follows.

Definition 3.5

> *Performance indicators are operationalised process characteristics, which compares the efficiency and/or effectiveness of a system with a norm or target value*

Performance indicators link the process with its success factors, i.e. factors that are decisive to the success of a company or process. They provide process management with evidence of a process's efficiency and effectiveness (Österle, 1995). The relevant performance measures are derived from the performance objectives. A particular useful way of determining the relative importance of competitive factors is to distinguish between what Hill (1993) calls *'order-winning'* and *'qualifying'* factors. Order-winning factors are those things that directly and significantly contribute to winning business. They are regarded by customers as key reasons for purchasing the product or service. Qualifying factors are those aspects of competitiveness in which the operation's performance has to be above a particular level just to be considered by the customer. Below this 'qualifying' level of performance many customers probably won't even consider the company (Hill, 1993).

Box 3.1 Food industry in the Netherlands hardly measures performances

In 1994 PriceWaterhouseCoopers conducted a survey, amongst 118 producers in the food industry and agribusiness delivering to retailers of other industrial producers, to evaluate logistical performances. The results were remarkable. Few producers measured logistical performances, and if it was measured at all, the score was not particularly positive. 63% of the producers measured delivery reliability and only 57% of these producers measured completeness and timeliness per order line. Only 25% of this last group had a delivery performance of 95% or higher. Only 36% of the companies measured throughput times, but only 40% of these did so for order processing as well as production. Finally, 46% of the companies measured set-up times. When performance is not measured, it is hard to improve it! *(source: Faber, 1995)*

Ploos van Amstel and D'Hert (1996) present a framework of performance indicators that is divided into hierarchical decision levels. Similarly, we distinguish three levels of performance indicators[1] (Figure 3.3):

1. Supply Chain Performance
2. The performance of an individual organisation
3. The performance of an individual business process

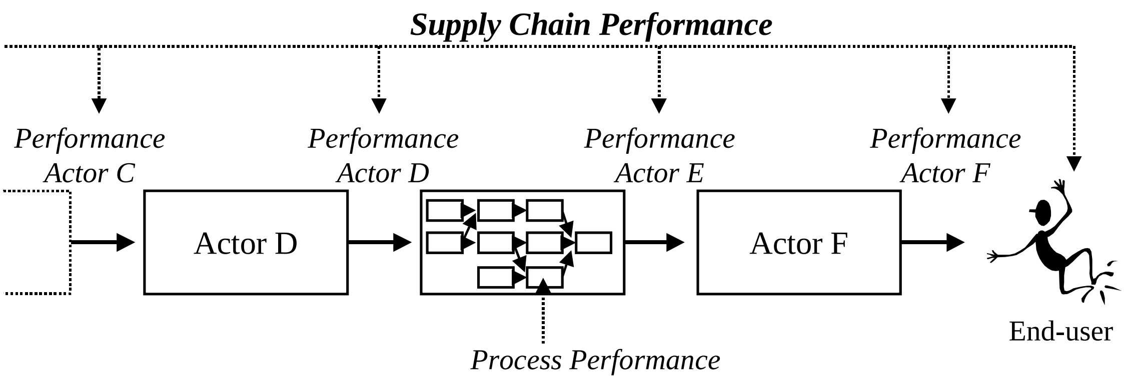

Figure 3.3 Three levels of SC performance

[1] Ten Broeke et al. (1987) and Slack et al. (1998) make a distinction between internal logistical performance (throughput time and cost) and external logistical performance (e.g. lead time, delivery reliability). This corresponds to the second and third level of performance indicators.

The establishment of performance indicators in a SC requires that each party agrees on the definition of each measure and the method of calculation. Furthermore, they must agree on the data sources (where does the data reside), frequency of measuring, the level of measurement (e.g. SKU, category, department, etc.) and the SKU's to be included.

3.3.2 Key Performance Indicators for Food SCs

Konrad and Mentzer (1991) and Caplice and Sheffi (1994) argue that three primary forms of measurement can be used to capture the performance of a transformation process:

- *utilisation* (actual input/norm input, e.g. hours of machine use/available capacity);
- *productivity* (actual output/actual input, e.g. orders processed/# hours of labour); and
- *effectiveness* (actual output/norm output, e.g. number of shipments on-time/total number of shipments).

Despite corporate focus on profitability and customer service and satisfaction, financial measures and customer-focused measures tend to be used less often than asset-based measures (e.g. inventory turns) (Deloitte Consulting, 1999). Utilisation and productivity measures are 'efficiency-based' rather than time-based or cost-based measures of overall SC effectiveness. The trend is towards more *integrated performance measures:* measurement of an entire process or series of processes across functional areas. Integrated measures help to avoid sub-optimisation and they offer more control over the SC since key managers have measures reflecting actions across a number of functional areas (Bechtel and Jayaram, 1997). These process-oriented measures flag potential problems within a process.

Box 3.2 Cost of stock outs

A recent study of the Coca-Cola Retailing Research Council and Anderson Consulting (1996) revealed that a significant cost penalty is incurred by both manufacturers and retailers when a stock out occurs on the shelf. The research, conducted in the United States, showed that 46% of the potential sales dollars that would have been spent on those out-of-stock items is lost because purchases are postponed or made elsewhere. Our own research in a student project at a large Dutch retailer indicated that on average stock-outs occurred about 3% of the time for each product. Research by AC Nielsen revealed that the stock-out percentage in the weekend is about 5% (Food Magazine, May 1999).

Reducing the time required to provide the (end) customer with products or services is one of the major forces that is leading organisations to participate in SCM initiatives (Stalk and Hout, 1990). According to Caplice and Sheffi (1994), in practice most effectiveness measures track two things:

1. Timeliness of delivery; and,
2. Availability and condition of product.

Table 3.1 presents the most common effectiveness measures. A metric for timeliness of delivery requires that both the norm of what constitutes being 'on-time' and the actual performance be measured for effectiveness. We refer to Caplice and Sheffi (1994) for a taxonomy of logistics performance measures. Also, Beamon (1998) presents an overview of (qualitative and quantitative) SC performance indicators. Groves and Williams (1997) recognise an interesting SC metric, namely *the SC response time*. It refers to the theoretical time needed to recognise a major shift in market demand, internalise that finding, re-plan demand, and change production.

Table 3.1 Common effectiveness measures used to track availability and timeliness (based on Caplice and Sheffi, 1994; and Beamon, 1998)

Measure	*Possible description(s)*
Order Fill Rates	Orders filled on time / orders requested
Line Item Fill Rates	Total line items not filled / shipped on time per period Line items not filled / shipped on time per order Incorrect units shipped
Damage Rates	Orders with no damaged line items Line items damaged per order
Order Cycle Time	Elapsed time between receiving request and delivering order Elapsed time between receiving request and readying order for shipment Elapsed time between receiving request and picking order
Deliver/Transit time	Elapsed time between readying order for shipment and delivering order
On-Time	Orders shipped on time Orders received by customer on time

According to Persson (1995) customer value is created by meeting and exceeding customer expectations on three dimensions: 1) responsiveness (or availability of products and services), 2) quality (according to requirements), and 3) cost efficiency (or productivity in the distribution process). Simultaneously, it is essential to create value for the shareholder, in other words, to produce profit and growth.

Key Performance Indicators (KPIs) refer to a relatively small number of critical dimensions which contribute more than proportionally to the success or failure in the marketplace (Christopher, 1998). Based on Persson (1995), Christopher (1992), Caplice and Sheffi (1994), Lewis and Naim (1995), Slack et al. (1998), Groves and Williams (1997) and our findings in Section 1.2, we identify the following list of generic KPIs for food SCs (Table 3.2).

Table 3.2 Key Performance Indicators for food SCs on three levels

Level	*Performance indicator*	*Explanation*
Supply Chain	Product availability on shelf	Presence of a large assortment and no stock-outs
	Product quality	Remaining product shelf life
	Responsiveness	Order cycle time of the SC
	Delivery reliability	Meeting guaranteed delivery times
	Total SC cost	Sum of all organisations' costs in the SC
Organisation	Inventory level	Number of products in store
	Throughput time	Time needed to perform chain of business processes
	Responsiveness	Flexibility of the organisation: lead time
	Delivery reliability	% Orders delivered on time and in right quantity
	Total organisation's cost	Sum of all process costs in the organisation
Process	Responsiveness	Flexibility of the process
	Throughput time	Time needed to perform the process
	Process yield	Outcome of the process
	Process cost	Cost made when executing the process

All indicators are composites of, and dependent on, lower-level measures. For example, the SC lead time and product quality are dependent on the throughput times of business processes in all SC stages. We acknowledge that Table 3.2 does not give a complete overview of all relevant measures. Another SC KPI could be, for example, the percentage of orders that is placed according to jointly agreed specifications. However, we think the main measures are summarised in Table 3.2 to suit our research purposes.

Box 3.3 'Stichting ketenmoduul'

For organisations in a SC to judge each other's logistical performances performance measures should be standardised. A recent initiative in the Netherlands is the establishment of 'Stichting Ketenmoduul' in which leading retailers and food companies participate. This foundation constructed a list of definitions of main Logistical Performance Indicators to facilitate unambiguous communication in food SCs.

Caplice and Sheffi (1994) give an overview of literature on performance metric evaluation. They conclude that eight criteria fully capture the essential characteristics of individual performance metrics and examine their interactions (Table 3.3). The selection of the metrics should be carefully analysed using these criteria to ensure that they support the selected strategy. Due to interactions or trade-offs between some of the criteria, it is not practically possible to develop metrics that excel in each of the criteria. We refer to Caplice and Sheffi (1994) for an extended discussion of these trade-offs.

Table 3.3 Eight evaluation criteria for performance indicators (Caplice and Sheffi, 1994).

Criteria	*Description*
Validity	The metric accurately captures the events and activities being measured and controls for any exogenous factors.
Robustness	The metric is interpreted similarly by the users, is comparable across time, location, and organisations, and is repeatable.
Usefulness	The metric is readily understandable by the decision-maker and provides a guide for the action to be taken.
Integration	The metric includes all relevant aspects of the process and promotes co-ordination across functions and divisions.
Economy	The benefits of using the metric outweigh the costs of data collection, analysis, and reporting.
Compatibility	The metric is compatible with the existing information, material, and cash flows systems in the organisation.
Level of detail	The metric provides a sufficient degree of granularity or aggregation for the user
Behavioural soundness	The metric minimises incentives for counter-productive actions or game playing and is presented in a useful from.

When evaluating SC scenarios, a trade-off is required between multiple measures of performance that usually have different dimensions. Often they cannot all be optimised simultaneously. There are three approaches to this dilemma (Hoover and Perry, 1989):

1. Make implicit trade-offs among the measures.
2. Make explicit trade-offs by combining all of the measures using a common dimension such as cost, or by installing weighing factors for each measure in an aggregating function. The techniques for making explicit trade-offs among several measures of system performance are designated as 'multiple-attribute' or 'multiple-objective decision making analysis'. A

complete discussion of these techniques can be found in Keeney and Raiffa (1976) and De Boer (1998).

3. Optimise the measure of most concern while constraining the other within some minimum acceptable range. Once an optimal solution is found, one or more of the constraints can be relaxed. The decision-maker can then weigh the cost of relaxing the constraint against the resulting improvement in the objective function.

3.3.3 Tools for Assessing SC performance

Benchmarking helps understand the business, its process and performance, and identifies 'gaps' between 'best practice' and the current operating environment. In so doing, benchmarking focuses on understanding how the 'best practice' companies achieve superior performance as well as understanding their objectives (Gattorna and Walters, 1996). Performance indicators can be compared to historical values, values from related organisations, expected targets, or engineered standards, such as capacity (Caplice and Sheffi, 1994). The following is a review of the literature on techniques to assess SC performances.

The main problem in analysing logistics flows is that companies seem to suffer from a lack of visibility of costs as they are incurred through the logistics pipeline (New, 1996). Ideally what logistics management requires is a means of capturing costs as products and orders flow towards the customer (Christopher, 1998). To overcome this problem it is necessary to radically change the basis of cost accounting away from the notion that all expenses must be allocated (often on an arbitrary basis) to individual units (such as products) and instead, toward the notion that they should be separated and matched to the activities that consume the resources (Cooper and Kaplan, 1988; Shapiro, 1999). The management accounting community has developed *Activity-Based Costing* (ABC). ABC recognises that activities cause cost and not products. The key to ABC is to seek out the 'cost drivers' along the logistics pipeline that cause costs because they consume resources. For example, the traditional way to assign the costs of order picking to orders is to calculate an average cost per order. The ABC approach might suggest that it is the number of order lines on an order that consume the order picking resource and this should be seen as the 'cost driver'. The result of the application of ABC is that it enables each customer's unique characteristics in terms of ordering behaviour and distribution requirements to be separately accounted for (Christopher, 1998). Hence, businesses can understand the factors that drive each major activity, the costs of activities, and the relationship between activities and products.

Box 3.4 Performance misperceptions

Harland (1995) investigated four SCs in the automotive after-market through semi-structured interviews. In this sample of SCs, evidence was provided of increasing customer dissatisfaction and misperception of performance upstream. On further testing it was found that customer dissatisfaction was significantly positively correlated to misperceptions in performance but not to misperceptions of requirement, mainly because both parties were using different measurements.

LaLonde and Pohlen (1996) give an overview of the pros and cons of several cost approaches for SCM (e.g. Total Cost of Ownership (TCO), ABC, and Direct Product Profitability (DPP)). They introduce the concept of *Supply Chain Costing*, which provides a mechanism for developing cost-based performance measures for the activities comprising the key processes within a SC.

Value Chain Analysis (VCA) is a method for identifying ways to create more customer value based on Porter's value chain concept (see Section 2.3.1). In a VCA, the firm's costs and performance are evaluated in each value-creating activity to identify improvement options (Kotler, 1994). Cavinato (1992) developed a cost model, which captures value across the SC. His model is a way for departments in a firm to evaluate the impact of decisions on upstream and downstream functions.

Kaplan and Norton (1992) introduced the *Balanced Scorecard*. The idea behind this scorecard is that there are a number of KPIs that will provide management with a better means of meeting strategic goals than the more traditional financially oriented measures. Examples are customer loyalty, employee satisfaction, and the capability to innovate. The intention is that the balanced scorecard provides ongoing guidance in those critical areas where action may be needed to ensure the achievement of those goals (Christopher, 1998).

The Supply Chain Council – a cross industry organisation – has developed and endorsed the *Supply Chain Operations Reference-model (SCOR)* to provide a standard way to measure SC performance and to use common metrics to benchmark against other organisations via scorecards (see Appendix B). The interested reader is referred to www.supply-chain.org.

3.3.4 Conclusion

This section provided definitions of SC performance and performance indicators. Several KPIs for food SCs were identified at three levels of analysis. Furthermore, eight evaluation criteria were given for performance indicators. We concluded this section with some tools for assessing SC performances. We will use the ABC methodology later when we evaluate SC scenarios quantitatively.

3.4 The Managed System

The first descriptive element of a SC scenario is the managed system. The company's manufacturing posture and operations should be specifically designed to fulfil the tasks demanded by the strategic plans (Skinner, 1978). The managed system, or as we call it the 'SC configuration', can be defined as follows:

Definition 3.6

> *The SC configuration refers to the set of participants with specified roles in the SC and the required infrastructures (Beulens, 1996) defined at three levels: network design, facility design, and resource and product characteristics.*

First, *network design* concerns decisions on the SC partners to be chosen and the roles (i.e. functions) they are to perform (Figure 3.4). Hoekstra and Romme (1992) have identified six basic types of designs that can be used to describe the relationships between actors or (on a lower level) processes in the network. These are pipeline (one actor), chain (one supplier – one actor – one customer), shared resource (several suppliers - one actor - several customers), converging (several suppliers - one customer), diverging (one supplier - several customers), and network (several suppliers - several customers) designs.

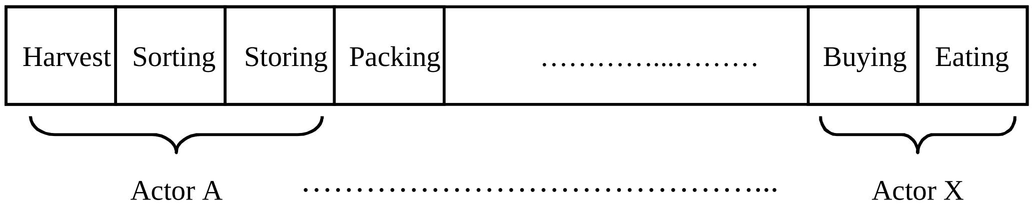

Figure 3.4 Assignment of roles to actors in the supply chain.

Second, *facility design* refers to facility layout and location, process type and (geographical) location of stock points. The principal function in the manufacturing process is to take inputs (materials, labour and energy) and convert them into products. To complete this, a business usually has a range of choices to make between different models of manufacturing. The classic types of process choices are project, jobbing, batch, line and continuous processing (see Slack et al., 1998). This process choice depends on the markets and product volumes and variety, and the roles the company has to perform. Closely related to process choice is process layout. We refer to Slack et al. (1998) for a detailed discussion of these elements. In general, the traditional industrial production process in food SCs distinguishes two production steps (Mellema and Van der Vorst, 1992; Hermans and Hol, 1993): batch production (mixing, ripening, etc.) of intermediates according to the recipe (e.g. bread or dairy products), and finishing and packing of the product. Usually, the two steps are decoupled by an inventory of half fabricates.

Often the manufacturing and business implications of the process choice (made by the engineering dimension) are given scant recognition. But once the investment is made not only are the processes fixed, but also the whole of the manufacturing infrastructure is fixed. The result is that this decision dictates the extent to which manufacturing can support the needs of the market place, the essence of business success (Hill, 1993).

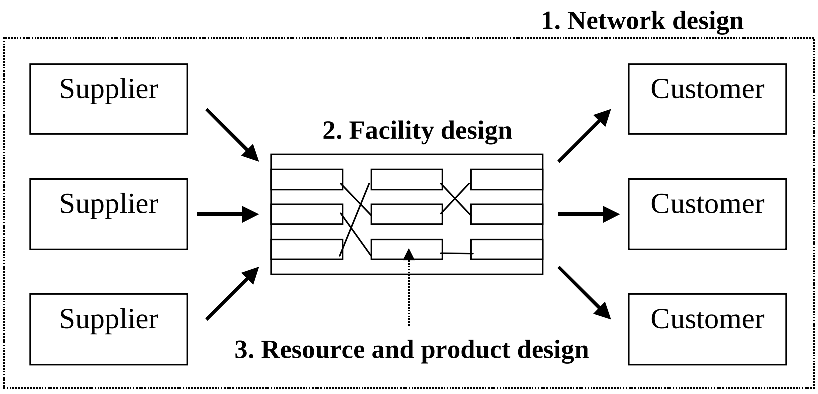

Figure 3.5 Three levels of SC configuration.

The third level is defined as *resource and product characteristics,* which refers to the detailed characteristics of the means, i.e. machines and personnel, and products. Krabbendam (1988) distinguishes six dimensions by which machinery can be characterised: automation, complexity, flexibility, expensiveness, regulation, and integration. One of the main characteristics of machinery is set-up times; if these are long this will tend to increase production batch sizes. Furthermore, the number, capabilities and knowledge of employees should match the processes and machine requirements. The specific product and process characteristics of food SCs (discussed in Section 1.2.1) impact SC operations and therefore SC performance. For example, seasonality of supply requires global sourcing, and process yield and duration are influenced by the quality of raw materials. Furthermore, product packaging characteristics determine the (extra) handling activities required in the SC.

3.5 The Managing System

The SC configuration defines the potential of the SC performance and provides the broad limits within which the system can operate. The managing (or control) system, the second descriptive element of a SC scenario, aims at the fulfilment of SC objectives by executing the roles of SC participants within the established SC infrastructures, whilst dealing with non-manageable inputs (such as machine breakdowns, strikes, illness of staff, etc.). The choice and establishment of the SC configuration is a strategic decision. The managing system as an element of a SC scenario refers more to the tactical and operational decisions.

According to Bertrand and Wortman (1981) and Meal (1984) the design of a (production) control system concerns the establishment of a comprehensive set of organisational and operational decision functions that can be implemented and budgeted. The *logistic control concept* is a model of the way the organisation controls its flows of goods and information, i.e. it is a model of the managing system. There is no generally accepted definition available for the logistic control concept. However, several authors do agree on the elements with which we can describe this concept (Bertrand et al., 1990; Hoeken and van der Mark, 1990; Ballegooie and De Jong, 1992):

1. Hierarchy in decision levels
2. Type of decision making
3. Position of the Customer Order Decoupling Point (CODP)
4. Level of co-ordination.

In analogy with Bertrand et al (1990), the following definition is given for the managing system, respectively the logistic control concept:

Definition 3.7

The managing system plans, controls and co-ordinates business processes in the SC while aiming at realising logistical objectives within the restrictions set by the SC configuration and strategic SC objectives. It can be described by four elements: hierarchy in decision levels, type of decision making, position of the CODPs and level of co-ordination.

3.5.1 Hierarchical Decisions with Rolling Horizon

Decision making in organisations is often hierarchical, with decisions made at one level of the organisational hierarchy constrained by those made at the next higher level and constraining those made at the next lower level. Just as constraints are passed downward, feedback (control information) is passed up the hierarchy. Understanding organisational decision making processes therefore entails understanding the interactions among managerial levels (Silver, 1991). 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 1965). In accordance with many authors (see, for example, Anthony, 1965; Blumenthal, 1974; McKay et al., 1995; Ganeshan et al., 1999) three levels of logistical management can be distinguished:

- *Strategic management*
  At this level the organisational goals and the strategies for attaining these goals are defined. Competitive decisions are made within multiple planning horizons, usually annually, or over multi-year planning horizons to achieve an enterprise-wide, or SC-wide, optimal solution which reflects global objectives. In fact, these decisions are mainly concerned with the establishment of the SC configuration: e.g. site selection, process choice, product/market combinations, and investments on new resources.
- *Tactical planning*
  At the second level the organisational goals and market performance demands are translated into logistical objectives. Tactical planning reflects decisions for the coming weeks or months. Decision rules and procedures are formulated and responsibilities and authorisation structures are set. Suppliers are selected and contracts with customers are made about sales and performance criteria. Emphasis is put on the availability of people, materials and other resources to meet actual demand. These decisions include the choices on and implementation of information systems and organisation structures to be discussed in the next sections.
- *Operational control*
  This managerial level is concerned with the daily operation of a facility to ensure that the most profitable way to fulfil actual order requirements is considered and executed. It contains all operational decisions, which directly influence the flow of materials or information. Typically, operational decisions reflect day-to-day operations up to two weeks in advance.

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 (Keen and Scott Morton, 1978; Meal, 1984). The higher the decision level, the longer the planning horizon, and the greater the uncertainty under which decisions have to be made. McKay et al. (1995) gives some remarks on hierarchical production planning but concludes that the approach is the right one, as long as the planning is dynamic and adaptive. Since relevant information can be gathered in certain time intervals, planning data should be updated at each period resulting in a *rolling planning* horizon. The greater the uncertainty, the more replanning occurs.

3.5.2 Type of Decision Making

Management is the process of converting information into action (Simon, 1976). This conversion process we call decision making. Mintzberg et al. (1976) define a decision process as ‘a set of actions and dynamic factors that begins with the identification of a stimulus for action and ends with the specific commitment to action’. Decision making is controlled by various explicit and implicit policies through which available information is interpreted. According to Forrester (1993) decisions involve three components:

- a desired state of affairs
- the apparent state of actual conditions, and,
- the generation of control actions.

Decision-makers are always attempting to adjust actual conditions toward desired goals. The amount of action depends on the discrepancy between goals and observed system status. Of course, the perception of the decision-maker of the problem situation determines the outcome.

A decision is *unstructured* when no predetermined and explicit set of ordered responses exists (information is missing or new variables have entered the problem field). Decisions are *programmable* to the extent that they are repetitive and routine, and to the extend that a definite procedure can be worked out for handling them (Simon, 1976). Keen and Scott Morton (1978) conclude that there are five approaches to managerial decision making:

- The *rational* way of decision making, in which the manager is completely informed, knows all the decision alternatives and can make an optimal choice (‘objective rationality’);
- The *satisfycing* way of decision making, in which a decision alternative is sought that satisfies all participants (‘bounded rationality’);
- The *organisational procedures* way of decision making, which sees decisions as the output of standard operating procedures invoked by organisational subunits;
- The *political* way of decision making, in which a decision is seen as a result of negotiations between actors; power and influence determine the outcome of any given decision;
- The *individual differences* way of decision making, which presupposes a very important role for the character of the individual, and in which personality and style are of great importance.

The rational way of decision making could be used for the reordering of standard products; and the political way of decision making could be used when selecting another supplier. But in general, a mix of the mentioned approaches is applied when making a decision (Benders et al., 1983). According to Simon (1976) ‘most human decision making, whether individual or organisational, is concerned with the discovery and selection of satisfactory alternatives; only in exceptional cases is it concerned with the discovery and selection of optimal alternatives’. Because of this bounded rationality the choice in most decision making situations is for satisfycing decisions.

Two characteristics of human decision making processes are central to understanding Decision Support Systems. First, decision making is not a point-event. Simon (1976) observes that we often mistakenly think of decision making activity as occurring only at the moment of choice. In fact, decision making is a complex sequence of differentiated activities occurring over time. Second, decision making is not monolithic. Numerous distinct paths can be followed to arrive at a decision. Often choosing the path (determining the structure of the process) is more important and more difficult than traversing it (executing the process).

Researchers have proposed numerous models that decompose managerial decision making processes into 'phases' or 'stages'. We refer to Simon (1976) and Mintzberg et al. (1976).

The tool for decision support we are developing in this thesis adheres to the bounded rational (satisfycing) approach to decision making. A 'best practice' SC scenario is characterised by an overall best performance (lowest cost, best customer service) that satisfies all SC participants. The actual decision of which SC scenario to implement is subject to the political and individual differences way of decision making. Even though the SC scenario improves SC performance, the attitude of a SC participant towards sharing information and the burden/benefits might result in a negative outcome towards the implementation of that scenario.

3.5.3 Position of the Customer Order Decoupling Point

An important characteristic of the interaction between an organisation and its customers is the extent to which customer orders penetrate the production system (Hoekstra and Romme, 1992). The Customer Order Decoupling Point (CODP) – also referred to as the Demand Penetration Point (Christopher, 1998) – separates the part of the organisation oriented towards customer orders from the part of the organisation based on planning. Downstream of the CODP the material flow is controlled by customer orders and the focus is on customer lead time and flexibility. Upstream towards suppliers, the material flow is controlled by forecasting and planning, and the focus is on efficiency (usually employing large batch sizes). It must be determined where the decoupling point should be for each product-market combination or product group in the company. Therefore a company can have several different CODP's and even a single product can have more than one, as it can serve multiple product-market combinations. Hoekstra and Romme (1992) distinguish five positions of the decoupling point (DP) depicted in Figure 3.6.

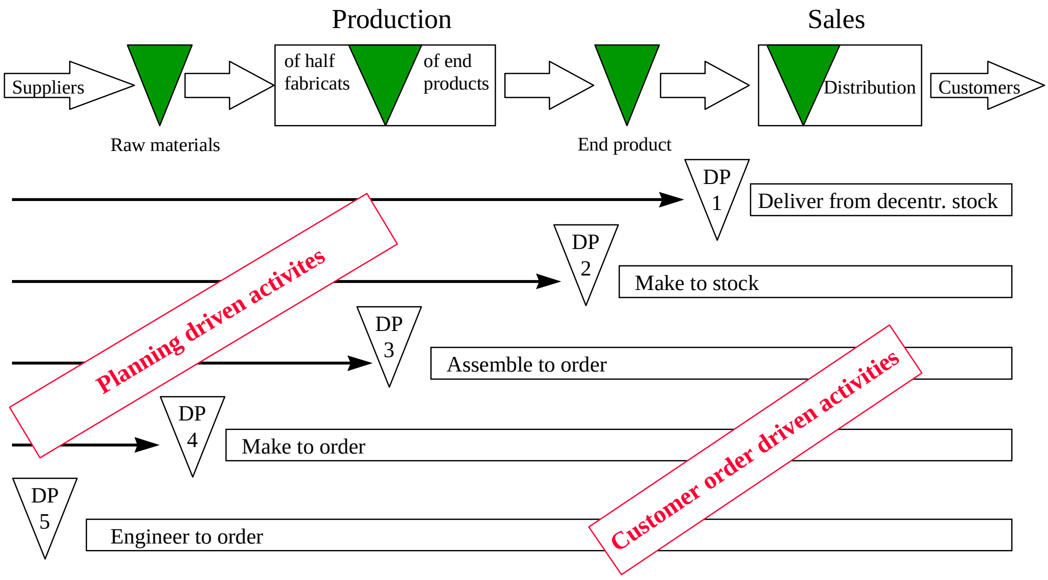

Figure 3.6. Five positions of the CODP (Hoekstra & Romme, 1992).

Hoekstra and Romme regard the CODP as important for several reasons:

- It separates order-driven activities from forecast-driven activities.
- It is the place where 'independent demand' is converted into 'dependent demand'.
- It generally coincides with the last major stock point in the goods flow.
- It creates the opportunity for upstream activities to optimise independently from irregularities in market demand (in contrast to the JIT concept in which inventories are seen as 'blocking the view on problems').
- It separates two areas in which the nature of decision making is very different: upstream from the CODP the focus is on planning and efficiency, downstream the focus is on the acceptance of orders and lead time management.

There are several elements exerting an upstream or downstream influence on the CODP (Figure 3.7). It is a balancing process between the delivery time requested by the customer, the throughput time in purchasing, production and distribution and the order winners of an organisation. Other factors, such as whether the products are universal or specific, also play a role in this trade-off process.

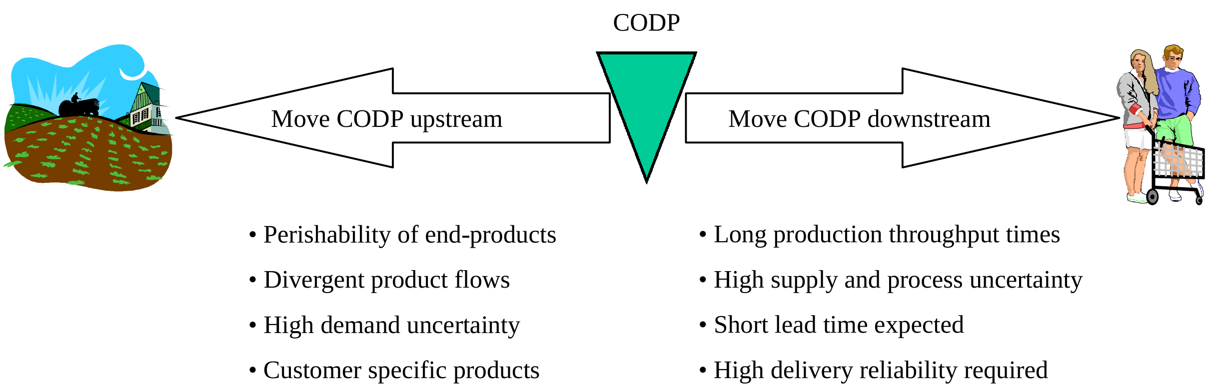

Figure 3.7 Elements that influence the position of the decoupling point.

A recent development in fresh food SCs is the shifting of the CODP upstream. Because of the detection of inefficiencies due to multiple repackaging of products in the SC, the information exchange of end consumer wishes to original producers and suppliers proved to improve performance. Nowadays, the Greenery tries to connect suppliers to customers so that products can be packed directly according to final customer wishes. In this respect, Trienekens (1999) refers to the *Chain Decoupling Point*, extending the CODP in SC perspective.

3.5.4 Level of Co-ordination

The final element that describes the managing system, i.e. the logistic control concept, is the level of co-ordination (or level of integration) between decisions taken:

1) at different functional subsystems within the organisation, or
2) at different organisations within the SC.

Malone (1987) defines co-ordination as 'the additional information processing performed when multiple, connected actors pursue goals that a single actor pursuing the same goals would not perform'. He states that a shared goal is needed for co-ordination. Later Malone (1991) defines co-ordination as 'the act of working together', and 'the act of managing interdependencies between activities'. The need for co-ordination may arise when systems interact. Two systems interact either because they are coupled (the output of one system becomes the input of the other), they share a resource, or they share a target system (a system which has the outputs of both focal systems as its inputs). Co-ordination is the adjustment of decisions leading to actions. This can be accomplished in two ways (Sheombar, 1995):

- by directly influencing each other's decisions.
- by influencing each other's information: the exchanged and interpretation of information regarding the processes, the status of the processes and the goals of the other party.

Co-ordination of decisions at different functional subsystems within the organisation

The co-ordination between subsystems in the organisation refers to the planning process, which translates customer orders into work orders and, consecutively, into deliveries to customers. The design of this planning process differs for each company, as the companies themselves differ in terms of their environment, e.g. customer demand and supplier lead times, and characteristics of the managed system. There are basically three ways in which the demand information can reach each of the production stages (Ruffini, 1999): from the preceding processing stage, from a central point, or from the next processing stages. *Push-type systems of control* that utilise demand forecast information are often associated with MRP. Kanban is often referred to as a *pull-type system of control* in which actual customer demand determines the goods flow. For more information on these subjects, we refer to Slack et al. (1998).

In his work on the structuring of organisations, Mintzberg (1979) distinguishes several co-ordination mechanisms. Production and sales could be co-ordinated via direct supervision (e.g. a logistical manager), mutual adjustment (weekly meetings), or standardisation of work processes (agreed procedures and action plans) (Ribbers and Verstegen, 1992). The use of co-ordination mechanisms to improve SC performance will be further discussed in Chapter 4 when we try to establish a list of SCM redesign principles.

Box 3.5 Multi-level tuning

Kreuwels introduced the concept of multi-level tuning, which enables the reduction of delivery time by using the available flexibility in the system. An order might already be specified in aggregated terms a long time before it is really needed. This order will over time be specified in more detail. Aggregation of requirements is based on time periods (adding day requirements to month requirements) and products (adding requirements of different product types to requirements of product families). When the customer provides the aggregated requirements to the supplier earlier, the supplier has the possibility of adjusting the production to the demands of the customer. This means moving the CODP upstream the SC. The supplier can now better control its production while simultaneously reducing investments in inventory.

(source: Kreuwels, 1994)

Co-ordination of decisions at different organisation in the Supply Chain
As already discussed in Section 2.4, a distinction can be made between centralised and decentralised control (Figure 3.8).

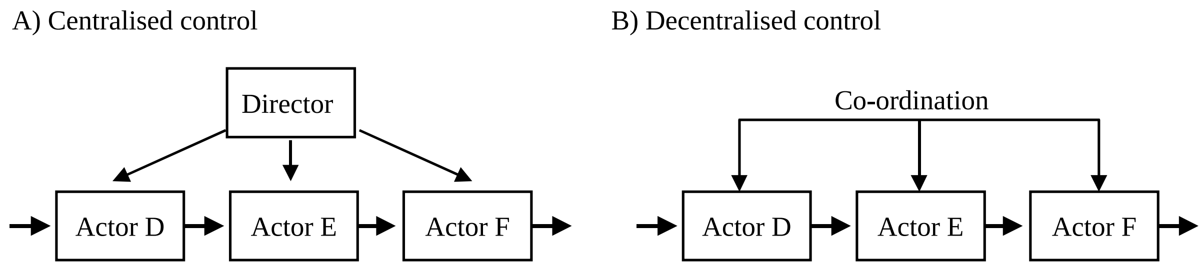

Figure 3.8 Types of SC control

Centralised (or SC) control refers to the situation in which a SC is optimised from a 'helicopter perspective', overviewing the complete SC. For example, a person or organisation takes the lead and functions as a SC director. Fransoo and Wouters (1999) refer to the 'SC cockpit'. *Decentralised control*, on the other hand, refers to the situation in which each individual organisation in the SC makes its decisions in consultation with the other SC participants. The type of control used depends on the SC under consideration.

3.6 The Information System

Logistics is a relatively 'transaction-oriented' function, in the sense that logistics activities entail many transactions per time unit. As an example, there are an extensive amount of movements in and out of a stock during one day, and there are a great number of shipments from suppliers and to customer during the year. The same goes for the number of operations or transactions in production. This simple fact implies that logistics is rather dependent on technology (Persson, 1995).

The managing system takes decisions on the basis of information and generates 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 (Bertrand et al., 1990). In this thesis, the latter three are most important when focusing on SC performance improvement.

- *Systems software*: application-independent software-packages which should be available before application programmes can run.
- *State-independent processing systems*: these allow the recording of recipes, routings, capacity types, standard lead times, and so on.
- *Application software*: these monitor the state and state-transitions of materials and orders.
- *Decision Support Systems (DSS)*: these support the decision process of managers with flexible access to models and relevant information. This approach emphasises analysis of key decisions with the aim of improving both the effectiveness and the efficiency of decision making (McCosh and Scott Morton, 1978).

Competitive advantage in SCM is gained not simply through faster and cheaper communication of data. Ready access to transactional data does not automatically lead to better decision making. Shapiro (1999) states that to effectively apply Information Technology (IT) in managing the SC, a company must distinguish between systems:

- *Transactional IT systems* are concerned with acquiring, processing and communicating raw data about the company's past and current SC operations, and with the compilation and distribution of reports summarising these data. Typical examples are point-of-sale recording systems and Enterprise Resource Planning (ERP) systems. These systems refer to state-independent processing systems and application software.
- *Analytical IT systems* evaluate SC decisions based on models constructed from SC decision databases, which are largely, but not wholly, derived from the company's transactional databases. Analytical IT is comprised of these SC decision databases, plus strategic and operational modelling systems (DSSs) and communication networks linking corporate databases to the decision databases. Typical examples are DSSs for scheduling weekly production, forecasting demand for the next month and allocating it to manufacturing facilities, or locating a new distribution centre.

The level of systems integration is closely related to the level of co-ordination of decisions of different subunits within organisations, and those of different organisations in the SC. The managing system defines the requirements for the information systems, i.e. it determines what information is required at what time to make the necessary decisions. Currently, the vast majority of companies use standard software packages, which are parameterised and in some way extended, modified or completed by the user. According to Kerkhof and During (1995), these IT-systems show a lack of standardisation and interfacing, which makes them less useful for SC integration. The next chapter will discuss the characteristics for SC integration in more detail.

Box 3.6
A survey amongst 75 practitioners responsible for production planning in the semi-process industry showed that 41% of these companies will buy scheduling and SC software within the next two years. At the moment, 29% of the respondents still uses spreadsheet models for production planning purposes, whilst 17% use electronic planning boards, and only 15% scheduling software.
(source: Lofvers, 1999)

3.7 The Organisation Structure

According to Mintzberg (1979), organisation structure comprises two main elements: the establishment of tasks and co-ordination of those tasks in order to realise objectives. The complexity of the organisation means that a specialisation of functions is required. According to Keuning (1995) and Brevoord (1991) the organisation structure comprises:

- the division of overall tasks in functions of departments and executives;
- the definition of authorities and responsibilities of departments and executives;
- the definition of communication lines and mechanisms by which departments, working groups, and executives co-ordinate their activities.

Hence, the organisation structure is closely related to the managing system since it facilitates, together with the information system, the co-ordination of activities. We have chosen to assign the co-ordination process to the managing system when describing SCs.

3.8 A Conceptual Framework for Supply Chain Analysis

In line with Handfield and Nichols (1999) SCM aims at the establishment of integrated SCs that provide end customers and SC organisations with the materials required, in the proper quantities, in the desired form, with the appropriate documentation, at the desired location, at the right time, and at the lowest possible cost. When system performance does not correspond to system objectives, system redesign is required. This section will focus on a conceptual framework to describe and analyse SC scenarios in detail (Van der Vorst and Beulens, 1999a). Such a framework refers to a choice of included variables, the way they are organised, the interactions among variables and the way in which alternative patterns of variables and company choices affect outcomes (Porter, 1991).

3.8.1 Supply Chain Redesign Variables

SC redesign variables are management variables responsible for the design of the SC and the operational management and control of the SC.

Definition 3.8

> *A SC redesign variable is a management decision variable at strategic, tactical or operational level that determines the setting of one of the descriptive elements of the managed, managing, or information system or organisation structure.*

Table 3.4 lists all the descriptive elements of the logistical concept of (organisations in) a SC scenario we identified in the previous sections, i.e. SC redesign variables. Detailed examples of SC redesign variables are facility location or type of machinery (managed system), decision policies or departure time of trucks (managing system), using EDI or fax (information system), and types of incentives or manager’s responsibilities (organisation).

Table 3.4 Classification of SC redesign variables

Managed System	*Managing System*	*Information System*	*Organisation*
Network design	Hierarchical decision levels	Transactional IT systems	Division of tasks
Facility design	Type of decision making	Analytical IT systems	Division of authority and responsibilities
Resource and product characteristics	Position of the CODP		
	Level of co-ordination • within organisation • within the SC		

The total setting of all (re)design variables in the SC determines the overall SC design, i.e. a SC scenario. In the redesign process, these elements should be redesigned concurrently, since each element influences the design of the other three.

3.8.2 Requirements for Effective Supply Chain Management

From an organisation perspective De Leeuw (1988) distinguishes five requirements for effective system management. If one or more of these requirements is not fulfilled, management will certainly not be effective (i.e. realise planned objectives):

1. The managing system should have an *objective* and corresponding performance indicators to manage the system in the right direction.
2. To estimate future system states one has to have *information* on the environment and current system state.
3. There should be enough *information processing capacities* to process information on the environment and system state.
4. In order to direct the managed system in the right direction one should be able to estimate the impact of alternative actions. This requires a *model of the system*, presenting the *relationships* between available redesign variables and SC performance indicators.
5. There should be enough potential *control actions*. Each environment - system state combination requires one or more different control actions to manage the system in the direction of the objectives.

Decision makers experience SC uncertainty when they are unable to accurately predict the impact of control actions on system behaviour (see Chapter 4). In this thesis we assume the situation in which multiple SC participants have jointly agreed upon SC objectives (see Chapter 1). Furthermore, by establishing a SC view, the number of control actions to be potentially taken increases significantly since additional co-ordination activities can be employed with suppliers and customers. Finally, we believe that the availability of information is a much bigger issue in SCM than the availability of enough information processing capacities. Hence the main objectives of a SC redesign methodology are to identify:

- requirements for information (or understanding) of the environment or current SC state;
- a consistent model of the SC presenting the relationships between SC redesign variables and SC performance indicators;
- effective control actions in SC perspective and its impact on the SC performance.

These requirements will be used in Chapter 4 when discussing and defining SC uncertainty.

3.8.3 A conceptual framework for SC analysis

The decision concerning which logistical concept an organisation (i.e. the SC scenario for that organisation) should use depends on a number of elements (Hoekstra and Romme, 1992; Ballegooie and De Jong, 1992; Hill, 1993):

- the SC strategy of the organisation, since it provides a framework to define and prioritise initiatives related to business process redesign;
- market demands: order winners and qualifiers have to be determined in terms of, for example, assortment, lead times and flexibility;

- product characteristics (such as quality decay) and process characteristics (such as possible technologies to be used) have to be registered in terms of complexity, uncertainty and flexibility.

All these factors have to be taken as input for the strategic decision concerning which SC scenario to implement in the SC, including the level of SC integration the organisation wants to obtain. The performance requirements for each role and for each process in the SC can be derived from these factors, which leads to a list of KPIs.

Figure 3.9 depicts a conceptual framework for SC analysis (Van der Vorst and Beulens, 1999a). It is an expansion of the model of Visser and Van Goor (1996). The framework begins with the establishment of co-ordinated *logistical objectives* for each organisation in the SC. These are derived from the *characteristics of each product/market combination* and overall *SC objectives* that need to be jointly agreed upon by the organisations in the chain. These logistical objectives must be translated into performance requirements at SC, organisation and process level and are evaluated by the jointly established *KPIs*. When the logistical SC performance does not satisfy SC objectives, alternative SC scenarios can be realised by adjusting some of the SC redesign variables. In the short term, design variables at the operational management and control level are the prime candidates for changing short-term 'givens' (Silver, 1991): for example, the delivery frequency, order policy or lead time. For more drastic results in the longer term, redesign variables at configuration level should be identified and changed: for example, changing the parties involved, the roles they perform or the IT and physical infrastructures to be used. When an organisation is analysed according to the proposed framework, a detailed picture emerges of the SC configuration and operational control of activities.

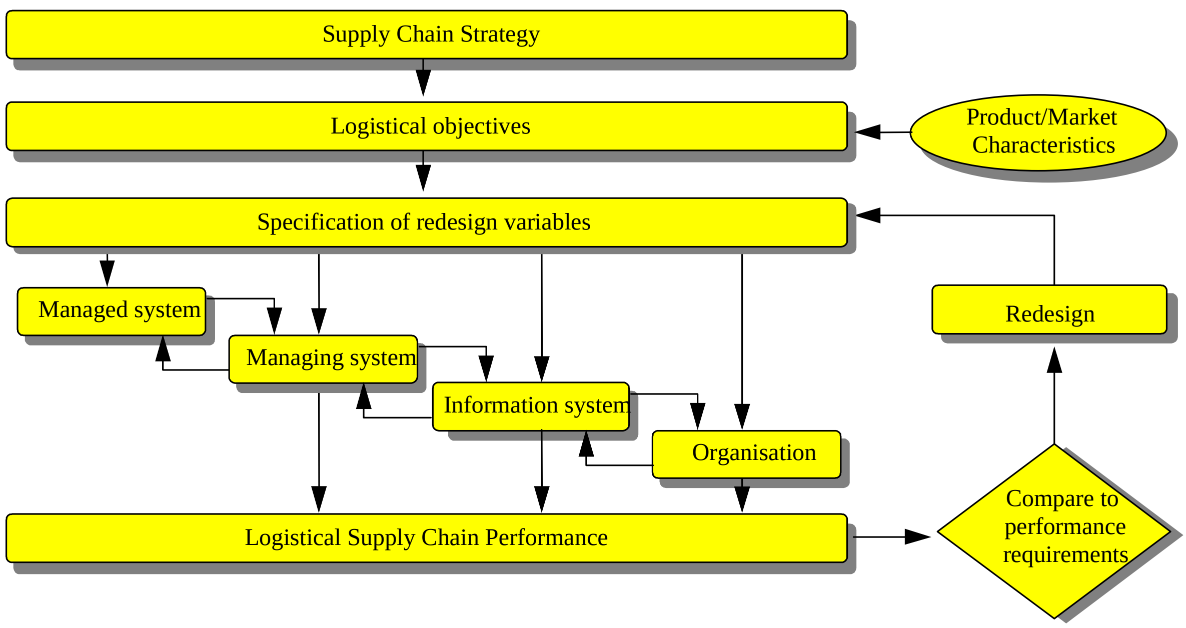

Figure 3.9 Conceptual framework for supply chain analysis (adapted from Visser and Van Goor, 1996)

3.9 Concluding remarks

This chapter discussed and defined the term SC scenario, starting from the systems and process approach. Four descriptive system elements comprising a SC scenario are described in detail. A SC scenario is defined as an internally consistent view of the settings of all SC redesign variables concerning the managed, managing, and information systems and organisation structure in the SC. Furthermore, we identified Key SC Performance Indicators that are needed to assess the effectiveness of SC scenarios, i.e. the degree to which the SC objectives are fulfilled. We concluded this chapter with a conceptual framework that captures all these elements and can be used to analyse and describe SCs to facilitate the redesign process.

Systems can be described and analysed in different ways depending one's view. For example, an aeroplane can be seen as a composite of technical elements, or as a transportation medium. The view of the world enables each observer to attribute meaning to what is observed (Checkland and Scholes, 1990). Our conceptual framework provides us with a view of SC scenarios and SC redesign, but not of actual redesign principles for improving SC performance. Therefore, in the next chapter we will look 'under the hood' and focus on SC uncertainty and SCM redesign principles to arrive at a research approach for analysing a SC network and identifying effective SC redesigns. Applying SCM is just searching for a means to reduce the complexity of the total system to make the system more manageable and perform better.

Chapter 4

A Preliminary Approach on Generating Effective Supply Chain Scenarios

'While we are free to choose our actions, we are not free to choose the consequences of our actions'
(Stephen Covey)

4.1 Introduction

Chapter 3 concluded with a conceptual framework for SC analysis that can be used to analyse and describe SC scenarios by identifying multiple SC redesign variables. But now a basic question arises: What SC redesign variable(s) should be adjusted, and in what direction, to improve SC performance? We have reviewed SCM literature in order to identify generic SCM redesign principles and we have related these to SC key performance indicators (see Section 3.3.2). Once these redesign principles are linked to problems recognised in the SC we have a means of identifying effective SC redesign variables for that SC. Following our research model (Figure 1.1) we believe the identification of sources of SC uncertainty may facilitate this process. The main contributions of this chapter will be:

- an overview of SC redesign methods found in literature;
- discussion and definition of SC uncertainty;
- typologies of sources of SC uncertainty and SCM redesign strategies;
- a generic list of SCM redesign principles derived from SCM literature;
- a preliminary theory on generating effective SC scenarios.

Section 4.2 starts with an overview of literature on SC redesign methods. Then Section 4.3 elaborates on the concept of uncertainty in SC decision making and sources of SC uncertainty. Section 4.4 will focus on SC redesign. Some preliminary SCM redesign principles are identified by discussing the Beer Distribution Game. This list of redesign principles is detailed in Section 4.5 by discussing the results of an extended literature research in management, marketing, Business Process Redesign as well as Operational Research literature. Finally, Section 4.6 links these SCM redesign principles with the conceptual framework for SC analysis and presents a preliminary theory on the generation of effective SC scenarios.

4.2 Literature on SC Redesign

As already stated in Chapter 1, the literature reviews of Beamon (1998) and Lambert et al. (1998) revealed that there are still research opportunities in developing models, rules-of-thumb, or techniques to aid in the design and analysis of SCs. Of course, some authors have already addressed (some of) these issues, often from completely different perspectives. This section presents a brief overview of this literature.

Stern et al. (1996) propose the most generic SC redesign method. They lay out a marketing channel planning approach that permits the reorientation of distribution systems so that they are more responsive to customer needs (Figure 4.1).

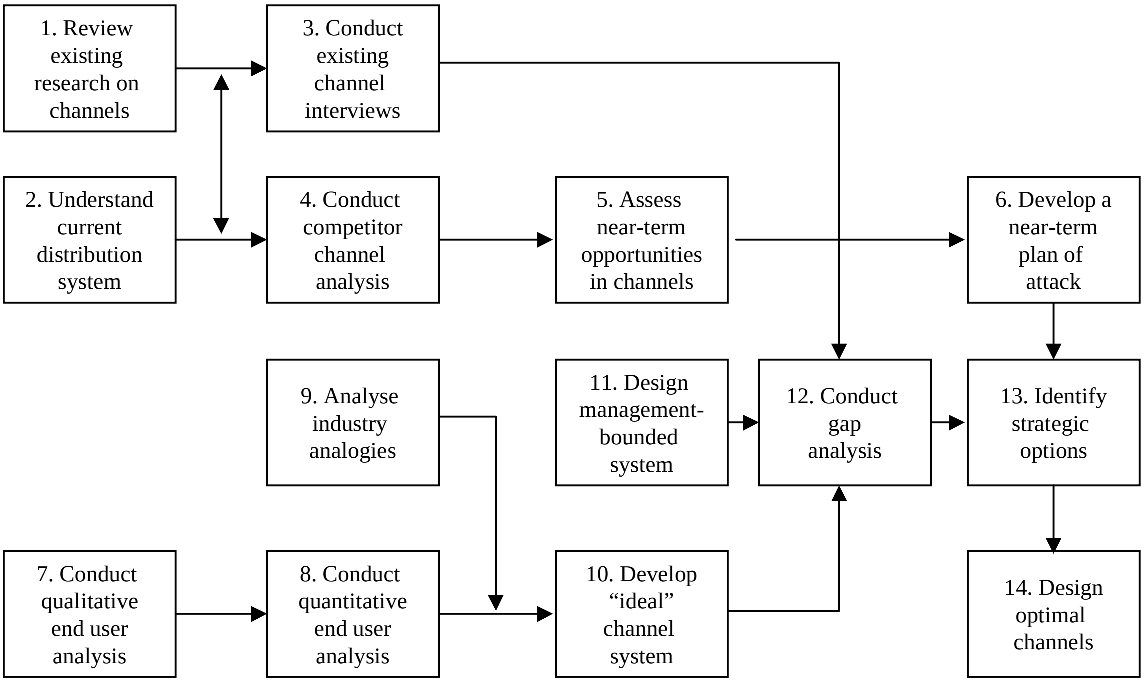

Figure 4.1 Analytic approach for designing customer-driven distribution systems (Stern et al. 1996).

Steps 1-4 aim to generate an accurate description of what the current distribution system looks like, the market coverage it provides, the value-added activities it performs, and the present and future challenges it faces. Steps 5 and 6 are for generating improvements on the short term. Starting from a blank sheet and designing the ideal system takes place in steps 7 through 10. They call for thorough research on end user wishes to segmentate markets on the way to actually delivering the service outputs. The following questions are relevant in this process (Stern et al., 1996):

- What functions can be eliminated without damaging customer or channel satisfaction?
- Are there likely to be any redundant activities? Which could be eliminated to achieve the lowest cost for the entire system?
- Is there a way to eliminate, redefine, or combine certain tasks in order to minimise the steps in a sale or reduce its cycle time?

- Is there the potential to automate certain activities that, although increasing fixed costs, will actually reduce the unit cost of getting products to market?
- Are there opportunities to modify information systems to reduce the costs of prospecting, order entry, or quote generation activities?

Step 11 of their redesign method accounts for the biases, objectives, constraints, and threats imposed by internal and external factors. In Step 12 the existing system, the ideal distribution system, and the constraints are compared and gaps are identified. After strategic options are identified, a best practice distribution system can be designed.

Although very useful at the strategic level, the main weakness of this redesign approach is located in the operational aspects. From a strategic perspective, end user wishes are identified and translated into SC requirements. But how these requirements are translated into relevant settings for all strategic and operational redesign variables is not clear. ‘Do what you think best’ is the character of this more detailed part of the approach.

From a more operational perspective, Handsfield and Nichols (1999) present an approach for cycle-time reduction comprising six steps. They use as a starting point two or more organisations that have agreed to set up a SC – in contrary to Stern et al. – but they focus solely on cycle-time reduction. There six steps are as follows:

1. Establish an inter-organisational cross-functional cycle-time reduction team.
2. Develop an understanding of the given SC process and current cycle-time performance by process mapping and detailed activity descriptions (e.g. frequency that activity occurs, responsibility, information required, average-, minimum-, and maximum activity cycle-time, causes of variability, and current performance levels on defined performance measures).
3. Identify opportunities for cycle-time reduction (by focussing on the parts of the process that have the longest average cycle-times or cycle-time variability).
4. Develop and implement recommendations for cycle-time reduction (in this process computer modelling of the process and proposed changes is highly beneficial).
5. Measure process cycle-time performance.
6. Conduct continuous improvement efforts for process cycle-time reduction efforts.

Based on a process approach, Trienekens (1999) proposes a generic method for SC analysis and redesign comprising five steps. Although useful, he does not provide us with a tool to identify the redesign variables that need to be changed to obtain effective SC scenarios. Furthermore, he ‘only’ provides qualitative tools to analyse the SC and improve SC performance.

Lockamy and Draman (1998) apply Goldratt’s Theory of Constraints (TOC) to a SC. TOC’s tools for effectively managing the flow of products through a system are based upon relaxing the SC bottlenecks. The steps are as follows: identify the system’s constraint, i.e. the SC stage that is limiting the SC’s ability to sell more of its end products (to generate money) to the final customer. Then exploit the limited resources of the constraint to the maximum. Subordinate all other activities to the rate of the constraint and try to elevate the constraint by, for example, bringing on an additional supplier or purchasing additional equipment. When this is accomplished, identify the next constraint and follow the same procedure.

Beamon and Ware (1998) developed a process quality model that, according to them, can be used to assess the performance of a SC system and its sub-systems, assist in identifying quality problem areas, and provide a framework for continuous improvement of SC systems. The model comprises seven integrated modules based on the work of quality 'gurus' such as Deming, Crosby and Feigenbaum. The major steps concern: 1) the definition of 'quality' in the SC by evaluating customer requirements, 2) identifying current process quality performance measures and performance gaps, 3) evaluating current processes and setting quantitative quality standards, and 4) identifying and implementing changes to improve the overall SC process performance by searching for causes of quality variation in the system. Similar to our approach, they pay attention to the reduction of SC uncertainties (from a quality perspective). However, they do not give a methodology on how to establish this reduction other than to 'identify and prioritise improvement plans' (Beamon and Ware, 1998).

Box 4.1 SC improvement at Dow Chemical

Dow Chemical (USA) initiated a SC improvement program in 1993 with the objectives of increasing responsiveness to strategic customers whilst decreasing the SC process costs and capital through waste reduction. Their approach involved:

1. identification of a critical business issue and a critical process for study (through an ABC analysis)
2. organisation and training of the process improvement team
3. mapping of the current state of the process to be studied
4. analysis of the process and identification of process wastes and their causes
5. development of a map detailing what the process should look like
6. implementation of recommended process changes and measurement of results

Sources of waste identified included over $1.8 million worth of excess inventory, which was targeted for elimination. The team then worked together to successfully deal with customer demand and lead-time uncertainty. Within three years, the results were impressive: supply chain demand forecast accuracy was improved by 25%; distribution lead time was cut by 25%; lead time variability decreased by 50%; customer responsiveness increased; working capital decreased by more than $880,000 (due to waste reduction); and a pre-tax annual cost savings of $170,000 was realised.

(source: Handsfield and Nichols, 1999)

This brief literature review reveals that other redesign methods also emphasise the reduction of SC uncertainties. However, their precise definitions of SC uncertainty differs. By combining our findings in Chapters 2 and 3 with these findings in literature we can identify the following generic steps in the SC redesign process:

Step 1 Identify SC customer requirements; determine order winning and satisfying criteria.
Step 2 Understand the current SC processes.
Step 3 Define the (logistical) objectives of the SC.
Step 4 Identify performance indicators and performance gaps.
Step 5 Identify opportunities for performance improvement; find the relevant SC redesign variables.
Step 6 Implement the improved SC scenario.
Step 7 Monitor and evaluate the SC; return to step 4 to check if performance gaps still exist.

All phases are rather generic but the *critical issue is step 5:* identify opportunities for SC performance improvement and find the relevant SC redesign variables. The redesign methods we found in the literature leave this detailed part out. The rest of this chapter and Chapter 5 focus on the development of a research approach that supports SC decision makers in identifying the most effective measures for improving SC performance. The leading step in this process is the identification of SC uncertainties and their corresponding sources.

4.3 Decision Making Uncertainty in the Supply Chain

This section focuses on uncertainty related to decisions made in the SC. We will present a definition of SC uncertainty, discuss and define sources of SC uncertainty, and conclude with a typology of sources of SC uncertainty.

4.3.1 What is SC Uncertainty?

The concept of uncertainty has long been a central component of a number of theories of organisation and strategy. March and Simon (1958) identified uncertainty as a key variable in explaining organisational behaviour. Thompson (1967) suggested that an organisation's primary task is coping with the uncertain contingencies of the environment, especially those of the task environment. Pfeffer and Salancik's (1978) resource dependency theory suggests that organisations structure their external relationships in response to the uncertainty resulting from dependence on elements of the environment (Sutcliffe and Zaheer, 1998).

Agreement on the conceptualisation of uncertainty is still lacking (c.f. Omta and De Leeuw, 1997). In literature several definitions, respectively views, of uncertainty are given:

- Galbraith (1977) defines *task uncertainty* as '... the difference between the amount of information required to perform the task and the amount of information already possessed by the organisation'. This definition starts from the assumption that uncertainty is caused by a lack of information and clarity about cause-effect relationships.
- Sheombar (1995) makes a distinction between uncertainty in the sense of *unexpected phenomena*, called disturbances (i.e. deviations from expectations), and uncertainty in the sense of expected phenomena, which have stochastic occurrence patterns, such as demand uncertainty. Uncertainty creates dynamics since anticipation of changes becomes more difficult (Bertrand et al., 1990).
- Daft and Lengel (1986) distinguish two types of uncertainty: uncertainty as in lack of knowledge regarding the *occurrence of events*, and uncertainty as in not knowing how to *respond to an event* when it occurs.
- Miles and Snow (1978) distinguish between (environmental) *change* and *predictability of change*; they refer to the latter as uncertainty.
- Mason and Mitroff (1973) distinguish between two classes of structured problems that lack certainty. With decisions under *risk*, decision-makers do not know with certainty the outcomes that will follow from their actions, but they do know the set of possible outcomes and their probabilities of occurring. With decisions under *uncertainty,* decision-makers do not even know the probabilities of the outcomes that follow from alternative actions.

In practice the boundary between risk and uncertainty is largely a matter of degree. Generally a manager is able to determine the most likely and relevant possible outcomes and associate (objective or subjective) probabilities with these outcomes (Leutscher, 1995). Therefore, we will not distinguish between risk and uncertainty in this thesis. Our definition of decision-making uncertainty in the SC focuses on the actions of the decision maker. It is based on the requirements of effective SCM (see Section 3.8.2) and is defined as follows:

Definition 4.1

SC uncertainty refers to decision making situations in the SC in which the decision-maker lacks effective control actions or is unable to accurately predict the impact of possible control actions on system behaviour because of a lack of:

- *information (or understanding) of the environment or current SC state;*
- *a consistent model of the SC presenting the relationships between SC redesign variables and SC performance indicators.*

The hidden proposition here is that if there were no SC uncertainty the SC performance would be optimal. 'The more uncertainty related to a process, the more waste there will be in the process' (Persson, 1995). The presence of SC uncertainty stimulates the decision-maker to create safety buffers in time, capacity or inventory to prevent a bad SC performance. These buffers will restrict operational performances and suspend competitive advantage.

Box 4.2 An example of SC uncertainties

Krajewski et al. report the findings of a project with the objective to determine which factors in a production environment have the biggest impact on performance. They found that the most important were: variability in weekly demand, vendor delivery reliability, vendor average lead times and the lead time variability, capacity slack, yield losses, equipment failures and the duration of the downtime, reporting errors in inventory transaction and the size of the errors, and processing times and set-up times per unit. Simulation results suggested that the selection of a production/inventory system could be of less importance than the improvement of the manufacturing environment itself.

(source: Krajewski et al., 1987)

4.3.2 What are Sources of Supply Chain Uncertainty?

Our proposition in Chapter 1 stated that in order to identify effective SC scenarios one should focus on the identification and management of the sources of uncertainties in SC decision making processes. SC managers must understand the sources of uncertainty and the magnitude of their impact (Lee and Billington, 1992). Or as Davis (1993) states:

'A company can make great strides by understanding the relative impact of different sources of uncertainty in the system and by then working to reduce (or avoid) the impact they have... it is important to measure the indirect effect of uncertainty on downstream or upstream nodes in the supply chain' (Davis, 1993, p.37).

According to Sheombar (1995) the level of task uncertainty is a function of external uncertainty, the internal design of an organisation and required performance. After internal design, task uncertainty is matched by co-ordination with the environment, deviation from required performance or cost of emergency measures. SCM provides the opportunity to further reduce the task uncertainty by the co-ordinated planning and control of all business processes in the SC (Figure 4.2). The *system design* refers to all four elements of the logistical

SC concept. It aims at reducing the external uncertainty but it also *creates* internal uncertainty; there might be bad internal co-ordination structures, information systems that do not correspond to the organisation structure, capacities that can not be relied on, and so on.

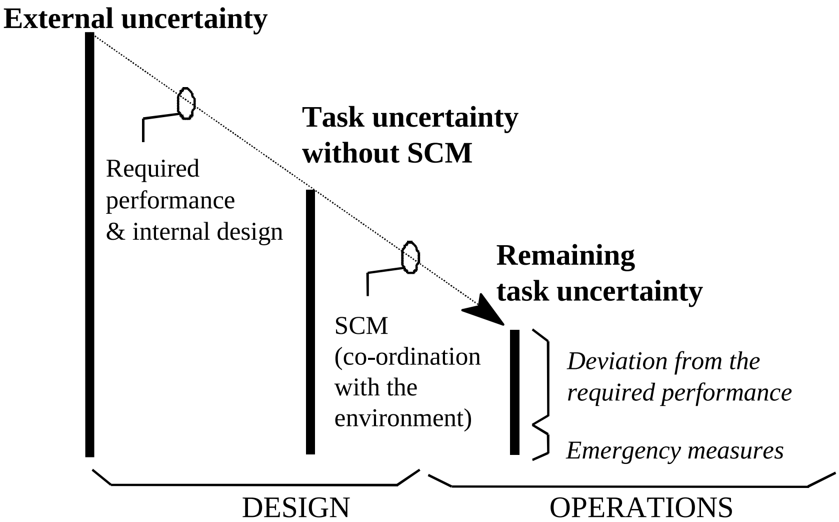

Figure 4.2 Task uncertainty as a design variable and its implications (adapted from Sheombar, 1995).

Next to sources of uncertainties in the internal SC design, we explicitly distinguish *inherent sources of SC uncertainty* caused by the natural physical characteristics of the SC. The Oxford *Advanced Learner's Dictionary* defines 'inherent' as 'existing as a natural or permanent feature or quality of something or somebody ... e.g. an inherent weakness in a design'. Inherent uncertainties can be caused by product characteristics (for example, product inhomogeneity and perishability of food products), process technology characteristics, and characteristics of logistical actors (for example, consumer eating habits). This leads us to the following definition of sources of SC uncertainty:

Definition 4.2

Sources of SC uncertainty are inherent characteristics of the SC and characteristics of the managed system, managing system, information system and/or organisation structure that are present at a certain point in time and that generate SC uncertainty

4.3.3 Typology of Sources of Supply Chain Uncertainty

To reduce decision making uncertainties in the SC, it is necessary to identify the different types of uncertainty present in that SC. Uncertainty is related to the task to be performed or decision that needs to be taken. In the case of logistics, the task to be performed can be, for example, the execution of an order, which results in tasks related to securing the availability of capacity or goods, and tasks related to delivering the order. The task uncertainty depends on the quality of predictions of the task's environment, which in turn depends on the willingness (due to economic reasons) and ability of the firm to make accurate predictions (Van

Donselaar, 1989; Simon, 1976). From a logistics point of view, Persson (1995), Sheombar (1995) and Van Donselaar (1989) distinguish four types of task uncertainty:

1. *Demand uncertainty* is uncertainty related to the customer's requirements; it refers to the combination of predictability of demand and product variety.
2. *Supply uncertainty* is uncertainty related to the delivery of raw or packing materials in time, in the right amount or according to the right specifications (quality or price).
3. *Process uncertainty* is uncertainty related to the production system, for example, the availability of adequate capacity to produce a particular product or the availability of sufficient raw materials.
4. *Planning and control uncertainty* is uncertainty related to the planning and communication structure, for example, uncertainty as to whether inventory levels are accurate or whether consumer wishes are communicated correctly and on time.

All four types of uncertainty contain three aspects: fluctuations with respect to quantity, quality and time. This leads us to a typology of sources of SC uncertainty, as presented in Table 4.1.

Table 4.1 Typology of sources of SC uncertainty and the aspects they concern.

	Quantity aspects	*Quality aspects*	*Time aspects*
Supply	Supply quantities	Supply qualities	Supplier lead time
Demand and distribution	Customer demand for product quantities	Customer demand for product specifications	Customer order distribution lead time
Process	Production yield and scrap Write-offs	Produced product quality Product quality after storage	Production throughput times Storing time
Planning and control	Information availability	Information accuracy	Information throughput times

4.4 Reducing Supply Chain Uncertainty by Supply Chain Redesign

By identifying the main sources of SC uncertainty[1] one identifies the main improvement areas in the SC. Section 4.4.1 presents a typology to structure the SCM redesign strategies. Section 4.4.2 discusses the Beer Distribution Game, which illustrates the necessity of a SC view to improve SC performance and is often referred to in SCM literature as the starting point of SC research.

4.4.1 Typology of Supply Chain Management Redesign Strategies

Newman et al. (1993) focus on flexibility to cope with uncertainty. They propose a model that represents the relationships and trade-offs between modern process technology options, the level of integration within the process, and the ability to compete in a cost-effective manner, based on speed, flexibility and quality (Figure 4.3). When manufacturing flexibility is increased, buffers may be reduced; and, vice versa, when uncertainty increases buffers or flexibility should be increased to re-establish the balance. In our view, SCM should focus on the reduction of SC uncertainties, which will reduce the necessity of buffers as well.

[1] Note that most of the times also the source of SC uncertainty is caused by another factor. In this research, we focus on the first-order sources of uncertainty.

Many approaches to reduce internal uncertainty by integration have been employed in recent years; these include the focused factory concept promoted by Skinner (1978), concurrent engineering, group technology, the Just-In-Time (JIT) manufacturing philosophy and Total Quality Management (TQM). In each case a more streamlined flow, both of information and of material, reduces the uncertainty that hampers a firm's ability to compete (Newman et al., 1993).

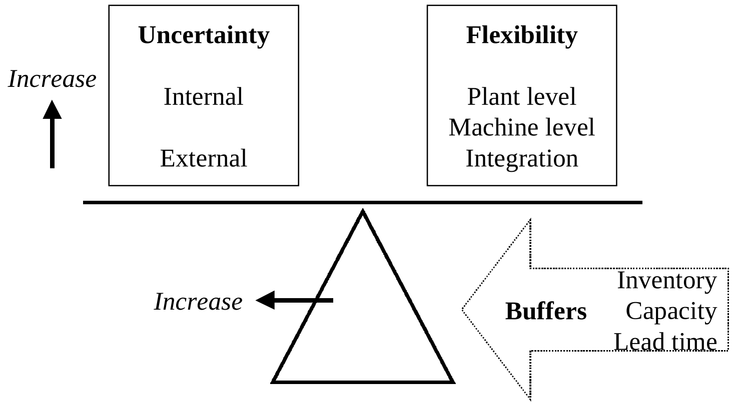

Figure 4.3 Balance between manufacturing flexibility and uncertainty (Newman et al. 1993).

We would also like to refer to Galbraith (1977), who distinguishes several ways of coping with uncertainty from an information processing perspective of organisations to improve the co-ordination of activities. The most important ways in our view are environmental management (reducing the uncertainty imposed by the environment) and the creation of lateral relationships. Based on Galbraith and the hierarchical structure of decision making (Section 3.5.1), De Leeuw (1988) distinguishes three control measures that can be applied to the system itself or to the environment when system performance is not satisfycing (Brevoord, 1991):

- strategic '*goal management*': changing the objectives of the managing system (internal) or the environment (external), for example, establishing strategic partnerships;
- tactical '*adaptive management*': changing the structure of the managed system (internal) or environment (external), for example, choosing another supplier;
- operational '*routine management*': changing the course of transformation processes by tuning control variables (internal) or changing system input (external), for example, auditing suppliers.

Based on De Leeuw and our findings in Chapter 3, we propose the typology of SCM redesign strategies presented in Table 4.2.

Table 4.2 Typology of SCM redesign strategies

	Local improvement strategy	*SC improvement strategy*
Managed system	• …………………………..	• …………………………..
Managing system	• …………………………..	• …………………………..
Information system	• …………………………..	• …………………………..
Organisation structure	• …………………………..	• …………………………..

4.4.2 Beer Distribution Game

The Beer Distribution Game is a management game developed at MIT's Sloan School of Management in the USA (Forrester, 1958; 1961) to give managers and students insight in the consequences of managerial actions in successive stages of a SC. It provides an exceptional means of illustrating the impact of a SC view on SC performance and it is often referred to in SCM literature as the starting point of SC research. Furthermore, some preliminary SCM redesign principles can be identified from the Game.

The Beer Distribution Game is a role-playing game in which the participants have to minimise costs by managing inventory levels in a production-distribution chain. The game consists of 4 SC stages: retailer, wholesaler, distributor and producer (Figure 4.4). Each sector has its own small buffer stock to protect it against random fluctuations in final consumption. All a sector has to do is to fill the orders it receives from its direct customer, and then decide how much it wants to order from its supplier. The game is designed so that each sector has good local information but severely limited global (SC) information about inventory levels and orders. This means that only the retailer knows real end customer demand. It takes two weeks to mail an order and two weeks to ship the requested amount of beer from one sector to the next. It is not possible to cancel orders; backordering does take place. Stock out costs (associated with the possibility of losing customers) are twice as high as inventory carrying costs. The objective of the game is to minimise the total sum of costs of all sectors in the beer SC.

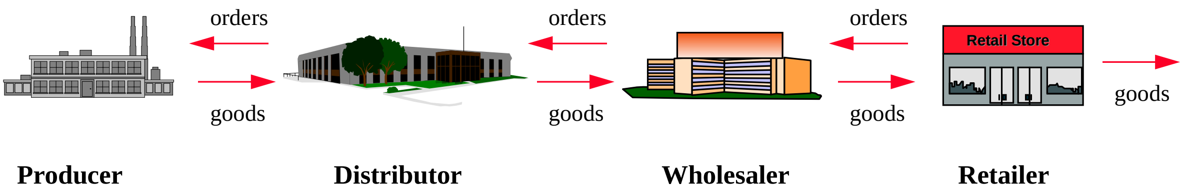

Figure 4.4 The beer supply chain.

The results of this game after 50 weeks of play are remarkable. Although consumer demand is only doubled once in week 5, huge order fluctuations and oscillations take place in the SC. Usually when playing the game, the producer receives demand patterns with 900% amplification compared to end consumer demand fluctuations (see Figure 4.5). Furthermore, huge stock outs occur at the retailer. When this game is played with different people (students or managers) but the same structure, similar results are produced. Even though the participants act very differently as individuals in ordering inventory, the overall (qualitative) patterns of behaviour are still the same: oscillation and amplification of order patterns and a phase lag in reaction time.

This phenomenon in which orders to the supplier tend to have larger variance than orders from the buyer, and the distortion propagates upstream in an amplified form (i.e. variance amplification) is called the *Forrester effect* (Towill, 1997), named after the person who discovered it. Lee et al. (1997) call it the *Bullwhip effect,* named for the variations in reaction down the length of a whip after it is cracked. The effect has serious cost implications. The increased variability in the order process (i) requires each facility to increase its safety stock in order to maintain a given service level, (ii) leads to increased costs due to overstocking throughout the system, and (iii) can lead to an inefficient use of resources, such as labour and transportation, due to the fact that it is not clear whether resources should be planned based on the average order received by the facility or based on the maximum order (Chen et al., 1999). Furthermore, material shortages can occur due to poor product forecasting.

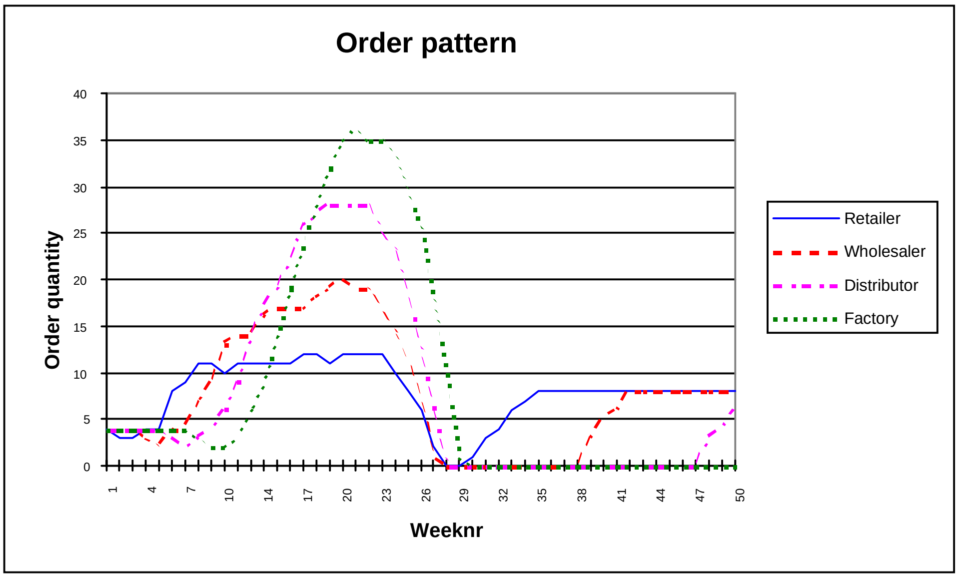

Figure 4.5 Simulation results of the Beer Distribution Game.

Jones (1995) showed that demand amplification was still present in UK Fast Moving Consumer Goods SCs in 1995. Keeping in mind that UK food SCs are ahead of most other countries in using SCM, optimal situations have still not been reached. The following causes of the Forrester effect are identified in literature:

- time varying behaviours of industrial organisations and the basic form and policies used by an organisation (Forrester, 1961);
- 'misperceptions of feedback', i.e. subjects tend to disregard the inventory in the pipeline they ordered earlier and keep on ordering more (Sterman, 1989);
- the perceived demand, the quality of information and the inherent delays that may be found within the SC (Lewis and Naim, 1995).

Several redesign options are proposed by Van Acker et al. (1993), Lewis and Naim (1995), Wikner et al. (1991) and Towill et al. (1992) to reduce demand amplification experienced in the Beer Distribution Game in order to reduce total chain costs:

1. Eliminate all *time delays* in goods and information flows from the SC.
2. Exchange information concerning true *market demand* with parties upstream the SC.
3. Remove one or more intermediate *echelons* in the SC by business take-over.
4. Improve the *decision rules* at each stage of the SC: modify the order quantity procedures or their parameters.

Evans et al. (1995) quantified the impact of these improvement options on SC performance. Their model showed that SC performance could be drastically improved if the configuration and operational management of the SC, the essence of SCM, is changed (Table 4.3). Our own simulation model of the game, based on their description of the game, showed slightly different figures for the scenario in which only the producer has access to consumer demand data. This is caused by the fact that he is surprised by the (unnecessary) variability in order quantity placed by the wholesaler (who does not know consumer demand), leading to out of stock situations. Probably, Evans et al. (1995) altered the ordering policy of the producer but did not report this in their paper.

Table 4.3 Implications of SC redesign strategies for the Beer supply chain (Van Ackere et al., 1993)

Scenario	*Total chain cost*	*Costs index*	*Demand amplification (%)*
Base case Beer Distribution Game	3358	1.47	900
No ordering delays	1944	0.85	500
No intermediaries between producer - retailer	939	0.82	350
Producer has access to consumer demand data	2295	1.01	425
All have access to consumer demand data	1293	0.57	200

4.4.3 Concluding remark

The current designs of SCs are causing inefficiencies and inflexibility, especially due to the generation of decision-making uncertainties in the SC. To improve SC performance, a SC redesign is required that focuses on the reduction of these SC uncertainties. Some preliminary redesign principles are identified in the Beer Distribution Game. Now it is time to develop a generic list of SCM redesign principles to facilitate the redesign process. The next section discusses ways to redesign SCs to improve performance found in management, Information Technology, Operational Research and marketing literature

4.5 Logistical SCM redesign principles

Numerous authors are conducting research into SCM from all possible directions (see Chapter 2). Each one applies SCM from his or her own point of view and comes up with possibilities to improve the SC performance. It is interesting to evaluate their findings and compile a list of general SCM redesign principles (SCM-RP). Each redesign principle aims at improving the performance on a certain KPI. Therefore, in the identification process, we will estimate the scoring of each SCM-RP on the identified SC KPIs (Table 4.4). We refer to Section 3.3.2 for the definition of each performance indicator. Note that the exact score of a SCM-RP can only be established by a quantitative analyses and should be evaluated in close co-operation with key SC participants, since this will differ for each SC.

Table 4.4 Performance scorecard for each redesign principle

			Performance indicator		
Score	*Product availability (A)*	*Delivery reliability (R)*	*Responsiveness Order lead time (L)*	*Product quality (Q)*	*Total SC cost (C)*
Score ++	The SCM-RP has a high positive estimated impact on the SC performance indicator.				
Score +	“ positive estimated impact “				
Score 0	“ no estimated impact at all “				
Score -	“ negative estimated impact ”				
Score ?	The estimated impact of the SCM-RP on the SC performance indicator cannot be given.				

The main generic SCM-RP can be deduced from literature concerning the Beer Distribution Game, our definition of SCM (Section 2.3), the taxonomy of SCM research (Section 2.8), and the guiding principles of Efficient Consumer Response (see Section 2.6). Table 4.5 presents six generic SCM redesign principles to improve SC performance categorised according to the four elements of the logistical concept. In the following sub-sections each principle is discussed and broken down into possible redesign actions. Note that it is not our intention to generate a full overview of all authors that advocate a certain SCM-RP. For each (sub)principle only some main references will be given.

Table 4.5 Typology of generic SCM redesign principles

SCM concept element	***SCM redesign principle***
Managed system	① Redesign the roles and processes in the SC
Managing system	② Reduce customer order lead times
	③ Synchronise all logistical processes to the consumer demand process
	④ Co-ordinate logistical decisions
Information system	⑤ Create information transparency in the SC
Organisation structure	⑥ Jointly define objectives and performance indicators for the entire SC

4.5.1 Redesign the roles and processes in the SC

In an interview with Michael Hammer (Quinn, 1999), he mentioned two important SC redesign principles. First, “work should be done by whoever is in the best position to do it”. Activities in the pipeline should be carried out by the channel member who can add the greatest value to the task of customer satisfaction. Second, “work should not be done more than once”. Also Stern et al. (1996) recognise these principles in the structure of marketing channels:

- One can eliminate or substitute institutions in the channel arrangement;
- The functions these institutions perform cannot be eliminated;
- When institutions are eliminated, their functions are shifted either backward or forward in the channel and, therefore, are adopted by other members.

Box 4.3 SC re-engineering at Anheuser-Busch

Since 1994, Anheuser-Busch, USA’s biggest brewer with 12 breweries, has been re-engineering its SC to better cope with the complexity caused by massive product proliferation. Because of supply and demand imbalances – and the fact that not all products are produced at all breweries – interplant transfers and out-of-pattern moves were common. A multidisciplinary re-engineering team defined four strategic initiatives to reduce costs: (1) focus production of smaller volume brands at fewer breweries; (2) deploy inventory at ‘wholesaler support centres’ that serve as distribution points for wholesalers within 200 miles; (3) decrease the number of trucking companies to increase control over transportation costs; and (4) support the primary process better by improving the systems and processes for production scheduling, planning inventories, scheduling orders and arranging transportation. The first two initiatives drastically reduced the number of transportation lanes. The team established an estimated 1996 transportation cost baseline of more than $400 million for the company’s SC.

(source: John and Willis, 1998)

Reorganising and relocating value-added activities in the SC can provide excellent opportunities for performance improvement (Thomas and Griffin, 1996). Lee and Tang (1997) present an excellent example. By delaying product differentiation one delays as much as possible the moment when different product versions assume their unique identity, thereby gaining the greatest possible flexibility in responding to changing consumer demands. Van Hoek (1998) calls this *postponed manufacturing*. Hewlett-Packard used this strategy to considerably reduce its inventories of desk-jet printers (see Lee et al., 1993). The concept can be realised by standardisation of components and subassemblies, modular design (so that assembly of the differentiating module(s) can be postponed), postponement of operations, and re-sequencing of operations.

Box 4.4 Vendor Managed Inventory

According to an investigation of IBM and PriceWaterhouseCoopers, about 70% of Dutch production and retail companies are involved in Vendor Managed Inventory (VMI) programs. For example, United Biscuits is responsible for the inventory management of biscuits in Albert Heijn's (one of the largest Dutch retailers) warehouses. In VMI systems, the upstream members of the SC become responsible for inventory levels located downstream the SC. Through EDI, the manufacturers gain access to demand and inventory information for each downstream SC site and make necessary modifications and forecasts for them. Estimates indicate that implementation of these types of applications have resulted in inventory reductions of up to 25%.

(sources: Handfield and Nichols, 1999; Van der Kolk and Lofvers, 1999)

Lee et al. (1993) suggest that European DC's are increasingly used to perform final manufacturing activities such as final assembly and configuration aimed at customising products in response to customer orders. Delaying customisation increases the company's flexibility to respond to changes in the mix of demands from different market segments. The company can improve its responsiveness to orders or reduce its investments in inventory. This leads us to the redesign principles listed in Table 4.6.

Table 4.6 SCM redesign principle 1.

Estimated impact on performance indicators	***A***	***R***	***L***	***Q***	***C***
SCM-RP 1. Redesign the roles and processes in the SC.					
a) Change or reduce the number of parties involved in the SC.	0	+	+	++	++
b) Change the location of facilities.	0	0	+	0	+
c) Re-allocate the roles actors perform and related processes.	++	+	++	+	++
d) Eliminate non-value-adding activities in the SC.	0	++	++	++	++

(Key: A = product availability, R = delivery reliability, L = lead time, Q = product quality, C = total SC cost).

4.5.2 Reduce customer order lead times

In 1976, Ballou stated that time lags cause periods of ignorance in physical distribution processes that possibly can result in high operating costs as actions for stock re-supply, delivery, and the like are delayed by the extent of the time delays. He refers to unavoidable delays as a result of attempting to overcome the distances that are inherent in geographically dispersed supply and demand points. Christopher (1992) agrees when he states 'the longer the pipeline from source of materials to the final user, the less responsive to changes in demand the system will be'. Longer pipelines obscure the 'visibility' of end demand so that it is difficult to link manufacturing and procurement decisions to market place requirements. Whilst many forecasting errors are the result of inappropriate forecasting methodology, Christopher states that the root cause of these problems is that the forecast error increases as lead time increases. Shorter lead times will allow inventory to be taken out of the value-added pipeline at every point. This is because safety stock is proportional to the square root of lead time for a given service level and variability of lead time (Gunn, 1994). Those advocating time-based competition (see for example Stalk and Hout, 1990) argue that improvements in overall performance are best achieved by focusing attention on reducing the time to develop and deliver the product or service.

Reductions in delivery lead time translate not only into less inventory but also less rework, higher product quality, and less overhead throughout every element of the SC (Slack et al., 1998; c.f. the JIT philosophy). Handsfield and Nichols (1999) give several causes for long cycle-times (defined as the total elapsed time required to complete a business process): waiting, non-value adding activities, serial versus parallel operations, batching, lack of synchronisation in materials flow, poorly designed procedures, outdated technology, lack of information and poor communication. Kim (1995) gives four guidelines to reduce lead times:

- eliminate processes or reduce the process throughput time by using ICT system;
- minimise the travel distance;
- reduce waiting times; or
- create parallel processes.

Persson (1995) adds that customer lead times can also be reduced at the expense of other customer lead times. Other authors seek internal improvements to reduce lead times. For example, Jordan and Graves (1995) focus on increasing manufacturing flexibility as a key strategy for efficiently improving market responsiveness in the face of uncertain future product demand. Also, Krabbendam and Boer (1989) refer to Flexible Manufacturing Systems as a means of increasing flexibility by decreasing production throughput times if it is used at the right strategic bottle-neck and supporting organisational actions are made.

Ploos van Amstel and D'Hert (1996) mention another important aspect: the reduction of the *variance* in throughput time. A smaller variance in the throughput times leads to more reliable lead times. Thus, safety stocks can be reduced.

One of the main elements that determine the order lead-time is the *position of the Customer Order Decoupling Point* (Hoekstra & Romme, 1992). As described in Chapter 3, this point distinguishes the activities that are driven by customer orders from those driven by production programs. In the case of SCM, we strive for customer order driven SCs with few inventories.

In general, lead time reduction means that the system becomes more sensitive to disruptions. Therefore, management must be able to rely on the system. In order to provide more certainty, quality auditing programmes and supplier certification programmes are implemented (Newman et al., 1993). We refer to literature on Total Quality Management (see for example Crosby, 1979; Deming, 1986; and Feigenbaum, 1986) for an elaboration on this subject. This leads us to the redesign principles listed in Table 4.7.

Table 4.7 SCM redesign principle 2.

Estimated impact on performance indicators	*A*	*R*	*L*	*Q*	*C*
SCM-RP 2. Reduce customer order lead times					
a) Change position of chain decoupling point.	++	++	++	++	?
b) Implement ICT systems for information exchange and decision support.	+	++	++	+	?
c) Reduce waiting times.	0	+	++	++	+
d) Create parallel administrative and logistical processes.	0	+	++	0	0
e) Increase manufacturing flexibility.	+	++	++	0	-
f) Improve reliability of supply and production quantity and quality.	+	++	++	+	0

(Key: A = product availability, R = delivery reliability, L = lead time, Q = product quality, C = total SC cost).

4.5.3 Synchronise all logistical processes to the consumer demand process

Just-In-Time scheduling (Womack et al., 1990) is a philosophy of scheduling in which the entire SC is synchronised to respond to the requirements of operations or customers (Ballou, 1999). It is characterised by frequent production runs and transport of goods in small quantities with resulting minimal inventory levels. Persson (1995) states that the higher the frequency (number of events per time unit; for instance deliveries per week) and a corresponding reduction in lot sizes, the lower the inventory level and the higher the flexibility. However, this policy will affect the filling degrees of trucks negatively.

The ECR-improvement concept 'synchronised production' is based on these thoughts. Ideally when one product is bought in the store, one product will be produced and consequently delivered to the store (with lead time zero). This theory is investigated by Graves (1996) who developed a multi-echelon inventory model with stochastic demand, and ordering at pre-set times according to an order-up-to policy. He shows that replenishment lead times and order frequencies greatly influence minimum optimal stock levels in a central warehouse.

What we are seeing is a fundamental shift away from the *economies of scale*, which is volume based and hence implies long production runs with few change-overs, to the *economies of scope* which is based upon producing small quantities of a wider range, hence requiring more change-overs (Christopher, 1992). This leads us to the redesign principles listed in Table 4.8.

Table 4.8 SCM redesign principle 3

Estimated impact on performance indicators	*A*	*R*	*L*	*Q*	*C*
SCM-RP 3. Synchronise all logistical processes to consumer demand					
a) Increase the number of events per time unit (frequency) for all SC processes.	++	++	++	++	?
b) Decrease the lot sizes applied in the SC.	+	0	++	0	?

(Key: A = product availability, R = delivery reliability, L = lead time, Q = product quality, C = total SC cost).

4.5.4 Co-ordinate logistical decisions

The Beer Distribution Game showed the importance of synchronising order and production processes and harmonising decision rules in the SC to improve SC performance. OR literature has paid significant attention to finding optimal policies for inventory control, order batch sizes and lead times in the SC. For example, in a one-supplier, N-retailer model with stochastic consumer demand for a slow-moving product, Cachon (1999) shows that when the alignment of the retailer's order intervals become balanced, the SC inventory holding and backordering costs decline. An elaborated discussion of OR literature is given in Section 2.4.

Lee et al. (1997) identify major causes for the presence of the bullwhip effect. One of them is shortage gaming; customers may exaggerate their orders to counteract the rationing by suppliers. Persson (1995) adds that transaction simplification could be achieved by eliminating human intervention in the system, thereby reducing errors and improving speed. We would also like to remind the reader of the bounded rational approach in SC decision making, which influences SC performance.

Persson (1995) also identifies two other possibilities to improve process performance. The first is to differentiate products, systems and processes to reduce complexity (one of the elements that determines the manageability of a SC according to Bemelmans (1994) and Bertrand et al. (1990)). By defining different categories for products, suppliers and customers, one can apply a different set of principles, methods and procedures to each category (with minimal co-ordination between groups). An example in current practice is ‘family grouping’, in which products are grouped in retail DC and stores according to customers’ use. The second improvement option is to simplify structures, systems and processes. Standardisation of components, unit loads, production, production methods and processes, modular-built products, and so on, are some methods used to simplify products and processes. Others are early involvement of logistics personnel in the product development process or reducing the number of (product, inventory, supplier) levels in the system.

Product designs that enable fast and precise manufacturing and assembly are critical for cost and quality effectiveness, but the implications for SC inventory are usually ignored or poorly understood. As a result, all of the anticipated savings may be lost owing to increased distribution and inventory costs. Lee et al. (1993) introduced the concept of ‘design for SCM’; product and process designs should be evaluated not only on functionality and design performance but also on the resulting costs and service implications that they would have throughout the product’s SC. Garg and Lee (1999) give an overview of literature and quantitative models on product variety issues. This leads us to the redesign principles listed in Table 4.9.

Table 4.9 SCM redesign principle 4

Estimated impact on performance indicators	***A***	***R***	***L***	***Q***	***C***
SCM-RP 4. Co-ordinate and simplify logistical decisions.					
a) Co-ordinate and redesign policies (especially batch sizes).	+	++	+	0	+
b) Eliminate or reduce human interventions.	++	+	+	+	?
c) Differentiate to products, systems and processes.	++	++	++	++	?
d) Simplify structures, systems, processes and products.	+	++	+	+	++

(Key: A = product availability, R = delivery reliability, L = lead time, Q = product quality, C = total SC cost).

4.5.5 Create information transparency

Virtually every author indicates that the information flow facility structure is key to SC success. Firms operate in an environment of partial information. The information available to SC partners concerning consumer demand, production schedules and inventory levels, and the speed and frequency at which it is available, has the potential to radically reduce inventories and increase customer service. Lewis and Naim (1995) state that ‘... direct computer links across supplier-customer interfaces can provide more up-to-date information and should therefore be considered carefully …. inventory control systems must be up-to-date and well managed in order to provide current information on stock levels and stock availability: demand distortion can occur if this is not done.' According to Bowersox and Closs (1996), timely and accurate information is more critical now than at any other time in history. Houlihan (1985) identifies the following requirements for effective SCM:

- management of data capture and flow across the functional boundaries without delay and distortion;
- linking systems for purchasing, production and inventory control, distribution, customer order entry and service;
- shared ownership of information and a high degree of visibility across all functions of plans, allocations, inventories and customer – as well as replenishment orders.

Helper (1991) points out that a rich flow of communications has been the most important contributor to better supplier relationships in the automobile industry. In another industry, Hewlett-Packard found, when it set out to redesign and radically improve relationships with suppliers, that the most common causes of problems involved such ordinary issues as misunderstood commitment dates, varying routing guides and data entry errors (Davenport and Short, 1990).

Box 4.5 Wal-Mart and Proctor & Gamble

Several well-known firms involved in SC type relationships (e.g., Procter & Gamble (P&G) and Wal-Mart, the US's fastest growing retailer) owe much of their success to the notion of information and the systems utilised to share this information with one another Through state-of-the-art information systems, Wal-Mart shares point-of-sale information from its many retail outlets directly (via satellite) with P&G and other major suppliers. The product suppliers themselves become responsible for the sales and marketing of their products in the Wal-Mart stores through easy access to information on consumer buying patterns and transactions. P&G expanded these working methods with a new distribution system that allowed customers to buy and receive all P&G products together on the same truck – regardless of which business sector manufactured the brand. This development, together with the introduction of new pricing structures, pallet standardisation, electronic invoicing and new procedures for handling damaged products resulted in huge savings. Because of the speed of this system, Wal-Mart pays P&G after the merchandise passes over the scanners as the consumer goes through the checkout lane.

(sources: Stern et al., 1996; Lewis and Talalayevsky, 1997; and Drayer, 1999)

Several OR-researchers have investigated information sharing in serial SCs with stationary stochastic demand. These serial SC models focus on how sharing demand information improves the ordering process of the supplier (e.g. Bourland et al, 1996; Van der Duyn Schouten et al., 1994; Gavirneni, 1999).

Of course, IT and BPR literature also considers how information will pass through and be analysed in the SC. One of the main issues is the establishment of a common database (Hewitt, 1994). This common database ensures that managers use consistent information in their decision making (Bechtel and Jayaram, 1997). It leads to centralised co-ordination of key data (order forecasts, inventory status at all sites, backlogs, production plans, supplier delivery schedules, and pipeline inventory) from the different entities (Lee and Billington, 1992). Gunn

(1994) identified a lack of common and integrated computer-based applications systems (to manage the company's logistics business processes) with the following characteristics:

- common time buckets that standardise planning and reporting periods, at a maximum, on days rather than weeks, months or quarters;
- real-timeliness both in the display of data or information, and in the ability to replan;
- feedback information so that progress can be assessed against a plan and the plan can be adjusted if something is awry.

The information technology system most often mentioned in SCM literature is Electronic Data Interchange (EDI). There are numerous studies available that clearly state how EDI is being used and the benefits gained. Evans et al. (1995) line out some benefits, such as greater accuracy and speed facilitating more frequent ordering, reduced handling costs, and closer relations with suppliers and customers, since investments in systems between trading partners creates a partnership environment.

Beyond EDI several other information technologies, such as Enterprise Resource Planning (ERP) systems with SCM functionalities, are creating tighter, more integrated SCs. These systems offer the promise of a transparent, transactional database that will enhance integration of SC activities. In many companies, however, the scope and flexibility of installed ERP systems have been less than desired or expected (Bowersox et al., 1998). Another disadvantage of ERP systems is the fact that they focus on cost prices and margins and function as feedback systems, whilst SCM is interested in identifying the added value per process, and aims at feedforward systems. This leads us to the redesign principles listed in Table 4.10.

Table 4.10 SCM redesign principle 5

Estimated impact on performance indicators	***A***	***R***	***L***	***Q***	***C***
SCM-RP 5. Create information transparency in the SC					
a) Establish an information exchange infrastructure in the SC and exchange demand, supply, inventory or WIP information.	++	++	0	+	++
b) Increase information timeliness by implementing real-time information systems.	+	++	+	0	++
c) Develop a common database and standardise bar-coding.	++	++	0	++	++

(Key: A = product availability, R = delivery reliability, L = lead time, Q = product quality, C = total SC cost).

4.5.6 Jointly define objectives and performance indicators for the entire SC

One of the elements of SCM that is mentioned in almost all SCM literature is the fact that the SC should be considered as a single entity (e.g. Oliver and Webber, 1982; Jones and Riley, 1985). Thus SCM starts by jointly defining SC objectives and SC KPIs. Gunn (1994) identified a lack of corporate-wide data definition, including a common vocabulary for employees to utilise in managing the logistics operation. Often, different organisations or even different departments within organisations use different words for the same thing. Furthermore, he identified a lack of appropriate and uniform enterprise-wide performance measures that relate to customer satisfaction and world-class business performance. This is confirmed by Champy (1995).

Box 4.6 Redefining incentives

In an interview with Michael Hammer, he referred to a pharmaceutical company that had a lot of success by redefining its sales representatives' bonuses. 'They are no longer based primarily on volume or profit. The number one factor now is achievement of customer objectives! In the beginning of the year, the customer says, 'Here are the objectives that I want to achieve.' At the end of the year, the vendor goes back and see how well the customer has achieved those objectives. The sales representative is then on that basis. All of a sudden, the representatives became focussed on what really counts which is supporting the strategy and enabling the customer. This is in contrast with the old behaviour, which consisted of just pushing product even if that was not in the customer's interest.

(Source: Quinn, 1999)

Christopher (1998) concludes his book on Logistics and SCM with a number of fundamental transformations organisations must go through in order to achieve leadership through logistics and SCM. Three of them are the following:

1. Make the transition from a functional orientation to a process orientation.
2. Switch the organisation's emphasis from product management to customer management, reflecting the fact that it is through the creation of customer value that SCs compete.
3. Change from a transaction mentality to a relationship mentality. It is through the management of relationships in the SC that the business gains and maintains competitive advantage.

These transformations require a shift in the organisational structures of the SC participants, in which the focus changes from functional divisions to cross-functional customer-driven processes and multidisciplinary teams to handle problems. This leads us to the redesign principles listed in Table 4.11.

Table 4.11 SCM redesign principle 6.

Estimated impact on performance indicators	***A***	***R***	***L***	***Q***	***C***
SCM-RP 6. Jointly define SC objectives and performance indicators. a) Jointly define logistical SC objectives and corresponding SC PIs; b) Agree on how to measure logistical performances in the SC; c) Align employee's incentives with SC objectives.	These are all requirements for effective SCM; they impact all performance indicators positively.				

(Key: A = product availability, R = delivery reliability, L = lead time, Q = product quality, C = total SC cost).

4.5.7 Summary of SCM redesign principles

In Table 4.12 all SCM redesign principles are summarised and categorised by the elements of the logistical concept. This list will be used in our methodology for generating relevant SCM scenarios.

Note that the detailedness of each redesign principle is a matter of choice. For example, manufacturing flexibility can be established in many ways: new flexible machines can be bought, working schedules can be changed, or set-up times can be reduced. However, from a SC perspective we believe to have identified the main redesign principles at a sufficient level of detail. In addition, note that the SCM redesign principles in Table 4.12 are interrelated. To establish, for example, a reduction in SC inventory levels, one can reduce the number of links in the SC or try to decrease the lead times. And the implementation of EDI can increase the availability of information but also the accuracy of data exchange. Applying SCM is searching for a means to reduce the complexity of the total system to make the system more manageable and perform better. And this can be done in more than one way.

Table 4.12 SCM redesign principles and estimated direct impact on SC performance indicators.

Managed system	***A***	***R***	***L***	***Q***	***C***
SCM-RP 1. Redesign the roles and processes in the SC.					
a) Change or reduce the number of parties involved in the SC.	0	+	+	++	++
b) Change the location of facilities.	0	0	+	0	+
c) Re-allocate the roles actors perform and related processes.	++	+	++	+	++
d) Eliminate non-value-adding activities in the SC.	0	++	++	+	++
Managing system	***A***	***R***	***L***	***Q***	***C***
SCM-RP 2. Reduce customer order lead times					
a) Change position of chain decoupling point.	++	++	++	++	?
b) Implement ICT systems for information exchange and decision support.	+	++	++	+	?
c) Reduce waiting times.	0	+	++	++	+
d) Create parallel administrative and logistical processes.	0	+	++	0	0
e) Increase manufacturing flexibility.	+	++	++	0	-
f) Improve reliability of supply and production quantity and quality.	+	++	++	+	0
SCM-RP 3. Synchronise all logistical processes to consumer demand					
a) Increase number of events per time unit (frequency) for all SC processes.	++	++	++	++	?
b) Decrease the lot sizes applied in the SC.	+	0	++	0	?
SCM-RP 4. Co-ordinate and simplify logistical decisions.					
a) Co-ordinate and redesign policies (especially batch sizes).	+	++	+	0	+
b) Eliminate or reduce human interventions.	++	+	+	+	?
c) Differentiate to products, systems and processes.	++	++	++	++	?
d) Simplify structures, systems, processes and products.	+	++	+	+	++
Information system	***A***	***R***	***L***	***Q***	***C***
SCM-RP 5. Create information transparency in the SC					
a) Establish an information exchange infrastructure in the SC and exchange demand, supply, inventory or WIP information.	++	++	0	+	++
b) Increase information timeliness by implementing real-time information systems.	+	++	+	0	++
c) Develop a common database and standardise bar coding.	++	++	0	++	++
Organisation structure	***A***	***R***	***L***	***Q***	***C***
SCM-RP 6. Jointly define SC objectives and performance indicators.	Impacts all performance indicators; are requirements for effective SCM.				
a) Jointly define logistical SC objectives and corresponding SC PIs.					
b) Agree on how to measure logistical performances in the SC.					
c) Align employee's incentives with SC objectives.					

(Key: A = product availability, R = delivery reliability, L = lead time, Q = product quality, C = total SC cost).

4.6 A preliminary approach on generating effective SC scenarios

Based on the findings of this chapter and Chapter 3, we can now present a preliminary approach to generate effective SC scenarios. This approach is tested and further elaborated in Chapter 5. It consists of the following steps:

Step 1. Identify SC objectives and define and rank SC KPIs, because these provide us with the intended direction of our control actions to improve SC performance.

Step 2. Understand the current SC processes.

Step 3. Identify SC uncertainties and the sources of SC uncertainty and classify them according to Table 4.1.

Step 4. Select SCM redesign principles from Table 4.12 that might deal with the main sources of SC uncertainty. Rank them according to the ranking of the KPIs they impact, and classify them according to our typology (Table 4.2).
Step 5. Construct SC scenarios from the main SCM-redesign principles for the short and longer term.
Step 6. Implement the improved SC scenario.
Step 7. Monitor and evaluate the SC; return to step 3.

Figure 4.6 depicts the expanded research model (c.f. Figure 1.1). The identified sources of SC uncertainties (see Section 4.3.2) can be used to identify the relevant SCM redesign principles (Section 4.5). A selection of these principles will redesign the logistical SC concept (see Section 3.8), i.e. construct a SC scenario, which will reduce or eliminate SC uncertainties (Section 4.3.1). Consequently, according to our proposition, the SC performance (Section 3.3) is improved.

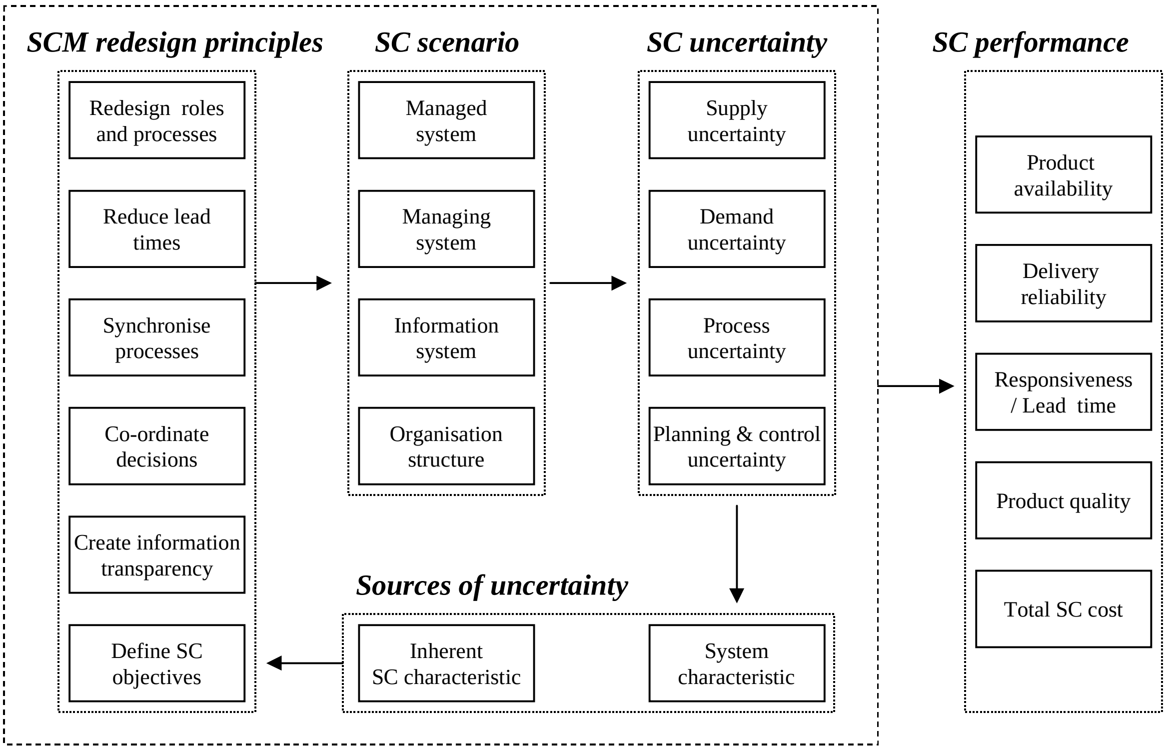

Figure 4.6 The expanded research model.

4.7 Concluding remarks

We concluded this chapter with an overview of a number of steps to identify effective SC scenarios. In this SCM approach the reduction of decision making uncertainties that restrict operational SC performance are of key importance. A review of SCM literature led us to a generic list of 22 SCM redesign principles. By identifying the main sources of the decision making uncertainties in the SC we can come up with the effective SCM-RPs to improve SC performance. This approach is tested and further refined in the next chapter, in which we will discuss the findings of three exploratory case studies.

Chapter 5

Case Studies: Generating Effective Supply Chain Scenarios

'We can not foretell the future – so stick with short cycles and don't try to forecast'
(Jack Burbridge)

5.1 Introduction

Now that we have presented and discussed the definition of a SC scenario in Chapter 3, and sources of SC uncertainty and SCM redesign principles in Chapter 4, it is time to further investigate the relationship between these elements as stated in our second research question. We have already stated that the identification of SC uncertainty and its sources are a major step in identifying effective SCM-redesign principles comprising SC scenarios. This chapter presents three exploratory case studies in food SCs that will elaborate on these thoughts. The aims of these case studies are the following:

- to check our proposition in Chapter 1 that SC uncertainties hinder SC performance;
- to test the applicability of our conceptual framework for SC analysis developed in Chapter 3;
- to test and further develop our preliminary step-by-step approach to generate effective SC scenarios (see Chapter 4) in three specific SCs.

In each case study the following questions will be answered:
① What are the SC objectives and SC performance indicators?
② What logistical SC concept have the SC organisations implemented?
③ What SC uncertainties are present and do they restrict SC performance?
④ What are the sources of these SC uncertainties?
⑤ What SCM redesign principles are effective for each source of SC uncertainty?
⑥ What effective SC redesign variables can be identified for this SC?

Section 5.2 will describe the settings of the case studies and Section 5.3 the case study design. Explicit attention will be paid to the mapping of SC processes. The findings of the three case studies are presented and discussed in Sections 5.4, 5.5 and 5.6. Section 5.7 presents the case study evaluation and, finally, conclusions are derived in Section 5.8.

5.2 Settings of the case studies

Three case studies were selected that represented both types of food SCs identified in Section 1.2.1. The first project was conducted in 1995 in a food SC for daily fresh vegetables and fruits in the Netherlands comprising multiple growers, multiple auctions, importers, a focal export firm, and multiple foreign retailers. Developments in this sector had made it necessary to change the way business was done (see Section 1.2 and Box 5.1). This project was partly subsidised by a government-related organisation (Foundation for Agri-Chain Competence (ACC)). It aimed at identifying SC scenarios that would establish SC performance improvement. Central in the SC network analysis is a focal exporting firm.

Box 5.1 The Greenery International

In 1996, 14 Dutch horticulture auctions merged into the Greenery International. This process was instigated by the increasing power of large retailers that demand year-round supply and pre-negotiated prices, something that the auction structure did not allow. A future logistics structure was developed comprising fewer logistical distribution centres, which was expected to lead to fewer handling activities and more efficient transportation. The marketing of the products would be done by the VTN (in Dutch: 'Verenigde Tuinbouwveilingen Nederland'), a trade organisation of fresh fruits and vegetables. Of course, this development raised questions among growers, exporters and retailers about the roles they would perform in this new network structure.

(source: Zuurbier et al., 1996; Trienekens, 1999)

The two other case studies are related to ECR projects in the Netherlands. In 1995, a Dutch ECR project began in a public and private partnership in which businesses, research institutes and universities were involved. The project was initiated by the businesses involved and enabled by subsidies of ACC. A consultancy firm was included for project organisation and co-ordination. On the business side, three retail companies and four food companies were involved in the project. Four research institutes and universities, including Wageningen University, also participated in the project. The complete project focused on analysing the potential of ECR for Dutch food SCs, both for the marketing aspects (Category Management) and the logistical aspects (Efficient Replenishment; see Section 2.5 for an elaboration). Our team was involved in the latter category. Our project comprised two phases:

1. SC analysis to identify ECR redesign opportunities for performance improvement;
2. assessment of the main ECR redesign strategies to identify a best practice SC redesign.

The two SCs we investigated refer to two producer–retailer combinations. The project aimed at the improvement of SC performance including a cost/benefit analysis for all parties.

In each case study, project teams were formed consisting of the key responsible persons in the SC stages: the managers responsible for logistics (purchasing, warehousing, distribution) and for information management, and the managing directors of both the producing and retailing companies. The project teams were used for expert testing purposes to validate the results obtained.

5.3 Case study design

This section describes the case study protocol comprising the steps that were followed in the case study research to arrive at the case study conclusions. Section 5.2.1 describes the case study protocol. Sections 5.3.2 will elaborate on process mapping and provide us with two usable mapping tools.

5.3.1 Case study protocol

The case study protocol is a major tactic in increasing the reliability of the case studies and is intended to guide the investigator in carrying out the case study (Yin, 1994). Our protocol follows the steps of our approach to generate effective SC scenarios defined in Chapter 4. We shall adhere to these steps in reporting the case study results.

According to Yin (1994) the quality of the research and case study design can be tested in four areas:

1. *Construct validity*, i.e. establishing correct operational measures for the concepts being studied. This was the main topic of Chapters 3 and 4, in which definitions were given of the main concepts. These definitions were discussed and approved of in project team meetings.
2. *External validity*, i.e. establish the domain within which a study's findings can be generalised. This domain is defined by replicating the use of our preliminary approach to SC analysis and redesign in three successive case studies.
3. *Internal validity*, i.e. establishing a causal relationship, whereby certain conditions are shown to lead to other conditions by data analysis.
4. *Reliability*, i.e. demonstrating that the operations of a study can be repeated and the same results will be achieved.

The latter two tests were supported in our research by the use of three principles of data collection:

- Use of *multiple sources of data collection* (also called 'triangulation'). In each case study the following research techniques were used:
  - Repeated semi-structured interviews with key representatives concerning current system structure and opinions about current and past system states.
  - Direct observations during field visits. We spent a great deal of time and effort with those familiar to (a particular part of) the SC system, identifying all the elements of the real system that could have a significant impact upon SC performance.
  - Mapping of all business processes, including discussions in project team meetings with key managers and employees to verify the mappings and identify redesign opportunities for performance improvements.
- Create a *case study database* (with narratives, notes, computerised files, etc.) so that all information can be retrieved later. In our research, all notes, interview reports, and other findings were transformed into computerised files, which were consecutively verified by the interviewees. Furthermore, the tables developed in Chapter 4 were used to structure all available information.
- Maintain a *chain of evidence*, i.e. allow an external observer to follow the derivation of any evidence from initial research questions to ultimate case study conclusions. This was done in the group discussions where our 'chain of evidence' was presented and criticised.

5.3.2 Process mapping

To redesign processes in a SC, one has to describe them thoroughly and analyse their relationships with other processes and SC performance. The inter- and intra-company value-adding processes have to be mapped to fully understand the value streams in which an organisation currently operates (Turner, 1995). In other words, we have to describe the current logistical SCM concept in detail. Christopher suggests that the key for success lies in recognising that the customer order and its associated information flows should be at the heart of the business. 'Everything the company does should be directly linked to facilitating this process and the process must itself be reflected in the organisational design and in its planning and control' (Christopher, 1992). Therefore, we define the following main criterion for selecting one or more process mapping tools:

The possibility to describe all business processes related to the customer order life cycle thoroughly in order to understand the relationships between these processes and the relationship between the processes and the SC KPIs.

Handsfield and Nichols (1999) emphasise that process mapping should start with the internal SC. Thereafter, the organisation needs to focus its efforts on those external supply chains that are most important to the organisation's success. Appendix C lists some available process mapping tools. Most of these process mapping tools focus only on one or two specific characteristics of SCs. We have found that a combination of two different mapping tools can fulfil our requirements.

- Organisation Description Language (ODL) for describing the inputs, transformation (including procedures and responsibilities) and outputs of a business process (Uijttenbroek et al., 1995); and,
- Event Process Chain (EPC) modelling (Kim, 1995) for describing the dynamic behaviour of the SC processes. It focuses on the exact timing of processes to be executed.

We used both techniques in the case studies for mapping the SC business processes.

Organisation Description Language

ODL is capable of describing complex business entities and their interrelationships in graphical process maps and associated process texts (Uijtenbroek et al., 1995). It focuses on the relationships of a business process with other processes (the inputs and outputs) and particularly on successive steps of transitions that can be hierarchically displayed. Because of the clear and detailed description of the system, ODL allows experts and users to validate the descriptive models. An example of an ODL process map is given in Figure 5.1. It shows the inputs and outputs of the business processes 'order entry' and 'order picking'. An ODL process text consists of the following elements (see Appendix D for an example):

- Process name
- Process objective
- Relations: determination and description of the inputs and outputs of a process and their source/destination
- Entity: identification of the inputs, outputs and resources
- Process transitions: descriptions of the successive steps of the transition
- Responsibilities related to the process

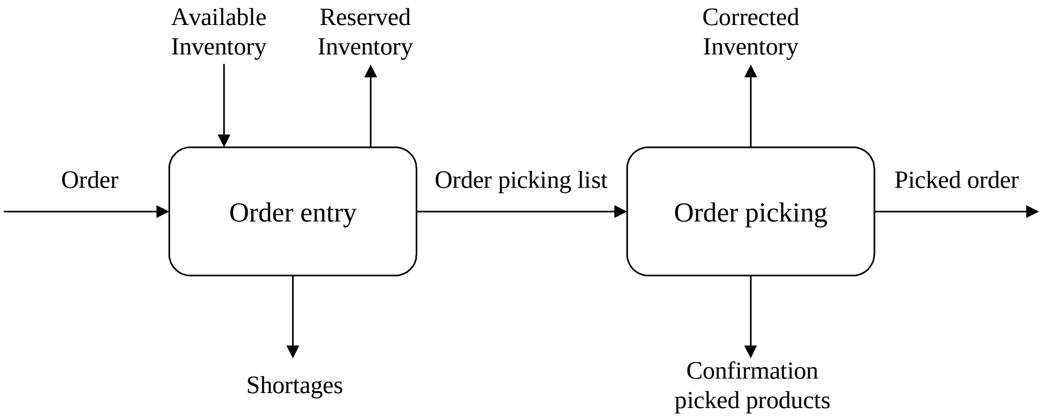

Figure 5.1 Example of an ODL map.

By using Activity Based Costing principles, cost can be assigned to the individual processes. ODL has proven to be a generally accessible, understandable and efficient tool in the redesign process since it explicitly focuses on the individual processes and their interrelationships. For an elaboration on ODL we refer to Uijttenbroek et al. (1995).

Event Process Chain Modelling

Kim (1995) proposes the Event Process Chain (EPC) modelling technique as a way to support BPR programs. This EPC approach is specifically focused on time and place (i.e. an organisational unit) to visualise and reduce throughput times. Only those processes that affect customer satisfaction are taken along in the modelling process. By explicit modelling of time, we can identify bottlenecks in both the administrative and the physical logistical activities. EPC diagrams have four constructs:

- *Event*: a perceived change of status at one point in time. The time period is negligible compared to the total activity cycles (depicted by a circle with a noun);
- *Process*: an activity or series of activities over time, often as a response to triggering events (depicted as a rectangle with a verb and a noun);
- *Branching*: a conditional split of an event-process flow into multiple sub-flows based on the values of certain status variables (depicted as a diamond with several outputs);
- *Wait*: the significant average delay before the start of an event or process due to a queue or other unfavourable conditions of the organisation(s) (depicted by a 'W').

Graphic depiction of all relevant processes in the SC offers an excellent tool for the discussion of relationships between processes and the definition of redesign strategies that reduce throughput times (see also Trienekens, 1999). And, as we have seen in Chapter 3, product freshness, hence product throughput times, are of the utmost importance in food SCs. Figure 5.2 presents an example of a simple EPC model.

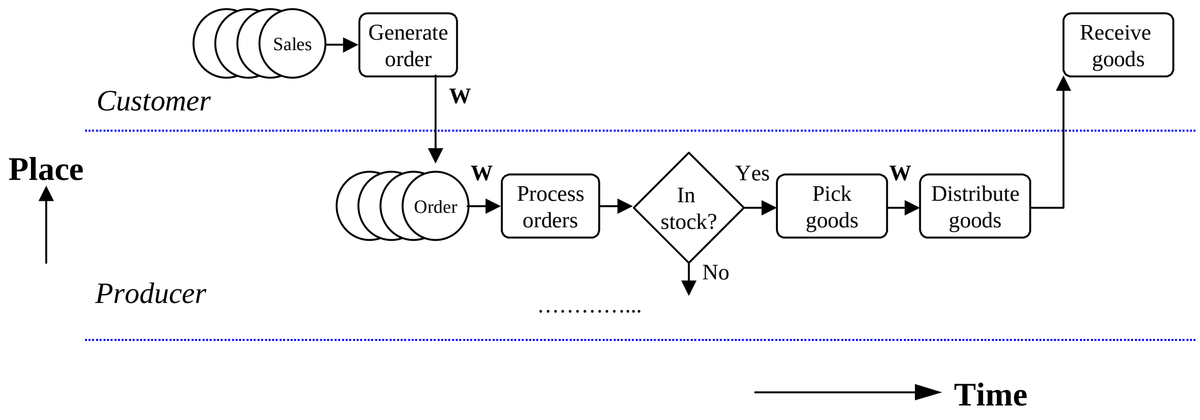

Figure 5.2 Example of a time-related EPC model.

5.4 Exploratory case study I: supply chain for vegetables and fruits

The SC network for vegetables and fruits we investigated involves growers, auctions, importers, export firms and retailers. This case study aimed at identifying SC scenarios for an export firm of vegetables and fruits, called EXPO, that would strengthen its position in the SC network and its performance. The project team in this case study comprised, next to the researchers, only members of the EXPO organisation. Hence, this SC is analysed from the point of view of only one organisation.

EXPO exports more than 300 product groups (distinguishable by product type, size and quality class) to over 400 customers in the world. The strategic goal of EXPO is to play a ‘leading role in the marketing and distribution of vegetables and fruits and to obtain sustainable profits in order to guarantee continuity’ (mission statement EXPO in 1995). The project team defined the following logistical goals and related performance indicators:

- to minimise EXPO’s logistics costs
- whilst satisfying the following restrictions to EXPO’s customer service:
  - all retailer orders are accepted at all times;
  - 100% delivery of (part of) retailer orders within 24 hours and in the agreed time window;
  - delivery of the agreed product quality class per product type;
  - at least 98% completeness of delivered orders.

In the case study we will apply our preliminary theory on SC analysis and redesign to find SC scenarios that are beneficial for EXPO. Note that this will provide us with other results than if the analysis were carried out from the point of view of other or all parties in the SC, since other goals would then be aspired to.

5.4.1 The supply chain network

We have analysed and mapped the SC network from growers to auction and via EXPO to retail organisations (Figure 5.3). In this section, we will give a descriptive overview of this SC. Section 5.4.2 will discuss the activities of EXPO in more detail.

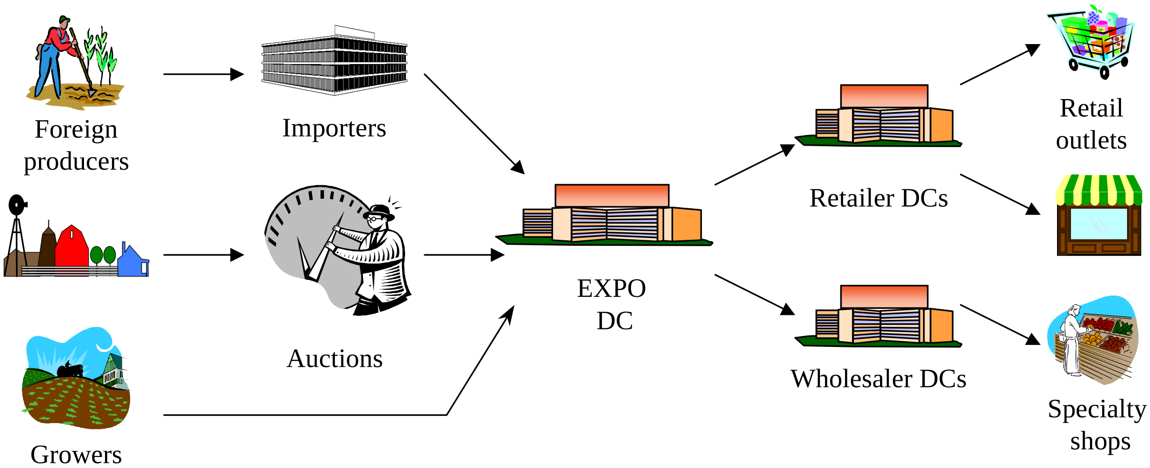

Figure 5.3 Goods flows in the supply chain network for the exporter of vegetables and fruits.

Customers of EXPO are either large *retail organisations* or *wholesalers* at wholesale markets. The most important customers are the large retail organisations that have strict logistical demands for EXPO deliveries. They want a variety of products with the requested quality delivered within 24 hours at a low price. An average customer order comprises about 50 different products.

The *exporter* EXPO buys its products at several auctions, from importers and/or directly from growers. For each transaction the transfer price, product quality and delivery lead-time can (and usually will) be different. In general, all bought products are transported to a central place, a distribution centre, where they are regrouped and sometimes repacked depending on the customer order specifications. It is also possible for EXPO to buy products for speculation (i.e. the products are stored until they can be sold at a higher price). The storage of products can either take place at EXPO or at the auction.

There are several ways to obtain products from the *auction*. The traditional way is to buy products at the '*auction clock*'; products are presented to multiple buyers and prices are determined by auction. These products are delivered to the auction in the previous afternoon. After quality inspection, products with matching characteristics are grouped (in a so-called 'block') and positioned in the auction hall. During the auctioning, uniform blocks are offered. Buyers can take a number of products out of the blocks for the price set by the clock. After the auctioning, products that have been bought are grouped at the dockside of each buyer. If the packaging does not satisfy the buyer, products can be repacked (at the auction or their warehouse).
The other way of obtaining products is by '*auction mediation*'. In this case, a buyer shortcuts the auction by dealing (via the auction) directly with the grower for direct delivery of products according to specifications. Then, transfer prices are pre-arranged, which are slightly higher due to the extra services provided. However, this method eliminates regrouping and repacking activities in the SC. The products can be delivered either directly to the buyer or to the auction, where the buyer can collect them. This is currently the most dominant form of marketing.

Growers are responsible for the growing, harvesting, sorting and packing of vegetables and/or fruits. If the grower is a member of an auction co-operative, he is obliged to market all his products via that auction. If he is not, he will sell his products directly to exporters or national wholesalers. The sorting takes place according to quality criteria (e.g. size or colour) and results in quality classes. Packing can be done in different packages, depending on the destination. The supply of vegetables and fruits is seasonal and market prices are unknown before hand. Some products, for example apples, can be stored at the farm and sold when prices are higher.

5.4.2 Description of the current SC scenario

All relevant business processes in the SC are mapped using ODL and EPC models. Since this SC is analysed from the point of view of EXPO, we will now discuss the elements of the logistical SC concept of EXPO in more detail according to the elements discussed in Chapter 3. Comparable exercises can be done for other SC participants.

5.4.2.1 Managed system

Table 5.1 describes the four elements of the managed system for EXPO. The supply structure results in a huge spread in supply delivery times, but also in customer lead times. Process capacities, in particular, are restrictions to the logistic system. The physical processes in combination with the control processes are discussed in the next sub-section.

Table 5.1 Main characteristics of the managed system

Element	*Characteristic*
Network design	• Multiple sources of supply located all over the Netherlands. • Multiple customers mainly located in Germany.
Facility design	• Divided in goods reception, storing facilities for different products, several repacking lines, and expedition space.
Resource design	• Storage facilities have restricted capacities. • Several company-owned trucks for supply of goods. • Distribution of goods is outsourced .
Product design	• The product itself is unchanged once harvested. The element that changes is the packaging, grouping and quality of the products. • Seasonal demand patterns.

5.4.2.2 Managing system

The managing system was characterised in Section 3.5 by four elements: hierarchical levels of decision making, type of decision making, position of the CODP, and level of co-ordination. We will discuss each one of these elements briefly.

Hierarchical decision levels

Yearly, agreements are made with major customers about quantities and prices and with contracted suppliers about quantities and specifications. Furthermore, contracts are made with transportation firms for the availability and usage of trucks during the year. In general, quite flexible contracts are made that allow for extra trucks on short notice. Repacking and storing facilities are checked and reconsidered every year. A general overview of the operational managing processes is depicted in the overview ODL map (Figure 5.4). An example of an individual ODL process map and text is given in Appendix D, concerning process 4.

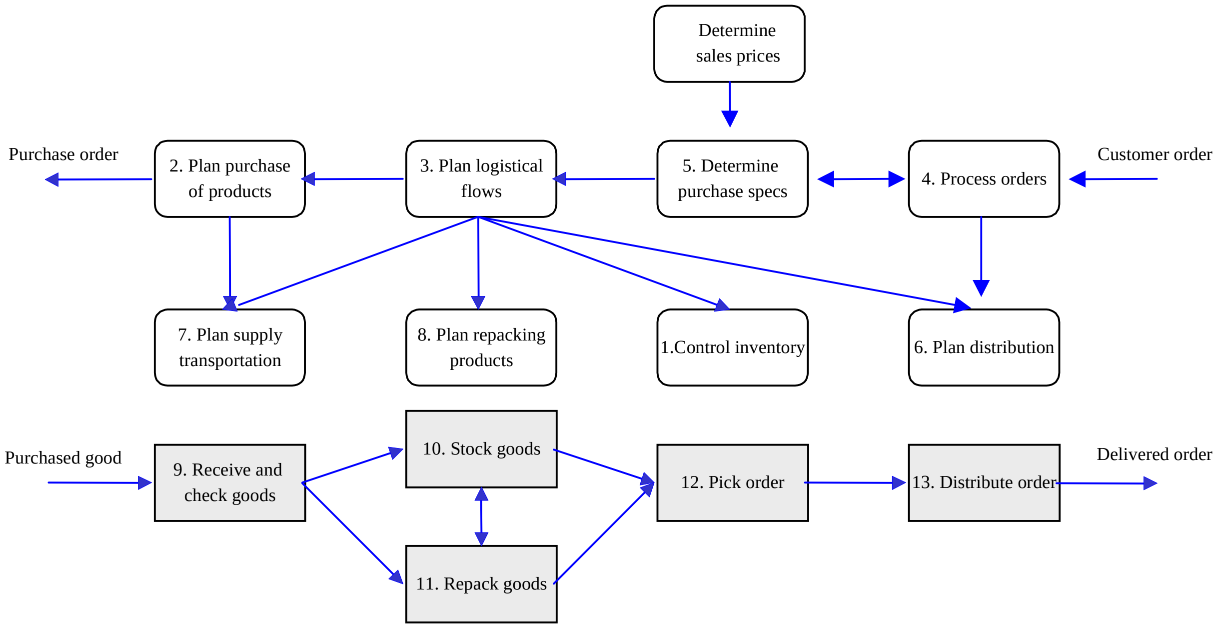

Figure 5.4 Simplified ODL process description of EXPO (goods transformation processes are shaded; administrative and decision making processes are not).

Figure 5.4 can be explained as follows. As will be described at the organisation structure of EXPO (Section 5.4.2.4), logistical personnel are allocated at one of the following departments: sales, purchasing, small packaging, or distribution. The purchasing department begins the day at about 6:00 in the morning with checking inventory levels (after the previous day's distribution process; *process 1*) and inventarising supplied quantities at all auctions (*process 2).* Successively, the purchasing department determines at what location products will be bought, based on the following factors (*process 3*):

- products available at the auction;
- expected price settings at the auction;
- number of already bought products through mediation at the auction; and
- location of the auction.

After 8:00 hrs customers start placing orders which are then written on an order form. This form is sent to purchasing and to data typists who enter the data into the information system to adjust inventory levels (*process 4*). Purchasing amounts are determined, based on current inventory levels, actual customer orders, expected customer orders and price settings (*process 5).* Of course, purchasing aims at buying products with the requested or expected product specifications. When shortages occur at a certain auction, the same products are bought at other auctions, which is made possible by different auction schedules. Meanwhile, the distribution department plans its shipments according to customer specifications and truck availability (*process 6*).

Purchased products are transported to the RDC according to the transportation plan (*process 7*), where they can be repacked and grouped according to customer orders (*process 8*). The planning is based on to-be-transported-products at auctions and available truck capacities. All products are transformed into standard spatial units to match transportation quantities with available transportation capacities. After arrival at the RDC, the goods are counted, checked for quality flaws and inserted in the information system (*process 9*). In the case of shortages or quality disapproval, the purchasing and sales departments are informed. Goods are then stored and sometimes repacked according to the result of planning process 7 (*process 10/11*). Order picking takes place based on the first-in-first-out principle (*process 12*). Finally, goods are distributed to customers according to a distribution plan (*process 13*). Every evening, stock on hand is counted and inventory levels in the inventory management system are updated. Furthermore, product prices of stocked items are revalued based on that day's purchase prices.

Process dynamics, i.e. the timing of the business processes, is illustrated in an EPC model in Figure 5.5. This EPC model immediately reveals some management problems. For example, purchase orders should be placed long before all customer orders have arrived. These and other problems are the basis for the identification of SC uncertainties and will be discussed in Section 5.4.3.

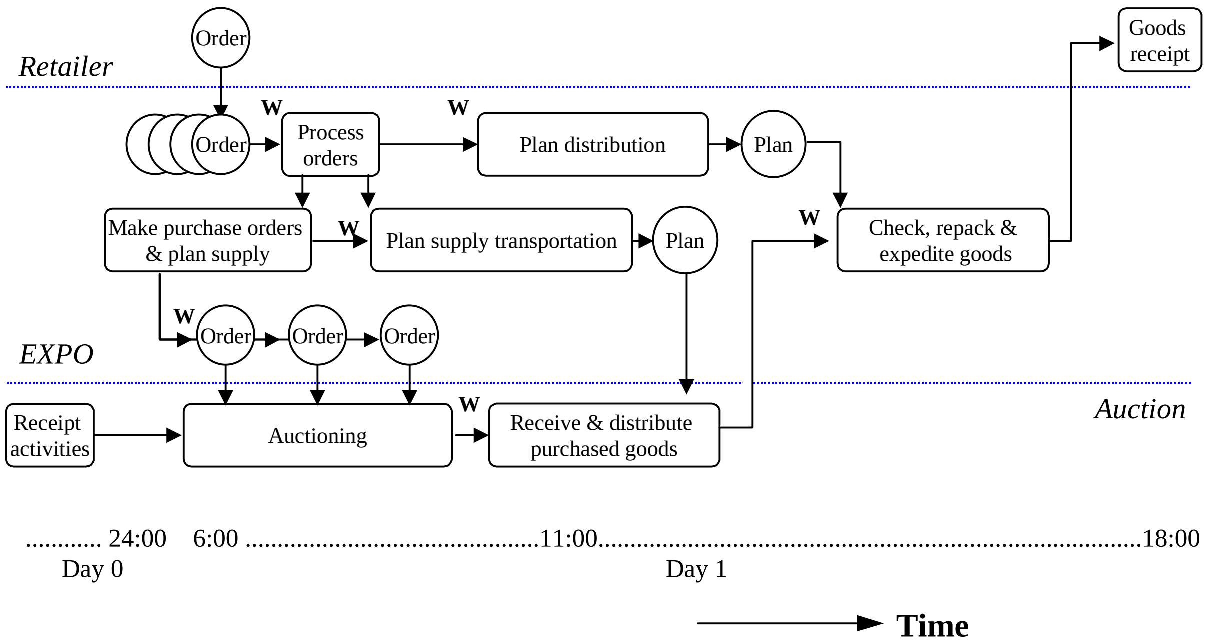

Figure 5.5 Simplified EPC model of the supply chain for vegetables and fruits (see Section 5.3.2).

Type of decision making

EXPO exploits all types of decision making. In general, one tries to make rational decisions based on available information. However, the *satisfycing* way of decision-making is most common (see Section 3.5.2). Furthermore, strategic decisions are subjected to the *political* and the *individual differences* ways of decision making; power and influence partially determine the outcome, for example, when negotiating long-term contracts with suppliers and customers.

Position of the CODP

When we analyse the product flows in EXPO's SC network, we can distinguish four different positions of the CODP:

1. Customers are delivered directly from stock.
2. Products are taken from stock and repacked according to customer specifications.
3. Customer orders initiate the purchasing, supply and sometimes (re)packing of products.
4. Customer orders initiate the packing process at primary producers including the succeeding delivery process.

The level of co-ordination

The co-ordination of business processes at EXPO is relatively low. Because of the different time windows supply and process/distribution control are unavoidably partly decoupled. The distribution plan to customers is based on: 1) actual customer orders (extracted from the information system), 2) customer delivery requirements (delivery time windows), 3) allowed product combinations for transportation (which influences product quality), 4) available tucks, and 5) roughly fixed transportation schedules. Note that the distribution plan is *not* based on the supply times of purchased goods. The distribution planner assumes that time tables are met. On the other hand, the supply transportation planner is *not aware* of the delivery time restrictions of customer orders! Hence, supply lead times are not co-ordinated with distribution departing times. EXPO tries to co-ordinate these activities by using several hand-made 'rules'. These are:

- ultimate departure times for distributing trucks;
- fixed purchasing locations for certain products and quantities;
- stocking products, which are often ordered very late by customers or usually bought at supply locations far away;
- priority rules for supply transportation (although the planner is not aware of the time, he can be informed of the urgency by flashing icons on his screen).

Hence, one can say that the internal co-ordination is not optimal. In the course of our project, the supply transportation planner and distribution planner were placed together in one room to improve the co-ordination between both processes.

Up to a few years ago, co-ordination at the SC level was practically non-existent. These SCs were characterised by stages that pursue individual successes and forgot all about the SC as a whole. Recently, more initiatives have been taken to co-ordinate SC processes. There are some examples of integration concerning the packaging materials used. EXPO hopes to gain SC control and function as a SC director in the near future. However, other partners in the SC are striving to achieve this as well.

5.4.2.3 Information systems

EXPO has a central information system comprising numerous databases (that register e.g. products supplied at auctions, price settings during auctioning, customer orders, customer delivery specifications, delivery routes, etc.). All departments use this system, but they exploit different domains of the databases. Every department is allowed to view other domains, but this hardly happens due to lack of time. Historical information on inventory levels, claims, price settings, quality controls, supplied quantities, etc. is hardly captured. All information is eliminated at the end of the day. There are hardly any analytical information systems available (see Section 3.6). Stock control takes place in batch mode; every evening stock mutations on the total of the day are registered. The system provides real-time information on administrative inventories, i.e. physical inventory + ordered goods in supply - customer orders. However, it is not always visible where the goods are located in the SC.

5.4.2.4 Organisation structure

As stated already, EXPO comprises four departments (see Table 5.2), which are managed separately.

Table 5.2 Objectives, tasks and information available to the functional areas.

	Purchasing	*Sales*	*Production*	*Distribution*
Objective	Purchasing and transporting (actual and expected ordered) goods at minimal cost.	Providing high sales whilst satisfying customer orders.	Store, repack and expedite at lowest cost and on given times.	Deliver products to customers at lowest cost and on time.
Main tasks	Inventory control Process purchase orders Determine purchase locations Purchase goods Getting products to RDC on time	Make agreements with customers Register customer orders Set customer prices Deal with complaints Promote high margin products	Check incoming goods Repack goods Pick orders Expedite goods Count inventory	Plan distribution of goods to customers Match trucks with goods and customers
Main information at hand	Customer orders Stock levels at RDC and all auctions Supply and price settings at all auctions Travel distances	Supply and price settings at all auctions (Already) purchased goods Stock levels (quantity and average price paid) Required margin	Purchased goods Customer orders Repacking orders Distribution schedule	Available truck capacity Customer orders Time windows customer orders

The sales department ‘determines’ what is sold to the customer. Purchasing determines where the products are bought (at lowest cost) and is also responsible for getting the products on time to the RDC. Distribution aims at delivering the products on time to the customer. Finally, the small packaging department is responsible for repackaging the products according to the right specifications and within the requested time frame. Procedures for activities, authorities and responsibilities are not defined formally.

5.4.3 SC uncertainty and sources of SC uncertainty

Now that we have identified SC performance indicators and described the logistical concept, the next step is to deduce SC uncertainties and identify their corresponding sources. In this process we will focus on the problems experienced by employees of EXPO in providing the right service to retailers (defined as the SC performance). In order to identify the SC uncertainties, interviews were held with key persons (including growers and managers at auctions), in which their tasks and decision rules were discussed. Table 5.3 gives an overview of the logistical uncertain elements that were dealt with, categorised by type of uncertainty (Section 4.3.3).

Table 5.3 Generic SC uncertainties for EXPO.

	Quantity aspects	*Quality aspects*	*Time aspects*
Supply uncertainty	• Will supply product quantities correspond to the purchase orders?	• Will supply product qualities correspond to ordered product quality?	• Will purchased goods be supplied on time to RDC for further processing?
Demand and distribution uncertainty	• What customer orders will be received today and when (variety and volume)? • Will delivered quantity per product correspond to orders?	• Will delivered product quality to customers differ from ordered product quality?	• Will the customer order lead time and time of delivery be within the requested time frame?
Process uncertainty	• Will enough products be available for distribution as required?	• Will the quality of products in stock be preserved until later?	• Will products be repacked on time?
Planning and control uncertainty	• Is stock level information accurate at this moment? • Are there still possibilities to obtain that product elsewhere before that time? • What is the status of that customer order?	• Is the information received (automatically or via personal communication) correct?	• Will information concerning changes of customer orders be distributed on time?

Based on the customer claims received by EXPO concerning product quality, quantity and lead time, we can conclude that the questions in Table 5.3 would often have to be answered negatively. Solutions currently often used to satisfy an unhappy customer are lowering prices, paying for lost sales, having products returned or promising to replace the products the next day. However, until now little attention has been paid to recovering the sources of these SC uncertainties to improve the next day's performance. For several weeks we kept track of all customer claims and tried, together with the staff, to identify sources of uncertainty that had led to these claims. By cause-effect analysis we could identify the sources of uncertainty and related redesign variables. A simple example is given in Figure 5.6.

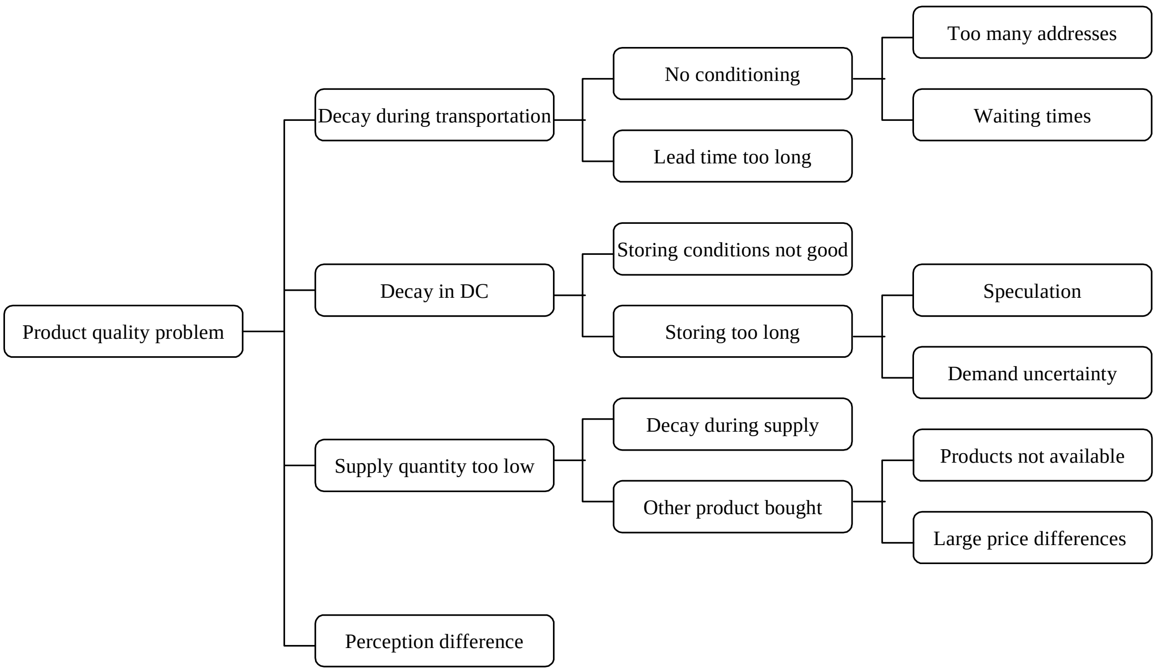

Figure 5.6 Overview of a simple cause-effect model concerning product quality claims.

In general, we can state that most uncertainties are related to each other in one way or another, starting with demand uncertainty on the one hand and supply uncertainty on the other. We can group the main sources of uncertainty into three major categories:

1. *Inherent SC uncertainty* in the system mainly due to product quality decay, leading to shortage of products or differences in quality perception. The auction also generates inherent uncertainty by the price-setting mechanism shifting purchasers from one auction to another (and consecutively influencing supply lead times and product quality).
2. *The lack of co-ordination between departments mainly caused by different objectives and rewarding systems.* The purchasing department is evaluated on purchasing costs, the sales department on customer satisfaction and revenues, and the distribution department on logistic costs. Hence, the sales department accepts all customer orders at all times and leaves the logistics departments with the task of delivering the requested products on time. But the purchasing department will buy its products at the lowest prices, sometimes at auctions far away, resulting in high transport costs and long supply lead times. Furthermore, goods often arrive at the RDC too late because the supply transport planner was unaware of changed time restrictions set by the distribution planner due to (late accepted) rush orders. The combination of all customer orders and their corresponding delivery times determines the distribution route and the latest departure time for the truck.
3. *The timing of activities*. Approximately 75% of the products have to be purchased before customer orders are actually received (buying on forecasts). But the purchasing locations (e.g. an auction) influence the supply lead times and the distribution planner optimises his truck utilisation and route schedule, unaware of these supply lead times, assuming all products will arrive on time at the RDC.

These cause-effect models, together with the findings of our process flow analysis, resulted in an extended list of sources of SC uncertainty that were responsible for performance flaws. To give an overview of our results, Table 5.4 lists the most important sources of SC uncertainty for each type of uncertainty (according to Table 4.1).

Table 5.4 Sources of SC uncertainties for EXPO.

	Quantity aspects	*Quality aspects*	*Time aspects*
Supply uncertainty	• No products available at auctions. • Because of the competitive nature of purchasing, too few products could be bought at the auction. • Supplied goods can be not accepted because of quality disapproval at arrival. • Large quantities arrive due to minimal order batch sizes at auctions.	• Product quality is unknown at the moment of purchase. • Product prices influence purchasing quality, quantity and location. • No products available of requested quality class. • Different auctions mean different quality controllers, which sometimes means different quality classes. • Purchases have the authority and means to change parameters in customer orders.	• Products are bought at auction far away. • Products have to be picked up at more auctions. • More product types are transported together but auctioned at different times, leading to waiting times. • Waiting times caused by clustering of customer orders. • No insight in loading times. • Ultimate supply delivery time not known. • Traffic congestion.
Demand and distribution uncertainty	• 75% of the customer orders are unknown at the time of auctioning. • Orders contain up to 50 different product types with different lead times. • Exotic products are not held on stock but have to be bought from importers. • Not up-to-date stock levels. • Product quality decay influences shelf life. • Product loss at RDC because of accidents.	• Rapid quality decay during unconditioned transportation. • Products with low quality accepted at quality control due to time restrictions (anything is better than nothing!). • Differences in quality perception; often different quality categories are used. • Customer ordered too much and wants to be relieved of the surplus. • Quality report with remarks not given to sales department.	• Waiting times for products to be supplied (see *supply time)* or repacked *(*see *production time)* • Products have to be picked up at more locations. • Delivery time overdue because of traffic congestion.
Process uncertainty	• Incorrect inventory levels. • Discarded products because of quality decay. • Conditioned storage capacity shortages.	• Products are stored under non-optimal conditions (wrong temperature or product mix). • Products are stored too long; FIFO principle not applied (for the sake of ease or time) or too many products are bought.	• Products are supplied much too late. • Too little time to perform packing activities (customer orders received too late). • Urgency of packing order not co-ordinated with planner. • Packing line downtime.
Planning and control uncertainty	• Inventory levels are not up-to-date. • No information available on work-in-progress.	• Unreadable order forms. • Order specifications made by phone are wrongly understood. • Products in stock are not correctly specified.	• Customer orders are communicated too late. • Waiting times for entering orders into the information system.

5.4.4 SCM redesign principles and SC scenarios

According to our definition of sources of SC uncertainty (Section 4.3.2), we distinguish between inherent characteristics and characteristics of the four elements of the logistical concept that cause SC uncertainty. In our discussions with key persons, we clustered all sources according to these five categories and linked them to the SCM redesign principles. Table 5.5 lists the results.

Table 5.5 Overview of all sources of SC uncertainty and corresponding SC redesign options.

Inherent sources of SC uncertainty		***SC redesign strategy***
• Orders contain up to 50 different product types with different lead times. • Product loss at DC because of accidents. • Product quality decay influences shelf life. • Delivery time overdue because of traffic congestion.		
Managed system	***SCM redesign principles***	***SC redesign strategy***
SCM-RP 1. Redesign the roles and processes in the SC. • No products available of requested quality class at auctions. • Because of the competitive nature of purchasing, too few products could be bought at the auction. • Products are bought at auction far away. • Products have to be picked up at more auctions. • Exotic products are not held on stock but have to be bought from importers. • Rapid quality decay during unconditioned transportation. • Products are stored under not-optimal conditions (wrong temperature or product mix) / shortage of conditioned storage capacity. • Packing line downtime.	a) Change or reduce the parties involved in the SC. b) Change the location of facilities. c) Re-allocate the roles actors perform in the SC and related processes. d) Eliminate non-value-adding activities in the SC.	• Eliminate the auction as supplier and make arrangements for direct supply according to specifications. • Standardise purchasing locations per product or select regular suppliers. • Reduce set-up times of packing machines. • Use air-conditioned transportation means. • Expand packaging and air-conditioned storing facilities.
Managing system	***SCM redesign principles***	***SC redesign strategy***
SCM-RP 2. Reduce customer order lead times • Customer orders are phoned in too late. • Waiting times for entering orders into the information system. • Waiting times for products to be supplied or repacked • Products are supplied much too late. • Various product types are transported together but auctioned at different times, leading to waiting times. • Products with low quality accepted at quality control due to time restrictions (anything is better than nothing!). • Too little time to perform packing activities. • Auctions are not open on Saturdays but retailers are!	a) Change position of CODP. b) Implement ICT systems for information exchange and decision support. c) Reduce waiting times. d) Create parallel administrative and logistical processes. e) Increase manufacturing flexibility. f) Improve the reliability of supply and production quantity and quality.	• Change chain structure: *see SCM-RP 1.* • Implement ICT systems: *see SCM-RP 5.* • Expand delivery time windows at retailers. • Change ordering acceptance procedure based on available stock and purchased goods. • Distribution planning should be made sooner and ultimate departure times should be communicated to purchasing. • Introduce fixed supply lead times per product.
SCM-RP 3. Synchronise all logistical processes to consumer demand • Large quantities arrive due to minimal order batch sizes at auctions.	a) Increase the number of events per time unit (frequency) for all SC processes. b) Decrease the lot sizes applied in SC.	• Decrease the minimal order batch size at the auction.

Table 5.5 Continued

Managing system	***SCM redesign principles***	***SC redesign strategy***
SCM-RP 4. Co-ordinate and simplify logistical decisions. • 75% of the customer orders are unknown at the time of auctioning. • Product prices influence purchasing quality, quantity and location. • Ultimate supply delivery time not known. • Products are stored too long; FIFO-principle is not applied (for the sake of ease or time) or too many products are bought. • Urgency of packing order not co-ordinated with planner. • Purchasing buys products on aggregated orders.	a) Co-ordinate and redesign policies. b) Eliminate or reduce subjective human decision making. c) Differentiate to products, systems and processes. d) Simplify structures, systems, processes and products.	• Change ordering patterns of retailers (orders should be placed before the auction or at fixed schedules). • Introduce price and quantity contracts with suppliers and retailers. • Apply demand forecasting module. • Standardise ordering and delivery times of retailers; use fixed transportation schedule (route + timing). • Change the procedure of supply planning and procurement. • Determine optimal stock levels. • Determine a CODP per product type and redesign the logistic concept accordingly.
Information system	***SCM redesign principles***	***SC redesign strategy***
SCM-RP 5. Create information transparency in the SC • Order specifications by phone misunderstood. • Unreadable filled-in order forms. • Inventory levels are not up-to-date. • Products in stock are not correctly specified. • Product quality is unknown at the moment of purchasing. • No insight in loading times. • No information available on work-in-progress. • Quality report evaluating supplied products not given to Sales department. • Supply is based on aggregated customer orders and hence quality control is not specified for a particular customer.	a) Establish an information exchange infrastructure in the SC. b) Exchange demand, supply, inventory or work-in-process information. c) Increase information timeliness by implementing real-time information systems. d) Develop a common database and standardise bar-coding.	• Eliminate data entry via data typists. • Implement route scheduling system. • Implement EDI. • Implement real-time inventory management system. • Install integral information system. • Suppliers provide inventory and WIP information to EXPO. • EXPO provides demand prognoses to suppliers. • Retailers provide inventory information of outlets. • Batch registration linking orders with supplied lots.
Organisation structure	***SCM redesign principles***	***SC redesign strategy***
SCM-RP 6. Jointly define SC objectives and PIs • Customer ordered too much and wants to be relieved of surplus. • Different auctions mean different quality controllers, which sometimes means different quality classes. • Purchases have the authority and means to change parameters in customer orders. • Differences in quality perception; often different quality categories are used. • Sales persons are overruled by the director who accepts all orders.	a) Jointly define logistical SC objectives and corresponding SC performance indicators. b) Agree on how to measure logistical performances in the SC. c) Align employees' incentives with SC objectives.	• Jointly define performance indicators. • Jointly define standardised quality classes. • Implement in every department the same objectives and rewarding system. • Make persons responsible for actions. • Co-ordinate the objectives of departments.

In Table 5.6 the identified SC redesign strategies are ordered according to our typology presented in Table 4.2, i.e. according to the four elements of the logistic concept and whether it concerns a local or a supply chain improvement strategy.

Table 5.6 SC redesign strategies.

Element	*Local improvement*	*Supply Chain improvement*
Managed System	• Standardise purchasing locations per product or select regular suppliers. • Reduce set-up times machines. • Use conditioned transportation means. • Expand packaging and storing facilities.	• Eliminate the auction; direct supply from growers to EXPO according to specifications.
Managing System	• Determine optimal stock levels at RDC. • Change order acceptance procedure. • Determine a CODP per product type and redesign the logistic concept accordingly. • Distribution planning should be made sooner and ultimate departure times should be communicated to purchasing. • Introduce fixed supply lead times per product.	• Change ordering patterns of retailers (orders placed before auctioning). • Expand delivery time windows at retailers • Decrease the minimum order batch size at auction. • Introduce price and quantity contracts with suppliers and retailers.
Information system	• Eliminate data entry via data typists; implement automated procedure. • Implement demand forecasting module or system to forecast the influence of purchasing locations on customer service. • Implement a real-time inventory management system. • Automate information exchange on ultimate departure times to supply transportation planner. • Implement new route scheduling system. • Batch-registration linking orders with supplied lots.	• Develop a system to match supply with demand. • Install a global chain-wide information and performance measurement system. • Implement EDI. • Suppliers provide supply prognoses, inventory and WIP/ATP information. • Retailers provide demand prognoses and inventory information of outlets; EXPO provides demand prognoses to suppliers. • Retailers provide inventory information of outlets.
Organisation structure	• Agree on common goals for all departments & standardise rewarding systems.	• Jointly define performance indicators and standardised quality classes.

Section 3.8 introduced the concept of SC redesign variables; decision variables that are responsible for the characteristics of goods and information flows through SC processes. The main SC redesign variables for this SC are summarised in Table 5.7. The estimated impact of each redesign principle on the relevant SC performance indicators (i.e. especially total cost and delivery reliability; see Table 4.8) results in a list of main SC redesign variables.

Table 5.7 Main SC redesign variables

Configuration level	*Operational management and control*
• SC network structure: direct suppliers. • Real-time integral information systems. • Re-allocation of processes.	• Define a fixed CODP per product type. • Change order time windows retailer. • Co-ordinate decision policies internally and in the SC. • Exchange process information internally and in the SC.

SC scenarios can now be defined by adjusting one or more of these SC redesign variables. In all cases, it is of utmost importance to adjust current rewarding systems to eliminate unwanted human actions. Based on Stevens' (1989) evolution path of functional control to SCM (see Section 2.2) four SC scenarios with different levels of integration are given (Van der Vorst, 1996):

Level 0: *Current situation: separate managing systems in the SC stages*.
Internal improvements are obtained by, e.g., the provision of real-time stock information together with a new order acceptance procedure, the integration of supply, production and distribution planning and the standardisation of purchasing locations.

Level 1: *Information exchange in advance between SC stages.*
Advanced information is exchanged concerning, e.g., expected orders, current stock-levels, ATP (available to promise) in time and quantity. For example, the retailer gives retail outlets point-of-sale and stock information to EXPO.

Level 2: *Co-ordination of the managing systems in the SC.*
At this level it is possible to influence the managing system of suppliers or customers in order to obtain a better logistical performance. For example, EXPO influences the capacity plan of growers or takes over the inventory management at retailers.

Level 3: *Changing the structure of the SC.*
At this level the roles and processes in the SC are changed. For example, the auction is eliminated from this SC and new suppliers are contracted.

From the viewpoint of the export firm, the levels are evaluated based on their implications for the logistic performance. The results of the analyses gave the managers insight in the firm's logistic control structure in SC perspective. For the short term, EXPO has chosen to standardise the rewarding systems and purchasing locations for certain products. Furthermore, some retailers now place their orders the evening before the day of auctioning, which gives EXPO additional time to co-ordinate the purchasing locations (i.e. supply lead times) with distribution schedules. For the long term, EXPO is investigating possibilities to redesign the SC structure by contracting suppliers for direct deliveries of high-quality products. EXPO is also investigating the possibility of increasing information transparency in the SC by exchanging inventory, WIP and demand (forecast) information. Finally, it hopes to implement a real-time inventory information system in the near future.

5.4.5 Concluding remarks

The preliminary theory on SC analysis and redesign proved to be useful in a SC for fresh fruits and vegetables. The identification of SC uncertainties and their sources led to the recognition of SC redesign strategies that will improve SC performance. In this process the list of SCM redesign principles helped in identifying a complete overview of SC redesign strategies. The ranking of SC redesign strategies was done qualitatively according to their potential and feasibility. We will conclude this section with some remarks made by SC participants concerning SC co-operation, which provide some extra insights into the current situation:

- 'We can predict the harvest quantity and quality pretty accurately, but we can not influence them.' (grower)
- 'Direct supply to EXPO will make the supplier highly dependable of EXPO, which could impact prices negatively.' (grower).
- 'The auction as an institution will be interesting only for small growers in the future.'(grower)

- ‘Retailers are dictating prices by determining what EXPO can ask for its products on the basis of price and quantity/quality information of goods supplied at the auctions.’ (EXPO employee).
- ‘The auctions do not provide us with enough possibilities to obtain standardised products at fixed prices at any time.’ (retailer).

This SC analysis is done from the perspective of EXPO and, accordingly, the results apply to beneficial SC redesign strategies for EXPO. However, comparable studies could be performed from the point of view of the growers, auctions, and retailers resulting in different SC scenarios. The current trend is that grower associations are emerging that deal directly with large retailers. Also, auctions have merged into the ‘Greenery International’ to provide facilities for these retailers. Hence, the results depend very much on the perspective from which the SC analysis is performed. The next two case studies are performed from a more overall SC perspective, i.e. SC redesign strategies should be beneficial to more SC stages.

Box 5.2 Chain information system

As a follow-up on this project, EXPO has begun investigating the potential of exchanging demand prognoses in the complete SC and allocating the responsibilities for retailer inventories into EXPO itself. Retailers send demand prognoses at fixed times via EDI. The retailer is obliged to order at least 80% of the forecasted demand. EXPO is obliged to deliver up to about 120% of the forecast according to the right specifications (delivery time, quantity and quality) at predetermined prices. When the order is increased over 120%, price agreements are abandoned. EXPO contracts suppliers to deliver a certain product assortment at fixed prices according to comparable arrangements. This system would increase the information transparency dramatically.

5.5 Exploratory case study II: supply chain for chilled salads

The second case study was performed in a SC network with organisations that process and market chilled salads. The aim was to improve the overall SC performance of a producer of chilled salads, who supplies to a retailer retailer distribution centre (RDC), which in turn delivers goods to about 100 outlets in the Netherlands. An overview of the SC is presented in Figure 5.7.

5.5.1 SC objectives and the SC network

Nowadays, order-winning factors for this producer in consumer markets are ultra-fresh products, product variation, and supply of an honest product (referring to environment-friendly produced products). These developments have led to an SKU explosion and the necessity to re-evaluate the current logistical SC concept. By improving the current logistical infrastructure and operational management, the producer intends to obtain category leadership for chilled salads and establish a long-term relationship with the retailer to secure future sales. He has recently started a VMI relationship with another large retailer in the Netherlands. However, although the producer experiences some benefits in this partnership he is very interested in the SC benefits. Or as the logistics manager stated: ‘I know what my costs and benefits are but what are those of the retailer?’.

The motivation for both parties to participate in this project was to obtain knowledge on SCM, to benchmark the current SC, and to improve the current SC by generating SC improvement teams/projects. The main objectives and performance indicators were (in order of importance):

1. As few as possible stock outs in retail outlets (resulting in higher sales).
2. Highest remaining shelf lives for products on outlet shelves.
3. Largest assortment, hence lowest inventory levels, in retail outlets.
4. Lowest integral cost of all SC business processes.

To fulfil the goals emphasis was put on reduction of inventory levels in the SC, especially in retail outlets, and product throughput times. The inventory levels are largely responsible for *product freshness*[1], the number of *write-offs*[2] and the non-value-adding activities that increase SC cost. The reduction of stock outs is very important; it ranked very high (number two) in a research project on consumer irritations in retail outlets (Food Magazine, 1998).

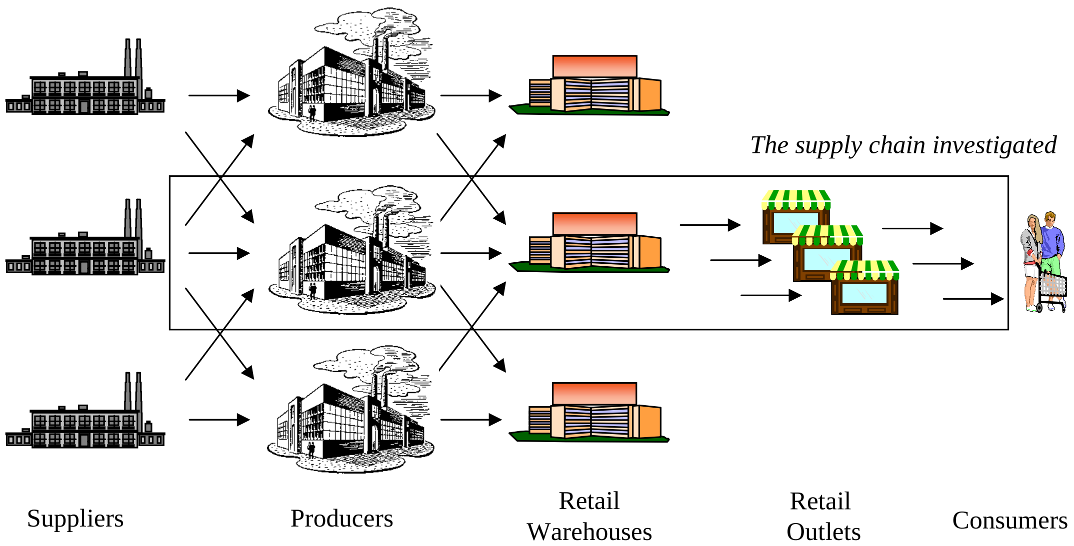

Figure 5.7 Goods flows in the SC network for chilled salads.

Retail outlets, i.e. supermarkets, sell a large assortment of products to consumers six days a week. Each store generates replenishment orders each day according to a fixed order and delivery schedule. For example, fresh fruits and vegetables are ordered each day and delivered the next day. In contrast, chilled salads are ordered twice a week and cookies only once a week.

[1] *Freshness* is a critical attribute of food products in the consumer's view and is defined as the number of days a product is still fit for consumption, i.e. the remaining shelf life. In the SC the total product shelf life is divided into a part available for the manufacturer (this will be the minor part, which will limit the maximum stock period), a part available for the trade and a part available for the end customer.

[2] A *product write-off* is a loss of a consumer product because there is no remaining shelf life.

The *Retailer Distribution Centre* (RDC) holds inventories for most of the products that are supplied by multiple suppliers. Daily fresh products are cross-docked (i.e. aggregate orders arrive on pallets, which are sorted and picked per outlet order). All other products are supplied on a regular basis, stocked and successively delivered to retail outlets.
The *producer* produces, packages and supplies about 60 different chilled salad products to the RDC from stock. Furthermore, many other retailers are supplied; the retailer in the case study accounts for only a small part of total sales volume.

5.5.2 The logistical Supply Chain concept

As in the previous case study, all relevant business processes are mapped using ODL. All four elements of the logistic SC concept will be discussed for both parties.

5.5.2.1 Managed system

The general layout of the physical SC network design has already been discussed (Figure 5.7). Table 5.8 lists the specific characteristics of the SC.

Table 5.8 Characteristics of the managed system.

Element	*Characteristics*
Physical SC design	• The producer provides multiple retailers with chilled salads from stock. • The retailer is supplied by multiple producers with different products. • The producer and retailer are located within two-hours driving distance from each other. • The retailer stores and handles products in his RDC. • Retail outlets are distributed over a large area, making transportation times variable.
Facility layout	• Retail outlets have restricted storing facilities and shelf capacities. • Transportation capacity is restricted in the SC and not outsourced. • The producer has 14 production / packaging lines.
Resource characteristics	• Raw materials, intermediate products and end-products are all stored in conditioned facilities. • Flexible production capacity: 2 production teams (8:00 – 22:00 hrs) expandable to three teams within one day.
Product/process characteristics	• There is a seasonal demand for chilled salads. • Variable process yield at producer.

5.5.2.2 Managing system

Here too, the managing system will be described by four elements: hierarchical levels of decision making, type of decision making, position of the CODP, and level of co-ordination. We will focus on the operational decision making and executing processes in the SC, i.e. we will identify and describe the business processes in retail outlets, the RDC and the producer. We will leave out processes that are not within our scope of interest in SC redesign such as invoicing and personnel management.

Hierarchical decision levels

During workshops with key employees, we mapped the business processes in ODL text and maps and in EPC models. Figure 5.8 gives an overview of the retailer’s main processes and Figure 5.9 of the producer’s most important logistical processes. Figure 5.10 presents an overview of the EPC model of this SC. We will discuss each of them according to the process number given in the figures.

Strategic planning concerns the provision of resources (capacity planning), formulating a year plan based on historical data and planning promotional activities about three months in advance. The producer's year production plan is translated into periodic plans for 4 weeks and consecutively in a week production plan. Furthermore, this plan is used to contract suppliers. Product promotions are planned jointly with the retailer several months in advance. About four weeks before the actual promotion week each outlet provides the RDC with demand estimates; the aggregate order quantity is passed on to the producer. This quantity will be delivered to the retailer on the Thursday prior to the promotion week. On Friday products are delivered to the outlets. In the promotion week, extra replenishment orders can be placed.

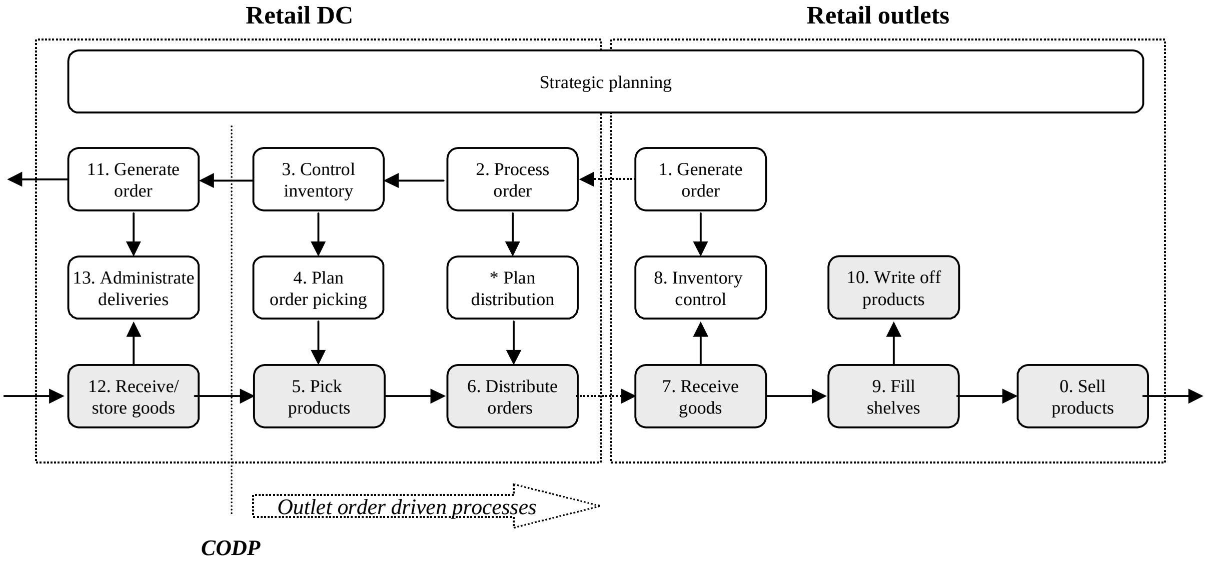

Figure 5.8 Overview of the ODL process description of the retailer (goods transformation processes are shaded).

Description of the retailer's processes

Three times a week at about 10:00 in the morning, outlet managers generate orders by checking shelves for product availability and refilling them to maximum capacity (*process 1*). Partially, order forecasting is incorporated by checking the order quantities of the last four weeks. At fixed times the order is sent to the RDC, where the orders are automatically entered into a central information system, which batches orders (*process 2*). During order processing, inventory levels are checked for product availability (*process 3*). If necessary, shortages are divided amongst retail orders; usually the last one in line is given most shortages.

The route plan[3] initiates the generation of picking lists for deliveries within the next 12 hours and delivery confirmations are sent to outlets (*process 4*). Order picking takes place that evening or the next morning (*process 5*) followed by transportation to the outlets (*process 6*). Order lead times are 24 hours. Departure times differ for each outlet and depend on the route plan; the first truck leaves at about 06:00 hrs and the last one at 15:00 hrs . A truck delivers to

[3] The RDC delivers various products in different time windows to each retail outlet each day. This is formalised in a route plan comprising combinations of order and corresponding delivery times (process *).

multiple outlets depending on the outlet order volumes. When the goods are delivered to the outlet, inventory levels are updated (*processes 7 and 8*). Goods are stored in the back until they are put in the shelves (*process 9*), usually in the evening. At various times during each week products are checked for remaining shelf life and written-off if necessary (*process 10*).

Each Tuesday and Thursday the RDC generates replenishment orders (*process 11*), taking into account current stock levels, the expected sales until the next delivery, products already on order and a safety factor to refill safety stocks. The resulting figure is rounded to full order units[4] (batches). At fixed times the producer supplies the goods to the RDC, and they are consecutively checked for shelf life and quantity (*process 12*). Next, inventory levels are updated (*process 13*). Finally, twice a week stored goods are checked for remaining shelf lives (to check the data in the information system) and written-off if necessary.

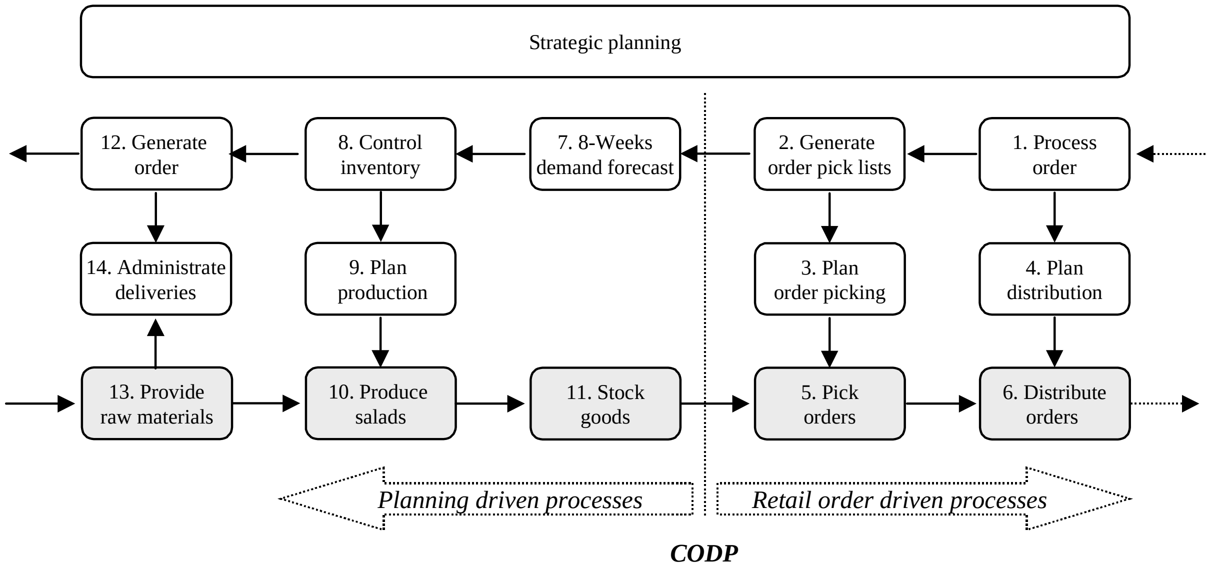

Figure 5.9 Overview of the ODL process description of the producer (goods transformation processes are shaded).

Description of the producer's processes

Each Tuesday and Thursday RDC orders are faxed to the producer before 12 noon. During order processing (*process 1*) the retailer is checked for creditability and order moment. Furthermore, the producer checks whether the retailer is allowed to order the product numbers mentioned on the fax. Sometimes, retailers 'mistakenly' order products via product promotion numbers, which are cheaper. After the order is entered into the information system, it is checked for product availability (current inventories plus available-to-promise[5] (ATP) from production). Shortages are divided automatically amongst retail orders. Products are allocated to the retail order and inventories are reserved.

[4] An order unit, or order batch size, is a number of products that are packed together in one transportation unit, such as a box or pallet.

[5] Available to Promise (ATP) shows the maximum amount of products in any one week that is being or going to be produced within the next few days that have not yet been assigned to customer orders.

Order pick lists are printed the same day around 17:00 hrs and sent to expedition (*process 2*). The order pick and distribution processes are planned based on the customer order lead times promised (*processes 3 and 4*). Order pick lists are sorted by delivery time and truck departure time. In general the FIFO[6] order picking takes place that evening or at night (*process 5*). When shortages occur – i.e. products have not arrived yet from production – a new pick form is generated, which allows for a second order picking run the next day (this is possible since additional products are added to stock from production runs that day). The next morning (i.e. Thursday and Monday) trucks are loaded and depart for delivery to the retailer RDC (*process 6*). The main part of transportation is done via the producer's own trucks; the surplus is outsourced.

Each Monday a demand forecast module estimates demand for the coming eight weeks per product type (*process 7*). This forecast is compared with current inventory levels, which results in a Master Production Schedule[7] for the coming eight weeks (*process 8*). The demand forecast for the first week is used to generate a production plan for that week, taking the customer demand distribution into account (*process 9*). Planning is against infinite capacity. Each day, the production plan can be adjusted until noon. Production quantities are determined incorporating retail orders, estimated demand till the next production moment, current inventory levels and safety stock levels. Net requirements are calculated, incorporating minimal production batch sizes. The planning is fixed for every three days (rolling horizon), which presents the ATP to order entry. Each product is produced two or three times a week (*process 10*). Alternative recipes are not used. Variable yield factors are estimated and incorporated in planning. When products differ only by packaging material, the recipe production is batched in one long production run to establish efficiency benefits. When capacity is short, an extra team is added or Saturday is used as an extra production day.

After production, pallets with products are entered into the warehouse automatically by use of bar coding (*process 11*). The information system registers the batch number and corresponding shelf life. In the expedition process, the computer assigns the pallet number to the order picker, assuring the FIFO principle. The producer has two warehouse parts: one where only complete pallets are stored and one where smaller unit loads (boxes) can be picked. Inventories are updated at fixed times (usually 07:30 hrs each morning), incorporating the actual produced quantities. Once a week (in the weekend) all stock is counted to check administrative numbers. End product inventory is about 2 to 3 working days. When the salads contain chicken or fish elements, a shelf life of 26 days is guaranteed to customers. For all other products, the shelf life is guaranteed for 33 days. When product shelf lives decrease below this value the product is removed from stock.

Via an MRP-I system, the gross requirements for raw materials and packaging materials are determined. The net requirements are calculated including inventory levels, safety stocks and lot sizes, resulting in purchasing orders (*process 12*). Some raw materials are delivered just in time (JIT), others have lead times of up to 15 days (the lead time of packaging materials can

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[6] Orders are picked in exactly the same sequence they arrive in (First in First Out).

[7] The Master Production Schedule (MPS) contains a statement of the volume and timing of the end products to be made. It is the basis of planning the utilisation of labour and equipment and it determines the provisioning of materials (Slack et al. 1998).

rise up to 8 weeks) (*process 13*). After delivery goods are checked for quantity and quality flaws. When accorded they are added to stock (*process 14*).

Type of decision making

Decisions in the SC are mainly based on the bounded rationality approach. However, these decisions are much more structured and formalised than in case I. Only in the order generation process do the character and experiences of the individual become more important.

Position of the CODP

There are two CODPs in the SC. First, retail outlet orders are delivered from RDC stock and, second, RDC orders are delivered from producer's stock. The producer's production planning is based on retail orders but is not directly initiated by these orders. Or, as the logistics manager says: 'We replenish stocks on order but deliver customer orders from stock'.

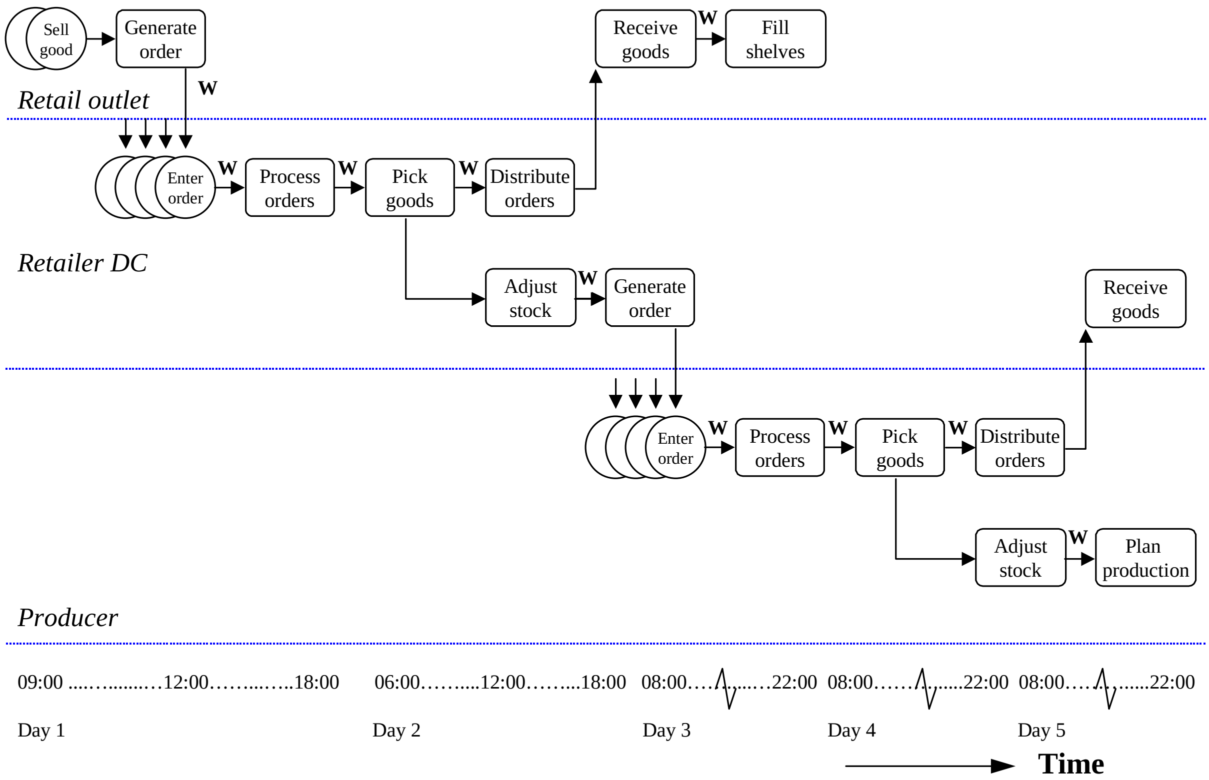

Figure 5.10 EPC model example of one order cycle in the SC for chilled salads.

Level of co-ordination

The internal integration, i.e. co-ordination, at the producer is established at several levels. At the strategic level year plans are made in all departments and co-ordinated in due time. At the operational level three persons meet every day. Sales indicate current not fulfilled orders and expected coming (rush) orders. A work floor manager presents the current state of affairs concerning the work-in-process at production. This gives the production planner enough information to adjust the production plan according to the new priorities. However, the co-ordination between departments is hampered by huge waiting times (see Figure 5.10).

At the SC level there is no real co-ordination except for promotional activities. The current way of organising activities is done from a between-company-walls-perspective as will be shown in Section 5.5.3.

5.5.2.3 Information systems

All *stores* have point-of-sale (POS) scanning facilities for products possessing bar codes. A chilled food manager uses hand terminals to generate retail outlet orders, which are sent to the RDC by modem. At the start of this research project, the retailer was investigating the potential of an automatic ordering system that would generate orders automatically using inventory levels, forecasted demand (based on the last six weeks' data) and product waste data.

The *RDC* uses a batch processing information system that clusters orders and processes them (checking for creditability, product availability, etc.) three times a day (01:00, 09:00 and 12:00 hrs). Actual inventories are not known at the time of order processing. Some of the orders are placed via EDI at suppliers, mainly those suppliers that deliver to the outlets directly such as tobacco producers.

The *producer* uses a batch-oriented information system that processes RDC orders and controls inventory. During production line scheduling, information about line utilisation degrees is available but not automated; wastes are not recorded. Actual inventory levels are only known at the end of the day. ATP from production is available during the day but is communicated by telephone. Furthermore, the producer has a production-planning tool developed by his own personnel. Most plans are made by hand (e.g. the generation of purchasing orders), relying heavily on past experience. Even the production plan is made by hand since planners question the reliability of the tool. Also, this producer is currently initiating EDI links with some of his main suppliers and customers. At the time of our research, the producer was evaluating an ERP system. However, our analysis is based on the situation that existed at the time, without such a system.

5.5.2.4 Organisation structure

Retail outlet managers are responsible for the operational management and control in the outlets. More strategic decisions such as the establishment of product assortments per retail outlet and promotional activities are deployed at the head office. There is a retail logistics manager responsible for all goods movements in the RDC and to the stores.

At the producer there are several departments. A physical distribution manager controls the warehouses and plans transportation activities to customers. A production manager plans and controls the production process and is responsible for inventory levels. A purchasing manager plans the supply of raw materials and packaging materials and manages inventory levels. Finally, at both links there is a marketing department that focuses on all category management activities (see Section 2.5) and an IT manager responsible for the information systems in the SC.

Box 5.3 Forrester effect

This SC demonstrates the Forrester effect. Demand is amplified when outlet orders peak due to weather improvement. The order generation policy in the RDC is heavily influenced by human decision making resulting in the requirement for extra safety buffers in the form of stocks. Hence, RDC orders peak even larger than necessary. This is even more so during weeks when certain products are promoted at lower prices. Due to the fact that the retailer can order additional products during that week he orders a surplus of products, which he intends to sell later on at the normal higher prices to either customers or franchised retail outlets.

5.5.3 SC uncertainty and sources of SC uncertainty

The following step in our preliminary methodology is to identify performance gaps, SC uncertainties and the sources of these uncertainties. As indicated, the SC KPIs are product freshness, the number of out of stocks, inventory levels and integral SC costs. The project team verified that the SC performance was not optimal, because many stock outs, write-offs and relatively high inventory levels were registered in the SC resulting in additional SC costs (see also Chapter 7). The SC uncertainties we identified in this SC are described in Table 5.9.

Table 5.9 SC uncertainties for the retailer ®, salad producer ❑ or both •.

	Quantity aspects	*Quality aspects*	*Time aspects*
Supply uncertainty	® Will supply product quantities correspond to the outlet orders? ❑ Will suppliers deliver the requested salads?	• Will supplied product qualities meet the requirements?	® Will goods be supplied on time? ® Will goods be supplied to the stores on time? ❑ Will suppliers deliver the goods on time?
Demand and distribution uncertainty	® How much will be sold? ❑ What orders will be placed in the SC?	® Will product quality please the customers in the stores?	® When will products be sold in the stores?
Process uncertainty	® Will we have enough products available for distribution as required? ❑ Will we produce enough products?	• Will stock turnover be high enough to preserve product quality?	❑ Will stocks be refilled on time? • Will throughput times for order processing and picking be small enough to deliver on time?
Planning and control uncertainty	• Is stock level information accurate at this moment? • What is the status of that customer order?	• Is the information received (automatically or via personal communication) correct?	• Will information concerning changes of customer orders be communicated on time?

Based on the process flow analysis, the ODL descriptions and EPC models, we were able to identify the elements that increased SC uncertainty and hampered SC performance; i.e. the sources of SC uncertainty. During workshops with key employees, cause-effect models were formulated and verified that identified the main sources of SC uncertainty. An example related to product freshness in retail outlets is presented in Figure 5.11.

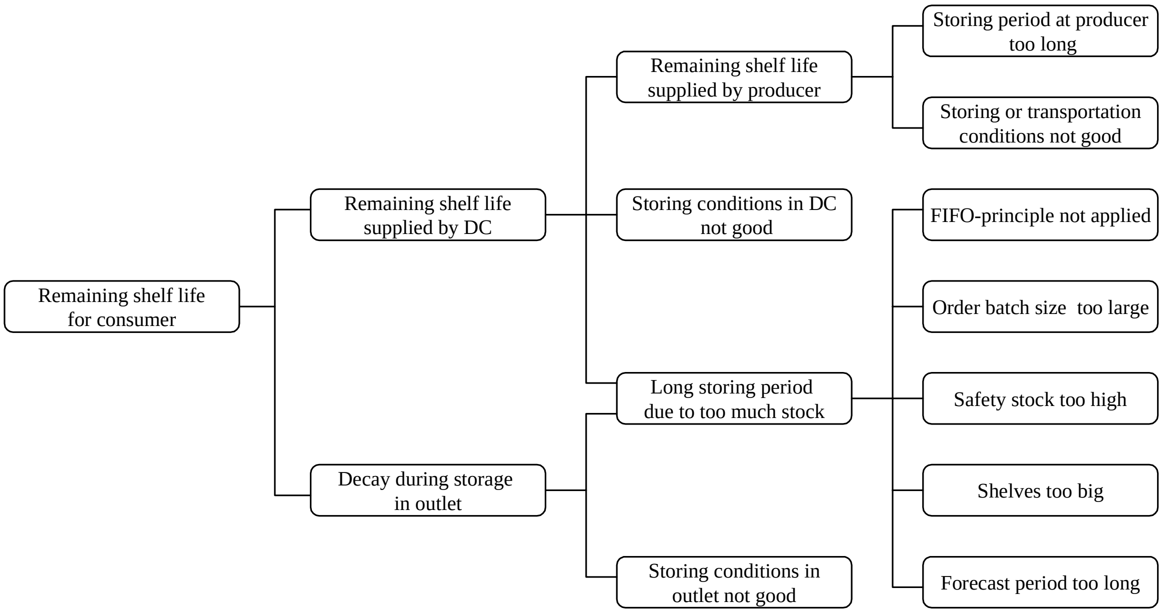

Figure 5.11 Overview of part of a cause-effect model concerning product freshness in retail outlets.

These cause-effect models, together with the findings of our process flow analysis, resulted in an extended list of sources of SC uncertainty responsible for performance flaws. Table 5.9 lists the most important identified sources of SC uncertainty.

Box 5.4 Communication in the SC.
One of the differences that arose during discussions with key employees of both companies related to the definition of the delivery reliability of the producer. Whereas the producer said he established a delivery reliability of 98.3% to this particular retailer, the retailer measured it as 99.6%. It turned out that the producer measured on product level whilst the retailer measured on order line.

Another communication problem related to the bar coding of promotional products. The regular and the promotional item have the same ‘unique’ product coding, leading to complications in the order and financial flows.

The main sources of SC uncertainty are incorporated in the system design, i.e. the current information technology infrastructure and the stock holding RDC. The relatively long RDC order cycle time (3 days) combined with the possibility to order only twice a week results in a relatively large order forecast horizon for the RDC. Because of inflexible production machinery at the producer, relatively large inventories are required to supply all retailers at all times.

Table 5.9 Main sources of SC uncertainties for the retailer ®, salad producer ❑ or both •.

	Quantity aspects	*Quality aspects*	*Time aspects*
Supply uncertainty	❑ Orders arriving after printing pick lists have more chance of stock-outs. ❑ Supplied goods have not passed the quality tests but are still administrative added to stock. ❑ Orders are in kilograms and not measured precisely (a 10% variation is accepted). • Too little products delivered: – shortages assumed but stock levels not up to date – orders are picked according to loading list; the last customer receives most shortages.	❑ Variable raw material quality impacts supply quantity and production time. ❑ The corrected order pick form (with shortages and so on) used as shipping list to RDC is prone to errors. • Products stored too long due to: – too much produced – FIFO not applied – wrong forecast. • Supply delivery performance disagreement because of different definitions for metrics.	® Outlets order products according to a fixed call-and deliver schedule. • Supplier delivers goods late. • Time for quality check required before raw materials are released. • Waiting times to add supplied goods to stock; sometimes shortages are reported whilst goods are just supplied. • Long supplier lead times in the case of product shortages. • Orders are sent too late. • Traffic congestion.
Demand and distribution uncertainty	® No insight in sales during the day. ® Stock outs due to time window refilling shelves. ❑ Forrester effect due to: - no insight in inventory levels at retailer RDC – no insight in demand pattern retail outlets. - human interacted order policy at RDC. • Too much products ordered due to data errors or minimal order batch quantity. • Peak in sales on Friday and Saturday. • Long forecast horizon resulting in large safety buffers in SC. • Forward buying of products during promotion weeks at lower product prices. • Peak in demand due to weather changes.	® Order picking uses sticky labels that sometimes fall off. ® Sometimes product shelf stickers are not correct. ❑ Producer's and supplier's quality perception of raw materials differs. • Shortages during picking are written down on forms which sometimes get lost resulting in extensive searches and discussions. • Shortages are not mentioned on shipment note to customer. • Products are allocated to a customer who is to be supplied later, whilst rush orders can not be delivered at that moment. • Order pick forms are not printed according to the route plan; they have to be sorted afterwards.	® Outlets order products according to a fixed call-and deliver schedule. • Supplier delivers goods late. • Time for quality check required before raw materials are released. • Waiting times to add supplied goods to stock; sometimes shortages are reported whilst goods are just supplied. • Long supplier lead times in the case of product shortages. • Orders are send too late. • Traffic congestion.

Table 5.9 Continued.

	Quantity aspects	*Quality aspects*	*Time aspects*
Process uncertainty	® Too much inventory due to order batch sizes or wrong order forecast. ® Shelf capacity shortages due to expanding product assortment. ❑ Too much inventory due to fixed production batch sizes or wrong demand forecast. ❑ Yield differs from production plan; scrap factors incorporated in BOM not correct. ❑ Product loss due to inaccuracy in production/RDC. ❑ Shortages in supply due to too low safety stock levels. ❑ Search for long production runs.	® Students fill shelves and do not apply FIFO principle ® Many people are authorised to adjust inventory levels leading to little data integrity ® Product batches with little remaining shelf life are not reported to sales department. ❑ Tracking product flaws in process not possible per batch resulting in large losses. • Product damaged in RDC during handling. • Quality decay due to long storage.	❑ Machine downtime. ❑ Raw materials require defrosting time. ❑ Waiting times due to shortage of raw materials; requires rescheduling. ❑ Long runs result in long production throughput times. ❑ Fixed production schedule. • Too little time to pick products.
Planning and control uncertainty	® There is no shelf life information available of stocked products in the RDC. ® Batch processing inventory management system. ❑ Inventory levels are never up to date, because production output usually differs from planning. • The information system provides no link between planning and operational progress.	® Scanning problems resulting in missing products in outlet. • Too much exchange of data by paperwork prone to errors. • Data errors in order entry process by phone. • Data not usable due to aggregation level. • Retailer and the producer use different article numbers. • Eliminated products from assortment are not removed from article list.	® Batch order processing in retail RDC starts at fixed times and takes 2 hours. ❑ Orders are send by fax or phoned in, so extra time is needed to enter them into the system. • Waiting times before printing pick lists.

5.5.4 SCM redesign principles and SC scenarios

Just as in the preceding case study, we have classified all sources of SC uncertainty and the relevant aspects of the current SC scenario by element of the logistic concept and inherent sources. These sources were linked to the list of SCM redesign principles in discussions with key persons, resulting in a list of relevant SCM redesign strategies. These are listed in Appendix E. We have classified all SC redesign strategies according to our typology in Table 5.10.

Table 5.10 SC redesign strategies for the retailer ®, salad producer ❑ or both •.

Element	*Local improvement strategy*	*Supply Chain improvement strategy*
Managed System	® Expand shelf capacity by expanding store space. ❑ Do quality check at certified / contracted suppliers. ❑ Reduce set-up times of packaging lines.	® Change position CODP: eliminate the RDC as storing facility and ordering partner; apply cross docking. ❑ Reduce the number of suppliers. ❑ Decrease supplier lead times. • Make supplier responsible for inventory levels of retailer (VMI). • Reduce the need for filling shelves; introduce standard containers to be used also in the store.
Managing System	® Adjust authorisation codes concerning inventory control. ® Increase the frequency of filling shelves. ❑ Increase the production frequency and decrease production batch sizes. ❑ Adjust scrap factors constantly. • In calculating safety stock levels differentiate the formula per product type. • Improve labelling at order picking or introduce Radio Frequency (FIFO) picking • Introduce rationing policy at order picking.	® Increase the ordering and delivery frequency and decrease order batch sizes. ❑ Establish long-term contracts with suppliers based on short lead times and frequent deliveries. • Decrease order lead times. • Decrease lot sizes in the SC. • Eliminate forward buying by co-ordinating consequences of actions.
Information system	® Automate order procedure in retail outlets and use demand forecasting modules. ❑ Implement integral information system; supplying WIP information and coming order at all times with possibility to track products per batch. • Implement real-time inventory management system . • Implement digital shelf stickers to be adjusted automatically and centrally.	❑ Inform customer via EDI on shipments. • Reduce waiting and processing times by EDI, automated order entry and aligning SC systems. • Exchange inventory and sales information to partners upstream in the SC. • Standardise and agree on bar coding. • Co-ordinate the type of data that needs to be exchanged in the SC in order to be usable.
Organisation structure	• Educate personnel on defined SC objectives and the impact of their actions on the realisation of those objectives; reward them accordingly.	• Jointly define SC objectives and corresponding performance indicators (including measurement). • Standardise quality perceptions in SC.

From Table 5.10 and Table 4.12 we can identify the SC redesign variables for this SC that are estimated to have a major impact on the SC performance indicators identified at the beginning of the case study description (Table 5.11). Since product freshness and stock outs are the major indicators, it is clear that the timing of activities and the amount of inventory in the SC are crucial. Effective SC scenarios can be defined by adjusting one or more of these SC redesign variables.

Table 5.11 Main SC redesign variables in the SC for chilled salads.

Configuration level	*Operational management and control*
• Role of the RDC (ordering, storing, picking, VMI) • Systems in the SC: automated order procedure in retail outlets, EDI and real-time inventory management systems	• Frequency of production, ordering, picking, distribution and filling of shelves • Order lead times in the SC • Lot sizes in the SC • Ordering and rationing policies applied in the SC • Availability of information concerning inventory and sales information in the SC

5.5.5 Concluding remarks

In this case study too, the preliminary theory on SC analysis and redesign proved to be useful in identifying the effective SC redesign variables to construct SC scenarios. We will conclude this section with some remarks made by participants of this SC concerning SC co-operation:

- 'If a new SC scenario reduces inventory levels in retail outlets this will provide additional space on shelves. Then, of course, we would like to benefit from this and add additional products to our assortment in the stores' (Logistics manager producer)
- 'We know the extra costs we incur as delivery frequencies to customers rise. But we would like to know the exact costs and benefits that are incurred at the other end of the SC' (Logistics manager producer and logistics manager RDC)
- 'Reducing stocks will be the order winner for the future. Since this enables inevitable expansions of the product assortment' (Retail outlet manager)

5.6 Exploratory case study III: Supply chain for cheese and desserts

The third case study was performed in a SC network in which cheese products and desserts are marketed. The research object was a SC consisting of two suppliers of desserts, a cheese producer, a RDC and about 25 retail outlets. Figure 5.12 depicts an overview of the SC network. This SC was analysed from the point of view of two organisations that wanted to explore the potentials of SCM, namely the cheese producer and the retailer.

5.6.1 SC objectives and the SC network

This section will present an overview of the SC network and the investigated SC. The retailer aims to attract consumers by providing high service with low product prices. The producer stores, cuts and packages cheese products and operates as a logistic service provider for the supply of desserts to retailers. The SC objective, and the reason to participate in this project, was to obtain a higher level of SC integration that would result in higher sales at less cost. Logistical SC performance indicators that were acknowledged by both parties are comparable to those identified in Case II. There are, however, some slight differences in ranking:

1. Lowest inventory levels, in retail outlets;
2. As few as possible stock outs in retail outlets (resulting in higher sales);
3. Highest remaining shelf lives for desserts on outlet shelves;
4. Lowest integral cost of all SC business processes.

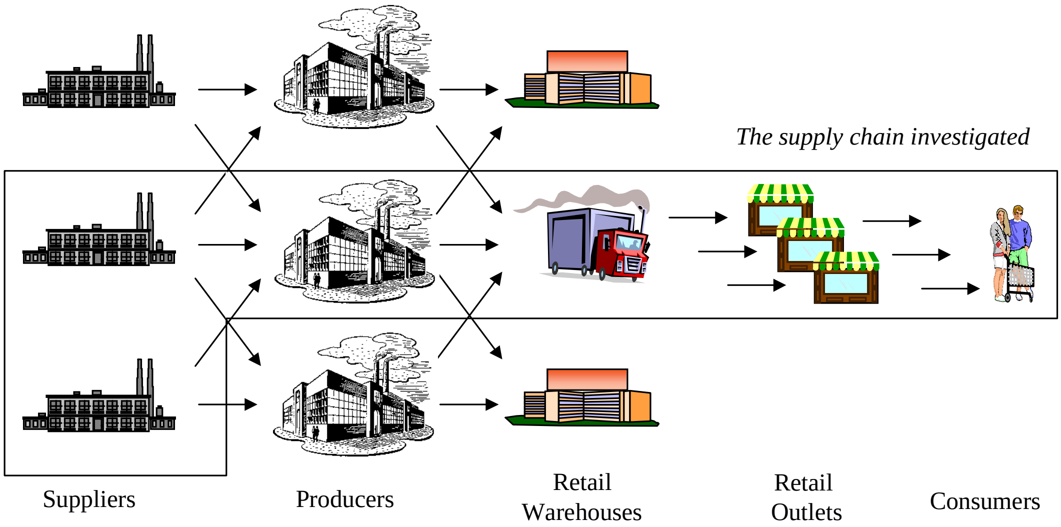

Figure 5.12 Goods flows in the SC network for cheese and desserts.

Because of the high value density of cheese products (making storage and lost sales more expensive) and required product expansions, emphasis was put on SC inventory levels to reduce total SC cost. Reducing throughput times, hence increasing product freshness, is mainly interesting for desserts. We will now first give an overview of the business processes in each link in the SC.

Each *retail outlet*, i.e. supermarket, holds a large product assortment comparable to the stores in Case II. The main difference is that in this SC the stores receive deliveries from two warehouses; one warehouse concentrates on less perishable products, the other on fresh and chilled food products. The latter will receive our attention.

The *RDC* for chilled food products operates via the 'cross-docking' principle. This means that goods are moved to loading docks and loaded aboard outbound trucks within 24 hours of goods receipt. There is no need to hold goods in a reserve stock area, or to install equipment to store them. Outbound trailers serve as extensions of the RDC because storage takes place only while trailers are being filled. Or as the logistics manager said: 'the trucks become the warehouse'. The distribution centre acts as a consolidator to reduce the number of trucks received at the stores. The RDC ends the day the same way as it began it, i.e. empty. This principle requires that orders sent to the suppliers equal the aggregate of all retail outlet orders, hence no product is left when all supplied goods are assigned to retail outlets. There are several ways to operationalise the cross-docking principle. The main difference lies in whether the supplied goods are already picked and grouped per retail outlet order or the aggregate order is delivered as a whole. In other words, whether order picking for a particular outlet order is done at the supplier or at the RDC. This particular supplier of cheese products and desserts applied the first concept, i.e. he supplied the RDC each time with 25 roll-in containers containing the ordered goods for each individual retail outlet. At the RDC, these often half-filled containers are filled-up with products of other suppliers that deliver products by an aggregate order.

Box 5.5 The working of Automated Store Ordering

Replenishment starts with the electronic capture of sales information at the point-of sale using UPC (Unique Product Code)-coded price tickets and scanning technology, which allow for instantaneous updating of inventory records. Periodically, the amount of inventory on hand of each SKU is compared with amount specified in a 'model stock' that is developed jointly by the supplier and the retailer for each individual store. The model stock for any particular time is usually based on recent sales history, modified to take into account anticipated promotional activities and market trends. The model stock quantity for an SKU is set at a level sufficient to cover expected demand, 95 percent of the time, between placement of an order and its arrival at the store.

Source: Stern et al. (1996)

The *producer* is a supplier of several types of whole, partitioned, sliced and grated cheese products. Together with dessert products, cheese products are offered to customers via large retailers in the Netherlands and abroad. The producer buys whole cheeses from an industrial supplier and then stores, preserves, processes, and packs the cheeses so they become customer-specific items. Products for the retailer in this project are easily recognised by a specific price tag on each item. This allows for the separate investigation of this SC, since these products are specifically produced, stored and picked for our retailer. Desserts are delivered by two foreign industrial producers and successively stored in the producer's warehouse. Desserts enter the system with a remaining shelf life of about 23 days. The shelf life of cheese products is about 70 days.

5.6.2 The logistical Supply Chain concept

In this SC too, all relevant business processes are mapped using ODL and EPC models. The results will be discussed by the four elements of the logistic SC concept for both parties.

5.6.2.1 Managed system

The overall layout of the physical SC network design was given in Figure 5.12. Table 5.12 lists the specific characteristics of the SC under investigation.

Table 5.12 Characteristics of the managed system

Element	*Characteristics*
Physical SC design	• The producer and retailer are located close together within a half-hour drive. • The order picking process is assigned to the producer. • The producer has outsourced transportation.
Facility layout	• Retail outlets have restricted shelf capacities. • Cross-dock RDC has no facilities for storage of products. • The producer holds a specific inventory for the retailers products due to the specific price tag and the cross-docking arrangement. • The producer has limited storing capacity of supplied whole cheeses. • The producer has 7 packaging lines laid out in production cells.
Resource characteristics	• Relatively long set-up times of packaging lines. • The producer's storage facilities are air-conditioned; transportation is not.
Product/process characteristics	• Perishable products with a shelf life ranging from two weeks (desserts) to 70 days (whole cheeses). • Specific price tag on products destined for the retailer. • Seasonal demand.

5.6.2.2 Managing system

The managing system will be described by four elements (see Section 3.5): hierarchical levels of decision making, type of decision making, position of the CODP, and level of co-ordination.

Hierarchical decision levels

The strategic planning structure, i.e. sales and production planning, is comparable to the one described in Case II. In co-ordination between retailer and producer, a plan for product promotions is defined every 6 weeks. Retail outlets generate 'promotion orders' each Monday the week before the products are promoted. The next Friday the producer delivers the orders to the RDC. Order corrections can be sent through on Tuesday in the promotion week in addition to the regular ordering cycle.

Figure 5.13 depicts an overview of the main business processes at the retailer. Those of the producer are depicted in Figure 5.14. We will discuss each of them according to the process numbers given in the figures.

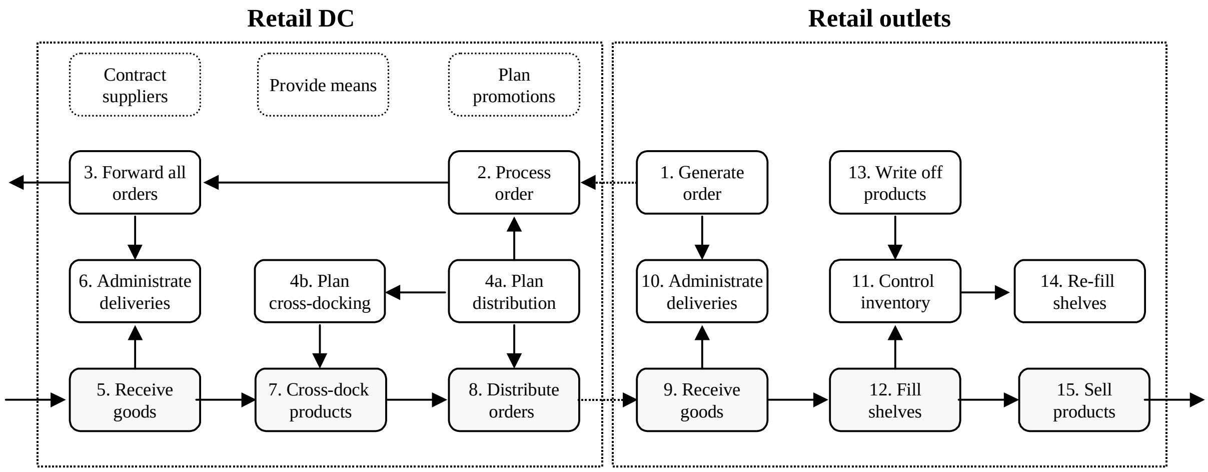

Figure 5.13 Overview of the ODL process description of the retailer (goods transformation processes are shaded)

Description of the retailer's processes

Retail outlets generate replenishment orders every Tuesday and Friday before 11:00 in the morning (*process 1*) by subtracting the current inventory from the shelf capacity (shelf space is filled up). These orders are sent to the RDC where they are batched, entered into the main information system and split up into orders per supplier (*process 2*). At 12:00 hrs the orders are forwarded to the producer (*process 3*). The distribution and cross-dock plans are based on the received orders (*process 4*). The cheese producer delivers the purchased goods each Thursday (before 07:00 hrs) and Monday morning (before 11:00 hrs) to the RDC (*process 5*). The goods are checked for quantity and quality flaws (*process 6*) and successively cross-docked (*process 7*) together with goods of other suppliers. At fixed times, trucks are loaded and depart for delivery to several retail outlets (*process 8*).

The retail outlets are supplied three days after ordering; each Tuesday and Friday morning by the RDC (at about 08:00 hrs) after which quantities and qualities of the goods are checked (*process 9*). Goods are stored temporarily in cooling cells (note that these are not available in all outlets) and inventory levels are updated (*process 11*). At the same time (corrected) delivery forms are sent to the administrative process to correct (if necessary) the order forms facilitating a correct invoicing process (*process 10*). At the end of the day (when schools are out and students are available for filling shelves) goods are taken from these cooling cells and put on the shelves (*process 12*). During this process, all goods that are already on the shelves are checked for their remaining product shelf life; when no shelf life is left the goods are eliminated (*process 13*). Products that do not fit onto the shelves are stored in the back and used for refilling shelves later on (*process 14*). Finally, customers come into the store and buy products (*process 15*), which again initiates a new replenishment process.

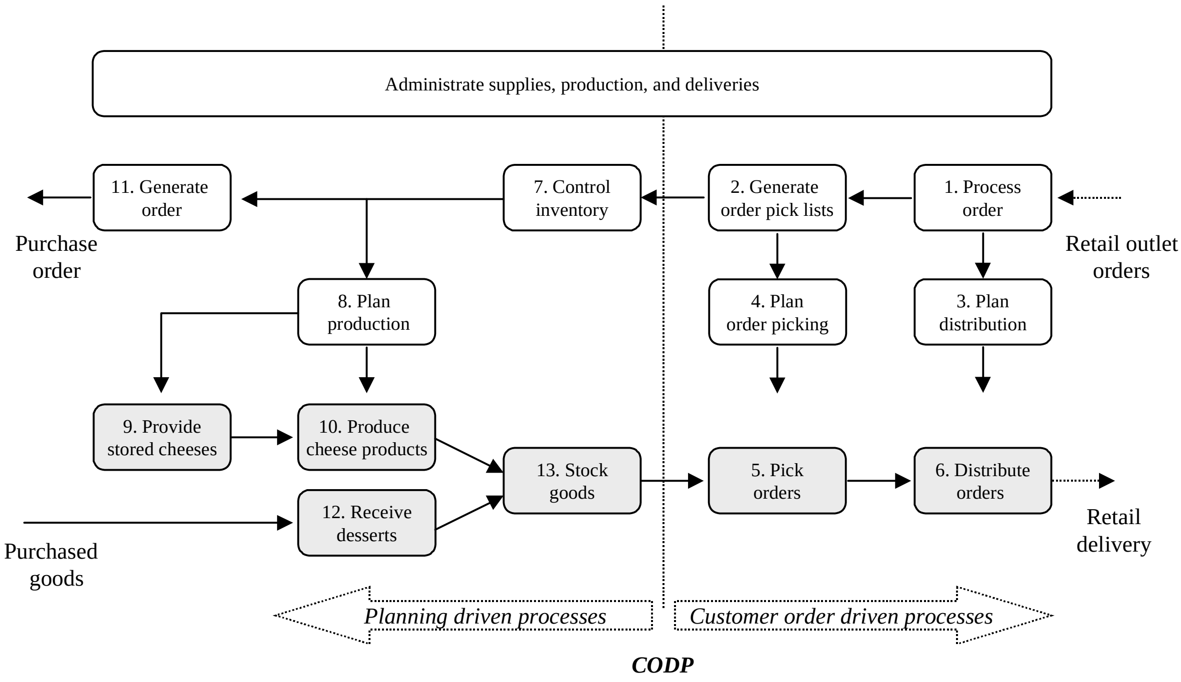

Figure 5.14 Overview of the ODL process description of the producer (goods transformation processes are shaded).

Description of the producer's processes

The producer receives the retail outlet orders two times per week within restricted time frames: each Tuesday and Friday before 12 noon. He receives 25 outlet orders (of course, in addition to other customers' orders) comprising order quantities for each of the product types delivered by this supplier (*process 1*). The order acceptance procedure, which starts after a certain waiting time, includes entering the orders into the central information system. This allows for the generation of order picking lists (*process 2*) and invoices on the same day at about 17.00 hrs. Consecutively, distribution (*process 3*) and order picking (*process 4*) is planned in order to provide distribution of the right products at the right time, placed on a roll-in container for each outlet. The actual order picking is done the following day, i.e. on Wednesday afternoon and Monday morning, during which time the picked order quantities are entered into an information system to generate loading lists (*process 5*). In the case of shortages, these are assigned pro ratio to the outlets. Thursday and Monday morning the products are distributed to the cross-dock RDC (*process 6*). Hence, the lead time from retail outlet order to the actual delivery to the retail outlet is about 3 days. These are the processes that are driven on customer orders (see also Figure 5.15).

Each Monday, the producer's inventories are checked and replenishment orders are generated based on inventory levels, customer orders of last weeks and expected changes in customer demand (*process 7*). Production plans are made stating how much to produce of what type of product (*process 8*). Production is carried out according to a fixed schedule and products for this particular retailer (with the specific price tags) are only made once per week. When sliced cheeses are required whole cheeses are taken from the warehouse and supplied to production (*process 9*). When stocks come below predetermined safety stock levels, new purchasing orders are generated. This is also the case for stock levels of desserts (*process 11*). One supplier delivers desserts to the producer every day. The other supplier delivers desserts with a lead time of 6 days on Monday, and on Wednesday. During the week, products are produced and supplied (*processes 10 and 12*), after which they are added to stock (*process 13*). Finally, all transactions are registered and invoices are sent to the RDC for each outlet order.

Type of decision making

Operational decisions in the SC are to a high degree formalised and captured in formulas. However, decision-makers are able to change the outcome, taking into account recent developments. This results in decisions that are subject to the bounded rationality approach (see Section 3.5.2). Especially in the order generation process the character and experiences of the individual become important.

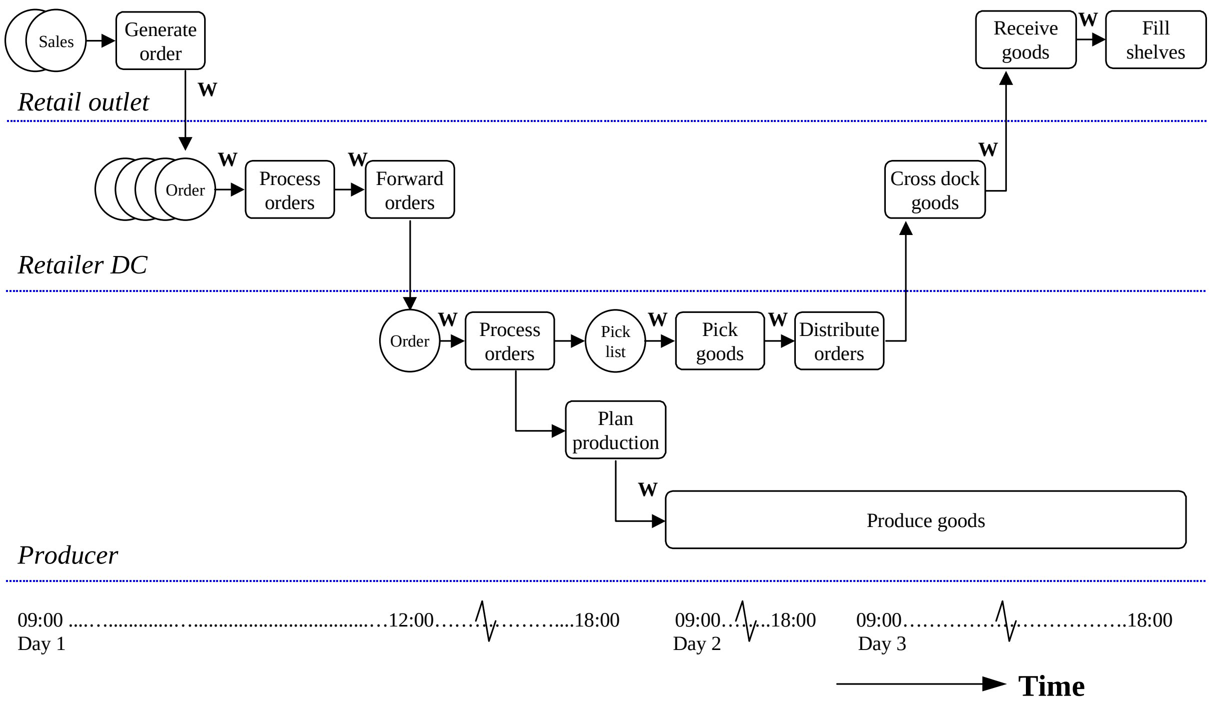

Figure 5.15 EPC model example of one order cycle in the SC for cheese and desserts.

Position of the CODP

The CODP in the SC is located at the producer's end-product inventory. Because of the specific price tags on end products, a specific inventory is designated to our retailer. Production planning and production itself are based on retail orders, but they are not directly initiated by these orders.

Level of co-ordination

The level of co-ordination between the production and marketing department at the producer could be improved, considering that the marketing department sometimes promotes products without first communicating this to production. But since this is a relatively small organisation, communication lines are short. Furthermore, the co-ordination between departments is hampered by huge waiting times (see Figure 5.10). There is no real integration in the SC. Except for promotional activities, the current way of organising activities is done from a between-company-walls-perspective as will be shown in Section 5.6.3.

5.6.2.3 Information systems

As in the previous case study, all retail outlets have POS-scanning facilities and hand terminals to generate retail outlet orders that are sent to the RDC by modem. At the start of this research project also this retailer was investigating the potential of an automatic ordering system that would generate orders automatically using inventory levels, forecasted demand (based on the last six weeks' data) and product waste data. The RDC currently uses a batch processing information system that clusters orders and processes them (checking for creditability, product availability, etc.) at fixed times. Also the producer in this SC uses a batch-mode information system that processes retail orders and controls inventory. Hence, inventory levels are only known at the end of the day. Furthermore, the production-planning tool is developed by his own personnel. Most plans are made by hand (e.g. generating purchasing orders), relying heavily on experiences. Even the production plan is made by hand since planners question the reliability of the tool. The producer is initiating EDI-links with some of his main suppliers and customers.

5.6.2.4 Organisation structure

Both organisations are relatively small, each employing about 200 employees. A marketing-, information-, and RDC-manager and the general manager form the management team of the retailer. A comparable situation is found at the producer, where also only three hierarchical levels are present (director – managers – labourers). The divergence in rewarding systems as found in the first case study was not found in this SC.

5.6.3 SC uncertainty and sources of SC uncertainty

The following step in our preliminary methodology is to identify SC performance gaps, SC uncertainties and the sources of these uncertainties. As in the previous case study, the project team identified performance gaps concerning stock outs, write offs and relatively high inventory levels in the SC. The SC uncertainties in this SC are comparable to the ones described in case II (Table 5.9) since comparable decisions are made. However, the sources of these decision making uncertainties are partially different.

Box 5.6 Co-ordination in the SC – point 1
During the SC analysis some aspects emerged that showed that the SC was not optimal. One of them was the following. Orders are generated at retail outlets and punched into the outlet information system. They are processed automatically at the retailer RDC and then sent to the producer by fax. Consecutively, the order is entered into the producer's information system manually. Then picking lists are generated and during order picking the number of picked items is entered into the information system again, after which a check is made on delivery reliability. Thus, each order is processed (typed over) three times in the SC; this makes the system prone to data errors and it requires many hours.

As indicated, the relevant performance indicators were inventory levels, the number of out of stocks, product freshness, and integral SC costs. Based on the process flow analysis, we could identify the elements that increased SC uncertainty and hampered SC performance. During workshops with key employees, cause-effect models were formulated and verified that identified the main sources of SC uncertainty. An example related to stock outs in retail outlets is presented in Figure 5.16.

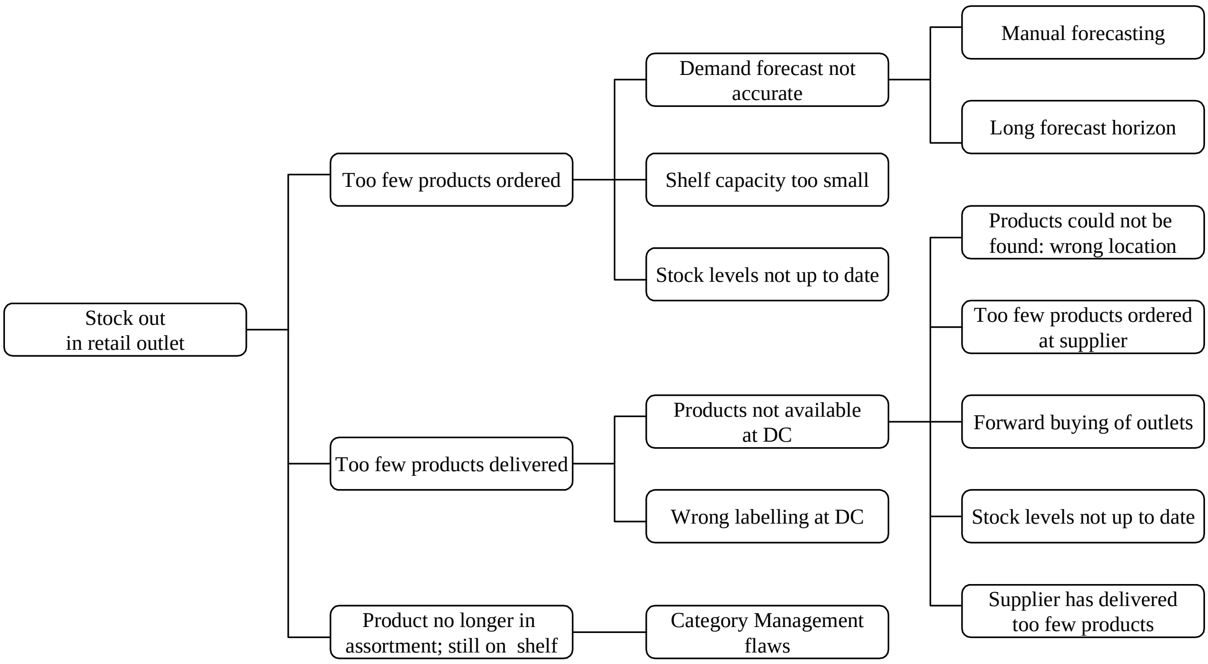

Figure 5.16 Overview of part of a cause-effect model concerning stock outs in retail outlets.

These cause-effect models, together with the findings of our process flow analysis, resulted in an extended list of sources of SC uncertainty that were responsible for performance flaws. Table 5.13 lists the most important identified sources of SC uncertainty that were confirmed in the project team meetings. Once again, we have to notice that the sources of SC uncertainty are interdependent; too much inventory could be a source for variations in product quality, but a large order batch size could cause the huge inventories.

Table 5.13 Main sources of SC uncertainties for the retailer ®, cheese producer ❑ or both •.

	Quantity aspects	*Quality aspects*	*Time aspects*
Supply uncertainty	® Volume of goods received at retail outlets are often not checked (mainly because the supplier not the # kilos delivered and not the # of pieces) or checked after shelves are filled, which is hardly feasible. ® When shortages are observed the supplier is directly contacted instead of the RDC resulting in wrong invoices. ❑ Too few desserts delivered/not reported in advance.	• Products are stored too long due to: - FIFO principle not applied at order picking; - too many products ordered due to minimal order batch sizes, a not optimal order procedure, forward buying or wrong forecast due to a long forecast horizon. • Supply delivery performance disagreement because of different measures.	® There is no personnel available to accept goods. ® Retail outlets cannot receive deliveries at all times due to noise pollution restrictions. ® Other supplier is too late causing delay in truck departure. ® Producer supplies too late because of delays. ❑ Orders are sent too late to the producer. • Delivery time overdue due to traffic congestion.
Demand and distribution uncertainty	® Systems give no insight in sales during the day. ® Too much products ordered due to long order forecast horizon. ® Empty shelves due to lack of product or inattention of personnel to fill shelves. • Friday & Saturday make up 50% of weekly demand • Promotions influence demand for regular products. • Stock levels are not up-to-date. • Product loss at RDC because of accidents.	• Desserts are delivered with 23 days shelf life. • Long throughput times in the SC. • Too much inventory leading to quality decay. • Additional decay during unconditioned transportation. • Purchasing personnel of retailer buys much more products than needed during promotions at a lower price (forward buying) resulting in peaks and, afterwards, dips in demand.	® There is no personnel available to accept goods. ® Retail outlets cannot receive deliveries at all times due to noise pollution restrictions. ® Other supplier is too late causing delay in truck departure. ® Producer supplies too late because of delays. ❑ Orders are sent too late to the producer. • Delivery time overdue because of traffic congestion.
Process uncertainty	❑ Packaging line downtime. ❑ Variable production yield / scrap rates. ❑ Promotional activities are not co-ordinated with production; one assumes they can produce all orders. ❑ No WIP information available. ❑ Fixed production schedule; little mix flexibility. • Incorrect inventory levels. • Discarded product due to quality decay.	® Students fill shelves and do not apply the FIFO principle. ® Products are stored too long because of too many products bought. ❑ Production flexibility restricted due to fixed product/line combinations • Products are stored too long or under the wrong conditions • Inventory checks on product tenability only takes place once a week whilst two is required (takes much time).	® Lot of time 'wasted' on (re-) filling shelves. ® Truck is not available; did not return on time from previous route. ® Loading papers are not ready ❑ Fixed production schedule; little flexibility. ❑ Long set up times of the packaging lines. ❑ Long production runs. ❑ Process throughput times not known. ❑ Capacity shortages at order picking; personnel used to unload arriving truck. • Too little time to pick ordered products.
Planning and control uncertainty	® Inventory levels are not up-to-date due to thefts. ❑ Batch processing inventory management system: at night the inventories are up dated. ❑ ATP information is not available. ❑ Working order sequences are changed by personnel; also because of rush orders.	® Problems with article bar coding in outlets (unreadable, unknown) ❑ Errors when entering order data into the system because the product array on the fax does not correspond to the array in the system. • Product freshness in stock not known. • Products in stock not correctly specified.	❑ Orders are sent by fax and entered into the system taking two hours. • After order generation, orders are entered into information systems by hand at RDC and supplier. • Batch order runs take much time. • Waiting times for entering orders into the information system. • Waiting times before plans are made.

The main sources of SC uncertainty are incorporated in the system design, i.e. the current information technology infrastructure and production – delivery structure with cross-docking. The relatively long outlet order cycle time (3 days) combined with the possibility to order only twice a week results in a large order forecast horizon for retail outlets necessitating large inventories to cope with demand variability. Figure 5.17 depicts a general overview of the time needed for processes in the retail outlets based on multiple time measurements in several retail outlets; filling shelves requires most time. Because of the inflexible production machine of the supplier, last-minute changes in retail orders cannot be handled, requiring relatively large inventories to realise a high delivery reliability.

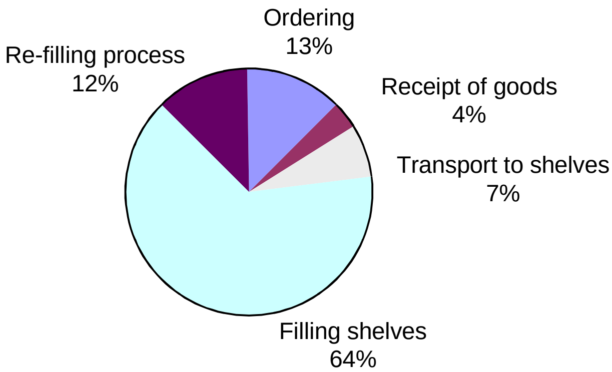

Figure 5.17 Average process time in retail outlets (in percentage of total time).

> *Box 5.7 Co-ordination in the SC - point 2*
> An example of an advantage of SCM in this SC is the following. The producer is obliged to deliver the retailer RDC before 11:00 hrs each Thursday. When the supplier arrives, shipment papers are immediately sent to the accounts department to confirm the retail orders. When the supplier is late, administration calls him demanding an explanation. However, the process flow analyses showed that the goods are not required until the end of the day when they are cross-docked. They are not distributed to the retail outlets until the next day. A confrontation of both parties with this issue revealed that the time restriction was based on last year's distribution schedule. The changes were mistakenly not passed through to the accounts department and the supplier.

5.6.4 SCM redesign principles and SC scenarios

Just as in the preceding case studies, we have classified all sources of SC uncertainty and the relevant aspects of the current SC scenario by element of the logistical SC concept and inherent sources. These sources were linked to the list of SCM redesign principles in discussions with key persons, resulting in a list of relevant SC redesign strategies. These are listed in Appendix F. Successively, we have ordered all identified SC redesign strategies according to the element of the logistical concept and whether it concerns a local improvement or a SC improvement (Table 5.14).

Table 5.14 SC redesign strategies for the retailer ®, cheese producer ❑ or both •.

Element	*Local improvement strategy*	*Supply Chain improvement strategy*
Managed System	® Reallocate the stores; larger stores at the edge of the city. ❑ Buy flexible packaging equipment. ❑ Invest in new production lines. • Provide enough air-conditioned storage capacity.	® Reduce the number of suppliers; higher chance all suppliers will then be on time at RDC. • Reduce need for filling shelves; introduce containers to be used also in stores. • Eliminate shipment papers and thus checking activities; producer registers shipments and credits accordingly (trust!).
Managing System	® Product promotions just on weekdays. ® Reduce number of promotions in SC. ❑ Reduce set-up times of packaging lines. ❑ Decrease length of production runs; decrease batch sizes. ❑ Increase production frequency. ❑ Co-ordinate promotions with the production department. • Determine optimal stock levels in SC.	❑ Decrease supplier lead times and increase supplier delivery frequency. ❑ Change content of shipment papers in accordance with retailer's wishes. • Change cross docking principle: order picking on outlet level at the retailer RDC. • Use Integral Quality Control in the SC. • Decrease the order lead time. • Increase order and delivery frequency. • Create parallel processes. • Co-ordinate timing of windows of activities in SC and explain necessity. • Eliminate forward buying: SC co-ordination.
Information system	® Automate ordering procedure in retail outlets and use demand forecasting module. ❑ Introduce automated support for order picking to pick FIFO. ❑ Implement an integral system providing information on WIP. • Implement real-time systems for inventory management, adapting to sales and supplies. • Implement a batch registration system (i.e. knowing product – shelf life – quantity).	• Implement EDI for order exchange. • Reduce waiting and processing times by automating order entry and aligning SC systems. • Make clear communication lines in the SC or notify retail outlet of shortages beforehand. • Unify bar-coding in the SC. • Co-ordinate product arrays in systems.
Organisation structure	• Educate personnel: make SC objectives known to all personnel. • Align tasks of personnel to SC objectives.	• Jointly define SC objectives: a.o. eliminate forward buying. • Reward behaviour/actions of personnel aimed at achieving these SC objectives.

From Table 5.14 and Table 4.12 we can identify the SC redesign variables for this SC that are estimated to have a major impact on the key SC performance indicators identified at the beginning of this case study. Table 5.15 lists these main variables. Since stock outs and product freshness are the major indicators, it is clear that the amount of inventory and the timing of activities in the SC are crucial. SC scenarios can be defined by adjusting one or more of these SC redesign variables.

Table 5.15 Main SC redesign variables for the retailer ®, cheese producer ❑ or both •.

Configuration level	*Operational management and control*
❑ Flexible production capacities • Role of the retailer RDC (order picking) • Systems in the SC: automated order procedure in retail outlets, EDI and real-time inventory management systems	❑ Production frequency/batch sizes ❑ Supplier lead times / delivery frequency • Order procedures (e.g. safety stock levels) • Outlet order lead time / order and delivery frequency

5.6.5 Concluding remarks

As in the previous cases, the preliminary theory on SC analysis and redesign proved to be useful in this case study in identifying the relevant SC redesign variables to construct SC scenarios. We will conclude this case study too with some remarks made by the SC participants concerning SC co-operation:

- 'You can invent the most sophisticated ordering procedure but if it takes me more time than a few seconds to order I won't use it because I just don't have the time; I have to order over 500 products each order moment.' (Dairy manager, Retail Outlet)
- 'It is interesting to do this SC analysis for this particular cheese producer but realise that we are located within a SC network. Hence all alterations concerning the configuration and operational management structure will impact the other SCs as well.' (Logistics manager, Retail RDC)
- 'The trend in retail is to decrease the number of suppliers. If this project intensifies our relationship with the retailer we might be able to function as logistics service provider for other suppliers.' (Managing director, Producer)

5.7 Linking sources of SC uncertainty to SCM redesign principles

The three case studies each resulted in a list of sources of SC uncertainty. In each case study these sources were then categorised to any of the five clusters (inherent, managed, managing, information, organisation) and, successively, linked to relevant SCM redesign principles to identify SC redesign strategies. The purpose of this section is to identify a generic list of sources of SC uncertainty that were identified in all three case studies. Consecutively, each source of SC uncertainty on this list is linked to effective SCM redesign principles, generating a valuable tool that can be used in SC redesign projects.

5.7.1 A generic list of sources of SC uncertainty

When the identified sources in all three case studies are gathered and compared, a generic list of 19 sources of SC uncertainty becomes apparent. We have listed these sources in Table 5.16. We will now discuss each of the sources and give some examples from the case studies (see also Appendix G).

Inherent characteristics

In the case studies, SC performance was hampered by inherent characteristics related to the product, demand, process and supply. The perishability of products led to a need for air-conditioned transportation and restricted storage time. Weather changes could increase the demand for products; for example, chilled salads are mainly sold when it is typical barbecuing weather. Inherent changes in consumer preferences result in a request for larger assortments, which impacts the need for shelf space in retail outlets. The producer of chilled salads and the producer of cheese had to deal with fluctuations in process outcomes and production times mainly due to variable process yield and scrap-rates. Finally, the supply of goods is sometimes hampered by bad weather conditions or traffic congestion.

Managed system

Sources of SC uncertainty in the managed system in the case studies refer to the SC infrastructure, parallel interaction, and the available SC facilities. *Parallel interaction* concerns the interaction of SCs with each other (Wilding, 1998). For example, a truck filled with products from one supplier that has to wait at a distribution centre for the supply of products from another supplier.

Table 5.16 Typology of generic sources of SC uncertainty

Generic sources of SC uncertainty	***Explanation***
Inherent characteristics	
1. Product characteristics	• Degree of perishability of the product.
2. Demand characteristics	• Fluctuations in consumer demand due to e.g. seasonal patterns and changing consumer preferences.
3. Process characteristics	• Fluctuations in process outcomes due to e.g. variable process yield, perishable end products, machine breakdowns, and scrap.
4. Supply characteristics	• Fluctuations in supply performance due to e.g. natural variations in quality, seasonal patterns and variable yield.
Managed system	
5. SC infrastructure	• Location of suppliers and customers.
6. Parallel interaction	• Interaction of goods and information flows in the SC with the flows of other SCs going through the same firm.
7. SC facilities	• Capacities available to perform tasks.
Managing system	
8. Information lead time and decision process time	• Time needed for the information sent to be received and fluctuations in information lead time, respectively, the time needed to come to a decision (e.g. order generation time).
9. Supply, manufacturing and distribution lead time	• Time that elapses from giving an order to the actual delivery of the ordered products at the customer.
10. Order sales period	• Time period for which a decision needs to be taken (e.g. when the goods are delivered they have to suffice for 1 week of sales until the next delivery).
11. Administrative and Decision Procedure	• Effectiveness of the procedure (e.g. it creates additional uncertainty by ignoring or aggregating available information).
12. Decision complexity	• Number of decision elements: # of products, # of suppliers, # of persons involved in decision, amount of information to be processed, heterogeneity of materials and information flows, etc.
Information system	
13. Data timeliness	• Is the available input data up-to-date (e.g. are stock levels real-time)?
14. Data and definition accuracy	• Specification of available input data (e.g. differences in definitions of performance indicators), information reliability and accuracy.
15. Data applicability	• Information transformation problems leading to unusable data (e.g. the data is accurate and reliable but not applicable because of the aggregation level or not translatable).
16. Information availability	• Lack of information to make a decision.
Organisation structure	
17. Regulations	• Regulations restricting operational management.
18. Authority / responsibility	• Organisational procedures not followed.
19. Human behaviour	• Can result in other outcomes because of e.g. cognitive or political influences or simplified communication structures.

Managing system

In the managing system, two main elements can be distinguished concerning causes for SC uncertainty. The first is the order forecast horizon; the second is the co-ordination of administrative and decision processes.

Order forecast horizon
The total order forecast horizon refers to the time period between placing an order (order 1) and the receipt of goods of the next order (order 2; see Figure 5.18). The available inventory should cover demand over the review period plus the lead time. When generating order 1, all supply, production and waste, and demand estimates within this total time frame need to be taken into account. Hence, the longer this period, the higher the SC uncertainty. We distinguish two relevant elements within the total order forecast horizon: order lead time and order sales period.

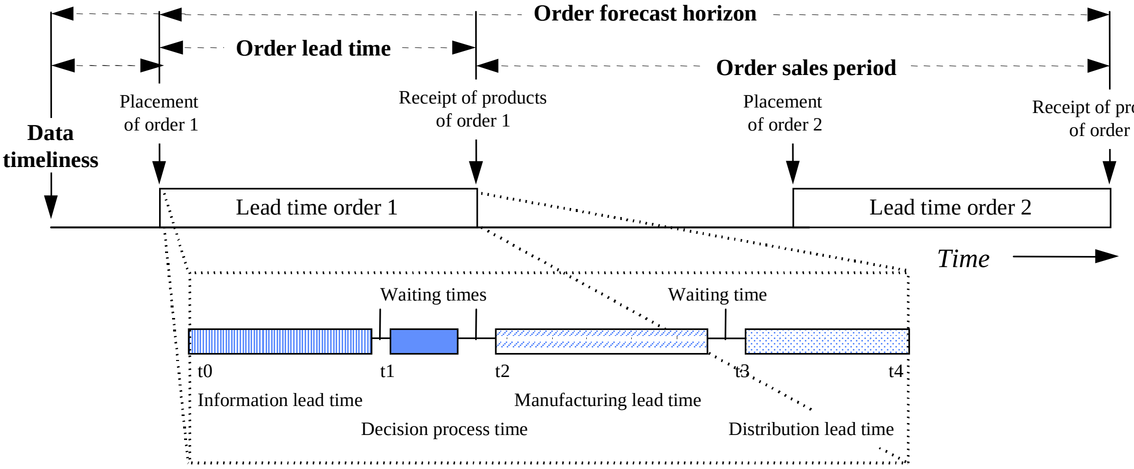

Figure 5.18 Time windows in the order cycle.

The *order lead time* is the time that elapses from the moment an order is placed to the point when ordered goods are received. In this time period, we consider five elements:

- information lead time, i.e. the time needed for the order to be received and processed by the supplier;
- administration or decision process time, i.e. the time needed to generate a production plan (in the case of production to order), picking lists and distribution schedules;
- time needed to produce the products (if applicable);
- distribution lead time, i.e. the time needed to pick, load and transport the products (which is very important);
- waiting times between processes.

Of course, each one of these aspects could be divided into sub-elements, but that would go beyond the scope of this research. The *order sales period* represents the time period between two successive deliveries. The order, of which the goods are delivered after the order lead time, should be large enough to suffice for sales during this order sales period. Low delivery frequencies and long order lead times may increase uncertainty leading to high safety stock levels and many non-value-added activities. Reducing the order forecast horizon has a high potential for improving SC performance.

Co-ordination of administrative and decision processes

The decision policies used in the SC often lead to bad performances. In the SC for fresh fruits and vegetables, the purchasing department of EXPO aggregated customer orders to be able to buy large batches. In the SC for cheese and desserts the delivery policy of the retailer required delivery to the cross dock RDC before 10:00 in the morning, which did not make any sense. Ignoring or aggregating information in administrative or decision policies may create SC uncertainty. Furthermore, customers demand many different products in one delivery, but each product may have different lead times. Hence, decision complexity is a major source of SC uncertainty.

Box 5.8 Example from practice.

An outlet manager gave an example of the impact of long lead times on SC performance. The order size is based on the number of products one expects to sell in the coming order forecast period. Hence, shelves are almost empty when the delivery takes place. When shortages occur in the supply of goods to the retail outlet, consumers will find empty shelves in a matter of hours. As a reaction they will purchase the substitute product (a comparable product of for example another brand or with a different taste). This results in an unexpected stock out for the substitute product too. And because of the long order forecast period, replenishments will take some time.

Information system

A lot of the SC uncertainty found in all SCs was related to a lack of correct, accurate and up-to-date information. Data timeliness and data applicability are prerequisites when exchanging information (Beulens, 1992). If information is not up-to-date and well managed in order to provide current information on stock levels and stock availability, the total time frame of consideration, i.e. the order forecast horizon, becomes even larger (see Figure 5.18). SC uncertainty because of a lack of accuracy in recording inventory levels is also mentioned by Inger et al. (1995); 'the computer says there should be 100; however, there are no more than 60; but your planing is based on the 100 items being available'.

In all three SCs the inventory levels were not known at all times, nor were product qualities. Order specifications were understood incorrectly by telephone or order forms were unreadable. Furthermore, there was a lack of information on demand, work-in-process and to-be-supplied goods. And if data was presented concerning consumer demand, it was often difficult to translate this data into the right format (see also Beulens, 1992). For example, when a producer receives all sales data of a certain product group, he would like to know how much of each particular product has been sold, so that he can plan his production accordingly. Similarly, a potato supplier of a salad producer has no use for consumer demand data of salads in retailer outlets if he can not translate them into quantities of potatoes; especially if he is not the only potato supplier to that particular producer. The final element found concerns data definitions; e.g. product quality is defined differently by the SC participants.

Organisation structure

As presented in the case studies, the company culture and division of responsibilities and authority has a huge impact on SC performances. Specific human behaviour in decision making processes can result in different outcomes because of cognitive or political influences. For example, in the SC for fruits and vegetables EXPO suspected that foreign customers sometimes ordered too many products and when these could not be sold they were returned claiming quality faults. Of course, this is also due to the lack of a product batch registration system, which would make it possible to refute the claims.

5.7.2 Relationship between sources of SC uncertainties and SCM redesign principles

Now that we have drawn up a list of sources of SC uncertainty, we can link them to the effective SCM redesign principles identified in Chapter 4 (Table 4.12) that eliminate or reduce the corresponding uncertainty and improve operational performance. Table 5.17 is the result of this exercise. It presents the opportunity to list effective SCM redesign principles when sources of SC uncertainty are identified in SCs.

5.8 Evaluation of the case studies

At the beginning of this chapter we identified the three aims of this exploratory case study research. The first aim concerned the verification of our proposition in Chapter 1 that SC uncertainties hinder SC performance. In all three case studies, SC uncertainties were identified that restricted the SC system from functioning optimally. Hence, our proposition is supported by the case studies.

The second aim concerned the testing of the applicability of our conceptual framework for SC analysis. This framework showed its applicability in all three case studies. By describing the SC objectives and the logistical SC concept in detail, an accurate description could be presented of the SC system. This facilitated discussions with key employees in the SC and helped identify SC uncertainties and, more important, sources of SC uncertainty. In this process, the ODL and EPC mapping techniques proved to be very helpful in making the SC business processes visible and understandable for all participants.

Our third aim was to test and further develop our preliminary step-by-step approach to generate effective SC scenarios. In all three cases, the identification of SC uncertainties and especially their sources led to the recognition of effective SC redesign variables. In this process the list of SCM redesign principles helped in identifying a complete overview of possible SC redesign strategies. By qualitatively assessing the impact of these strategies on the main SC performance indicators, potentially effective SC redesign variables were identified. In all three case studies, an extended list of sources of SC uncertainty was identified. This allowed us to create a generic list of sources of SC uncertainty that may be present in a food SC. By linking this generic list to the generic list of SCM redesign principles developed in Chapter 4, we have generated a valuable tool that can be used in SC redesign projects. It shows the estimated improvement areas in the SC when certain types of SC uncertainty are encountered.

SC redesign starts with the generation of SC scenarios, but the effectiveness of such a redesign cannot be estimated quantitatively until the impact of these scenarios on SC performance AND on the activities of personnel are assessed. This will be further discussed in the next chapter.

Table 5.17 Generic sources of SC uncertainty linked to SCM redesign principles (see Table 4.12)

Generic sources	***SCM redesign principles***
Inherent characteristics	
Product, demand, process and supply characteristics	1c) Re-allocate the roles actors perform in the SC and related processes. 1d) Eliminate non-value-adding activities in the SC. 2g) Improve the reliability of supply and production quantity and quality. 4a) Co-ordinate and redesign policies. 5b) Exchange demand, supply, inventory or work-in-process information.
Managed system	
SC infrastructure	1a) Change or reduce the parties involved in the SC. 1b) Change the location of facilities.
Parallel interaction	1a) Change or reduce the parties involved in the SC. 3a) Increase the number of events per time unit (frequency) for all SC processes. 5a) Establish an information exchange infrastructure in the SC and exchange demand, supply, inventory or work-in-process information. 6a) Jointly define logistical SC objectives.
SC facilities	1c) Re-allocate the roles actors perform in the SC and related processes.
Managing system	
Information lead time and decision process time	2c) Implement ICT systems for information exchange and decision support. 2d) Reduce waiting times.
Supply, manufacturing and distribution lead time	1a) Change or reduce the parties involved in the SC. 1b) Change the location of facilities. 1c) Re-allocate the roles actors perform in the SC and related processes. 1d) Eliminate non-value adding activities in the SC. 2a) Change position of chain decoupling point. 2d) Reduce waiting times. 2e) Create parallel administrative and logistical processes. 2f) Increase manufacturing flexibility. 4a) Co-ordinate and redesign policies.
Order sales period	3a) Increase the number of events per time unit (frequency) for all SC processes. 3b) Decrease the lot sizes applied in the SC.
Administrative and Decision Procedure	2c) Implement ICT systems for decision support. 4a) Co-ordinate and redesign policies.
Decision complexity	1a) Change or reduce the parties involved in the SC. 1c) Re-allocate the roles actors perform in the SC and related processes. 1d) Eliminate non-value-adding activities in the SC. 4c) Differentiate to products, systems and processes. 4d) Simplify structures, systems, processes and products.
Information system	
Data timeliness	2c/5b) Implement real-time ICT systems for information exchange. 2d) Reduce waiting times.
Data & definition accuracy and applicability	2c) Implement ICT systems for information exchange and decision support. 5c) Develop a common database and standardise bar-coding. 6a) Jointly define logistical SC objectives and SC performance indicators. 6b) Agree on how to measure logistical performances in the SC.
Information availability	5a) Establish an information exchange infrastructure in the SC and exchange demand, supply, inventory or work-in-process information.
Organisation structure	
Regulations	1a) Change or reduce the parties involved in the SC. 1b) Change the location of facilities. 1c) Re-allocate the roles actors perform in the SC and related processes.
Authority / responsibility	6c) Align employees’ incentives with SC objectives.
Human behaviour	4b) Eliminate or reduce human interventions. 6c) Align employees’ incentives with SC objectives.

Chapter 6

A Framework for Modelling and Simulation of Supply Chain Scenarios

'Models are tools for thinking'
(Michael Pidd)

6.1 Introduction

The overall aim of our research is to develop a step-by-step approach to generate, model and evaluate SC scenarios. Therefore, to complete our approach, the contribution of this chapter is:

- to develop ① an approach to model SC scenarios and ② a method to evaluate SC scenarios quantitatively and qualitatively to determine a best practice SC scenario.

We will mainly focus on the development of a framework that allows for realistic modelling of SC scenarios that are applicable in existing (food) SCs. Section 6.2 gives a general discussion of the evaluation of SC scenarios. Section 6.3 examines the trade-offs between different kinds of mathematical models to be used. Section 6.4 discusses the pitfalls of a simulation study and Section 6.5 discusses the stages of modelling and characteristics of discrete event simulation models. A framework for modelling SC scenarios is developed in Section 6.6. Sections 6.7 and 6.8 discuss two types of simulation languages and their backgrounds. We conclude this chapter with a section about model validation and some concluding remarks.

6.2 Evaluating Supply Chain Scenarios

Law and Kelton (1991) distinguish different ways in which a system might be studied (Figure 6.1). It is rarely feasible to experiment with the actual system, because such an experiment would often be too costly or too disruptive to the system, or because the required system might not even exist. For these reasons, it is usually necessary to build a *model* as a representation of the real system and to study it as a surrogate for the real system. Pidd (1999) defines a model as follows:

Definition 6.1
A model is an external and explicit representation of part of reality as seen by the people who wish to use that model to understand, to change, to manage, and to control that part of reality in some way or another (Pidd, 1999).

Law and Kelton (1991) distinguish between physical and mathematical models. Physical models refer, for example, to cockpit simulators or miniature super tankers in a pool. *Mathematical models* represent a system in terms of logical and quantitative relationships that are manipulated and changed to see how the model reacts, and thus how the actual system *would* react – *if* the mathematical model is valid (Law and Kelton, 1991). A model is a convenient world in which one can attempt to change things without incurring the possible direct consequences of such action in the real world. In this sense, 'models become tools for thinking' (Pidd, 1999).

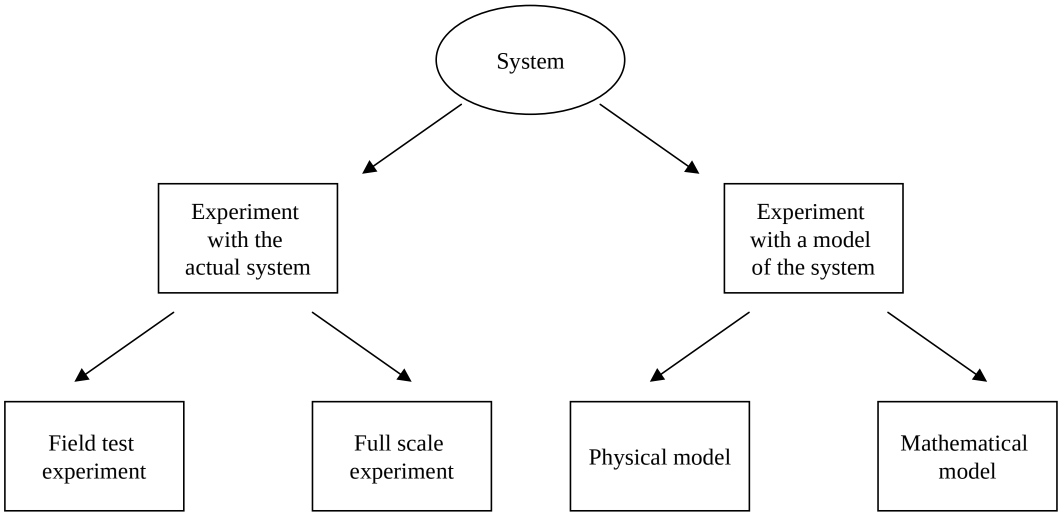

Figure 6.1 Ways to study a system (adapted from: Law and Kelton, 1991).

Experiences in the three exploratory case studies have revealed that the effectiveness of SC scenarios can be estimated quantitatively only after the impact of SC scenarios on SC performance AND on the activities of personnel have been assessed. Van der Zwaan (1990) agrees: 'One of the main drawbacks of modelling with logistical variables is that one is not able to generalise the findings because social variables are usually not taken along. These social variables are crucial in daily practice and can restrict the practical feasibility of outcomes of the simulation study'.

Mathematical models have the advantage of providing the possibility to evaluate numerous SC scenarios on countless SC performance indicators. One of the main disadvantages of mathematical models is that they cannot precisely predict the feasibility of the modelled SC scenario in real-life (in addition to the fact that such a model is only reliable if the right assumptions underlying the model are made). On the other hand, field test experiments can provide us with the necessary data on the feasibility of such SC scenarios, but they will not give us detailed evaluations of all performance indicators, such as SC costs, due to the confined implementation area. Furthermore, because of the risks and costs involved, it is impossible to test all SC scenarios in practice. Therefore, in this research a combination of both methods is applied to identify a best practice SC scenario:

- A *mathematical model* will be built that allows for realistic modelling of SC scenarios applicable in existing (food) SCs to quantitatively assess the impact of the scenario on all SC KPIs.
- A *field test experiment* will be conducted in the SC, comprising one of the most promising SC scenarios to provide us with practical and organisational restrictions that can reveal the feasibility of alternative SC designs.

The remainder of this chapter focuses on how to model the dynamic behaviour of a SC in order to evaluate SC scenarios.

6.3 Mathematical Model: Analytical versus Simulation Model

To study a system of interest, we often have to make a set of assumptions about how it works. These assumptions are used to constitute a model that in turn is used to try to gain some insight into the behaviour of the corresponding system. If the relationships that compose the model are simple enough, it may be possible to use *analytical methods* (such as algebra, probability theory or linear programming) to obtain exact information on questions of interest. In analytical models the relationships between the elements of the system are expressed through mathematical equations. However, most real-world systems are too complex to allow for analytical modelling, and these models are preferably studied by means of *simulation* (Law and Kelton, 1991). This is also the case for modelling complete SCs at the operational level.

Box 6.1 Analytical SC modelling

Cohen and Lee (1988) discuss one of the few analytical models that consider an 'entire' SC. They present an analytical model for linking decisions and performance throughout the material-production-distribution supply chain, based on stochastic and heuristic optimisation. The purpose of the model is to support the search for and evaluation of alternative manufacturing material/services strategies by predicting the performance of a firm with respect to the costs of its products, the level of service provided to its customers, and the responsiveness and flexibility of the production/distribution system. Their methodology specifically considers relationships between production and distribution control policies that affect inventory control, plant product mix and production scheduling. We agree with Van Houtum et al. (1996), who criticise this model because the approach is completely based on simple decompositions in single-state queuing systems, which subsequently are treated as systems not correlated in time, ignoring the complex material relationships that occur if upstream installations fail to serve downstream installations.

Hoover and Perry (1989) identify some advantages of analytical models: conciseness in problem description, closed form solutions, ease of evaluating the impact of changes in inputs on output measures, and in some cases the ability to produce an optimum outcome. On the other hand, they recognise some disadvantages, such as assumptions regarding the system description which may be unrealistic, and complex mathematical formulations which defy solutions. For example, many systems can be modelled as queuing networks, but either the assumptions required for analytic solution are somewhat unrealistic (e.g. exponential inter-arrival and service times), or the mathematical formulation necessary to reflect the desired degree of realism is intractable (Hoover and Perry, 1989). Silver et al. (1998) state that if mathematical models are to be more useful as aids for managerial decision making, they must be more realistic representations of the problem; in particular, they must permit some of the usual ‘givens’ to be treated as decision variables. Moreover, such models must ultimately be in an operational form such that the user can understand the inherent assumptions, the associated required input data can be realistically obtained, and the recommended course of action can be provided within a relatively short period of time.

Simulation models can compensate for the disadvantages of analytical models, but not without sacrificing some of the advantages of the analytical models. Several methodologies have been developed to improve SC performance and introduce integrated logistics management (e.g. Harland et al., 1993; Davis, 1993; Slats et al., 1995; Silver et al., 1998). Law and Kelton (1991) also mention a number of advantages and disadvantages of simulation (Table 6.1).

Table 6.1 Advantages and disadvantages of simulation (adapted from Law and Kelton, 1991).

Advantages	*Disadvantages*
• Most systems with stochastic elements are too complex for analytical evaluation. Thus simulation is the only possibility. • Simulation allows one to estimate the performance of an existing system under some projected set of operating conditions. • Alternative proposed system designs can be compared to see which best meets a specified requirement. • Better control over the experimental conditions than when experimenting with the system itself. • Allows one to study a system with a long time-frame, in compressed time, or even in expanded time.	• Each run of a stochastic model produces only estimates of a model’s true characteristics for a particular set of input parameters. Thus several independent runs of the model are required. An analytical model, if appropriate, can produce the exact true characteristics. • Expensive and time consuming to develop. • The large volume of numbers produced or the persuasive impact of a realistic animation often creates a tendency to place too much confidence in a study’s results. • If a model is not a valid representation of a system under study, the results are of little use.

As discussed in Section 2.6, most analytical models only take a few SC variables into account. For example, they may look at inventory and the cost of running out of stock, but ignore other costs such as order processing, handling and transportation. SCM specifically focuses on the interrelated two-way flow of products (materials and services) and information with the associated managerial and operational activities to obtain a high degree of responsiveness. The complexity of analysing SCs is much too large for analytical models, also due to the dependent demand in the SC. Furthermore, probabilistic demand in SC modelling creates extreme modelling complexities in a multi-echelon inventory situation (Silver et al., 1998). We feel carefully constructed analytical models have several important roles to play in supporting improvements in operations management, and have identified the following:

1. to provide conceptual insights as to the general nature of policies to be followed;
2. to quickly evaluate whether or not to initiate a specific improvement action under consideration;
3. to verify simulation models;
4. to identify upper and/or lower boundaries or the exact settings of variables in specific SC designs.

Proposition

Because of multiple performance- and time-related process aspects that need to be taken into account when modelling complete SCs and the need for credibility of the model in the eyes of the decision-makers, it is better to focus on simulation instead of analytical models. However, analytical models are useful for the reasons given above.

Note that companies are not necessarily searching for *optimal* SC scenarios but for SC scenarios that perform better than the current SC scenario AND that are robust enough to withstand changes in market or internal circumstances. We will come back to this in the next chapter when we try to identify a robust best practice scenario for real-life SCs.

6.4 Modelling and simulation of complex systems

Law and Kelton (1991) present some guidelines for determining the level of model detail. The most important are to understand the managers needs and specify the measures of interests; to concentrate on the most important factors by using 'experts' and sensitivity analysis of the model; and, to ensure that the level of model detail is consistent with the type of data that are available.

Once developed and validated, a model can be used to investigate a wide variety of 'what if' questions about the real system. Potential changes to the system, SC scenarios, can first be simulated in order to predict their impact on system performance. Pidd (1999) gives some general principles of modelling:

- *Model simple; think complicated*. Models should be transparent and should be easy to manipulate and control. Transparency is desirable because successful OR/MS practice depends on trust between consultant and client.
- *Start small and add*. Start with simple assumptions and add complications only as necessary.
- *Avoid Megamodels*. Use object-oriented methodology in which the idea is to divide the model into components that can be replaced if they are too simple, without the need to redevelop the entire model. But be aware of system effects: the whole is more than the sum of its parts, and the part is more than a fraction of the whole. Each component model should be developed with exactly the same set of modelling assumptions to prevent problems caused by the interaction of the components.
- *Do not fall in love with data*. Only after thinking about the model can one determine the type of data to be collected. Also remember that information equals data plus interpretation and be careful when extrapolating results into the future. The future may simply differ from the past, and the population from which the data sample comes may behave differently in the future.
- *Modelling is not a linear process*. Develop models not in one burst, but over an extended period of time marked by heavy client interactions.

Other authors agree on this last modelling principle. Figure 6.2 shows the steps that will compose a typical, sound simulation study and the relationships among them according to Banks et al. (1995) and Law and Kelton (1991). A simulation study is not a simple sequential process. As one proceeds with a study and obtains better understanding of the system of interest, it is often desirable to go back to a previous step. The first validation step concerns the involvement of people who are intimately familiar with the operations of the actual system. In the second validation step, pilot runs can be used to test the sensitivity of the model's output to small changes in an input parameter. If the output changes greatly, a better estimate of the input parameter must be obtained. Furthermore, if a system similar to the one of interest currently exists, output data from pilot runs of the simulation model could be compared with those obtained in reality.

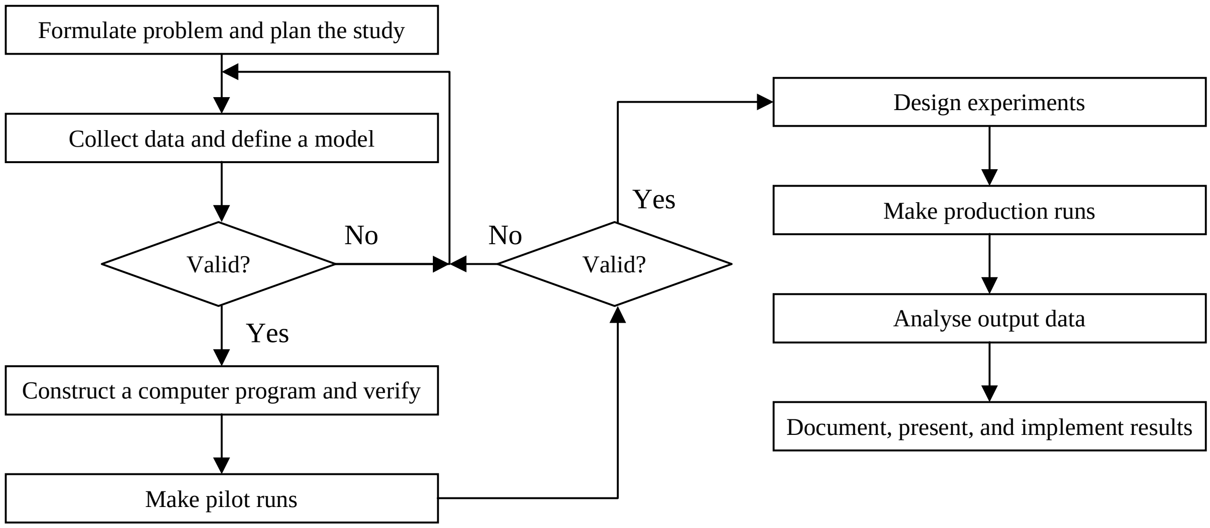

Figure 6.2 Steps in a simulation study.

Law and Kelton (1991), Beulens (1992) and Davis (1993) identify a number of generic pitfalls that can prevent successful completion of a simulation study. The following issues are relevant when modelling SCs:

- A set of well-defined objectives and performance measures should be defined at the beginning of the simulation study that suit all parties in the SC. Furthermore, key persons should be involved in the project on a regular basis.
- Some degree of abstraction is usually necessary. Some parts may be left out of the model completely; others may be aggregated. The summarised characteristics of the aggregated parts must be checked against expert opinion to see if they represent the situation fairly.
- Data must often come from different disparate locations: to ensure the success of the modelling effort, it is necessary to obtain sufficient commitment of resources to ensure accurate, useful data about each of the links in the supply chain.
- Accuracy of data: often the collected data paints a false image of an operation due to data entry errors, inconsistent collection procedures, and system incompatibilities.
- Commercial simulation software may contain errors or complex macro statements that may not be well documented and may not implement the modelling logic desired.

Box 6.2 Make the model understandable!

Schlegel, former president of APICS, propagates the use of SC optimisation to achieve operational excellence. He discusses a plan of approach for SC optimisation from a practitioner's perspective and states that the term 'optimisation' itself is the biggest obstacle for application in practice. 'Images of 'black boxes' and esoteric mathematical concepts tend to frighten people off'.

(source: Schlegel, 1999)

6.5 Modelling approach

6.5.1 Stages of modelling

In order to evaluate the impact of SC scenarios on the SC performance, relevant aspects and mechanisms of the SC should be modelled. Therefore, when building a simulation model of a real system, we must pass through several stages or levels of modelling (Figure 6.3).

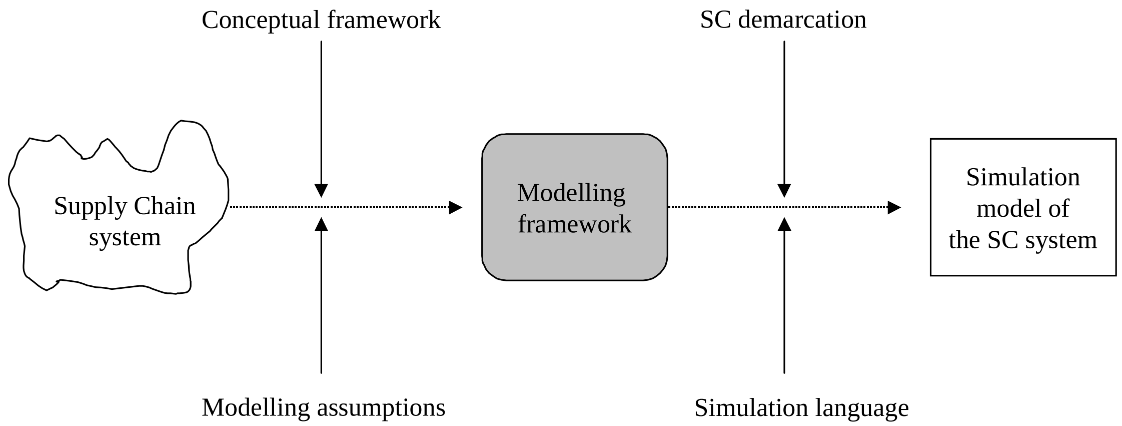

Figure 6.3 Stages of modelling.

(1) Define a modelling framework

Starting with the real system, we first form a *conceptual model* of the system that contains the elements of the real system that we believe should be included in our model (Hoover and Perry, 1989; Checkland and Scholes, 1990). That is, one should identify all facilities, equipment, events, operating rules and descriptions of behaviour, state variables, decision variables, measures of performance, and so on, that will be part of the model. Other authors use other terms. Van Hee and Van der Aalst (1997) refer to *ontology*, defined as a system of clearly defined concepts describing a certain knowledge domain. Wilson (1993) refers to the *world view* or *Weltanschauung*, i.e. that view of the world which enables each observer to attribute meaning to what is observed. Date (2000) refers to *semantic concepts*.

Consecutively, we must identify the relationships between the elements identified. From the conceptualisation of the system a *logical model* (or flow chart model) is formed that contains the classification of and logical relationships among the elements of the system, as well as the exogenous variables that affect the system. In accordance with Van der Zee (1997), we use the term *modelling framework* to combine these first two steps. A modelling framework is defined as a set of basic modelling constructs and their possible relationships required to model the behaviour of the SC completely. To include all relevant elements of the real SC system in our modelling framework, we make use of:

- a set of basic modelling assumptions (see Section 6.6); and
- our conceptual framework for SC analysis presented in Chapter 3.

(2) Devise a set of symbolic objects

The next step is to devise a set of corresponding symbolic (i.e. formal) objects that can be used to represent the foregoing modelling constructs (Date, 2000). This includes identifying the integrity rules that go along with those formal objects (i.e. how to use the objects). In this thesis this step is taken in two stages:

- First, we use ODL and EPC modelling techniques to capture the identified modelling constructs in the SC and validate them in discussions with experts (see Chapter 5). For example, the main symbolic objects in EPC modelling are Process and Event. A Process is represented by a rectangle with a verb and a noun; an Event by a circle with a noun. And one of the EPC integrity rules is that a Wait can only be present before a Process and not before an Event.
- Second, these modelling constructs and their relationships are implemented in a simulation language. The symbolic objects used and its integrity rules are determined by the formalism of the simulation tool. For example, the simulation language ExSpect® is based on the formalism of Timed Coloured Petri Nets, hence the symbolic objects will correspond to the objects used in these Petri Nets (see Section 6.7).

(3) Building the simulation model

Using the modelling framework and the symbolic objects defined we develop a *computer model,* in a specified simulation language, which will execute the logic described. Which aspects of the SC are modelled depends on the *demarcation of the SC*. The decision on how much of the real system should be included in the conceptual model to bring about a valid representation of the real system must be jointly agreed upon by the simulation analyst and the decision-makers.

Developing a simulation model is an iterative process with successive refinements at each stage. The basis for iterating between the different models is the success or failure we have when verifying and validating each of the models (see Section 6.9). The modelling framework will be discussed in Section 6.6. The formalism of the simulation languages used is discussed in Sections 6.7 and 6.8. But first we start the discussion by introducing the basic semantic concepts used in Discrete Event Simulation Models.

6.5.2 Discrete Event Simulation Models

Law and Kelton (1991) and Kelton et al. (1998) classify simulation models along three different dimensions:

1. *Static* versus *dynamic* models
   A static simulation model, sometimes called a Monte Carlo simulation, represents a system at a particular point in time (time is irrelevant). Dynamic models represent systems as they change over time.
2. *Deterministic* versus *stochastic* models
   Deterministic models contain no probabilistic components; the output is determined once the set of input quantities and relationships in the model have been specified. Stochastic models encompass some random input components.
3. *Continuous* versus *discrete* models
   When state variables change instantaneously at separated points in time, the model is discrete; otherwise it is continuous (usually using differential equations).

SCs are characterised by a high degree of dynamism and are influenced by random processes (we refer to the identified sources of uncertainties in Chapter 5). Furthermore, we are only interested in system state when state changes occur because these influence system performances. Hence, in this thesis we focus on dynamic discrete SC models simulating both deterministic and stochastic SC scenarios. The latter is used when inherent sources of SC uncertainty are considered. Note that some authors use continuous simulation to model SC systems (see e.g. Towill et al., 1992; Lewis and Naim, 1995). The main difference is that these authors focus on less complicated SC problems, incorporating for example only one product and less interaction facilities.

Discrete Event Dynamic Systems (DEDS) are characterised by the fact that the system has a discrete array of possible states and there is a sequence of events that moves the system from one state to another (Van Hee, 1994). DEDS can suppose the presence of one or more probabilistic components. Because DEDS characteristics and the main characteristics of a SC system correspond, DEDS promises to be useful in SC modelling.

For DEDS it is assumed that state changes are connected to a certain moment in time and result from the initiation or completion of activities (Van der Zee, 1997). The set of all states that a system may have is called a *state space* (Van Hee, 1994). A system's state can be regarded as a snapshot of the system, showing all relevant details. An *event* signifies the transition from one state to another at a specific point in time. Entities are the dynamic objects in a simulation; they move around, change status, affect and are affected by other entities and the state of the system, and they affect the output performance measures (Kelton et al., 1998). When the system state is depicted in a graph for some variable during a certain time period, we see a *state-time diagram*. It represents the *path* of the variable in the system, i.e. a sequence of events. The *time domain* is a set of so-called time points; the state of the system is only defined at these points. Which paths a certain system can have is determined by a function called the *transition law* (Van Hee, 1994). It represents a list of possible next events. For example, an order can be accepted or not, resulting in different activities and thus system states.

The *event list* keeps track of the events that are supposed to happen in the (simulated) future. When the logic of the simulation calls for it, a record of information for a future event is placed on the event list. This event record contains identification of the entity involved, the event time, and the kind of event it will be. Newly scheduled events are placed on the list so that the next event is always at the top of the list (the events are sorted). When it is time to execute the next event, the top record is removed from the list and the information on this record is used to execute the appropriate logic.

Table 6.2 presents the main semantic concepts of discrete-event simulation models. Note that different simulation languages use different terminology for the same or similar concepts.

Table 6.2 Semantic concepts in discrete-event simulation (adapted from Banks et al., 1996)

Concepts	*Definition*
System	A group of objects in reality that are joined together in some regular interaction or interdependence toward the accomplishment of some purpose.
Model	An abstract representation of a system, usually containing structural, logical, or mathematical relationships which describe a system in terms of state, entities and their attributes, events, activities, and delays.
System state	The collection of variables necessary to describe a system at any time (entities) relative to the objectives of a study.
Entity	Any object or component in the system that requires explicit representation in the model.
Attribute	A property of an entity.
Entity list	A collection of associated entities, ordered in some logical fashion.
Event	An instantaneous occurrence that may change the state of the system.
Event notice	A record of an event scheduled to occur at the current or some future time, along with any associated data necessary to execute the event.
Event list	A list of event notices for future events, ordered by time or occurrence.
Activity	Represents a time period of specified length (e.g. a service time or inter arrival time) which is known when it begins.
Delay	Duration of time of unspecified indefinite length, which is not known until it ends.
Clock	A variable representing simulated time.

Underlying the simulation package, but usually hidden from a modeller's view, events are being scheduled causing one process to temporarily suspend its execution while other processes proceed. It is important that the modeller has a basic understanding of the concepts and the simulation language being used, and a detailed understanding of the built-in but hidden rules of operation. Banks et al. (1998) make a distinction between three world views:

- With the *event scheduling approach* the simulation analyst concentrates on events and their effect on system state. Scheduling a future event means that at the instant an activity begins, its duration is computed and the end time is determined resulting in the start of the next activity on the event list. One by one each event on the event list is executed. The analyst views the model from the viewpoint of the events such as 'arrival truck' and 'begin order processing'.
- With the *process-interaction approach* the simulation analyst concentrates on processes. A process is defined as a time-sequenced list of events, activities and delays (queuing to wait for resources), including demands for resources, that define the life cycle of one entity as it moves through a system. The analyst views the model from the viewpoint of the entities such as 'truck A' and 'data manager'.
- With the *activity scanning approach* the simulation analyst concentrates on the activities of a model and those conditions that allow an activity to begin. At each clock advance, the conditions for each activity are checked and if the conditions are true, then the corresponding activity begins. The analyst views the model from the viewpoint of the activities such as 'load truck' and 'process order'.

The first two approaches use a variable time advance; that is, when all events and system state changes have occurred at one instant of simulated time, the simulation clock is advanced to the time of the next imminent event. The third approach uses a fixed time increment and a rule-based approach to decide whether any activities can begin at each point in simulated time. Because of the slow runtime on computers (due to repeated scanning to determine if an activity can begin) the activity scanning approach is modified into a three-phase approach in which unconditional activities are scheduled ahead of time (just as the event scheduling approach) and conditional activities are scanned for the fulfilment of the conditions. Most discrete-event simulations are actually executed in the event orientation (Kelton et al., 1998), including the two tools we used for SC modelling (see Sections 6.7 and 6.8).

6.6 Modelling framework for supply chain modelling

Figure 6.4 depicts an overview of the modelling framework based on the process approach. It departs from the following *set of basic assumptions* in order to model the relevant aspects of dynamic system behaviour:

- *System hierarchy*: the boundary of the system chosen places the system at a particular level within a series of levels. Thus a system is simultaneously a subsystem of some wider system and itself a wider system to its subsystems (Wilson, 1993). We view the SC as a series of actors that fulfil certain roles. Each actor comprises multiple business processes, and a business process may be defined as a system comprising sub-systems.
- We view the SC as a *network of business processes with precedence relationships*.
- We pay attention to the *functional behaviour* of the (sub)system(s). We are interested in the *interfaces* between business processes, i.e. the inputs and outputs. For example, in the modelling process we are not interested in the physical picking activity, the layout of the warehouse or the person who does the picking. We are interested in the characteristics of order picking such as the total picking time and the possibilities for errors. This assumption results in the fact that we are not focussed on *resource utilisation* itself, but are able to determine the required capacities to obtain the desired system behaviour.
- We are interested in the *performance* of the SC system within certain *time windows*. We view the SC as a dynamic system with changing performance characteristics especially when the time window considered changes (for example, another year).

The simulation model should be able to simulate the SC behaviour under various conditions. Therefore, the model should embrace all kinds of characteristics of the dynamic situation at hand. The modelling framework depicted in Figure 6.4 captures the key abstractions of the SC and relates them to each other logically. In later stages of modelling, when one works towards programmed and experimental models, one needs a formal specification of the system under study in order to enable simulation. These formal specifications used will be explored in Sections 6.7 and 6.8. Note that we do not aim to arrive at *the* simulation model of the SC, but at *a* model that is appropriate for evaluating SC scenarios.

A SC model consists of the instantiations of the modelling components comprised in the modelling framework. By using the conceptual framework for SC analysis and the ODL and EPC process mapping techniques presented in Chapter 5, the relevant business processes and their characteristics can be identified in the SC. This is done for each SC actor including the specifications of the business entities that flow between the processes, the resources (for example, a machine) and information databases (for example, inventory levels) used. After using the step-by-step approach for generating SC scenarios the relevant (re)design variables and performance indicators are identified. The installation of these redesign variables for each business process will facilitate the establishment of new business processes structures, contents and dynamics, that is, new SC scenarios. We will further elaborate on three elements: business processes, business entities and system dynamics.

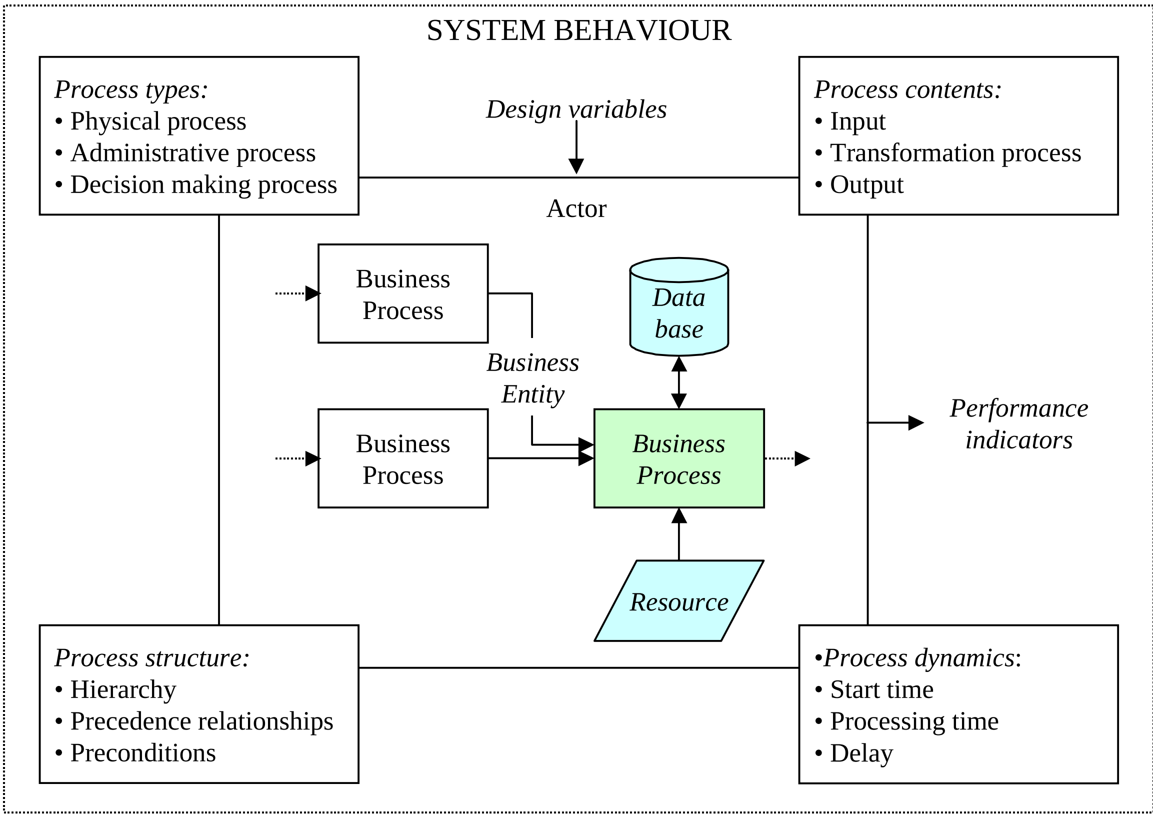

Figure 6.4 A framework for modelling a SC.

6.6.1 Business processes

The SC comprises a set of business processes and their interrelationships. In Section 3.2.2 we defined a process as 'a structured measured set of activities designed to produce a specified output for a particular customer or market'. And an activity is a (set of) time-consuming action(s) carried out by a specific resource with a specifiable result. Since the SC is focused on creating value for its customers, the companies concentrate on those processes that are directly related to customer orders. Each process is an elementary system in the order life cycle. Examples of business processes are 'order generation', 'order picking' and 'distribution'. Next to the process characteristics discussed in Section 3.2.2, there are some additional characteristics of business processes that are relevant when modelling SCs.

Process types

In the SC we distinguish between physical, administrative and decision making processes. Each type of business process is modelled as a transformation process in which inputs (goods, information, policies) are transformed by place, form and/or time. Decision making processes control the goods and information flows using control policies (e.g. generating an order). The exact definition of a business process depends on the level of detail. For example, in some models distribution is split into the loading, transportation and unloading of the truck. Our interest lies in the characteristics of the distribution process (such as total distribution time) and this does not require such a detailed division of activities.

Process contents

Business processes transform inputs into outputs. This transformation process comprises a set of tasks to be executed in a specific order and according to a specific policy. Outputs are the results of a process, which go to internal or external customers (hence they cross organisational boundaries). The recipient of an output is another process either within or outside the company. In the modelling process all types of business processes are modelled in this manner.

When designing the SC scenario to be modelled and simulated we can distinguish between two types of variables: controllable or uncontrollable variables. Controllable variables can be manipulated by the modeller when developing the simulation model. In this thesis these are called redesign variables (e.g. delivery frequency or order policy; see Chapter 3). Uncontrollable variables are called *parameters* (e.g. safety stock levels or truck capacity). The designation of an input variable as either of the two depends to a large degree upon the resources under the control of the decision-maker involved or the desired or chosen control. Thus the model and the subsequent analysis of the same system may be quite different depending on where in the organisation the study is performed (Hoover and Perry, 1989). Note that SCs are modelled from the *perspective* of the SC director (see Figure 3.8), who is able to redesign all SC business processes.

Another aspect that needs to be mentioned is the *aggregation level of the data*. The modelling of SC operations should incorporate suitable aggregations of products, customers, and sometimes suppliers (Shapiro, 1999). It is not always necessary or desirable to describe operations at the individual SKU level for the purpose of strategic or tactical SC analysis. Products selected for a single family should have similar characteristics with respect to SC costs, resource utilisation, transformations, and so on. Therefore, we distinguish between product unit level, batch level (clustering of products), and group level (clustering of batches).

Process structure

Business processes are interrelated since one activity is performed after the other and can only start when the preceding activity is successfully completed. That is, there are *precedence relationships* between business processes. The process sequence describes whether an activity is undertaken after another activity (sequential), at the same time (parallel) or independently (concurrent).

The execution of processes requires the availability of *resources* to perform tasks, either machines or personnel. In our modelling effort there are two ways to deal with resource availability. We can estimate the resources needed to perform all tasks within a certain time frame. When the available resources suffice, we can determine the actual process throughput times and costs. But if the available resources do not suffice within that time frame, we can determine the extra resources and/or additional time needed to complete the process. Consider, for example, order picking that needs to be done within two hours to facilitate a certain SCM scenario and extra personnel is needed to realise this tight schedule.

Finally, processes can have *preconditions*: i.e. processes will only be triggered by an event if certain restrictions are fulfilled. In this way the model approaches reality. For example, order picking does not start when picking orders arrive, unless capacity is available.

6.6.2 Business entities

SCs are networks of organisations that are involved, through upstream and downstream linkages, in different processes and activities that produce value in the form of products and services in the hands of the ultimate consumer. The linkages between processes encompass goods and information flows comprising sets of products or information. A business entity is used to represent an information flow and/or goods flow, or it may represent the availability of certain capacities of resources (machines, labour). It is therefore a complex, well-identified entity with a set of descriptive attributes. Or as Österle (1995) states 'an *entity* is an individual object in the real or conceptual world, which is unambiguously distinguishable from other objects'. In our definition each business entity must have:

- a unique identification key, which is an attribute or combination of attributes that uniquely identifies each entity and does not change as long as the entity exists;
- time stamps indicating the time at which the entity was created and the time it is released for further processing;
- descriptive attributes.

And each business entity can have:

- a number of characteristic entities (a repeating group) that depend on the business entity for their existence;
- attributes that relate the business entity and/or the characteristic entities to attributes of the business entities used in processing the business entity.

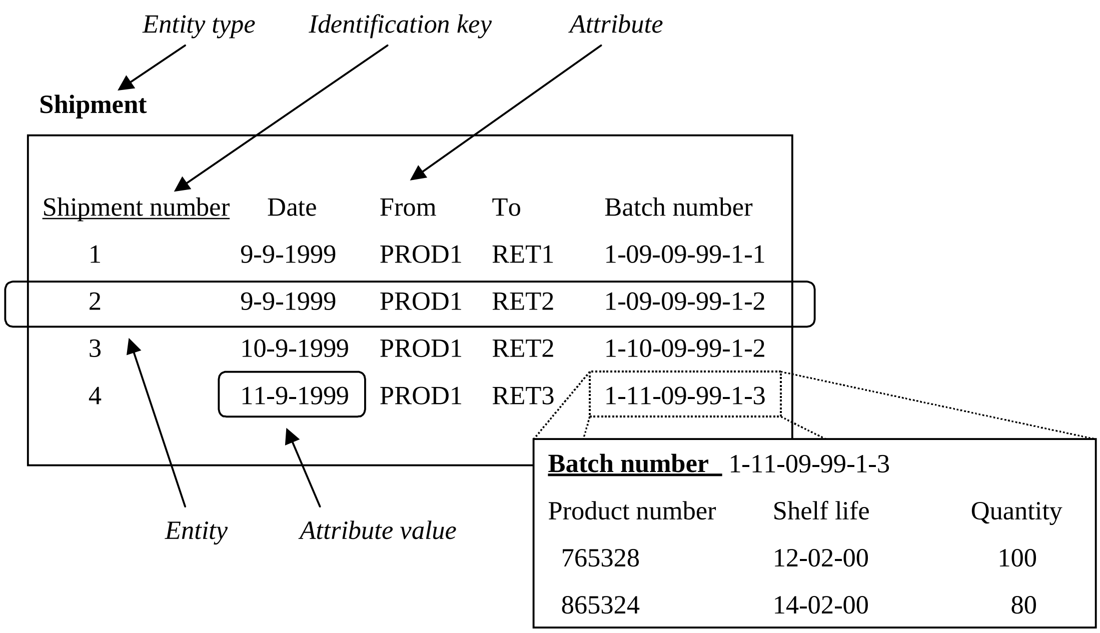

Figure 6.5 Terminological overview of the business entity concept

For example (see Figure 6.5), a Shipping List can be identified by *SL(2, 9-9-1999, PROD1, RET2, 1-09-09-99-1-2).* This refers to shipment number 2, released on 9-9-1999, shipped from producer PROD1 to retail outlet RET2. The list further contains a number of shipment lines; each characteristic entity describes one part of the delivery for a product from a particular batch (attributes of such a line are batch number and quantity delivered). The batch number 1-09-09-99-1-2 refers to a combination of a product number and a remaining shelf life, and is an example of a relationship of that entity to entities used to produce it. This is necessary for tracking and tracing of products and for calculating performance indicators. When modelling a SC we see a continuous process of the creation and flow of transitions of these business entities, which means a conversion of place, time and state/content.

6.6.3 System dynamics

The SC model should be capable of calculating system state at each relevant moment in time in order to calculate system performance. This requires the capability to register the state, time and place of each business entity after each transition. The dynamic character of the model is expressed in a number of equations, which calculate values for local model variables during a transformation process. For example, when orders are processed into order pick lists, inventory levels are checked and compared with total demand. If total demand at that time exceeds total inventory per product, shortages may be divided according to a rationing policy. Figure 6.6 depicts an overview of business entity flows between different business processes. For simplicity reasons a number only represents the unique identification key. For example, retail order *O(2)* is transformed by the business process 'Order Processing' into picking list number 2, *PL(2).* Consecutively, this picking list is transformed by the process 'Picking and Shipping', using inventory list *I(2),* into shipping list *SL(2)*. Note the correspondence with EPC models (Section 5.3.2).

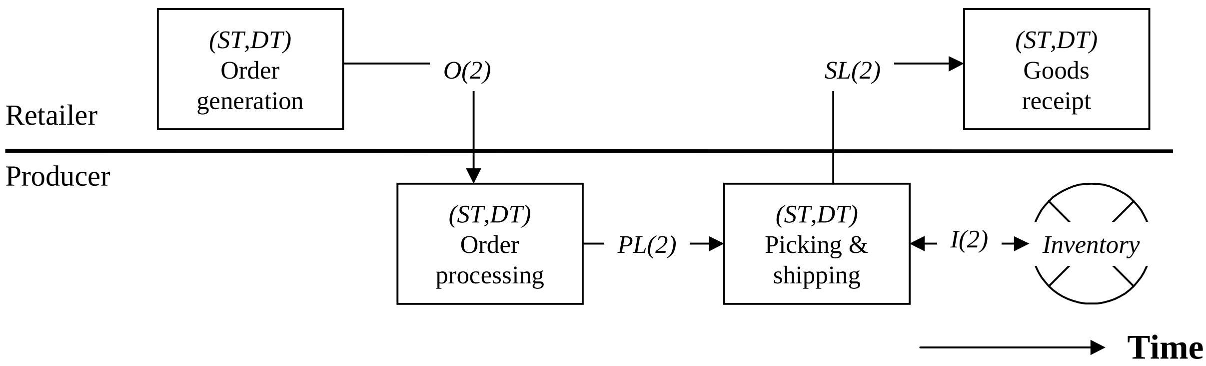

Figure 6.6 Flows of business entities

Each process is related to an actor in the SC in which it is executed using and processing complex business entities, which enter the process and satisfy certain time window constraints. How these processes are organised is mainly determined by the time frames applied. A process can be executed during a certain time window; it has a starting time *ST*, a process throughput time *DT* (that depends on the work to be done and the available capacity) and a time at which it should be finished. Processes are triggered by events in the network such as the arrival of a business entity (the completion of one process may trigger the execution of another process) or system time reaching a pre-set time stamp (e.g. Tuesday

09.15 h). However, not all required business entities may arrive at the same moment in time, resulting in waiting times. This problem is known as the synchronisation problem in logistics (Van der Zee, 1997). The timing of each process is crucial.

We model a SC as a network of administrative and physical logistical activities with precedence relations in time. The business entity that is the output of one transition forms the input for the next transition. In this way the timing of each transition (logistical process) can be arranged, and throughput times of processes and waiting times can be calculated. There is a schedule of pre-set times at which processes (such as ordering, inventory control, receiving goods, and processing write-offs) may start and must be completed (that is the time at which the business entities produced must be dispatched to receiving processes). Further, we may distinguish fixed and variable processing times per business process, depending on the content of the entities to be processed (for example the number of products to be picked) and the way capacity availability is modelled. Finally, processes exhibit *parallelism*, i.e. activities of a process may be processed simultaneously with activities of other processes.

Using uniquely identified time stamps and/or batch numbers as attribute values in business entities, we keep track of the connection between input and processed entities for tracking and tracing and performance measurement. Given the importance of remaining product shelf lives, it should be possible to calculate these values for all products at all times. The value of the attributes influences the processes in which they are transformed. For example, products with the shortest remaining shelf life should be picked and delivered first, unless their remaining shelf life has diminished to zero, in which case they should be discarded. These processes result in complex transitions of business entities, which are further complicated by the existence of combined truck loads. For example, a shipment comprises multiple products and can also encompass multiple customers.

6.6.4 Requirements for SC modelling

Van der Zee (1997) found that in currently available techniques for simulation modelling, relatively little attention is paid to the representation of control. He states:

‘Often, developers concentrate on the description of physical transformation processes. Control structure, that is the parties (managers) responsible for control, their activities and the mutual tuning of these activities, often have no explicit place in the modelling framework underlying the technique. Instead, control logic, attributable to management is often hidden in the specification of the model components constituting the primary process and/or is an indistinguishable part of simulation facilities for time-indexed scheduling of events. Given the important role of control for logistic performance in terms of both customer service and costs, we regard this lack of attention striking.’ (Van der Zee, 1997)

Our modelling effort aims at modelling the physical transformation processes as well as the control structure. We conclude this section with an overview of requirements of a simulation language from a SC modelling perspective. The simulation language should (at least) be able to:

- capture the dynamic behaviour of the SC processes, i.e. modelling the SC as a network of business processes with precedence relationships; these processes can be triggered by multiple causes and have processing times that depend on the entities processed and process capacity;

- model physical transformation, registration and decision making processes; the policies used in the SC especially deserve specific attention;
- incorporate hierarchical systems in the model, i.e. actors with certain roles and processes;
- model business entities as defined in Section 6.6.2;
- determine system state and calculate the values of multiple performance indicators at all times;
- allow for the efficient design and evaluation of SC scenarios.

The modelling framework is an extension of the semantic DEDS concepts described in Table 6.2. Since most simulation tools are direct representations of DEDS concepts, the selection of a simulation tool results in some difficulties. Swain (1995) provides an extensive survey of commercial simulation software packages available for process analysis. Among them, software packages like Extend, +BPR, Ithink, SIMAN and SIMPROCESS-III allow modelling and analysis of business processes. Currently there is no commercial simulation software that provides domain-specific primitives for modelling and analysing SC co-ordination problems (Swaminathan et al., 1998). In addition, most of the software systems are built around simple control mechanisms for processing events such as FIFO queues. However, SC interactions typically involve more sophisticated control mechanisms (Swaminathan et al., 1998).

Swain's paper, together with the availability of academic versions of certain packages, resulted in a choice of two simulation tools to test the applicability of our modelling framework. We used ExSpect® and Arena® to model and simulate the dynamic behaviour of the two SCs discussed in Chapter 5 (that is, the SC for chilled salads and the SC for cheese and desserts). In the following sections we will discuss these two simulation tools. The outcomes of the application of these models will be discussed in the next chapter.

6.7 SC modelling with ExSpect®

ExSpect® (EXecutable SPECification Tool) is a specification language for the formal description of a general category of DEDS (Van Hee et al., 1989; Van Hee, 1994). Its semantics is related to *Timed Coloured Petri Nets* (Van der Aalst, 1992). Specifically, we worked with ExSpect 5.0.

6.7.1 Formalism of Timed Coloured Petri Nets

With Petri Nets, a system can be modelled as a hierarchical network of business processes with interacting and concurrent components. In this way, the system, i.e. the SC, can be divided into linkages with logistical activities, and each activity can be divided into successive process steps. It represents an analytic and graphical approach that is useful for modelling, analysing and simulating DEDS.

Classic Petri Nets (Petri, 1962) represent systems by means of a network structure comprising *places* and *transitions* (or processors) that are connected by means of *arcs*. Arcs are only allowed to connect a place with a transition, or a transition with a place. The first type of place refers to an input place, whilst the last one is regarded as an output place. The state of a Petri Net is related to the presence of *tokens* in places. Typically, tokens represent flowing objects (e.g. data, goods), while arcs, transitions and places model the infrastructure (e.g. a production system). Timed Coloured Petri Nets are extensions of the classic Petri Nets:

- *Colour* makes it possible for tokens to have more values. Hence a token can represent a business entity with its complex structure. The colours used in our modelling approach match the characteristics of a business entity.
- Each activity is related with all other activities by the flow of business entities (tokens) through the model. Timed Petri Nets use a timing mechanism that associates time with tokens (*time stamps*) and specifies *delays* by an interval. Such a time stamp indicates the time a token becomes available for a transition.
- To enable the structuring of large systems, *hierarchy* is introduced. If a transition is too complicated to be grasped as a whole, then the transition can be modelled as a subsystem.

Another state can be reached as a consequence of the *firing* of a transition, which is basically to the consumption of tokens from all its input places and the production of tokens for all of its output places. A transition is only allowed to fire (it is enabled) if there are sufficient tokens available in its input places. Timed Coloured Petri Nets recognise two types of places: the *store* and the *channel*. While the channel represents a place, the store is considered to be a special place which always contains precisely one token. This allows for the modelling of data bases and buffers (e.g. inventory levels). Petri Nets are capable of handling parallelism and synchronisation and they result in simulation structures that are logistically transparent. Figure 6.7 specifies the notation for Timed Coloured Petri Nets. An example is also given illustrating the added value of the extensions colour and time. For an elaboration on Timed Coloured Petri Nets we refer to Van der Aalst (1992) and Van der Zee (1997).

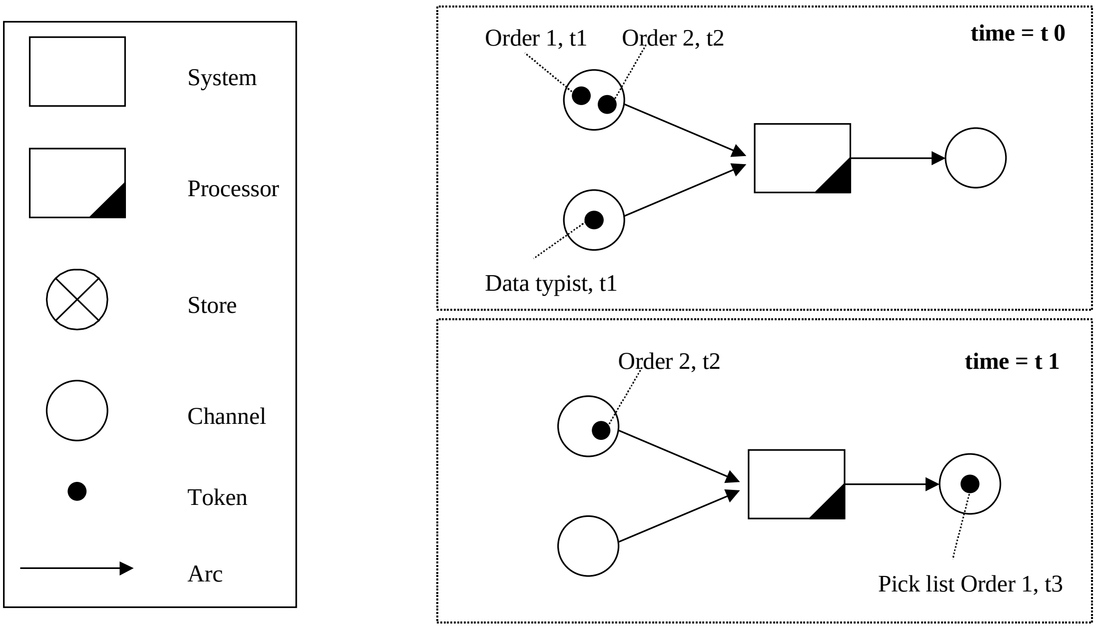

Figure 6.7 Formalism of Timed Coloured Petri Nets

The example shows the transformation of incoming orders into order pick lists. Order 1 has a time stamp at which it is released for further processing at time = t1, whilst order 2 will be released at time = t2. At time = t1 order 1 is processed resulting in the presented situation.

6.7.2 ExSpect

ExSpect is a so-called functional specification language by which the transition laws can be specified in a functional way. The language was developed at Eindhoven University of Technology (Van Hee, 1994), and is supported by a software package also called ExSpect (Bakkenist, 1994). The ExSpect language consists of two parts: a functional part and a dynamic part. The functional part is used to define four constructs (Van der Aalst, 1992):

- The *type* definition specifies the attributes of a token (i.e. the attributes of the businesses entities used). Basic types are numeric, Boolean, string, real, and void.
- The values of tokens are specified by *functions.*
- Transitions are described by *processor* definitions comprising a header and a body. The header shows its interaction structure (inputs and outputs), value and function parameters and preconditions. The body shows how tokens are manipulated with the help of functions and/or delayed by giving them a time stamp.
- The *system* definition defines a subnet and also has a header and a body. The header specifies its input and output pins, and possibly a number of value-, function-, processor- or system parameters. The body lists all objects that make up the system: subsystems, processor and channels.

The dynamic part of ExSpect is used to specify a network of transitions and places, and therefore, the interaction structure of the system. The behaviour of a transition, i.e. the number of tokens produced and their values, is described by the functions. Triggering of processes in ExSpect are based on:

- autonomous triggers: system time reaching a specific time point that corresponds to the time stamp of a specific business entity;
- the ending of a former process whose output functions as an input and triggering value;
- satsifying a certain precondition (e.g. outlet number 2).

The software package ExSpect is a workbench made up of a number of software tools (Van der Aalst, 1992). The *design interface* is used to construct or to modify an ExSpect specification stored in a source file. This source file is checked by the *type checker* for type correctness. If the specification is correct, then the type checker generates an object file; otherwise the errors are reported to the design interface. The *interpreter* uses the object file to execute a simulation experiment described by the corresponding ExSpect specification. This interpreter is connected to one or more *runtime interfaces* that allow the user to interact with the running simulation. For further details the reader is referred to the ExSpect reference manual (Bakkenist, 1994).

Figure 6.8 depicts an example of a logistical model in ExSpect. Note that the notation of the modelling constructs matches the notation in Timed Coloured Petri Nets (see Figure 6.7). The example concerns a producer of food products, where orders are transformed into picklists if enough inventory is available. Successively, the orders are picked and distributed to the customers. In the mean time, the orders initiate a production plan for packing activities, which increases inventories. During the execution of these processes data is registered to calculate performance measures.

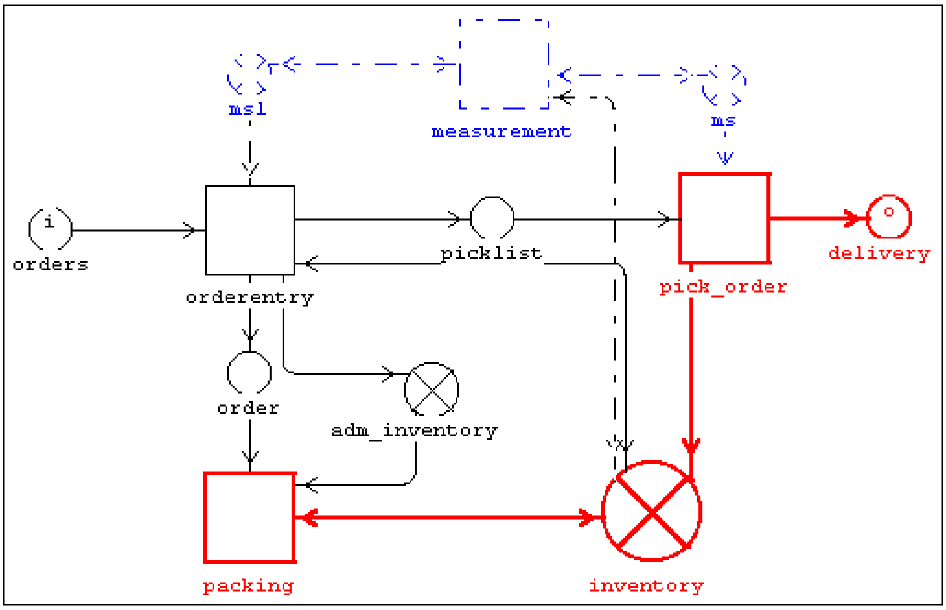

Figure 6.8 Screendump of part of a Timed Coloured Petri Net model in ExSpect.

6.8 SC modelling in Arena®

SIMAN (SIMulation ANalysis) is a simulation language developed by Dennis Pegden in 1982 and distributed by Systems Modeling Corporation (Sewickley, Pennsylvania). It allows for building a process-oriented model, an event-oriented model, or a combination of both (Law and Kelton, 1991). Arena is a graphical user interface based on SIMAN providing animation possibilities. We worked with Arena® 3.0.1.

6.8.1 Formalism of SIMAN

A SIMAN process simulation model is broken into two distinct parts, a model frame and an experimental frame, which are kept in separate files (Law and Kelton, 1991). In this way, a particular model structure may be employed using many different sets of data without re-compiling the model code.

- In the *model frame*, modelling constructs called *blocks* are used to describe the logic by which the model's entities and resources interact dynamically. Each block has a corresponding pictorial representation, and these symbols can be combined into a linear top-down block diagram, which graphically describes the flow of entities through the system. Table 6.3 lists the main SIMAN blocks. A complete overview of SIMAN blocks can be found in Kelton et al. (1998).

- In the *experimental frame*, modelling constructs called *elements* are used to specify the particular parameter values (e.g. mean service time) for the present simulation run(s), to define resource types and quantities, and to delineate the output statistics desired (Law and Kelton, 1991). For example, the element RESOURCES specifies the capacity of resources. A TALLY collects statistics such as the mean, standard deviation, maximum value, and minimum value on a designated output variable. (Hoover and Perry, 1989).

Table 6.3 Overview of the main SIMAN building blocks

SIMAN building block	*Description*
ASSIGN	Assigns values to attribute and variable
BRANCH	Controls flow of entities through code
CREATE	Creates entities
DELAY	Delays processing of entities
DISPOSE	Disposes of an entity
RELEASE	Releases a resource from an entity
ROUTE	Transfers an entity between stations
SEARCH	Searches a queue for an entity
SEIZE	Lets an entity capture a resource
SIGNAL	Signals WAIT to release entities
STATION	Defines a location in the model or the beginning of a submodel (series of blocks) which represent logic to be replicated in more than one place
QUEUE	Queues up entities before a business process
WAIT	Holds entities until signalled

The separation of model and experiment allows one to make two distinct runs of the model, perhaps only differing in some parameter value, without recompiling the model frame. The SIMAN Output Processor allows one to perform certain statistical procedures such as confidence intervals and hypothesis tests on the output data produced by simulation runs from the same or different system configurations. The analyst can also choose the desired output data treatments after the simulation runs have been made.

The world view assumed is that of entities flowing through the blocks, which define system components. The blocks may alter the nature or the flow of entities, or both. Entities may represent a wide variety of animate or inanimate objects: for example, patients in a clinic, customers in a bank, cars in a tollbooth queue, manufactured parts in a production facility, or parts in an inventory system. Each block in SIMAN has an identifying flow chart symbol. When the flow of entities is described using these symbols, converting the flow chart to computer code for the model frame of SIMAN is simply a matter of recording the corresponding statement for each symbol.

A simulation model written in SIMAN can be thought of as a collection of entities, described by attributes, flowing through a piece of simulation code. Entities can be created and disposed of. They can be sent to other pieces of code by conditional branch statements. Code that is restricted to one physical location can be assigned to a STATION. Entities may be routed between stations and stations may contain queue/resource combinations that act on items (Van Eijck, 1996).

6.8.2 Arena

The Arena environment includes menu-driven point-and-click procedures for constructing the SIMAN V model and experiment; animation; the Input Processor that assists in fitting distributions to data; and the Output Processor that can be used to obtain confidence intervals, histograms, and so on. Figure 6.9 depicts a screendump of part of a simulation model in Arena.

Arena provides alternative and interchangeable templates of graphical simulation modelling-and-analysis modules that one can combine to build a fairly wide variety of simulation models. For ease of display and organisation, Arena has grouped the modules into panels to compose a template. By switching templates, one gains access to a whole different set of simulation modelling constructs and capabilities (Kelton et al., 1998). At any time, one can pull in modules from the SIMAN template and gain access to simulation-language flexibility if one needs to. For specialised needs, like complex decision algorithms, one can write pieces of the model in a procedural language like Visual Basic, FORTRAN or C/C++. All of this takes place in the same consistent graphical user interface (Kelton et al., 1998).

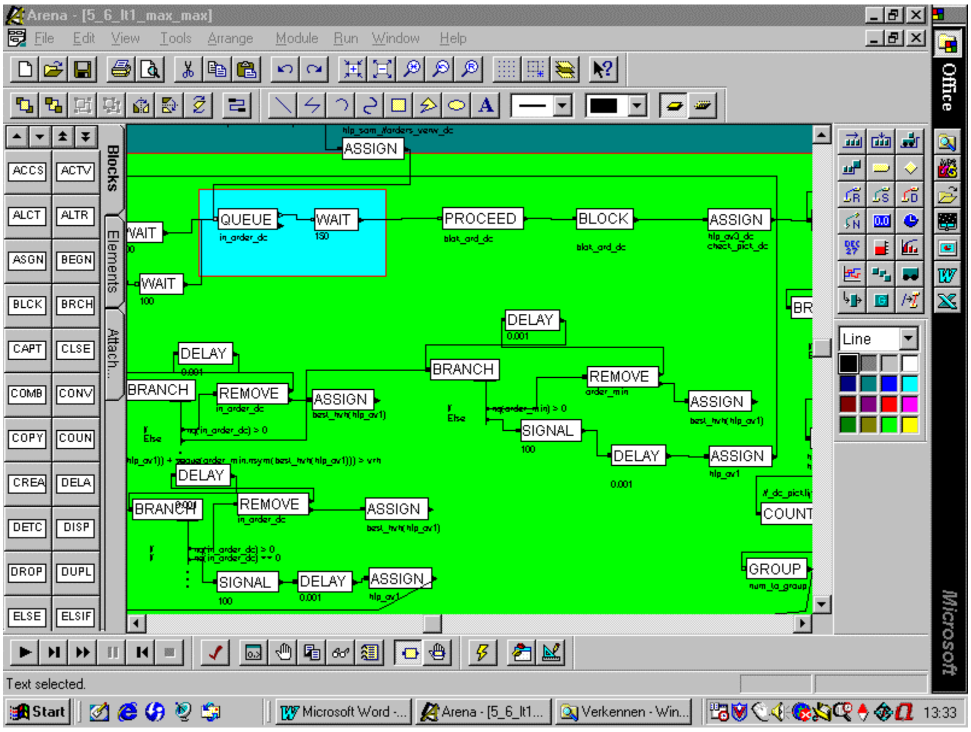

Figure 6.9 Screendump of part of a simulation model in Arena.

Arena's specific characteristics are the following (Kelton et al., 1998; Van Dijk, 1999):

- *Entities* can be grouped into new entities, but all the original entities remain in the model and keep their specific characteristics.
- *Attributes* are characteristics of ALL entities, but with a specific value that can differ from one entity to another. For example, all types of attributes of the entity 'Order' are also assigned to 'Delivery' and vice versa. The data type of an attribute is always numerical.
- Entities often compete with each other for service from *resources* that represent things like personnel, equipment, or space in a storage area of limited size. A process can only start when an entity succeeds in seizing a resource and releases the resources when finished. Resources are explicitly modelled in Arena. The resource availability is determined by a *schedule.* There are three possibilities to deal with breakdowns during resource utilisation (Ignore, Wait or Pre-empt).

- In Arena, *queues* can also be explicitly modelled; they have names and can also have capacities to represent, for instance, limited floor space for a buffer. In the queue, entities are ordered by means of a predefined procedure (e.g. FIFO, LIFO, etc.).
- *Global variables* are (numerical) pieces of information that reflect some characteristic of the total system, regardless of how many or what kinds of entities might be around (for example, inventory level or simulation time).
- As the simulation proceeds, Arena keeps track of *statistical variables* to calculate the output performance measures. A *Dstat* measures the value of attributes continuously (for example, inventory levels). A *tally* measures the value of an attribute as an event occurs (for example, the total amount of no-sales) and a *counter* counts the number of times a certain event occurs (for example, the number of stock outs).

6.9 Model validation

Experimenting with a simulation model is a surrogate for actually experimenting with an existing or proposed system. Hence, one of the most important aspects in simulation studies is the validation of the model. If the model is not valid, then any conclusions derived from the model will be of doubtful value. Law and Kelton (1991) refer to Balci and Sargent (1984), who give a comprehensive bibliography on model validation. Three words play a central role in model validation: verification, validation and credibility (Law and Kelton, 1991):

- *Verification* is determining that a simulation computer program performs as intended, i.e., debugging the computer program. Verification checks the translation of the conceptual simulation model (the process models and assumptions) into a correctly working program.
- *Validation* is concerned with determining whether the conceptual simulation model (i.e. the modelling framework) is an accurate representation of the system under study.
- When a simulation model and its results are accepted by the problem owners as being valid, and are used as an aid in making decisions, the model is *credible*.

Law and Kelton (1991) present two basic thoughts in model validation that we adhered to. First, it is extremely important for the modeller to *interact with the problem owner(s) on a regular basis throughout the course of the simulation study*. The model is more credible when the manager understands and accepts the model's assumptions. Another important idea for validity/credibility enhancement is for the modellers *to perform a structured walk-through of the conceptual model (prior to the beginning of coding) before an audience of all key people*. This meeting helps ensure that the model's assumptions are correct, complete and consistent (i.e. that 'local' information obtained from difference people is not contradictory). They specified these thoughts in a three-step approach for developing valid and credible simulation models based on Naylor and Finger (1967):

1. Develop a model with high face validity, i.e. a model that, on the surface, seems reasonable to people who are knowledgeable about the system under study. Use conversations with system 'experts' in multiple layers of the organisation, observations of the system and collections of empirical data, existing theory, relevant results from similar simulation models and your own experience/intuition.
2. Test the assumptions of the model by sensitivity analysis.
3. Determine how representative the simulation output data are.

If the decisions to be made with a simulation model are of particularly great importance, *field tests* can be used to obtain system output data from a version of the proposed system (or a subsystem) for validation purposes. According to Law and Kelton (1991) the most definitive test of a simulation model's validity is establishing that its output data closely resemble the output data that would be expected from the actual (proposed) system. If the two sets of data compare 'favourably', then the model is considered 'valid'. But how one defines correspondence and determines if it is sufficient is not universally agreed upon (Law and Kelton, 1991). Figure 6.10 presents an approach to model validation. After the model is developed we observe the system for a period of time, collecting data for all exogenous variables and performance measures. The exogenous variables are then used as model inputs, which yield performance measures from the model. A decision on model validity is based on the degree to which the performance measures produced by the model and those observed in the system are similar.

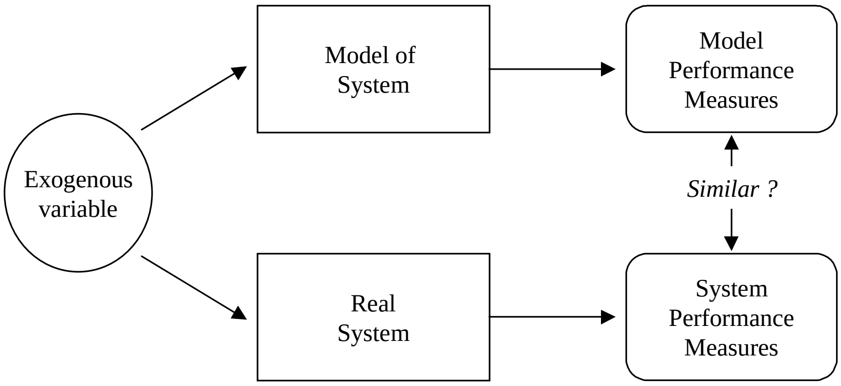

Figure 6.10 An approach to model validation (Hoover and Perry, 1989)

It is generally impossible to perform a statistical validation between model output data and the corresponding system output data (if it exists), due to the nature of these data. The output processes of almost all real-world systems and simulations are non-stationary (the distributions of the successive observations change over time) and autocorrelated (the observations in the process are correlated with each other). Law and Kelton (1991) believe that it is most useful to ask whether or not the differences between the system and the model are considerable enough to affect any conclusions derived from the model. They also recommend that the system and model be compared by driving the model with historical system input data (e.g. actual observed consumer demand data and service times) without the use of a formal statistical procedure. Thus the system and the model experience exactly the same observations from the input (random) variables.

6.10 Concluding remarks

Because of multiple performance-and time-related process aspects that need to be taken into account when modelling SCs and the need for credibility of the model in the eyes of the decision-makers, we focus on simulation instead of analytical models. Furthermore, in this research the combination of simulation and a field test experiment are used to identify a best practice SC scenario. The simulation model is used to assess the impact of a SC scenario quantitatively on all key SC performance indicators; the field test experiment provides practical and organisational restrictions revealing the feasibility of alternative SC designs.

This chapter presented a modelling framework for modelling the dynamic behaviour of food SCs. We feel the modelling framework captures all relevant concepts of the SC system needed to adequately model and simulate SC scenarios. Two simulation tools are introduced that are used in two case studies for evaluating SC scenarios. Chapter 7 presents the main findings.

Chapter 7

Case Studies: Modelling and Evaluating Supply Chain Scenarios

'If we are to achieve results never before accomplished,
we must expect to employ methods never before attempted'
(Francis Bacon)

7.1 Introduction

This chapter discusses the findings of two case studies[1], that were conducted for the following main reasons in no specific order:

- to support organisations operating within food SCs in deciding whether to implement a new SC scenario by quantifying the impact of new SC scenarios on pre-defined SC KPIs;
- to show that simulation studies and field tests are complementary in identifying a best practice SC scenario;
- to test the applicability of our modelling approach proposed in Chapter 6 to model the dynamic and complex character of food SCs.

In Chapter 1 we identified two types of food SCs; SCs for fresh food products and SCs for processed food products. The second type of food SC is more complex because of the processing activities that are incorporated; fresh food SCs mainly consist of merchandising activities. This made us decide to mainly focus on SCs for processed food products.

The explorative case studies presented in Chapter 5 resulted in a list of main SC redesign variables for, respectively, a SC for chilled salads (case II) and a SC for cheese and desserts (case III). By changing the settings of one or more of these redesign variables, SC scenarios can be generated for each SC. This chapter discusses the findings in these two SCs concerning the modelling and evaluation of such SC scenarios to identify a best practice SC scenario. Hence, they depart from the findings in Chapter 5.

[1] These case studies were partly funded by the Foundation of Agri-Chain Competence as part of the Dutch Efficient Consumer Response project. We would like to acknowledge ATO-DLO, PriceWaterhouseCoopers and the participating companies for their co-operation in this research project.

For each of these two (revisited) case studies (called case IIA, respectively IIIA) the following three questions will be answered in this chapter:

① Will the implementation of new SC scenarios improve SC performances?
② What are the main organisational and infrastructural restrictions of SC scenarios?
③ What is the best practice SC scenario for the SC with respect to the SC objectives?

Section 7.2 will present the overall case study design comprising the field test design and simulation study design. The results of both case studies are discussed in Sections 7.3 and 7.4. Section 7.5 discusses an analytical approach to assess the impact of SC scenarios on inventories. Section 7.6 focuses on the cross case analysis and discusses our findings in the modelling process in both case studies. Finally, this chapter ends with some conclusions.

7.2 Case study design

7.2.1 Overall case study design

The overall case study design was determined in a co-ordination process between the project teams that were established in the SC for chilled salads and the SC for cheese and desserts. As we have seen in the preceding chapters, the use of our approach to generate SC scenarios resulted in a list of main SC redesign variables for both SCs (see Sections 5.5.4 and 5.6.4). Some of these variables are related to the configuration level and others to the operational control level. Furthermore, some relate to one actor (for example, increasing the production frequency) whilst others relate to several SC stages (for example, decreasing the order throughput time). Remember that a SC scenario is defined as the combination of specific chosen settings for all SC redesign variables involved. When we compare the main SC redesign variables of both SCs, some variables are the same. The project teams agreed upon evaluating these variables in both SCs to allow for a comparison of the consequences. They are:

- The order and delivery frequencies between all stages in the SC
- Role of the RDC (cross-docking or storing)
- The order lead times between all stages in the SC
- The time windows of all related business processes
- The ordering policies used in SC stages
- Lot sizes in the SC
- The installation of Information and Communication Technologies (EDI, real time inventory systems and automated ordering in retail outlets)

In both project teams the settings of the SC redesign variables were discussed. In case III goods are distributed using *cross-docking,* hence connecting the distribution frequency of the producer to the distribution frequency of the RDC. Of course this results in quite different settings than in case II where the stock holding RDC functions as an order decoupling point.

As described in Section 6.2 the use of both a field test and a simulation study will provide a great deal of information which enables us to evaluate SC scenarios and come up with a best practice SC scenario for the investigated SC. Each project team closely followed the development of the simulation model and the settings of the field test in their SC and influenced the parameters that were finally chosen. The relationship between the field test and simulation study is shown in Figure 7.1. The configuration of the field test is partly based on preliminary results of simulated scenarios. Furthermore, during the field test data was gathered that was used as input data in the simulation model. For example, picking times per order line in the new SC scenario. The results of the field test and simulation study were verified in project team meetings and adjustments were made where necessary. Finally, the project was concluded by comparing the results of the field test with the results of the equivalent simulated SC scenario, indicating a degree of validity of the simulation model.

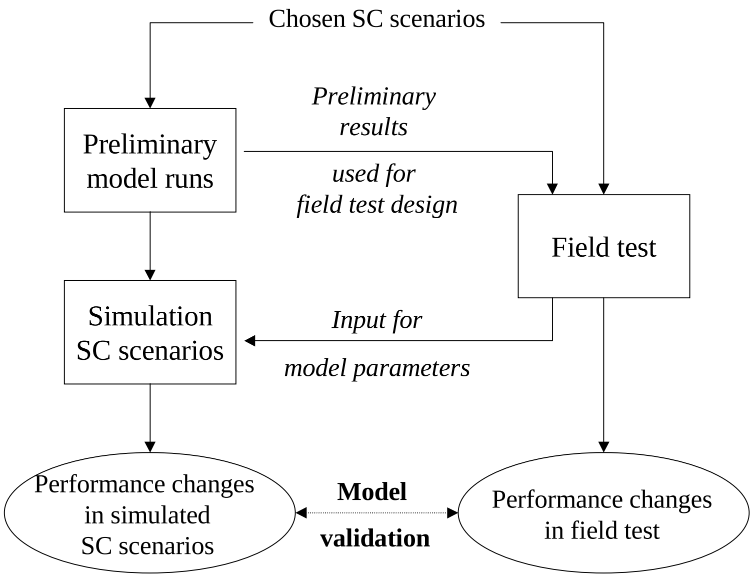

Figure 7.1 Relationship between field test and simulation model

The SC performance indicators required to assess SC performance are the same in both case studies. However, the exact definition of each indicator (e.g. the cost driver chosen), as well as the ranking of a specific indicator, differs in the case studies because of different SC objectives. As we will see later, this may have significant implications for the outcomes of the redesign project. The following performance indicators are considered:

Service

- Average remaining product freshness for consumers
- The product assortment: average inventory level
- Number of stock outs at retail stores
- Number of missed sales caused by stock outs
- Delivery reliability of producer and retail RDC
- Utilisation degrees of secondary unit loads[2] and trucks

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[2] Three packaging unit loads can be distinguished in the SC. First, each outlet *sales unit* refers to an individual consumer product. Second, the producer packs several sales units of one product type together in one *distribution unit* (a box); this refers to the outlet's minimum order batch size for that product. Third, these distribution units are transported on *secondary unit loads* in trucks (i.e. pallets or roll-in containers).

Costs

- Costs related to average stock level at distribution centre and retail outlets
- Costs related to all relevant processes at all stages in the supply chain
- Costs of product write-offs and necessary price reductions

7.2.2 Field test design

When designing a field test the objective is to obtain results that allow us to draw conclusions on two aspects:

1. the impact of the implemented SC scenario on the main SC performance indicators;
2. organisational and/or infrastructural aspects that limit the feasibility of a SC scenario in a particular SC stage.

The crucial question in the field test is not one of determining the *optimal* frequency or lot-size, for example, but rather how one can identify the barriers and change the prerequisites in order to *be able to* increase the frequency if this turns out to be beneficial.

7.2.2.1 Field test assumptions

Retailing is a dynamic process in a dynamic environment, hence there could be changes in SC performance even though the SC scenario has not been changed. For example, the weather, festivities or promotional activities could increase demand and lower stocks. It is essential to eliminate these inherent changes from our results so as to not relate them to the new SC scenario. Therefore, the outlets were divided into *test outlet(s)*, where the new SC scenario was implemented, and *standard outlet(s)*, where the settings of the outlet SC redesign variables were left unchanged. Then the comparison of the results in both outlets enabled us to deduce solely the impact of the new SC scenario.

In order to measure the impact of a SC scenario, data was gathered on the main SC performance indicators. Because a great deal of data had to be gathered (see 7.2.2.2), the retailers were reluctant to use all retail outlets for the field test, to measure the consequences for all products of the producer, or to measure for a long period of time. This was mainly because, in both SCs, real-time inventory management systems were not present (see Chapter 5); thus data had to be collected manually, which takes a lot of time and effort. Furthermore, the data collection requires additional activities whilst daily work continues. Therefore, the following was agreed upon in both project teams:

- to measure daily performance in the current situation for two weeks (from here on called *0-index)* and, consecutively, to implement and measure daily performance in the new SC scenario for six weeks (called *pilot*);
- to choose a small number of test outlets and a standard outlet; and
- to consider only a small number of products in the SC (about ten) that together are thought to be able to represent the whole product assortment of this particular producer in the retail stores. Each product belongs to a product class with specific characteristics resulting in a specific response to system changes.

By comparing the results of 0-index measurements with pilot measurements, the impact of the SC scenario on SC performance indicators can be determined (Figure 7.2).

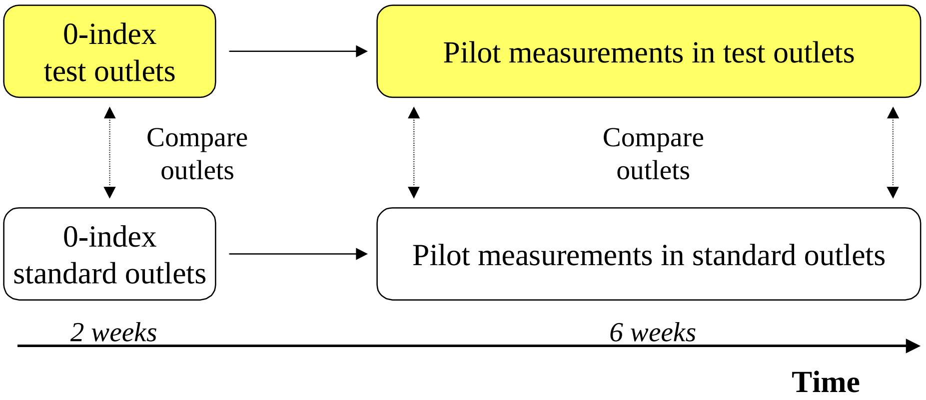


Figure 7.2 Field test design

Because only part of the product assortment and retail outlets are considered, not all performance indicators can be measured, such as truck utilisation degrees and SC costs. As a result, the field test evaluates only the following performance indicators (the other indicators are evaluated in the simulation study):

- average remaining product freshness for consumers
- average inventory levels at the outlets
- number of stock outs in retail outlets and missed sales caused by these stock outs

7.2.2.2 Field test measurements

The frequency of ordering and delivery and the order lead time are important redesign variables in the SC scenarios. To measure the number of stock outs and missed sales caused by stock outs, it is important to know stock levels before and after each delivery. Furthermore, it is important to know when the stock out occurs in order to measure the impact it has. Unfortunately, there was no inventory and point-of-sale (POS) data per hour of the day available to compute this information. Therefore, it was decided to count stock at retail outlets three times a day for the selected products; in the morning (about 9 AM), at noon, and at the end of the day (about 7 PM). Note that retail outlets are open from 8 AM until 8 PM. At each measurement the number of products in stock per Best-Before-Date[3] (BBD) was written down to calculate average product freshness. Furthermore, the number of products delivered and written-off that day were recorded (Figure 7.3).

The same metrics were gathered at the RDC and at the producer. Only here it sufficed to measure stocks once a day, since demand for these products only takes place (at most) once a day. This provided us with enough information to evaluate the relevant SC performance indicators.

[3] A Best-Before-Date refers to the minimum date up to which a product is still fit for consumption. The time between the BBD and the current date is the remaining shelf life.

Friday 18-10 Article number	Delivery	Measurement 1 After delivery (09:00)		Measurement 2 Between 12:00 - 14:00		Measurement 3 Between 19:00-20:00		Write-offs End of day
		BBD	*Number*	*BBD*	*Number*	*BBD*	*Number*	
8830509	50	28/10	5	28/10	5	28/10	3	
		1/11	10	1/11	8	1/11	6	
8831203	20	28/10	6	28/10	2			
		2/11	11	2/11	11	2/11	8	
8831807		18/10	7	18/10	7	18/10	5	5
		28/10	12	28/10	12	28/10	11	
8832307	10	28/10	8	28/10	8	28/10	4	
		1/11	13	1/11	12	1/11	12	
…..	…..	…..		…..		…..		…..

Figure 7.3 Example of a data-gathering list in retail outlets

7.2.3 Simulation study design

The simulation model was used to quantify each of the performance indicators for SC scenarios and to evaluate them according to the logistical SC objectives. The detailed process models presented in Chapter 5, i.e. the ODL and EPC models, were used to identify and describe relevant modelling constructs. The modelling framework and the simulation languages used are described in Chapter 6. To evaluate the applicability of our modelling framework we used Arena in case IIA and ExSpect in case IIIA. Figure 7.4 depicts an overview of the general structure of the simulation models created.

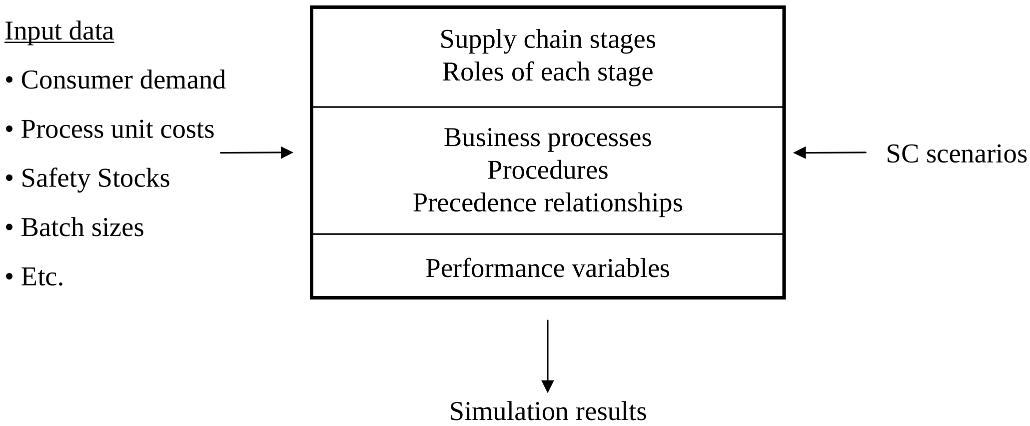


Figure 7.4 General structure of the SC simulation model.

Note that our modelling approach also allows for the modelling and simulation of SC scenarios that focus on other SC redesign variables than the ones chosen (see Section 7.2.1). Examples are the implementation of flexible production capacities, the co-ordination of inventory or production policies in the SC, or the choice of a specific order pick policy.

7.2.3.1 Model demarcation

The main SC demarcations to capture the real system in the model (see Figure 6.3) concern the modelling of consumer demand, product types and retail outlets.

Consumer demand

Consumer demand in retail outlets is not explicitly modelled as a process. We used real life consumer demand data in the model, assuming an independent relationship between the model and consumer behaviour. In reality this is not the case, since consumer demand depends in part on product availability, price and quality (shelf life). However, this would make the model unnecessarily complicated for our purposes.

As discussed in Chapter 6, the SC model should be capable of calculating system state at each relevant moment in time in order to calculate system performance. This requires the capability to register the state, time and place of each business entity after each transition. Since we are interested in the impact of different logistical activities during the day, the model time unit is an hour. In the simulation model consumer demand data per product of 20 weeks is used as input data. This concerns the aggregated week demand, since both SCs were unable to provide demand data per hour of the weekday. Hence, the consumer demand had to be transformed into consumer demand per hour of the week for each outlet. To do this, two demand distribution functions were introduced. Both functions were determined by the project team on the basis of practical experiences and measurements:

- A *week demand distribution function* that captures the average percentage of weekly consumer demand for products in retail outlets on each weekday.
- A *day demand distribution function* that captures the average percentage of daily consumer demand for products in retail outlets on each opening hour of the day.

Product assortment

Not all products of the producer were taken along in the simulation model, to ease the performance evaluation afterwards. In general, one is only interested in the effect of a certain SC scenario on the performance of a specific product class. As in the field test, about ten products were incorporated in the model that together represent three product classes: fast movers, middle movers and slow movers. These products were selected by the field experts. Furthermore, to calculate total SC costs, the volumes of goods and information flows concerning these selected products were transposed to the total volume of the producer’s product class. For example, products 3 and 5 together represent a group of 12 products with comparable characteristics such as shelf life, unit load, consumer demand and available shelf space.

Retail outlets

In the SC model not all retail outlets are modelled individually since this would create an enormous and inefficient simulation model. One test outlet in the field test is modelled explicitly, as it is assumed to have characteristics that are representative for all retail outlets (as recommended by the project team). By changing these characteristics, other (larger or smaller) outlets can easily be simulated. For this *modelled test outlet* data was gathered to calculate the value of performance indicators.

The other retail outlets were modelled by one so-called '*Mega-outlet*' to capture the total amount of products that flow through the SC. If these other outlets are not taken along, the inventory levels and turnover rates at the RDC (that influence product freshness) would not be realistic. Orders of this Mega-outlet are generated via total outlets' demand and a so-called *week order distribution function* that gives the average percentage of week demand for products at the RDC on each weekday.

7.2.3.2 Input data

To run the SC simulation model we need input data. The collected data was verified by key participants, especially the cost driver definitions. For both SCs the following data was gathered:

- Consumer demand (POS) data of the test outlet
- Week and day demand distribution function of the test outlet
- Retail outlets order data
- Week order distribution function of the Mega-outlet
- The capacity and timing of each business process (start time and duration)
- The Best-Before-Date (BBD) for each product after it is created at the producer
- The BBD constraints for each product at the RDC
- The number of consumer products that are grouped in one distribution unit
- Outlet shelf capacity per product (i.e. the number of products that fit in the shelf)
- The procedure for forecasting demand
- Cost driver definition for each business process

For each SC scenario the warm-up period of the model was determined by plotting inventory levels during the course of a simulation run. From these plots we concluded that a warm-up time of 3 weeks and a run length of 20 weeks was sufficient to draw conclusions. Furthermore, the initial settings of the model were based on the results of some preliminary runs.

7.2.3.3 Building a valid model

As suggested in Section 6.9 in each case study an informal 'structured walk-through' with the key SC participants was done in which we explained the detailed logic of the model. The detailed ODL mappings and EPC models presented in Chapter 5 were used for this purpose. Each process was discussed extensively to capture the real system in the best way possible. Where necessary, corrections or additions were made to the model. Bottom-up testing provided the *verification* of the simulation model. The lowest, most basic modules were tested and verified first. Integration tests were then performed in which the interfaces between two or more modules were tested. Finally, the complete SC model (including the input data) was tested and verified. The actual *validation* of the simulation model itself was done in various ways:

1. The state of simulated sub-systems (the business entities) was printed out and compared with *manual calculations* to see if the program was operating as intended.
2. *Animation* facilitated finding errors in the simulation code.

3. *Verifying with analytical models*. The output of the simulation model was compared to the results of analytical studies (see Section 7.5). Amongst others, the model intends to find lower bounds for SC inventories. These lower bounds can also be assessed by analytical modelling.
4. *Verifying with the field test results*. The results of the simulation study on the main performance indicators were compared to the results of the field test.
5. *Expert validation*: the results of multiple simulated SC scenarios were presented and discussed with key participants in the SC, supporting the validity of the model.

7.2.3.4 Trade-off between SC scenarios

One of the main problems of comparing scenarios when more than one performance indicator is used is the trade-off between multiple measures of performance that usually have different dimensions. What is better: a SC scenario with very fresh products and very low stocks but huge SC costs, or a SC scenario with medium fresh products and low stocks at medium SC costs? Taking into account the trade-off possibilities presented in Section 3.3.2, the following was decided:

To be able to compare the simulation results of different scenarios on all performance indicators, the project team decided to calibrate scenarios with respect to 0% no-sales in all SC stages. This means that each scenario is calibrated to minimum stock levels in the test outlet, whilst still satisfying consumer demand.

The consequence of this calibration process is that average inventory levels in retail outlets will be higher than in reality since additional safety stocks are required to eliminate stock outs.

When all SC scenarios were simulated, the results were presented in the project team meetings in which the SC participants were to make a trade-off between the benefits obtained and extra costs incurred. That is, the SC participants themselves decided, on the basis of the experiences in the field test and the simulation study, which SC scenario performed best.

7.2.4 Case study report

The case study results will be reported in the following way (Figure 7.5). First a detailed description is given of the field test design (*step 1*). That is, what were the settings for each design variable: what types of products were selected, what delivery frequency was implemented, and so on. Second, the qualitative results are presented (*step 2*) followed by the quantitative findings on the main SC performance indicators (*step 3*). The field test report concludes with some overall conclusions (*step 4*).

Then the simulation study in both case studies will be reported. First a detailed description is given of the modelled business processes (*step 5*). Next the detailed design of the study is presented, i.e. the allowed settings for each design variable and input data used (*step 6*). Third, the simulation results are presented and discussed (*step 7*) followed by the results of the sensitivity analysis (*step 8*). The simulation study report ends with some overall conclusions (*step 9*).

Finally, both case studies are concluded with a comparison of the field test results and the results of the simulation model (*step 10*) and with the case study conclusions (*step 11*).

If the reader is only interested in the main results of each case study, we recommend to focus on the shaded steps in Figure 7.5; i.e. the field test design, simulation study design and conclusions. For a more in-depth analysis of the case studies with all ins-and-outs, the reader is also referred to the other steps.

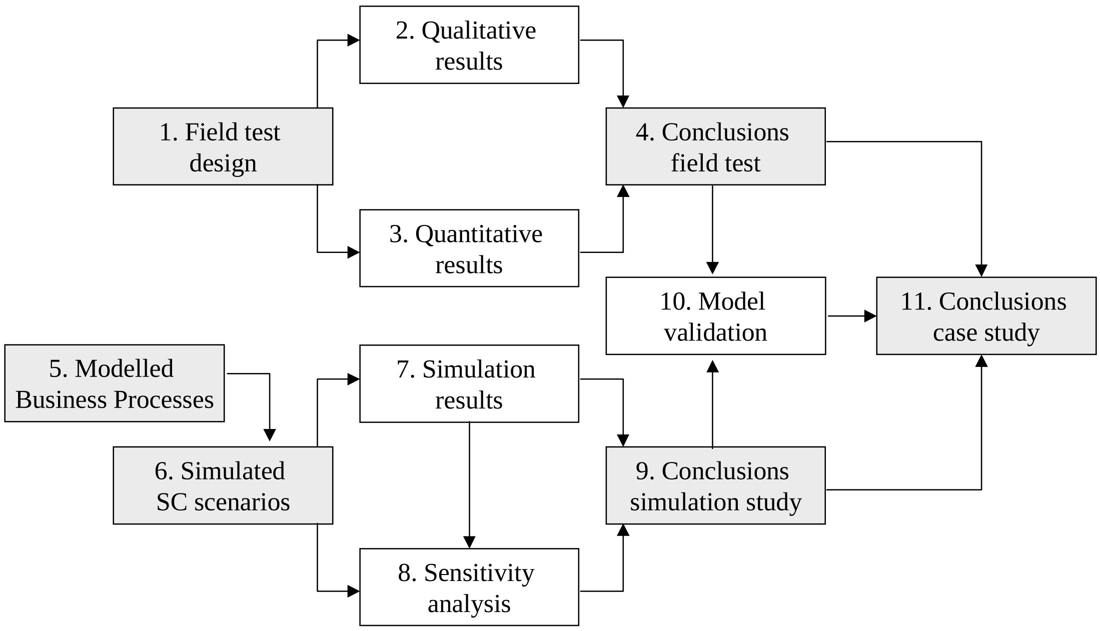
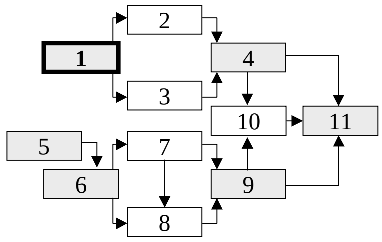


Figure 7.5 Reporting steps of the case study (the main reporting steps are shaded).

7.3 Case IIA: the supply chain for chilled salads (revisited)

In this section the results of the field test and simulation study in the SC for chilled salads are discussed. For a complete description of the SC we refer to Chapter 5. The quantitative impact of SC scenarios on the producer's inventory was not tracked because it was felt that the percentage of volume of this particular retailer was insufficient to expect significant changes in the producers operations.



7.3.1 The field test

7.3.1.1 Field test design

At the time of the field test one of the retail outlets was trying out a computer assisted ordering (CAO) system in which orders are based on detailed demand forecasts and a real-time inventory system. This provided us with the opportunity to evaluate the use of this system and assess the impact on SC performance. Three large retail outlets were chosen for the field test: a test outlet with CAO, a test outlet ordering in the traditional way, and a standard outlet where no adjustments were made.

Based on three factors, i.e. insights obtained from literature, preliminary simulation results, giving indications of what performance improvements to expect, and finally, the participation of companies, the following SC scenario was chosen for the pilot:

- The delivery frequency of the producer is increased from two times to five times a week. The order lead time is decreased from three days to about 24 hours. Orders of the RDC are faxed before 11:00 in the morning resulting in a delivery from stock the next morning. This means that the producer makes a special delivery to the RDC.
- The forecasting element in the RDC ordering procedure is eliminated and changed into ‘simply’ replenishing stock to a predetermined base stock level.
- The delivery frequency of the RDC is increased from three times to six times a week. This could be done easily since goods could be added on trucks that visited each outlet already every working day, delivering fruits and vegetables according to a fixed delivery schedule (see Section 5.5.2).
- Currently, promotional products can be (re)ordered three times: Friday before the promotion week starts and Tuesday and Thursday together with the regular order in the promotional week. During the pilot the test outlets could use the extra ordering moments to order additional products.
- All other processes are unchanged. Of course, the time windows of each critical business process had to be changed (i.e. in most cases the waiting times were reduced significantly).

Figure 7.6 depicts an EPC model of the pilot SC scenario. The changed time windows for the business processes are evident when we compare this figure with the EPC model of the standard SC scenario (Figure 5.10).

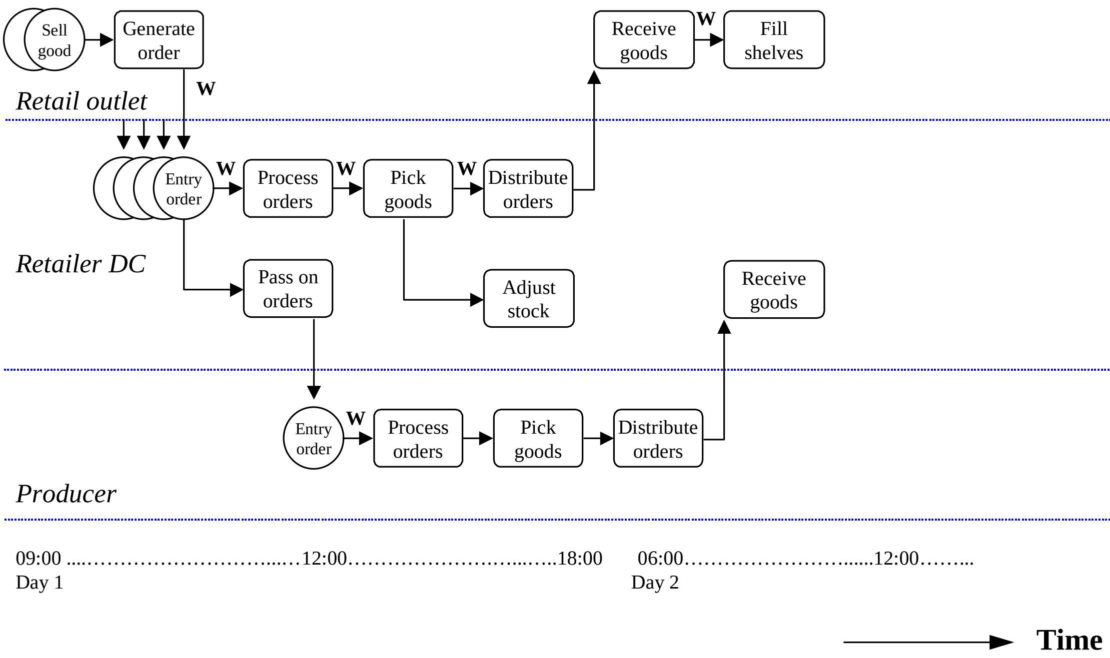
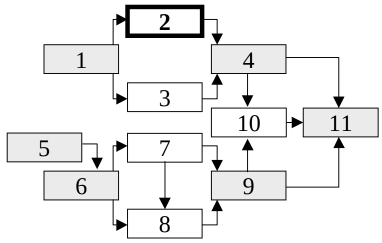


Figure 7.6 EPC-model for the pilot SC scenario in the SC for chilled salads.

The field test was performed in the months October and November, which have a relatively low and constant sales volume. All products from this producer were delivered more frequently in the SC but only 8 typical products were selected (unique article numbers) to be followed closely by measurements of stock levels and product freshness. Performers at all stages were urged to minimise stocks (i.e. lowest inventory levels with no lost sales) during the field test to make it possible to identify maximum potential benefits in product availability and product freshness.



7.3.1.2 Qualitative results

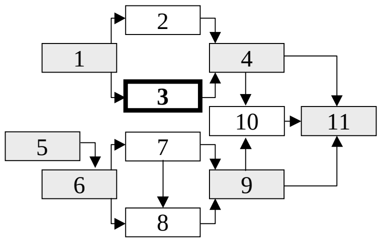
During the field test several aspects of the SC system presented problems concerning the new SC scenario and the corresponding data-gathering:

- One of the main aspects in making a field test successful is to include all key persons in the design and execution of the field test. When retail outlets were visited and attention was paid to the work of the persons responsible for filling in the forms, the attention of those persons for the forms increased significantly. However, during the first week of the 0-index very little data was recorded, eliminating the usefulness of that week. Therefore, the pilot was delayed one week to obtain a valid representation of the standard SC scenario. This meant that the pilot would have to last until December (with a peak demand at St. Nicholas). To decrease work load in that week, the pilot period was shortened to 5 weeks.
- In the current situation retail outlets have extra stocking facilities in the back of the store. The trend is that these stocking facilities will be eliminated in favour of additional shop floor space. However, this is not yet the case resulting in situations in which stock measurements were not always accurate because products in the back were not added to the products on the shelves. Fortunately, these failures could be corrected by analysing the stock levels in time.
- The dairy manager ordering the products at the standard outlet found it inconvenient to fill in the data forms each day since he experienced no benefits at all from the pilot. Here the issue of rewarding systems and aligning them to SC objectives became relevant. He felt that if his performance were to decrease during the pilot (because he spent too much time filling in the forms) he would be reprimanded. On the other hand, he would get no bonus at all for filling in the forms; so why should he?

During the field test discussions were held with performers at the producer, RDC and retail outlets. Furthermore, the field test was concluded with a workshop at which all participants could discuss their experiences. The following conclusions were made:

- The retail manager of the test outlet without CAO did not increase his ordering frequency in the new SC scenario. He felt that filling shelves is much easier, and fewer errors are made when all fresh products arrive at the same time at the outlet. Furthermore, things ‘got too complicated’, he said, when all these products have to be ordered so many times. He only used the extra ordering possibilities in the case of impending stock outs. It proved to be very difficult to alter the current way of working.
- The test outlet with the automated ordering procedure had start-up problems with the system. The CAO system only works well when numerous weeks are incorporated. Furthermore, the system requires manual interference to correct for unexpected peaks in demand. Otherwise, these peaks will influence the order pattern for several weeks. Such a correction was done for about 15% of the orders.

- The retail managers foresaw significant problems if all products were to be delivered more frequently. Although stocks would decrease, more manpower would be required to fill shelves. In the new situation, filling shelves would have to take place during the day, which requires more expensive workers compared to the students that are available in the evening. Furthermore, if all outlets would be able to order products each day of the week, peaks in RDC deliveries would occur on Saturday and Monday to fill up empty shelves. This would inevitably result in capacity problems in the RDC on those days.
- The project participants forecasted huge timing and capacity problems at the producer and the RDC if these higher frequencies are actually implemented in the complete SC network. To realise a lead time of 24 hours for all customers each day, all of the time available would have to be used to pick products. Hence, as much manual labour as possible should be eliminated by implementing EDI, a Warehouse Management System, and other Information and Communication Technologies.
- During the field test, the invoicing process in the SC was hindered. Additional profits could be made if this process were also optimised; for example, by aggregating the invoices per week or month, or even by no longer sending invoices, since the customer already knows what his debt is.



7.3.1.3 Quantitative results

The quantitative results are based on the data gathered daily during the field test to assess the impact of the pilot SC scenario on SC performance. Figure 7.7 depicts the overall results for all three retail outlets for the selected products. The figure shows that the main results are obtained in the CAO test outlet (note that the three outlets have different sales volumes). The second test outlet revealed no notable inventory reduction. This was because the ordering frequency was not increased in the pilot, as we described above. The standard outlet experienced no notable change in inventory levels either.

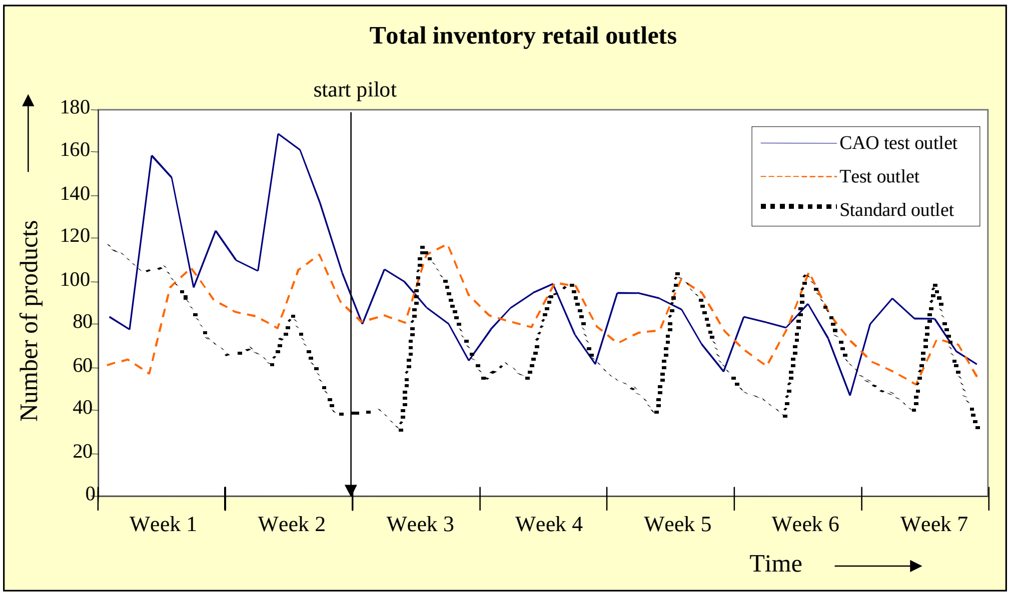


Figure 7.7 Total inventory in retail outlets (for 7 products) during the field test.

Because the order and delivery frequency was increased from two to five times a week, fast movers were defined as products of which five or more sales (consumer) units were sold each week. Middle movers sold between two and five sales units, and slow movers sold less than two units a week.

When we zoom in on the CAO test outlet we find noteworthy reductions in inventories for fast movers (on average about 47%) and middle movers (about 20%) (see Figure 7.8). In these calculations the data of week 3 has been removed to eliminate change-over effects. Slow movers revealed no benefits. Even worse, the inventories increased by 49%!

The retail manager emphasised that stock levels can only be reduced to a specified level. When this level is crossed, product sales will be reduced. As the retail manager said: “No one wants to take those last products, thinking there must be something wrong with it”. Hence, retail outlets work with a minimum amount of each product that should always be present.

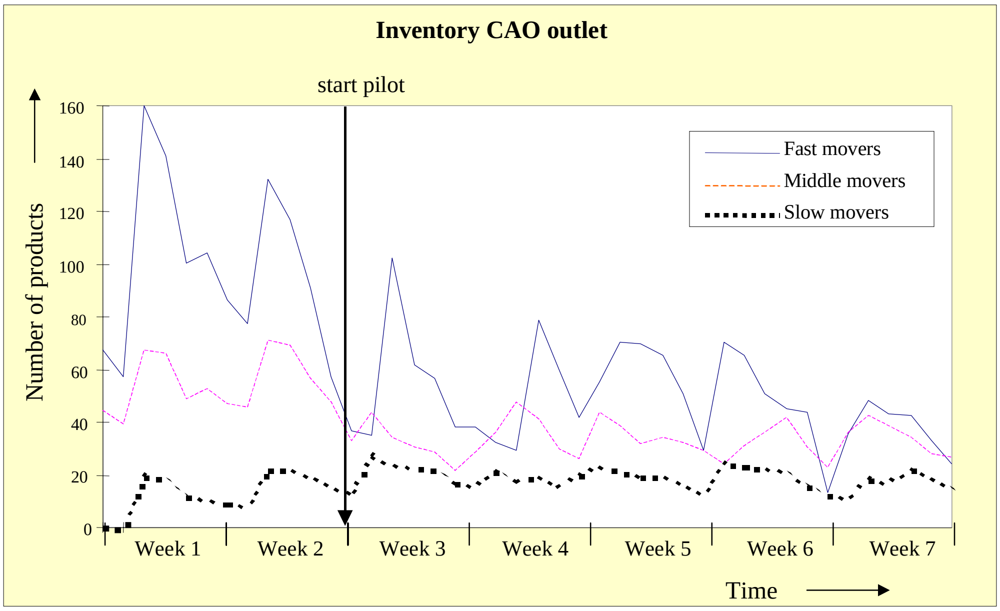


Figure 7.8 Inventory levels in the CAO test outlet during the field test.

From the analyses it became clear that the current distribution unit sizes (the order batch sizes) hindered reducing inventories for slow movers. For example, one product sells on average 0.7 distribution units a week. Hence, increasing the order frequency makes no sense. However, in the pilot this product is ordered on average 1.7 times a week resulting in a build-up of stock. Furthermore, this leads to several write-offs, since products are kept in the shelves too long. Retail managers had great difficulties in differentiating ordering policies for different kinds of products. This calls for an automated system to aid the retail manager when higher frequencies are actually implemented in this SC.

Comparable results are found when product freshness is investigated (Figure 7.9). On average consumers experienced an increase of product freshness of fast movers by 3.5 days and middle movers by 7.7 days, whilst the product freshness of slow movers decreased by 2.8 days due to the increase of inventories. The significant increase in product freshness of middle movers was mainly caused by a major inventory reduction in the RDC. The sudden increase in product freshness of the slow movers was caused by a new delivery of products from new batches at the RDC.

An element found from the data analyses was that consumers often take those products from the shelves that have the highest remaining shelf life. This indicates the importance given to product freshness by the consumers.

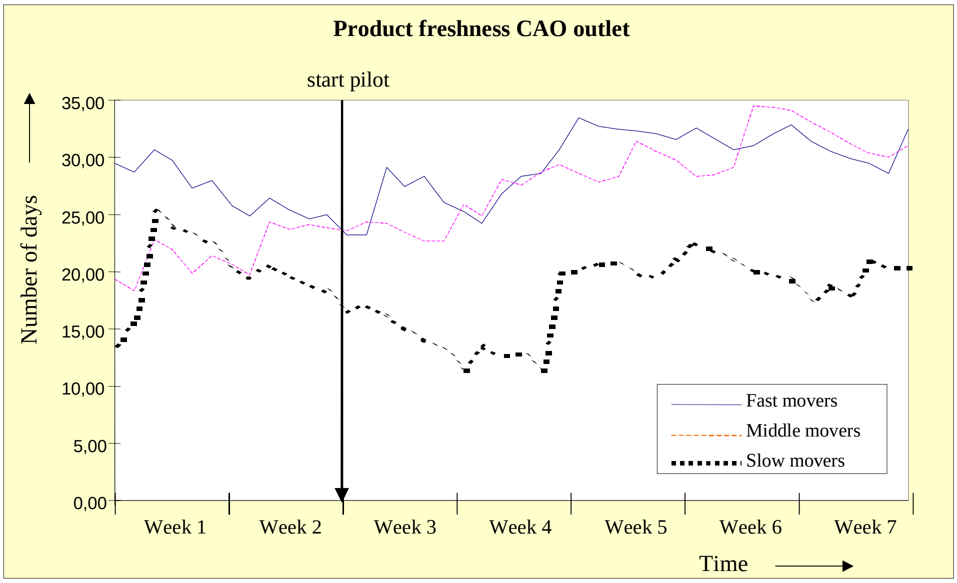


Figure 7.9 Product freshness in the CAO test outlet during the field test.

Several times the RDC delivered to the CAO test outlet too late. Sometimes this resulted in stock outs in retail outlets. On average, the CAO outlet experienced stock outs in 4.2% of all measurements during the 0-index versus 2.6% in the pilot. As expected, most stock outs occurred on Saturdays and Mondays.

The project team concluded that the 0-index measurement period was too short for the system to arrive at relatively stable behaviour. In order to draw conclusions that are statistically valid, field test measurements should be made for a much longer period. Unfortunately, that was not possible in this case study. Therefore, the data are not evaluated statistically. These findings should be seen as indicatives of the pilot SC scenario potentials. We will therefore focus on the average performances and leave out a discussion of variances.

Figure 7.10 shows the decrease in inventory levels at the retail RDC, mainly caused by the increased delivery frequency of the producer. RDC inventories of fast movers decreased on average by 52%, middle movers by 67% and slow movers by 52%. Product freshness of stored products at the RDC increased on average by 3.4 days. Fast movers won 1.6 days, middle movers 5.7 days and slow movers 3.1 days. Figure 7.10 further demonstrates that average minimum stock was still relatively high, leading to the conclusion that safety stock levels could be reduced even further. This was particularly so for fast-moving articles, since one traditionally takes extra precautions with them. As the RDC manager said: “A stock out for a fast mover causes the phones to ring all day, whereas a stock out for a slow mover passes by without a signal from retail outlets”.

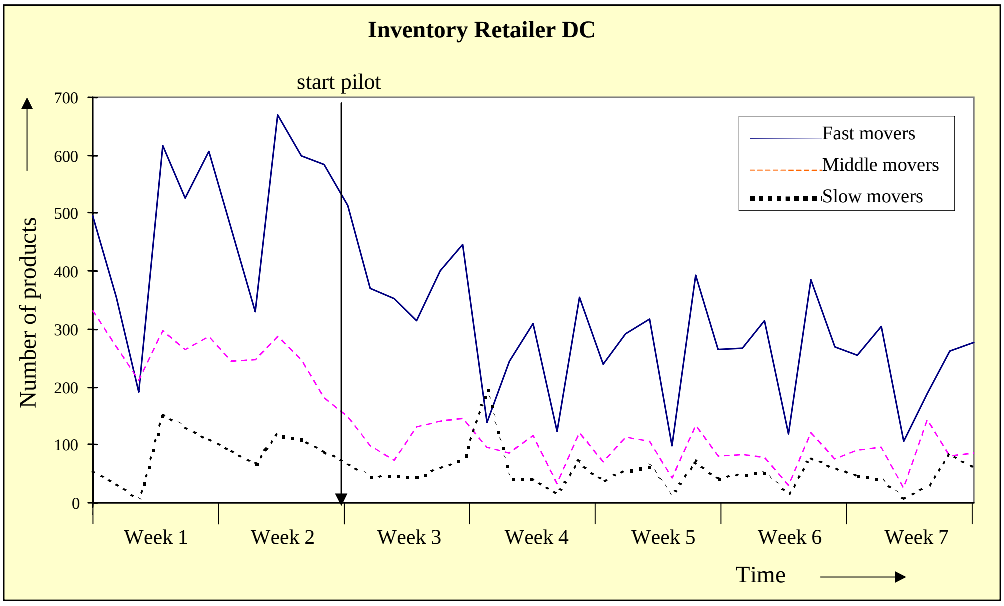


Figure 7.10 Inventory levels in the distribution centre during the field test.

Although inventories were reduced in the pilot, the RDC manager had some problems with eliminating all slack. This is even more evident in Figure 7.11, which depicts the order pattern of the RDC during the field test for a fast-moving article. The Forrester effect (see Section 4.5) is clearly visible, since the aggregate of all outlet orders is still exaggerated by the RDC order. It was not until the end of the pilot that the RDC manager was convinced that the order-up to level could be further decreased, resulting in a much smoother ordering pattern. This was also due to the fact that the producer had some difficulties with his delivery reliability. Although the producer’s delivery reliability concerning quantity was 100%, timing was a problem. Sometimes trucks were an hour late caused by difficulties in transportation planning. Note that the extra deliveries of the producer required extra transport for sometimes only one pallet. Figure 7.11 also shows that the RDC did not increase its ordering frequency until the third week of the pilot (week 5). This also explains why the product freshness in the retail outlets started to increase only two weeks later (see Figure 7.9); the RDC first had to dispose of the surplus of products.

Finally, when the remaining shelf lives of products delivered by the producer in the 0-index is compared with the shelf lives in the pilot period, the following results are obtained: fast-movers delivered in the pilot had 0.5 days less remaining shelf lives than in the 0-index; middle movers were 1.4 days fresher, and slow movers were 1.1 days older. This also explains part of the high benefits of the middle movers in retail outlets.

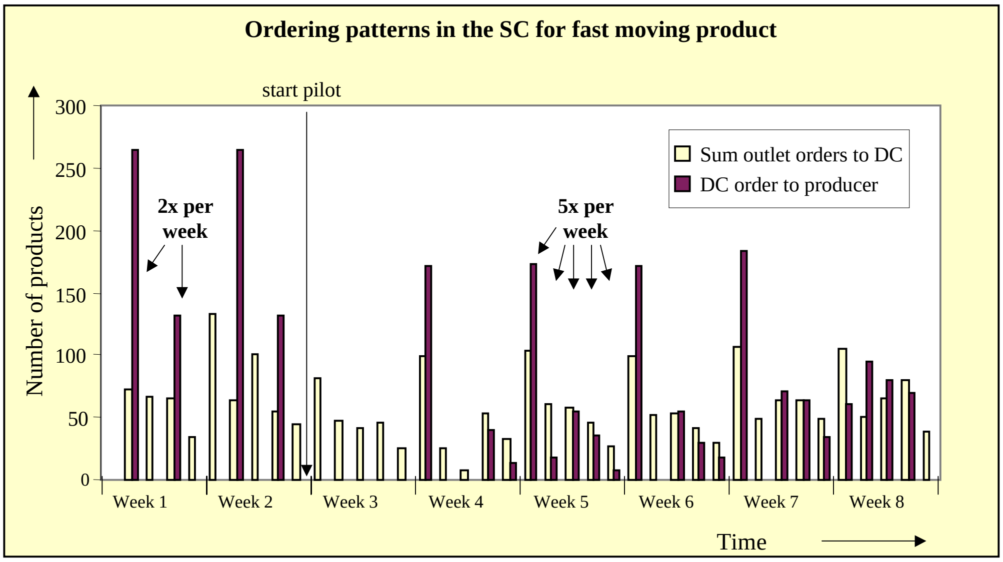
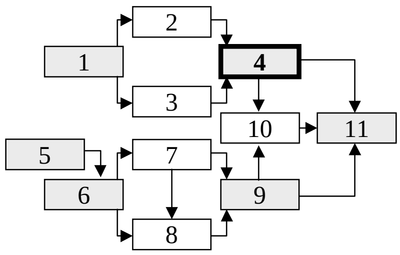


Figure 7.11 Order patterns in the SC during the field test.



7.3.1.4 Conclusions field study

All parties recognised that the field test was not long enough to give statistical evidence of the performance improvements realised. However, the main objective of the field test was to identify the potentials of, and restrictions to, the new SC scenario. The project team concluded that the field test did provide insight into these aspects. Table 7.1 presents an overview of the quantitative results of the field test. From these numbers the impact on the performance of each SC stage can be calculated. For example, on average the RDC delivered fast-moving products with 1.6 days longer remaining shelf lives to retail outlets. Since the producer delivered fast-moving products with 0.5 days less freshness, the RDC is responsible for an increase in product freshness of 2.1 days.

Table 7.1 Measured average performance changes for each stage in the SC for chilled salads when implementing the pilot SC scenario.

Product type	**Producer**	**RDC**		**Outlet**	
	Freshness	*Inventory*	*Freshness*	*Inventory*	*Freshness*
Fast mover	- 0,5 days	- 52%	+ 1.6 days	- 47%	+ 3.5 days
Middle mover	+ 1,4 days	- 67%	+ 5.7 days	- 20%	+ 7.7 days
Slow mover	- 1,1 days	- 52%	+ 3.1 days	+ 49%[4]	- 2.8 days

From Table 7.1 we can conclude that the new SC scenario offered the following benefits concerning product freshness (i.e. the outlet's freshness compared to producer's product freshness):

Fast movers	+ 4.0 days
Middle movers	+ 6.4 days
Slow movers	- 1.7 days

[4] This is caused by more frequent ordering of relatively large distribution unit sizes.

The field test showed that changing the SC scenario creates a shift in capacity requirements in volume and time. This holds especially true for filling shelves and ordering in retail outlets and picking orders at the RDC and producer. A CAO system seems necessary to order the complete product assortment more frequently. It will just take too much time if each product is ordered each day manually. From the field test it is clear that the main barriers to improving SC performance are the current information technology infrastructure and the reliance on decision-makers. EDI and real-time control systems seem necessary together with training and education of personnel to obtain the potential benefits for the complete product assortment.

Finally, the interdependence of SC stages increases significantly when all slack is removed from the SC. This was especially experienced by the retail RDC in the field test when goods were delivered too late, resulting in stock outs. The overall benefits obtained depend heavily on the trust between SC stages, which determines the required amount of slack. It also results in a quest for a reduction in supplier base to be able to give these processes the attention they deserve.

7.3.2 The simulation study

Figure 7.12 presents an overview of the simulation model for the SC for chilled salads. In this case study the Mega-outlet represents 100 retail outlets.

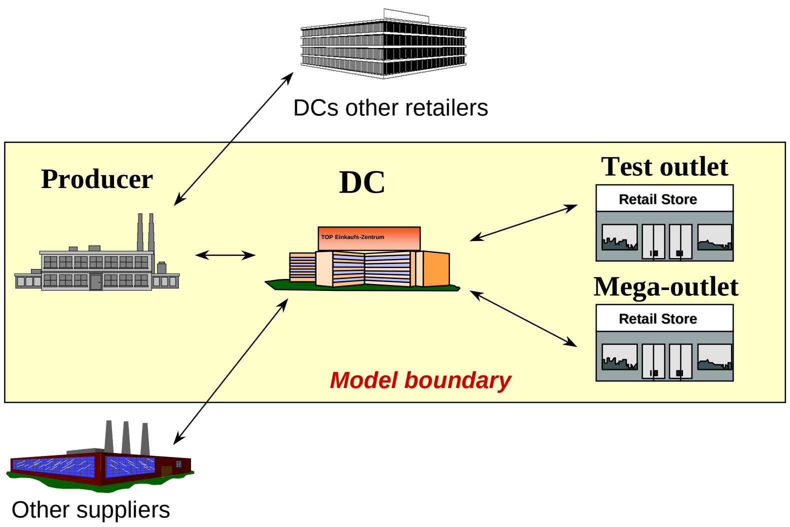
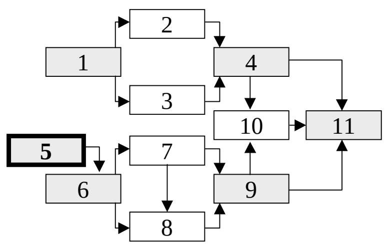


Figure 7.12 Overview of the simulation model of the SC for chilled salads.

7.3.2.1 Modelled business processes



A detailed description of the SC for chilled salads is already given in Chapter 5. However, the complete SC with all its aspects is not modelled. Only those business processes that are considered to impact the main performance indicators are dealt with in the modelling process. Figure 7.13 gives an overview of the modelled business processes. Based on the findings in Chapter 5 we can list the main (local and global) performance indicators including norms for this simulation project in order of ranking:

1. Less to no stock outs in retail outlets resulting in higher sales
2. Highest remaining product shelf lives for consumers
3. Lowest inventory levels in retail outlets to allow for product assortment expansions
4. Lowest integral cost of all SC business processes

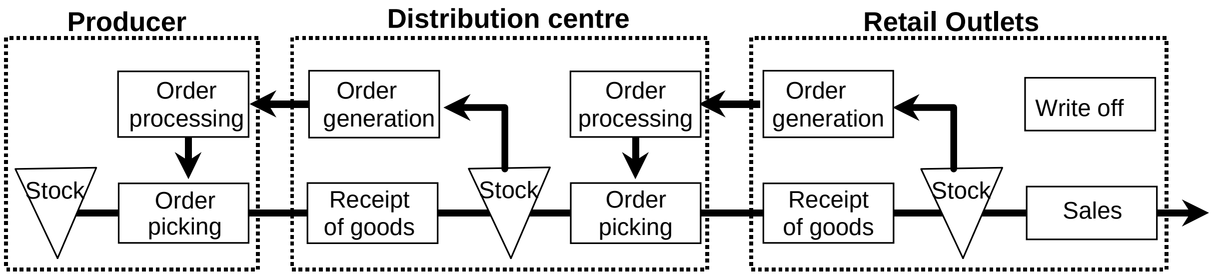


Figure 7.13 The business processes modelled within the supply chain for chilled salads.

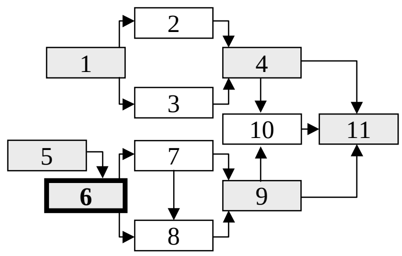
In the model, retail outlets sell salads during opening hours. At a certain frequency and at fixed times retail outlets place orders at the RDC according to a base stock policy. Basically orders are placed to fill up available shelf capacity:

$$Order = Shelf\ capacity - current\ stock - on\ order$$

Because of a one-day lead time, backordering does not apply. The order batch size is a fixed number of consumer products that varies for each product. During closing hours, all stocked goods are checked for their remaining shelf life. If there is none, goods are written off.

At the RDC the outlet orders are processed at fixed times, which results in order pick lists per retail outlet. Some time later orders for all products are picked and collected into shipments, which, after a short delay, are shipped to the outlets. The RDC supplies each retail outlet with chilled salads several times a week from stock. Each outlet has its own ordering and delivery schedule to level the workload of the RDC. The times at which corresponding shipments leave the RDC are pre-set, but the actual arrival time at the site depends on process throughput times. If there are shortages, a rationing policy is followed giving each outlet the same percentage of the shortage. The RDC generates an order several times a week based on sales forecasts (derived from outlet orders and historical sales patterns), a safety factor and the previous day’s inventory levels. Alternatively a base stock order policy can be chosen.

Finally, the producer processes the orders at fixed times and supplies the RDC with the selected products with an order lead-time of three days or one day dependent on the SC scenario. We assume shortages do not occur at the producer.



7.3.2.2 Simulated SC scenarios

In the simulation study we quantified the consequences of different SC scenarios with respect to the performance indicators for the eight selected products (representing three product classes). Consecutively, these results were transposed to the complete product assortment related to this producer. Table 7.2 presents the relevant SC redesign variables (see also Section 7.2.1) and the settings per variable defined by the project team. A combination of settings for all these SC design variables defines a SC scenario. Most SC scenarios require the installation of ICT systems to facilitate the changing of time windows of SC business processes, e.g. EDI. For these scenarios these ICT systems are assumed to be present.

Table 7.2 SC redesign variables and their state space.

SC redesign variables	*Allowed settings*
Order and delivery frequencies between producer and RDC	2, 3, 4, or 5 times a week
Order lead time producer (see Appendix H)	3 days or 1 day
Order and delivery frequencies between RDC and retail outlets	3, 4, 5, or 6 times a week
Order policy retail outlets	Base stock or CAO forecast procedure
The distribution unit size	Current size (6 or 12) or size = 1
Role of the RDC	Storing goods or cross-docking

By analysing and evaluating all possible order and delivery days and times for the different order and delivery frequencies, the project team determined the settings that were used (see Figure 7.14 and Appendix I).

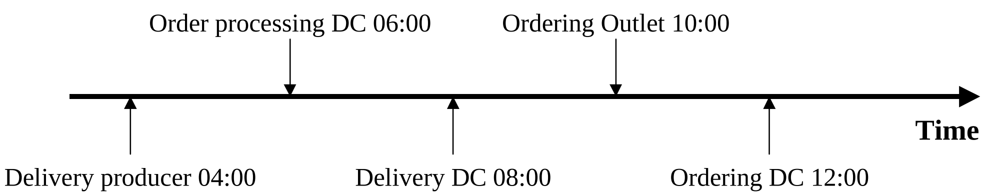


Figure 7.14 Time windows in the simulated SC.

When the point-of-sale data in the test outlet is analysed, the buying pattern, i.e. the *week demand distribution function*, presented in Table 7.3 is found.

Table 7.3 Test outlet week demand distribution functions in percentage of total week demand.

	Monday	*Tuesday*	*Wednesday*	*Thursday*	*Friday*	*Saturday*
Sales percentage	10%	10%	13%	14%	27%	26%

The (aggregated) orders of the Mega-outlet differ in volume for the weekdays. When an outlet is able to order more frequently, its orders will follow consumer sales and show a demand peak on Friday and Saturday. Therefore, the *week order distribution* of the Mega-outlet will shift at higher frequencies. The distribution function of the Mega-outlet was determined for the current situation, i.e. when all outlets are delivered 3 times a week (see Table 7.4: delivery frequency RDC 3x) and during the field test when all outlets are delivered 6 times a week (delivery frequency RDC 6x). The other demand function (at frequency 4x and 5x) was based on real-life demand data and justified by expert testing.

Table 7.4 Mega-outlet week order distribution functions in percentage of total week demand.

Delivery frequency RDC	*Monday*	*Tuesday*	*Wednesday*	*Thursday*	*Friday*	*Saturday*
3x	18%	19%	19%	11%	11%	22%
4x or 5x	15%	16%	17%	13%	16%	23%
6x	12%	14%	14%	15%	20%	25%

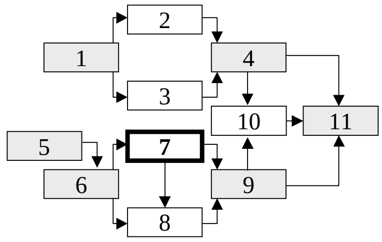
The cost drivers for each business process were determined during extensive discussions with the project team (Table 7.5). Note that the outcomes of such discussions may differ for other SCs; and this could have a great impact on benefits to be obtained. For example, the cost driver for producer transportation differs in this case from case IIIA as we will see later.

Table 7.5 Cost drivers per SC business process for the SC for chilled salads.

SC stage	*Process*	*Cost driver*
Retail outlet	Goods receipt and filling shelves	Number of secondary unit loads + number of products
	Inventory	Number of products (interest and consumer price)
	No-sales	Number of products (consumer price)
	Write-offs	Number of products (purchase price)
	Order processing	Number of order lines
RDC	Goods receipt	Number of deliveries + number of secondary unit loads
	Inventory	Number of products (interest and purchase price)
	Order picking	Number of orders + number of order lines
	Write-offs	Product value
	Transportation	Number of secondary unit loads
	Order processing	Number of orders
Producer	Order processing	Number of orders
	Order picking	Number of unit loads
	Transportation	Number of secondary unit loads

Total costs per link are calculated by adding costs related to all business processes in that link (including the costs of write-offs) and by transposing the results for the 8 products to the total product assortment. Total chain cost is the sum of the cost of producer and RDC and 100 times the costs made in the average retail outlet. To leverage the influence of write-offs (which can be quite significant in 100 retail outlets) the term *total process cost* is introduced, which refers to total cost minus (write-offs and no-sales). It gives insight into the cost of human labour related to the execution of all business processes.

7.3.2.3 Simulation results



Numerous scenarios were simulated but we will focus on the most important results. Subsequently we will discuss the impact of different order and delivery frequencies and lead times, order policies and distribution units. The simulation model is run as a deterministic model with variability in consumer demand. The presence of inherent uncertainties is evaluated in the next section where the robustness of specific SC scenarios is discussed. Because of the confidentiality of the data all outcomes are transformed into changes relative to the current SC scenario with lead time 1 day (scenario 2_3). For example, 110 means a 10% increase compared with the value obtained in scenario 2_3. Furthermore, the following notations are used:

$FREQ_{p,rdc}$	order and delivery frequency per week between producer and RDC
$FREQ_{rdc,o}$	order and delivery frequency per week between RDC and retail outlets
LT_p	producer's lead-time to the RDC (in days)
a_b-3	SC scenario with $FREQ_{p,rdc}$ = a, $FREQ_{rdc,o}$ = b, LT_p = 3
a_b	SC scenario with $FREQ_{p,rdc}$ = a, $FREQ_{rdc,o}$ = b, LT_p = 1 (for typographic reasons we abbreviate a_b-1 to a_b)

Frequencies and lead times

The average values of the performance indicators for the simulated scenarios over the simulated period (i.e. 20 weeks) are presented in Table 7.6. Note that scenario 2_3-3 is the current scenario in the SC.

Table 7.6 Overview of the most important results of simulated SC scenarios (values printed in bold refer to the base-case SC scenario 2_3 and the best scenario 5_4).

	SCENARIO										
Performance indicator	2_3-3	**2_3**	3_3	4_3	5_3	3_4	3_5	3_6	4_4	**5_4**	5_6
Producer											
Total cost	101	**100**	103	106	108	103	103	104	106	**108**	109
Distribution centre											
Stock level	121	**100**	80	82	60	86	86	94	89	**72**	86
Throughput time	138	**100**	81	83	64	87	87	93	90	**75**	87
Total cost	103	**100**	101	102	102	111	118	127	113	**113**	128
Outlet											
Stock level	98	**100**	99	100	100	69	71	74	69	**72**	73
Throughput time	96	**100**	101	103	104	80	88	93	80	**83**	90
Write-offs	*139*	***100***	*75*	*120*	*49*	*56*	*50*	*65*	*56*	***49***	*67*
Total process cost	100	**100**	100	100	100	105	110	117	105	**105**	116
Chain											
Throughput time	113	**100**	93	95	88	83	87	93	84	**80**	89
Product freshness	19.55	**21.29**	22.28	22.03	22.99	23.68	23.06	22.29	23.51	**24.06**	22.88
Process cost	101	**100**	102	103	104	106	110	114	108	**109**	116
Total cost	*99*	***100***	*99*	*102*	*102*	*103*	*107*	*112*	*106*	***106***	*113*

When LT_p is decreased to one day (scenario 2_3), inventory levels at the RDC decrease on average by 21% and throughput times fall by 38%. This results in fresher products delivered at retail outlets, leading to 39% fewer write-offs. At these low delivery frequencies it is not possible to install safety stock levels at which no stock outs and no write-offs occur. When inventory is too high, products perish because they remain on the shelf too long. And when inventory is too low, stocks run out. When $FREQ_{rdc,o}$ is increased it is possible to eliminate both stock outs and write-offs.

By trading off the extra costs incurred in each SC scenario with the benefits obtained, the project team concluded that scenario 5_4 seems to perform best (i.e. $FREQ_{p,rdc} = 5$ *and* $FREQ_{rdc,o} = 4$*).*

In scenario 5_4 average outlet stock levels fall by about 28% and chain throughput time falls by 20%, which means an average increase in remaining product shelf life of 2.8 days[5]. Chain process cost (hence write-off costs are not included) increases by 9%, mainly because of higher order generation, order picking, and transportation costs. We will discuss the details of process cost later in this section.

When $FREQ_{rdc,o}$ is increased from 3 to 4, significant advantages are obtained. Further increasing the order and delivery frequencies to the retail outlets does not result in an overall improvement; when $FREQ_{rdc,o}$ is increased to 5 or 6 times a week, average inventory even increases a bit (Figure 7.15). The distribution unit sizes (i.e. the minimum order batch) restrict major benefits for slow and middle moving products since they hinder more frequent ordering (on average, current distribution units contain 6 or 12 products). The increase of average inventory is caused by the fact that shelves are filled at every delivery moment because of the base stock ordering policy.

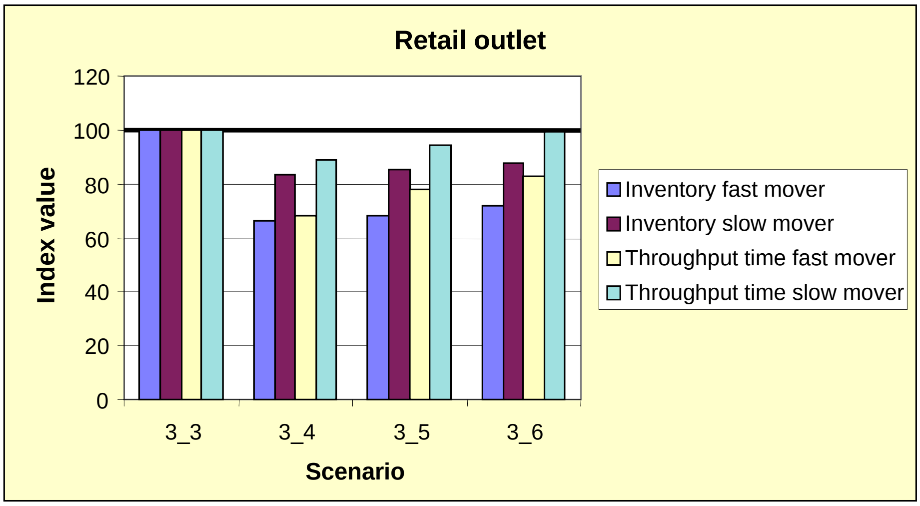


Figure 7.15 Results for fast moving and slow moving articles in the retail outlet.

5 Note that the absolute values for product freshness differ a bit from the field test values. This is because the BBDs of the products delivered to the retailer DC in the field test varied within a range of about 7 days as a result of stock fluctuations due to production cycles and deliveries to other retailers. In the model the BBD-values are based on the BBD-values that are guaranteed to the retailer (which are a bit lower).

When $FREQ_{p,rdc}$ is increased to 5 times a week, RDC inventory levels are lowest (see Figure 7.16). However, this positive effect is partly eliminated when $FREQ_{rdc,o}$ is increased as well to improve outlet performance. Analysis showed that this is caused by the changing week demand distribution of the Mega-outlet at higher frequencies, as we will illustrate later on in the sensitivity analysis (the outlet ordering pattern shows more variability at higher frequencies, resulting in a need for extra safety stock).

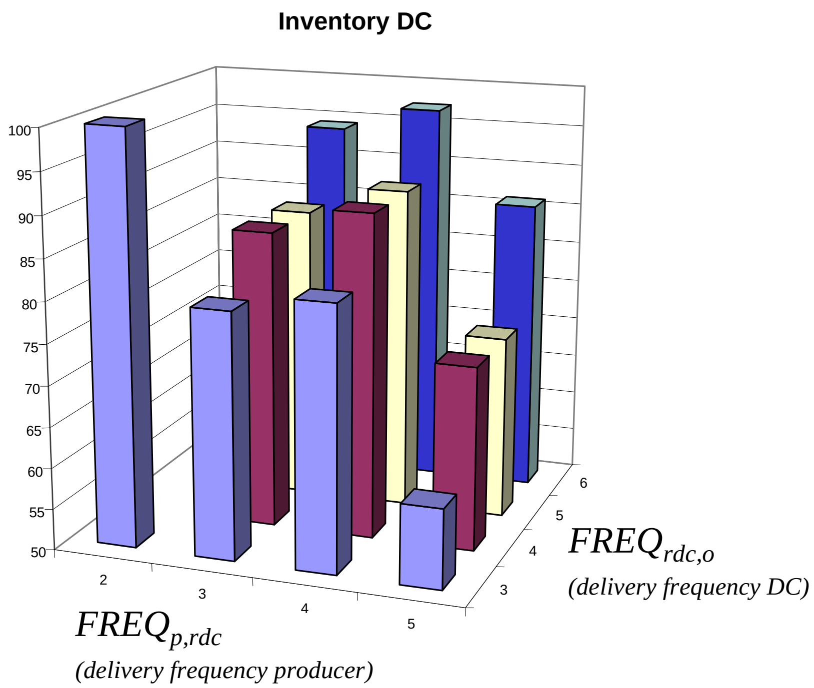


Figure 7.16 Impact on RDC inventory levels when increasing the delivery frequencies in the SC.

Table 7.7 gives more detailed results concerning costs of the simulated SC scenarios. Here too, all costs are indexed to the values obtained in scenario 2_3. The increase of $FREQ_{rdc,o}$ especially increases total SC cost. This is mainly caused by higher RDC order picking cost.

The increase of transportation costs in the SC at higher delivery frequencies is relatively low because of the chosen cost drivers, namely the number of secondary unit loads (pallets/ roll-in containers) transported in a week. When the producer increases his delivery frequency, the total number of pallets transported in a week hardly changes. However, the number of pallets transported per delivery changes drastically, hence the truck utilisation degree is reduced (see Figure 7.16). But since the producer has outsourced his transportation, his costs hardly increase. Note that this cost calculation method has significant effect on the best SC scenario chosen.

Also, when $FREQ_{rdc,o}$ is increased, transportation costs do not change significantly. This is because in the current situation the RDC already delivers each outlet six times a week (see the detailed SC description in Chapter 5); at each delivery other types of products are delivered.

The project team assumed that an increase of the outlet delivery frequency for each product would result in a shift in truck contents, but would not significantly impact the number of RDC transportation movements.

Table 7.7 Cost overview of the most important simulation results (values printed in bold refer to the base-case SC scenario 2_3 and the best SC scenario 5_4).

	SCENARIO										
Performance indicator	2_3_3	**2_3**	3_3	4_3	5_3	3_4	3_5	3_6	4_4	**5_4**	5_6
Producer											
Order entry	100	**100**	150	200	250	150	150	150	200	**250**	250
Order picking	101	**100**	100	100	100	100	100	101	100	**100**	101
Transportation	101	**100**	102	104	105	102	102	103	103	**105**	105
Total Cost	101	**100**	103	106	108	103	103	104	106	**108**	109
Distribution centre											
Inventory	123	**100**	79	80	60	85	85	93	88	**73**	87
Order picking	101	**100**	101	101	101	120	132	147	120	**119**	145
Order generation	100	**100**	150	200	250	150	150	150	200	**250**	250
Transportation	100	**100**	100	100	100	100	100	101	100	**100**	101
Goods receipt	100	**100**	102	104	109	102	102	102	104	**105**	106
Total Cost	103	**100**	101	102	102	111	118	127	113	**113**	128
Outlet											
Filling shelves	100	**100**	100	100	100	106	111	117	106	**106**	117
Order generation	101	**100**	101	101	101	116	122	131	116	**114**	128
Inventory	98	**100**	101	102	102	76	78	81	76	**80**	78
*Write-offs**	*24*	***100***	*18*	*28*	*12*	*13*	*12*	*15*	*13*	***12***	*16*
Total process cost	100	**100**	100	100	100	105	110	117	105	**105**	116
*Total cost**	*94*	***100***	*93*	*97*	*93*	*97*	*101*	*107*	*100*	***97***	*106*
Chain											
Process cost	101	**100**	102	103	104	106	110	114	108	**109**	116
Total cost	*99*	***100***	*99*	*102*	*102*	*103*	*107*	*112*	*106*	***106***	*113*

* Because write-offs can influence total outlet cost considerably and they depend heavily on the model calibration process, main attention should be given to the total outlet process cost (see also page 187).

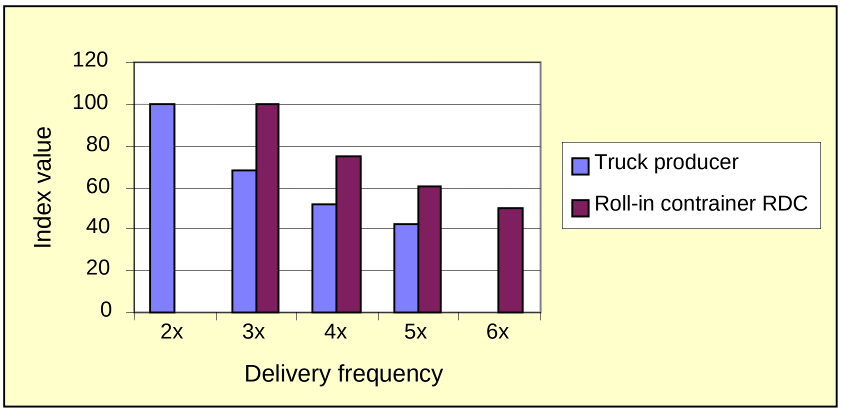


Figure 7.17 Utilisation degrees per delivery (indexed at scenario 2_3).

Figure 7.17 also shows the decreasing volume of chilled salads that is transported per delivery for different frequencies. Note that order-picking (handling) costs increase significantly. Total chain costs rise less, as a result of fewer write-offs at higher frequencies.

Figure 7.18 presents the relative portion of each business process in the total cost per stage in order to evaluate the absolute differences between performances of SC scenarios in Table 7.7. It shows that 70% of the producer's total process cost is incurred by transportation. The RDC's biggest cost component is order picking (63%) and in the outlet filling shelves is most expensive (62% of total outlet costs). Hence from a pure cost perspective, inventory reduction is not the most interesting aspect. However, from a strategic perspective inventory reduction gives more room for expansions in product assortment, which happens to be one of the main strategic objectives.

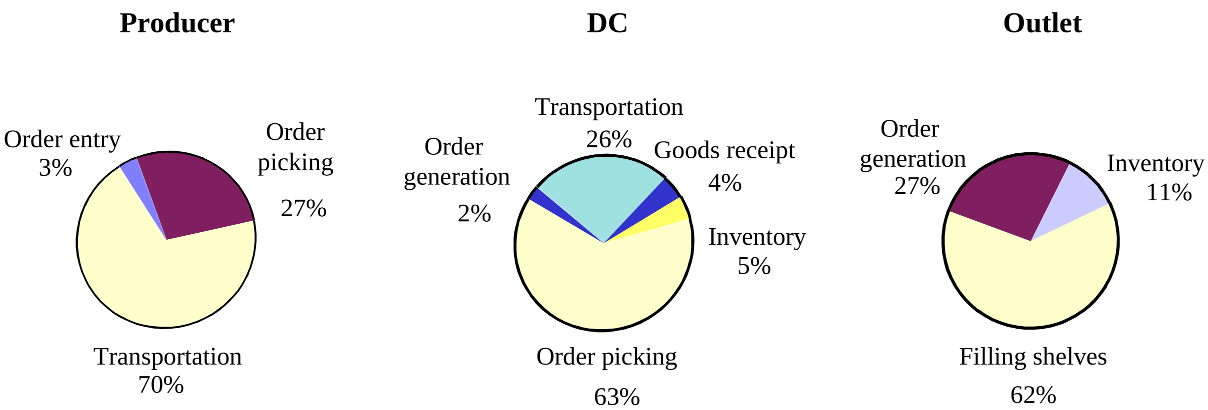


Figure 7.18 Distribution of costs in percent per business process in the base case scenario for each SC stage.

Order policy

The second redesign variable relevant in this case study is the order policy used in the SC. The current base stock order policy in retail outlets aims at filling up shelves. For each scenario the settings of the simulation model are calibrated to obtain 0% no-sales. This means that shelves are made big enough to cope with peak demand in the simulated period. This automatically leads to large shelves that are stuffed with many products; too many for most days. It might be interesting to use a system driven by order forecast. We evaluated the impact on SC performance when the following forecast procedure is used:

$$\text{Order} = (\text{Expected sales during order sales period} + \text{Safety stock}) - (\text{Current stock} + \text{On order})$$

$$\text{where Expected sales} = \sum_{i=t-6}^{t-1} \alpha(i) * \text{sales week } i \text{ during order sales period}$$

Simulation results showed that the implementation of such a forecast-driven ordering system in retail outlets as well as in the RDC could further reduce inventory levels, if the right parameters concerning the validation of historical POS data are chosen. One can imagine that if peaks in demand are forecasted correctly, total inventory levels could further decrease.

However, with the simulation model is was difficult to predict realistic benefits; in particular the simulation of human interventions that occur in reality during peak demand periods or due to other disturbances raised difficulties. And if these sudden demand peaks are not smoothed in the data, this will result in peak orders for several weeks.

Distribution unit size
The final redesign variable we would like to discuss is the distribution unit size. Current distribution units, hence the order batch size, contain 6, 9 or 12 consumer products. If the sizes of these distribution units are reduced higher delivery frequencies to retail outlets become more beneficial. For example, suppose that an outlet sells 30 units of a certain product a week. When the distribution unit is 10 on average the product can be ordered 3 times a week. But when the distribution unit is decreased to 5 this particular product can be ordered up to 6 times a week.

When all distribution units are reduced to one individual consumer product (batch size 1), the simulation of SC scenarios shows that on average this may result in 5 to 10% additional improvements in inventory levels and product freshness for fast movers. Figure 7.19 shows that even higher benefits are obtained for slow movers: a 20 to 35% inventory reduction. However, costs (especially handling costs) will rise considerably.

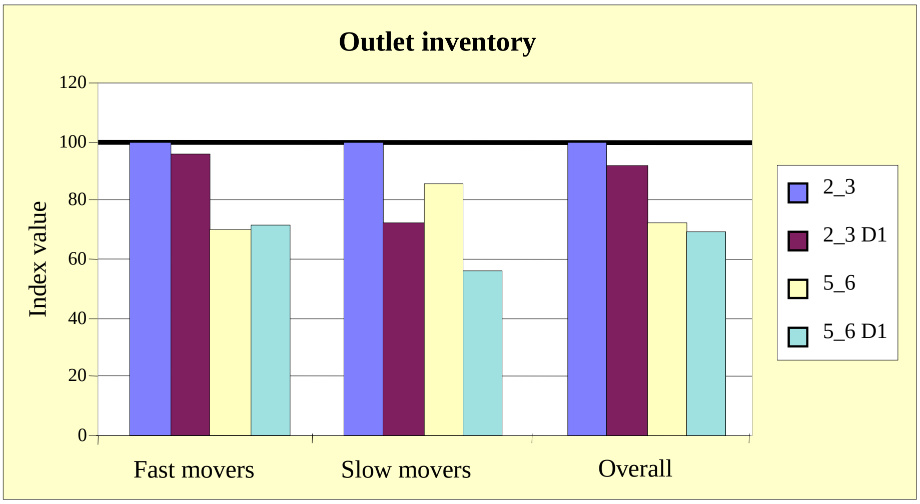
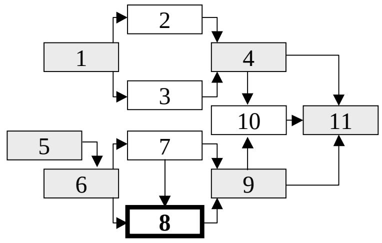


Figure 7.19 Outlet inventory levels when distribution units are reduced to 1 individual product (D1).

7.3.2.4 Sensitivity analysis



The obtained results are sensitive to some of the parameters and input data of the model. *Sensitivity analyses* need to be performed to evaluate the ranking of SC scenarios if minor changes to the data are made. That is, will scenario 5_4 still perform best compared to the other SC scenarios? And how big can the changes be in order to imply a scenario shift? We performed sensitivity analyses on consumer demand data, week distribution functions, delivery days, inherent uncertainty in the RDC lead time, the calibration process to 0% no-sales and, finally, cost definitions. In this section only the main results will be presented; more details can be found in Appendix J.

Consumer demand

Up to now all scenarios were run with real consumer demand data that is subject to considerable demand variability. We evaluated system behaviour in different SC scenarios for 20 weeks of consumer demand without demand variability. Results showed that the ranking of the scenarios does not change; scenario 5_4 still performs best. However, the relative differences between scenarios are smaller. Furthermore, in absolute terms much better results are obtained since inventory levels can be further reduced.

Week demand distribution function in modelled test outlet

The week demand distribution function in the modelled test outlet represents the consumer demand variability within a week at the modelled test outlet. Up to now all scenarios were run with the function presented in Table 7.3, showing major variability.

When the function is smoothed with 1%, fast movers' outlet inventory is reduced slightly especially at lower frequencies. Slow movers show fewer changes. When the week demand distribution function is completely levelled (i.e. constant demand at all days), simulation results show that outlet inventories decline significantly, but also that SC scenarios with $FREQ_{rdc,o}$ 3, 4 and 5 perform practically equal. Note that this function is not realistic since most consumer purchases still take place in weekends. However, according to the project team, scenario 5_4 still performs best. We can conclude that when the week demand distribution function shows less variability the benefits of higher frequencies become less.

Week order distribution function in Mega-outlet

The week order distribution function in the Mega-outlet (see Table 7.4) represents the demand variability at the RDC within a week and depends on $FREQ_{rdc,o}$. The order distribution functions could be deduced from practice for scenario 2_3 (current situation) and 5_6 (field test). The others had to be predicted by the project team.

The sensitivity analysis showed that RDC inventories are very sensitive to changes in demand variability. When the function changes as $FREQ_{rdc,o}$ increases, average RDC inventories increase considerably (see Figure 7.16). This is explained as follows: when $FREQ_{rdc,o}$ increases the outlet orders are more and more based on consumer sales of the day before (to replenish stock). When $FREQ_{rdc,o}$ is maximal each order corresponds to the sales of one day. And since consumer demand shows a peak near the weekend (see Table 7.3) the week order distribution function shows more demand variability as well. From this effect we can explain the increasing RDC inventories depicted in Figure 7.16 as $FREQ_{rdc,o}$ increases.

Order and delivery days
The order and delivery days in each SC scenario were determined by data analysis and expert knowledge. Simulation results showed that it is very important to select the correct days since they have a major impact on performance. It is evident that when peaks in consumer demand occur near the weekends, deliveries should not all take place at the beginning of the week. The model enabled us to evaluate all possible settings and determine the optimal settings for each SC scenario. We will come back to this in Section 7.5, when we evaluate the model results using an analytical approach. We can conclude that the week demand distribution function in retail outlets (the consumer demand variability) combined with the order and delivery days chosen determine for a great deal the benefits that can be obtained in new SC scenarios.

Inherent uncertainties in the SC
What happens to the results when we include inherent uncertainties in the SC? One of the sources of SC uncertainty identified in this SC in Chapter 5 concerned shortages in the RDC resulting in late deliveries of goods and possible stock outs in retail outlets. Up to now the SC scenarios did not consider the presence of inherent uncertainties in business processes (next to demand variability).

We ran SC scenarios in which delays in goods supplies of 24 hours were simulated. The results (see Appendix J) showed that delays cause few no-sales in retail outlets at low delivery frequencies mainly because safety stocks are large. Orders are made to suffice sales for several days, hence when the goods are delivered the next day there is a good chance that no harm will be done. But at higher frequencies, when all slack is removed from the SC, incidents will reduce SC performance immediately. On the other hand, we could conclude that although the system is much more sensitive to disturbances at higher frequencies, problems are solved much quicker.

Calibration to 1% RDC stock outs
The next element in the sensitivity analysis concerns the calibration process of the simulated scenarios. All scenarios were calibrated to 0% stock outs in the RDC and test outlet. In practice such performances are hardly ever realised. Hence, it might be interesting to evaluate the impact of calibration to 1% stock outs in the RDC (Figure 7.20). When we do so, RDC inventory levels drop significantly as expected. On average the order-up-to level is lowered by more than 40% resulting in (allowed) stock outs at demand peaks. Consecutively, this impacts the delivery performance in the outlets.

Allowing stock outs does not influence the ranking of the SC scenarios concerning inventory reductions and product freshness. However, stock outs do significantly influence the absolute benefits to be obtained, which could lead to the conclusion that it costs too much to deliver more frequently. The model can provide information on the exact benefits when different delivery performances are compared. The key practitioners should decide on the trade-off between the benefits to be obtained and costs to be incurred in each SC scenario.

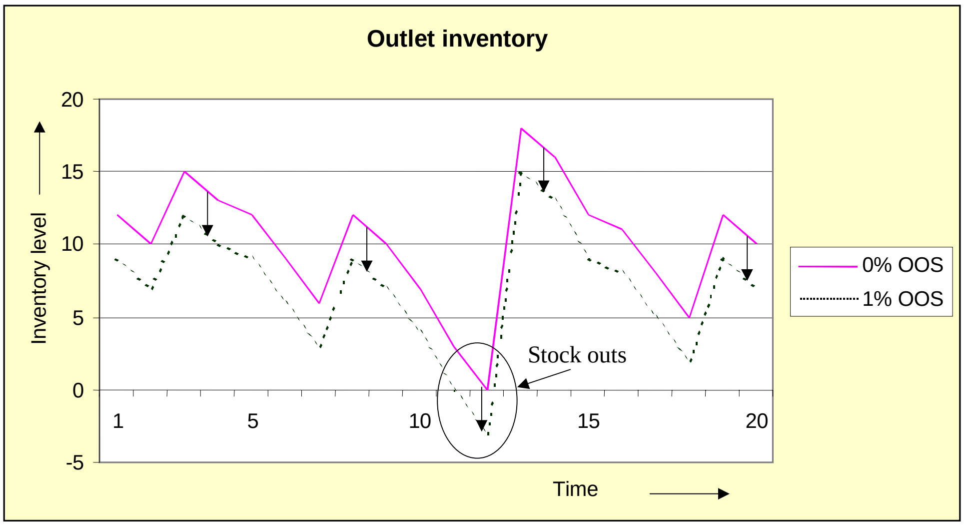
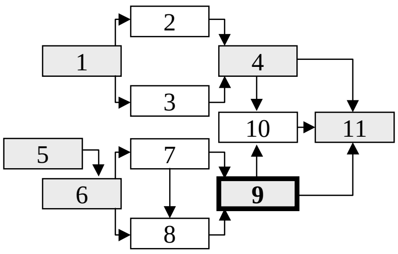


Figure 7.20 Example of dropping inventory levels when 1% stock outs are allowed.

Cost definitions

The final aspect for the sensitivity analysis is the settings of the cost drivers used. Simulation results show that the ranking of the scenarios concerning total SC cost is very insensitive with respect to variations in cost driver settings. However, the absolute cost differences can become relatively small, causing the project team to change their preferred scenario in favour of a scenario revealing higher product freshness at slight higher costs.

7.3.2.5 Conclusions simulation study



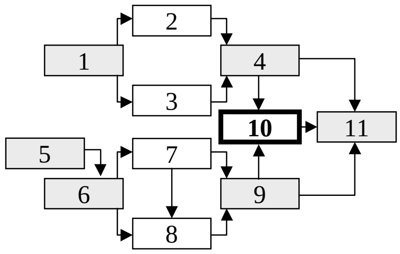
In the simulation study the project team concluded that scenario 5_4 provides the best trade-off between additional cost and obtained benefits. The sensitivity analysis showed that this scenario is relatively insensitive to changes in input data. Preferably an order forecast policy should be used but more research is required to optimise these systems. Furthermore, it would be interesting to decrease distribution unit sizes in the SC.

Table 7.7 showed that in scenario 5_4 process costs will rise by 9%. However, implementation of ICT systems could decrease cost. Furthermore, when we quantify the additional benefits, total SC cost will decrease! These additional benefits stem from:

- reduction in occupied warehouse ground floor (or rented warehouse space);
- fewer no-sales;
- expansions of the product assortment due to inventory reduction at retail outlets;
- field experts expect an increase in sales volumes since fresher products might attract new customers.

Finally, the simulation study showed that each SC scenario has its own optimal order and deliver days in the SC. This is particularly interesting since the RDC uses different delivery schedules for each retail outlet at the moment (to level the workload at the RDC). Because of this, performances could differ significantly between the outlets. Simulation results showed that in this case it might be interesting to use category management principles to try to smooth consumer demand variability within a week.

7.3.3 Model validation: field test results versus simulation results



We validated the simulation model and its results in several ways as described in Section 7.2.3.3. Simulation of the current real life scenario (scenario 2_3-3) revealed that the simulated performance approached reality (empirical validation).

We were also able to obtain an indication of the validity of the results of the simulation study by comparing the results of the field test (scenario 5_6 in the model study) with the simulated scenarios (see Table 7.8). Because only few retail outlets were involved in the field test no change in the demand variability at the RDC, i.e. the week order distribution function, is made in the model. Hence, scenario 5_6 is run with the same week order distribution function as scenario 2_3-3 (the standard situation).

Table 7.8 Comparing the results of the field test with the results of the simulated field test.

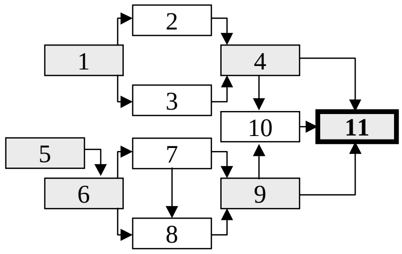
Performance indicator	*Product type*	*Field test*	*Simulation model*
Change in RDC inventory	Fast mover	- 52% (from 5.3 to 2.6 days)	- 51% (from 4.4 to 2.1 days)
	Middle mover	- 67% (from 6.6 to 2.1 days)	- 52% (from 3.9 to 1.9 days)
	Slow mover	- 52% (from 5.3 to 2.5 days)	- 53% (from 5.2 to 2.4 days)
Change in retail outlet inventory	Fast mover	- 47% (from 6.4 to 3.3 days)	- 31% (from 4.3 to 3.1 days)
	Middle mover	- 20% (from 9.5 to 6.2 days)	- 19% (from 5.5 to 4.6 days)
	Slow mover	+ 49% (from 6.0 to 8.9 days)	+ 5% (from 6.1 to 6.4 days)
Change in product freshness for consumer	Fast mover	+ 4.0 days	+ 5.0 days
	Middle mover	+ 6.4 days	+ 4.4 days
	Slow mover	- 1.7 days	+ 3.9 days

Table 7.8 shows that in general the results of the model study correspond to the results of the field test. The differences can be explained as follows:

- In the simulation study two “optimised” scenarios (both 0% stock outs) were compared, which (virtually) increased inventories (see Figure 7.19). In the field test a “nearly optimised” situation (on average 2.6% stock outs in retail outlets in the pilot) was compared with a situation with more slack (on average 4.2% stock outs in the 0-index).
- The order forecast driven system in the outlet was very difficult to model. Hence, Table 7.8 uses the simulated SC scenario with a base-stock policy. We already showed that a CAO system out-performs this policy.
- The simulation model was fed with 20 weeks of sales data, which showed more demand variability than sales data during the pilot study. This required the presence of higher safety stocks.
- The simulation model uses the order policies as formalised. This was not the case in the field test; managers ordered too much for slow movers. Hence, inventory of slow movers increased in retail outlets in the pilot by 49% and in the simulation model by only 5%.
- The results of the field test are not statistically evaluated. The measurement periods should be extended to a much longer period to obtain more reliable figures.

Although the outcomes were not identical for the reasons given above, the experts concluded that the model did discriminate satisfactorily between different scenarios. They concluded the model did predict probable trends and directions in the potential benefits to be obtained. This was mainly because all participants had been involved in developing the simulation model and were fully aware of all underlying assumptions.

7.3.4 Conclusions case IIA



In Chapter 5 the main sources of SC uncertainty were identified for the SC for chilled salads:

- lack of insight into sales and inventory levels in the SC due to current ICT systems;
- the relatively long RDC order lead time (3 days) combined with the possibility to order only twice a week.

This case study showed that a reduction of these SC uncertainties may improve service levels significantly, although current SC configurations restrict possible benefits. Comparable trends in results were obtained in the field test and with simulation studies, thereby indicating a degree of validity in the trends predicted by the simulation model. On the other hand, the model showed that the results obtained in the field test, especially at the RDC, will not occur in practice if all outlets are delivered more frequently. The reason for this is that the RDC will have to cope with increased demand variability.

The project team concluded that the model captured the relevant characteristics of the SC. It provided good insight into the potential benefits and could distinguish between SC scenarios. Which scenario a SC should choose depends on the trade-off between service levels and total SC costs, which should be made by the key SC participants.

Although the simulation study advises the participants to implement scenario 5_4, the field test provides us with some additional information that changes this advice. The project participants experienced timing and capacity problems in all SC stages when the higher frequencies were implemented and the lead time was decreased to 24 hours. The implementation of new ICT systems is a prerequisite for overcoming these barriers. EDI and real-time control systems as well as training and education seem to be necessary. The project team concluded that at this moment scenario 3_4 would be the best practice SC scenario. However, higher frequencies could become interesting as these timing constraints are solved and especially if distribution unit sizes are reduced (or consumer demand increases!) for slow and middle movers. Of course, from Figure 7.21 it can be imagined that the discussion would then focus on the cost/benefit division. This figure shows the distribution of the extra costs incurred at higher order and delivery frequencies. We will pay more attention to this feature in Chapter 9.

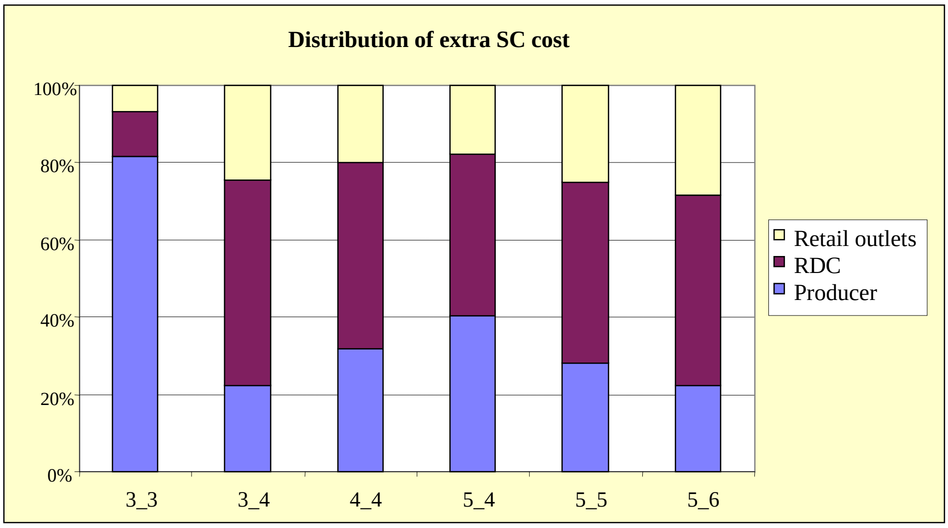
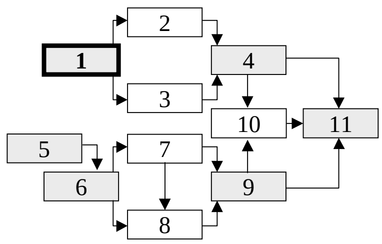


Figure 7.21 Distribution of extra costs made in the SC over the SC participants.

7.4 Case IIIA: the supply chain for cheese and desserts (revisited)

In this section the results of the field test and simulation study in the SC for cheese and desserts are discussed. For a complete description of this SC and its processes we refer to Chapter 5. In this case the producer's end-product inventory is taken along in the analysis. Because the retailer requires specific packaging for cheese products the producer holds a customer specific end-product inventory. Furthermore, the retailer accounts for about 15% of sales volume for desserts.

7.4.1 The field test



7.4.1.1 Field test design

For the general design elements we refer to Section 7.2.2. In this SC, two retail outlets were chosen for the field test: one test outlet and one standard outlet. Both are representatives of the larger retail outlets. Preliminary simulation results indicated that a delivery frequency of four times a week would perform best. Hence, the project team decided to implement the following pilot scenario in the field test:

- The order and delivery frequency was increased from two times to four times a week; the test outlet sends orders by fax on Monday, Wednesday, Thursday and Friday before 12:00 hrs directly to the producer. In this way the time benefits of EDI are approached since the order flow skips the RDC. (Also, the array of article numbers on the fax was adjusted to the array in the producer's system 'eliminating' data search errors).
- The cheese producer processes, picks and delivers the test outlet orders to the RDC within 4 hours, i.e. he delivers the products before 16:00 hrs to the RDC. The test outlet is supplied by the RDC the morning after together with other (fresh, frozen or non-food) products for which the delivery schedule was left unchanged.
- Currently, promotional products are ordered on Friday before the promotion week and Tuesday together with the regular order in the promotion week. During the pilot the test outlet had two additional (corrective) order moments to order additional products.

- All other processes were kept the same. Of course, the time windows of each critical business process had to be changed to facilitate the shorted throughput times (in most cases the waiting times are reduced considerably).

Figure 7.22 depicts an EPC model of the pilot SC scenario. The changed time windows for the business process are evident when we compare this figure with the EPC model of the standard SC scenario (Figure 5.15).

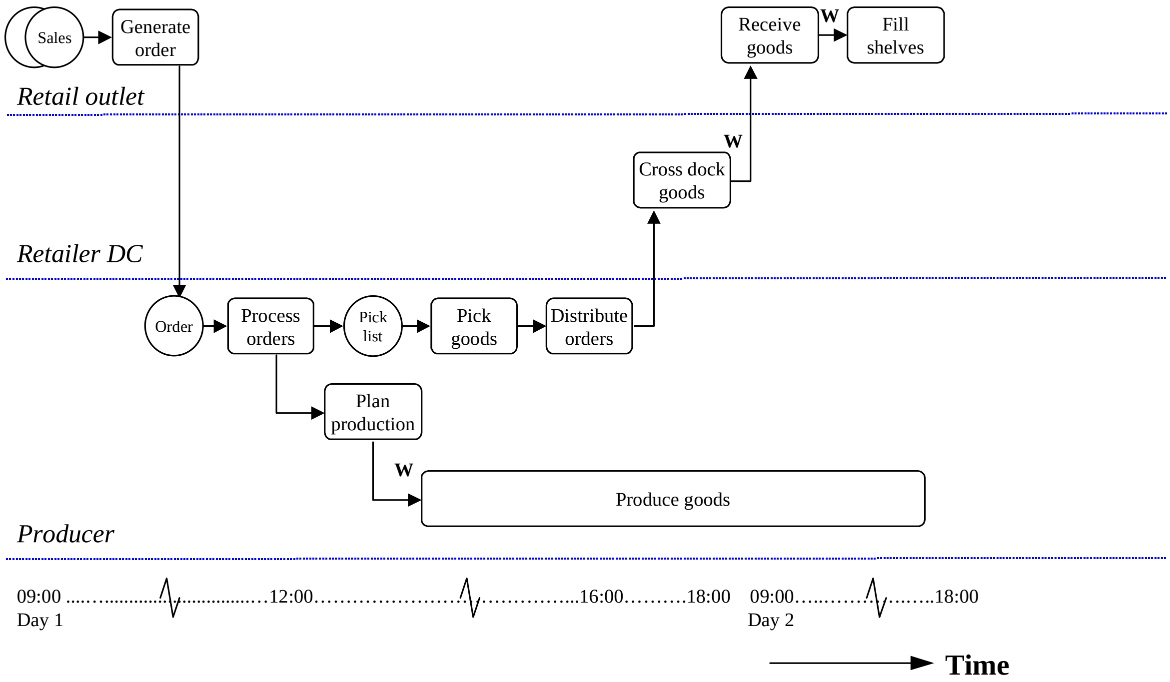
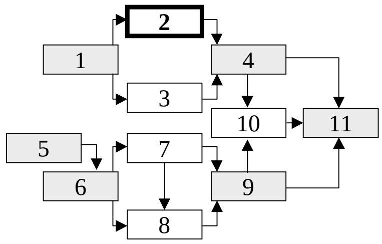


Figure 7.22 EPC-model for the pilot SC scenario in the SC for cheese and desserts.

The field test was performed in the period from September 30 to December 7. During the test, the complete product assortment of this producer was delivered more frequently. The SC partners selected 12 products (unique article numbers) for detailed measurements including 7 cheese products and 5 dessert products. This selection was based on point-of-sale information of the last four months and aimed at selecting products that represented slow-moving, middle-moving and fast-moving products.

A very important change in the field test design was made because the SC participants were afraid that two weeks for the 0-index was too short. But an extension of the field test to December was not possible because of capacity restrictions. Therefore, in this SC we started immediately with the pilot SC scenario and tried to measure the base case SC scenario afterwards. In order to eliminate the change effect in the standard SC scenario the 0-index measurement was extended to 3 weeks.

7.4.1.2 Qualitative results



During the field test several aspects of the SC system presented problems concerning the new SC scenario and the corresponding data gathering:

- In this SC too, the retail manager responsible for ordering the goods at the standard outlet felt uncomfortable filling in the data forms each day (he experienced no benefits at all in the pilot). Unfortunately, because of this the results of the standard outlet could not be used for comparison.
- The first week of the pilot revealed many errors in the data collected. Furthermore, the retail manager had to get acquainted with the new SC scenario. Therefore, the pilot was extended to 7 weeks.

This field test was also concluded by a workshop in which all key participants could discuss their experiences. The main points made by the retailer's employees were the following:

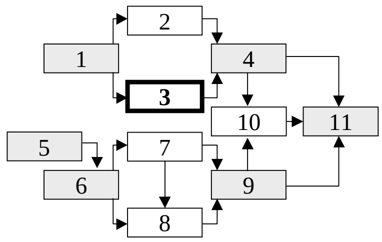
- Stock levels for some slow movers could be decreased to about 4 products. However, this is not possible due to the required presentation stock in shelves; a certain minimum amount of products is required to make the products attractive to consumers. To avoid the problem of empty shelves, empty boxes were used to fill up shelves (this did, however, require extra cooling costs).
- Because the retail manager had to check inventory levels several times a day he gained more insight into consumer demand for these products. This provided him with an additional benefit when ordering the products. But when many more SKUs need to be ordered frequently, this 'insight advantage' disappears since it is impossible to keep sight of demand patterns of all products. Then an automated system is required to show demand patterns to the retail managers and to assist them in the ordering process.
- According to the retail manager, the total time needed to generate orders and fill shelves in the pilot SC scenario was less than in the standard SC scenario even though these processes were executed more times a week. The reason for this (according to the retail manager) is that in the standard SC scenario products that do not fit in the shelves are stored in the air-conditioned storage facility requiring additional re-filling activities during the week.
- The additional opportunities to order extra products in promotion weeks proved to be very useful since one could then order more restrictively and make corrections later if necessary. The new SC scenario partially eliminated forward buying.
- On three occasions the RDC had some 'SC interaction' problems; for example, a truck left the RDC much too late because other suppliers (whose products were also transported by that truck) had delivery problems. This resulted in deliveries arriving much too late at the test outlet, which decreased performance.

The main points made by the producer's employees were the following:

- The order entry at the producer took less time since the array of article numbers on the outlet fax was adjusted to the array in the producer's system.
- The four-hour time span given to the producer to supply the RDC with the outlet orders was sufficient in the pilot. But it would not suffice if more customers demand shorter lead times. Without EDI and corresponding order processing technologies, such SC scenarios are not feasible. Another possibility would be that outlet orders come in the night before and order picking is transferred to the night.

- Furthermore, time measurements at the producer's order picking process showed that the total picking time needed in a week increases significantly when the order and delivery frequency increases.
- The production planner was sceptical of the implementation of the new SC scenario since this will eliminate his safety time to produce rush orders. He thinks the producer's safety stock levels need to be increased to compensate for the elimination of this safety time.
- The test outlet proved to be favoured in order picking situations during the pilot. Because order pickers knew their performance was being measured, they favoured the test outlet by sparing that outlet when shortages occurred. This influenced performance indicators.

7.4.1.3 Quantitative results



The data gathered during the field test was processed to assess the impact of the pilot SC scenario on SC performance. When data was missing on the forms, we were able to recovere it using historical data and data (such as deliveries and orders) from the other SC partner. The adjustment made to the new order frequencies proved to be difficult for the participants in the first two weeks, as the desired order pattern was not completely followed (see the order peak in Figure 7.23).

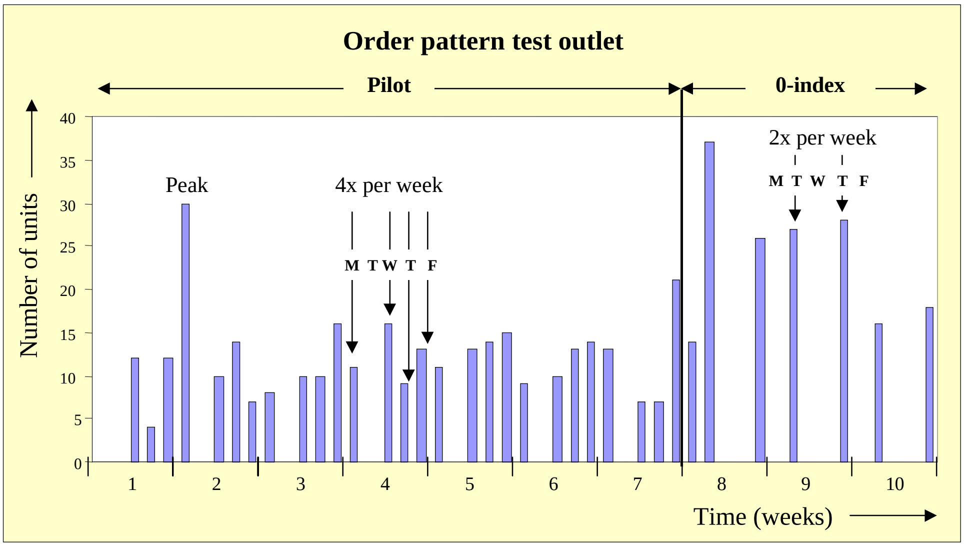


Figure 7.23 Order pattern of the test outlet during the field test (the letters refer to the weekdays Monday (M) to Friday (F)).

On average fast movers were ordered 3.8 times a week during the pilot versus 2 times in the standard situation. Middle movers 2.5 versus 2 times a week and slow movers 1.1 versus 0.5 times a week. This indicates that most benefits are obtained by fast movers. Middle and slow movers only used the extra order moments in the pilot to optimise the specific day of ordering.

Figure 7.24 depicts the stock levels of the test outlet during the field test. This figure confirms the high fluctuations in inventory in the first two weeks, especially for fast movers. Therefore, in the performance calculations the data of week 1 and 2 are not taken along. Also, data from weeks 7 and 8 are eliminated to avoid the change-over process from the pilot SC scenario to the standard scenario.

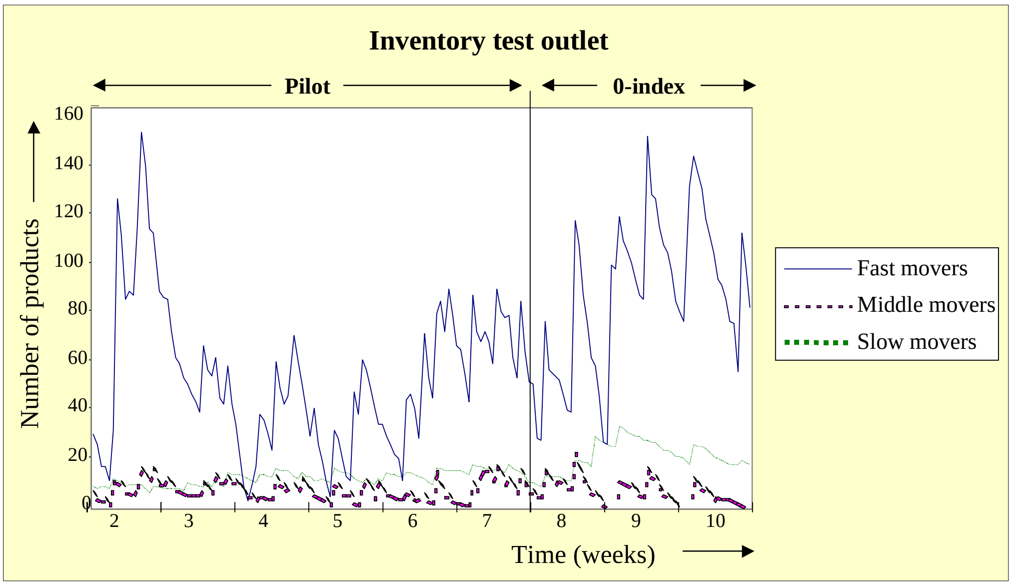


Figure 7.24 Inventory levels in the test outlet during the field test.

On average, the inventory levels during the pilot SC scenario (weeks 3-6) in the test outlet were lower than during the standard SC scenario (weeks 9-10). When the standard SC scenario was re-established, fast movers inventory increased on average by 50%; based on average point-of-sale data inventory increased from 2.3 days to 4.7 days of stock. Also, slow movers inventory increased on average by 50% from 5.6 days to 11.4 days of stock. But these products were partly over-ordered at the end of the pilot. Middle movers showed about 30% less stock in the 0-index (from 1.8 to 1.4 days of stock). However, these low inventories for middle movers caused a relatively high degree of stock outs.

From the analysis it became clear that the retail manager had great difficulties in determining the best order moments and order quantities for these middle movers. This was mainly caused by the minimum order batch size (which is up to 20 units), which restricts more frequent ordering. Furthermore, he did not have enough time to analyse each product. This confirms the findings in case IIA, in which high importance was given to automated ordering in retail outlets to assist the ordering process. Such a forecasting system can determine the optimal order moment and quantity for all products in order to prevent stock outs.

Product freshness is mainly relevant for the desserts, since shelf lives for cheese products are over 70 days. The results of focusing on the desserts are listed in Table 7.9. Note the remarks just made concerning the inventory changes.

Table 7.9 Changes in product freshness for desserts when implementing the pilot SC scenario.

	Supplier	**Producer**		**Outlet**	
Desserts product type	*Average shelf life delivered*	*Average shelf life in stock*	*Change of shelf life in pilot*	*Average shelf life*	*Change of shelf life in pilot*
Fast mover	22.1 days	21.4 days	+ 0.0 days	16.5 days	+ 2.3 days
Middle mover	23.4 days	22.7 days	+ 0.6 days	17.9 days	+ 1.3 days
Slow mover	22.1 days	21.2 days	+ 0.3 days	8.1 days	+ 2.9 days

Figure 7.25 depicts the course of the remaining shelf lives for a fast-, a middle- and a slow-moving dessert in the test outlet. It shows that the product freshness for fast and middle movers follows a saw-tooth pattern, i.e. it increases suddenly and then decreases for several days. This is because the products the producer delivers sometimes come from the same batch number. Hence, they have the same remaining shelf lives as the products already in the shelves. This is even more so for the slow mover, which is also a slow mover at the producer. This also led to some write-offs for slow movers in the field test. The SC benefits will be higher when the producer is able to purchase his desserts more frequently at both suppliers and lower his inventory turnover rates.

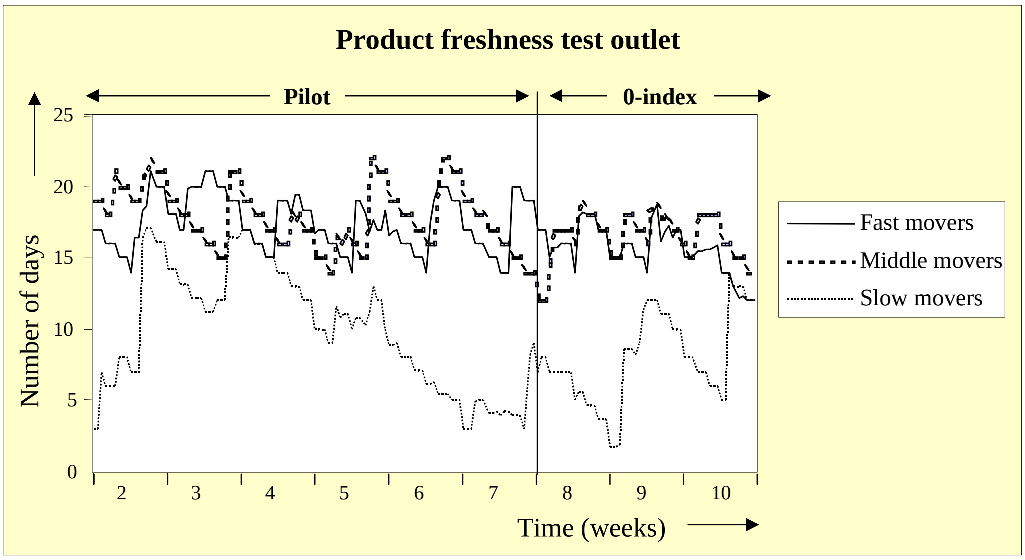
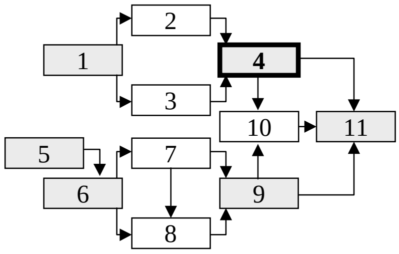


Figure 7.25 Remaining shelf lives of desserts in the test outlet during the field test.

Time measurements for order picking at the producer showed that the total picking time for the test outlet in an average pilot week was higher than in an average 0-index week even if total quantity was the same. This confirms the findings in case IIA that higher delivery frequencies result in shifts in required process capacities.

Finally, the project team concluded that the measurement periods (of especially the 0-index) were probably too short for the SC system to arrive at relatively stable system behaviour. Unfortunately, Christmas was approaching so it was impossible to go on. Therefore, the data are not statistically evaluated. Also note that in this case the retail manager could use the insights obtained during the pilot period in the 0-index.



7.4.1.4 Conclusion field test

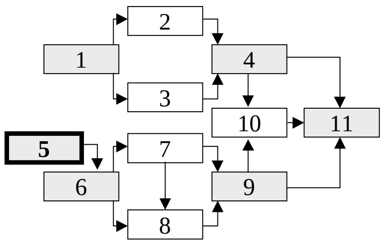
The project team concluded that the field test did provide good insight into the organisational and infrastructural consequences of the new SC scenario and it also gave an indication of the benefits to be obtained. To realise the potential benefits some infrastructural changes need to be made. First of all, EDI is required to eliminate the time-intensive manual order processing at the producer. Second, an automated ordering system in retail outlets should assist retail managers in the order processing and differentiate between product types. If more benefits are to be obtained, a good option is to reduce the sizes of the distribution units used. Finally, increasing the delivery frequency of the dessert supplier to the producer would further improve performance.

Table 7.10 concludes the field test with an overview of the quantitative results obtained. In general we can conclude that if the retail manager had followed the ordering patterns correctly, slow movers, and some of the middle movers, would reveal few changes in the new SC scenario, since it is simply not possible to significantly increase the order frequency.

Table 7.10 Overall field test results for the SC for cheese and desserts.

Product Type	**Producer**	**Outlet**		**SC scenario**
	Delivered freshness	*Inventory*	*Freshness in shelf*	*SC freshness*
Fast mover	+ 0.0 days	- 50%	+ 2.3 days	+ 2.3 days
Middle mover	+ 0.6 days	+ 30%	+ 1.3 days	+ 0.7 days
Slow mover	+ 0.3 days	- 50%	+ 2.9 days	+ 2.6 days

Note that the increase of stock levels at the retail outlet for the middle movers was caused by wrong ordering patterns; too little products were ordered in the 0-index resulting in many stock outs.



7.4.2 The simulation study

Figure 7.26 presents an overview of the simulation model for the SC for cheese and desserts. In this case study the Mega-outlet represents 25 retail outlets.

7.4.2.1 Modelled business processes

A detailed description of the SC for cheese and desserts is already given in Chapter 5. This case study does not model the complete SC with all its aspects. Only those business processes that are considered to impact our main performance indicators are dealt with in the modelling process (see Figure 7.27). Note that the RDC in this SC cross-docks perishable products; hence it holds no inventory. Based on the findings in Chapter 5 we can list the main performance indicators for this simulation project in order of ranking:

1. fewer to no stock outs in retail outlets resulting in higher sales
2. lowest inventory levels in retail outlets
3. highest remaining product shelf lives for consumers
4. lowest integral cost of all SC business processes

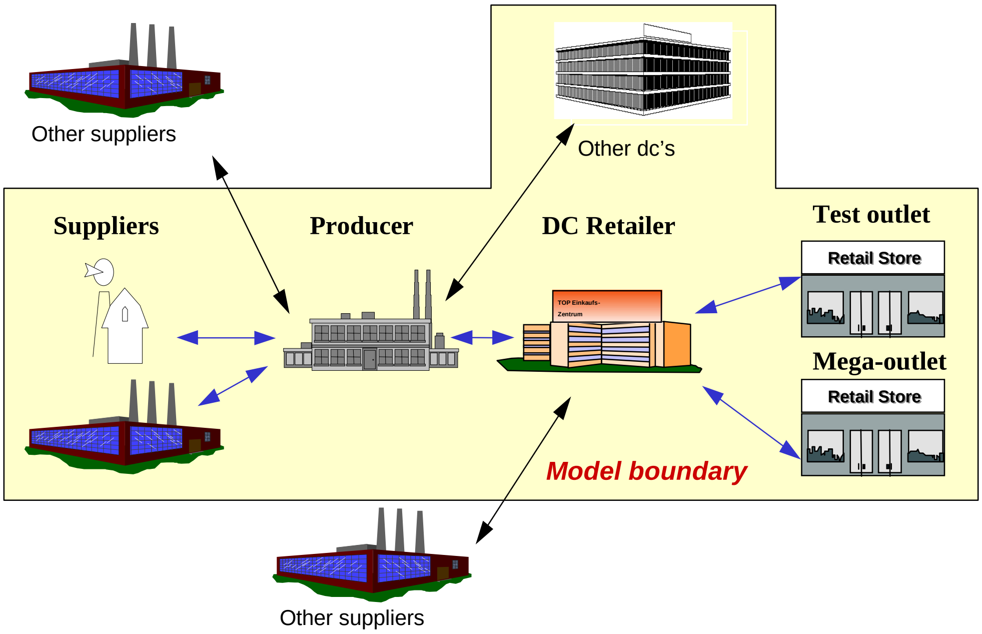


Figure 7.26 Overview of the simulation model of the SC for cheese and desserts.

In all *retail outlets* cheese and desserts are sold during opening hours. At a certain frequency and at fixed times retail outlets place orders at the RDC according to a base stock policy (on order refers to orders that are not yet delivered):

New order = Shelf capacity – Current stock – On order

The order batch size is a fixed number of consumer products that varies for each product varying from 1 to 20 units. During closing hours, all stocked goods are checked for their remaining shelf life. If the BBD is reached, goods are written off.

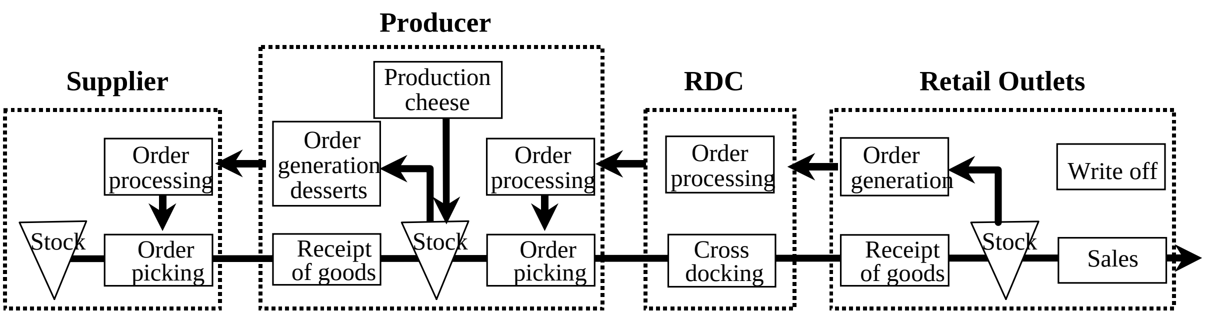


Figure 7.27 The business processes modelled within the supply chain for cheese and desserts.

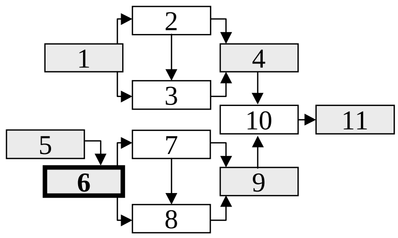
At the RDC outlet orders are processed at fixed times, which means that they are checked and forwarded to the producer. Some time later goods are received and consecutively cross-docked with other products to retail outlets according to a fixed delivery schedule.

The *producer* processes the orders directly, which results in an order pick list per retail outlet. Some time later the orders are picked per retail outlet and grouped on a secondary unit load (roll-in container). All containers are collected into a shipment, which after a short delay are shipped to the RDC. The producer supplies the RDC several times a week from stock. If there are shortages, a rationing policy is followed giving each outlet the same percentage of the shortage. Stocks for cheese products are replenished during the week according to the production schedule. Furthermore, desserts are ordered at suppliers using a base stock order policy.

Finally, one *supplier* supplies the producer with desserts every day of the week. The other supplier delivers the producer two times per week with an order lead time of 6 days. Hence, the producer has to deal with overlapping order periods. We assume shortages do not occur.

Note that the products in this SC can be characterised in two groups. Cheese products are packed at the producer specifically for this retailer. Desserts are supplied by suppliers and delivered to multiple retailers. Hence, when discussing the simulation results we will distinguish between cheese products and desserts.

7.4.2.2 Simulated SC scenarios



In the simulation study we quantified the consequences of different SC scenarios with respect to the performance indicators for the 12 selected representative products in the pilot. Table 7.11 presents the relevant SC redesign variables (see also Section 7.2.1) and the allowed settings that were defined by the project team (based on expert judging).

Be aware that the delivery to the RDC and the delivery to the outlets are coupled in this SC because of the cross-docking principle. A combination of settings for all these SC design variables defines a SC scenario. Most SC scenarios require the installation of ICT systems to facilitate the changing of time windows of SC business processes. For these scenarios these ICT systems are assumed to be present.

Table 7.11 SC redesign variables and allowed settings

SC design variables	*Allowed settings*
Order and delivery frequencies between producer and outlets	2, 3, 4, or 5 times a week
Order lead time producer (see Appendix H)	3 days or 1 day
Order policy retail outlets	Base stock or CAO forecast procedure
The distribution unit size	Current size or size = 1

In this SC too, the project team, based on practical experiences, determined the settings for the order and delivery days and times (see Appendix K). Figure 7.28 clearly shows the timing of each business process needed to realise an order lead time for outlets of about 24 hours.

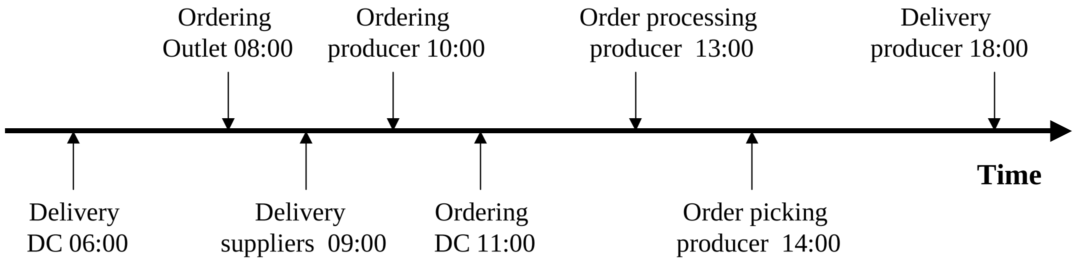


Figure 7.28 Time windows in the simulated SC for cheese and desserts.

When the point-of-sale data in the test outlet is analysed the general buying pattern presented in Table 7.12 is found. In this case we refer to the *week demand distribution function*.

Table 7.12 Test outlet week demand distribution functions in percentage of total week demand.

	Monday	*Tuesday*	*Wednesday*	*Thursday*	*Friday*	*Saturday*
For all frequencies	11%	13%	15%	21%	19%	21%

The *week order distribution* of the Mega-outlet in this SC is presented in Table 7.13. The distribution function of the Mega-outlet is determined for the current situation, i.e. all outlets are delivered 2 times a week (delivery frequency 2x), and during the field test in which the outlets are delivered 4 times a week (delivery frequency 4x). The other demand functions are based on real demand data and were justified by expert testing.

Table 7.13 Mega-outlet week order distribution functions in percentage of total week demand.

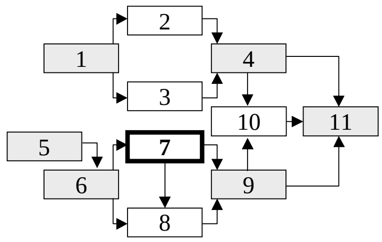
Delivery frequency	*Monday*	*Tuesday*	*Wednesday*	*Thursday*	*Friday*
2x		60%		40%	
3x	36%		40%	24%	
4x	28%		21%	19%	32%
5x	13%	15%	21%	19%	32%

The cost drivers for each business process were determined in the project team (Table 7.14). In general the same cost drivers were chosen as in the SC for chilled salads (see Table 7.5). The main differences compared to the SC for chilled salads are presented in *italics*.

Table 7.14 Cost drivers per SC business process for the SC for cheese and desserts.

SC stage	*Process*	*Cost driver*
Retail outlet	Goods receipt and filling shelves	Number of secondary unit loads + number of unit loads
	Inventory	Number of products (interest and purchase price)
	No-sales	Number of products (consumer price)
	Write-offs	Number of products (purchase price)
	Order processing	Number of order lines
RDC	Order processing	Number of orders
	Goods receipt	Number of deliveries + number of unit loads
	Transportation	Number of secondary unit loads
Producer	Order processing	*Number of order lines*
	Order picking	*Number of orders + number of order lines*
	Inventory end-products	Number of products (interest and customer price)
	Transportation	*Number of deliveries*

Total costs per link are calculated by adding costs related to all business processes in that link (including the costs of write-offs) and by transposing the results for the 12 products to the total product assortment. Total chain cost is the sum of the cost of producer and RDC and 25 times the costs made in the average retail outlet. *Total process cost* refers to total cost minus write-offs. This gives an insight into the cost of human labour related to the execution of all business processes.



7.4.2.3 Simulation results

Numerous scenarios were simulated, but we will focus on the most important results. Subsequently, we will discuss the impact of different order and delivery frequencies and lead times, order policies and distribution units. The simulation model was run as a deterministic model with real consumer demand. The presence of inherent uncertainties is evaluated in the next section, where the robustness of specific SC scenarios is discussed. Because of the confidentiality of the data all outcomes were transformed into changes relative to scenario 2-1 (i.e. the original SC scenario but with a SC lead time of one day). In this SC scenario 2-3 is the real-life scenario. Furthermore, the following notations are used:

FREQ	The order and delivery frequency per week between the producer and the RDC and the RDC and retail outlets
LT	The lead-time to retail outlets (in days)
a-b	SC scenario with FREQ = a and *LT* = b (for typographic reasons b is only given when *LT* = 3).

Lead time and frequency

The average values of the performance indicators for the simulated scenarios are presented in Table 7.15. The ordering and delivery days used at each frequency are listed in Appendix K. For scenario 2-3, 2 and 4 the ordering days for retail outlets correspond to the days used in the field test.

When *LT* is decreased to one day (scenario 2-3 versus 2), the outlet inventory decreases on average by 21%. Products gain on average about 4 days of freshness when the lead time is shortened from 3 days to 1. In the sensitivity analysis (see also Appendix L) we will see that these benefits are mainly obtained by a shift in delivery days in the SC scenario (now products are delivered on Saturday instead of Friday). Furthermore, scenario 2 has a much shorter reaction time than 2-3 enabling the outlet to lower safety stocks.

When *FREQ* is increased, both outlet inventories and throughput times decrease. On average, lowest stock levels are obtained when *FREQ* = 4. Increasing *FREQ* further gives no additional benefits. Figure 7.29 depicts the benefits obtained per product type.

Table 7.15 Overview of the most important results of simulated SC scenarios in the SC for cheese and desserts (the base-case scenario 2 is printed in bold).

SCENARIO					
Performance indicator	2-3	**2**	3	4	5
Outlet					
Stock level	121	**100**	87	82	87
Throughput times	123	**100**	88	88	92
Write-offs	0	**0**	0	0	0
Total cost	102	**100**	103	105	107
Distribution centre					
Total cost	100	**100**	150	200	250
Producer					
Stock level cheese	119	**100**	109	108	109
Stock level desserts	130	**100**	100	100	100
Total cost	103	**100**	134	164	189
Supply Chain					
Product freshness cheese (in days)	64.1	**68.4**	67.1	67.5	67.3
Product freshness desserts (in days)	10,0	**13,0**	14,5	13,7	13,9
Total cost	102	**100**	112	123	133

Figure 7.29 shows that middle movers perform best when *FREQ* = 3. The inventory of slow movers is practically the same for *FREQ* = 3 and 4. Just as we found in case IIA, the sizes of the distribution units (i.e. the minimum order batch sizes) restrict major benefits for slow and middle moving products as they hinder more frequent ordering.

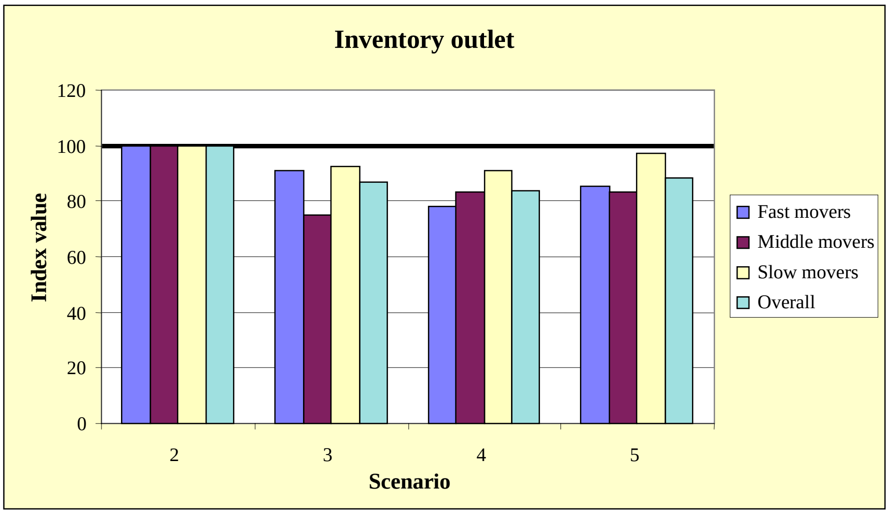


Figure 7.29 Stock levels in the retail outlet.

The additional ordering moments at higher frequencies are not always useful (see Appendix M). Because of the base stock ordering policy, shelves are filled at every replenishment cycle, sometimes increasing stock levels when there is no actual need for it. Figure 7.30 depicts the results in retail outlets for the simulated SC scenarios concerning throughput times. It shows that middle movers obtain the highest benefits as a result of significant inventory reductions.

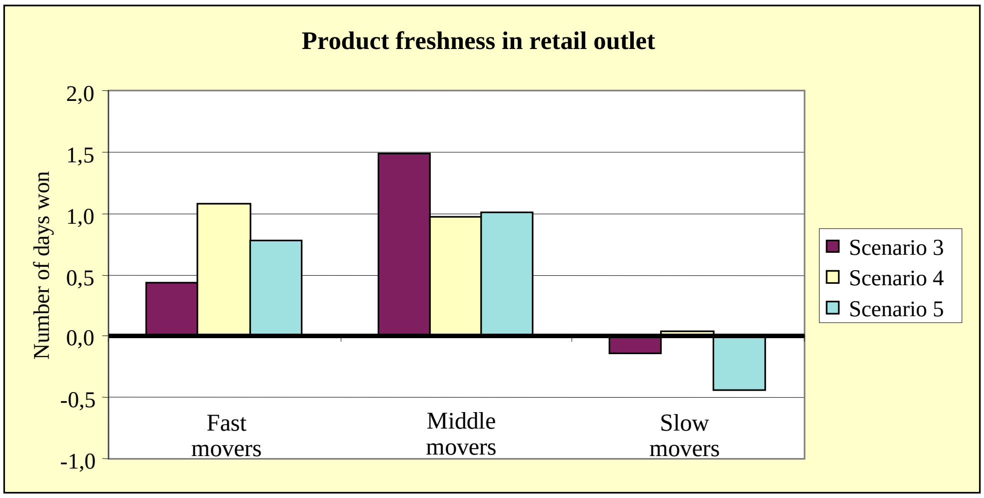


Figure 7.30 Throughput time reduction in retail outlets per product type compared to scenario 2.

Table 7.15 also shows that when *FREQ* is increased, the producer's inventory of cheese products and related throughput times increase slightly. This is because, at the moment, cheese products are only produced once a week, on Monday. Hence, when the retailer is delivered to more frequently in the week, the inventory decreases more gradually, resulting in an increase of average inventory at the producer. For example, the 50 products that are supplied on Monday in scenario 2 are partly delivered on Monday (e.g. 30 products) and Wednesday (20 products) in scenario 3. And at these successive delivery moments to retail outlets, products from the same original production batch are delivered. Consequently, the remaining product shelf life decreases at each delivery. On the other hand, desserts are supplied to the producer more frequently. Furthermore, the producer also delivers desserts to other retailers, resulting in a high inventory turnover for these products (about 3 days). These features are responsible for the difference in gains in product freshness for desserts and cheese products in the SC (see Table 7.15). These results indicate the necessity to increase the producer's production frequency in order to obtain the extra shelf life benefits more frequent delivery could bring.

Table 7.15 further shows that the producer and RDC process cost increase notably when *FREQ* increases. In particular, the order pick cost at the producer and the transportation cost of the producer and RDC increase considerably. Table 7.16 gives more detailed results concerning costs of the simulated SC scenarios. All costs are indexed to the values that are obtained in scenario 2. The table shows that each extra delivery increases SC process cost by about 10%.

In the *retail outlets*, especially the order generation cost will rise. As the field test already showed, automated support seems necessary to generate orders for all products in case the order frequency is increased. The time needed for receipt of goods and filling shelves increases but not drastically. One aspect that was not taken along in the model but was found in the field test is that when using low delivery frequencies shelves are too small to fit all products. Hence, shelves need to be refilled several times (a day), which further increases process cost. At higher frequencies this refilling process is eliminated. Note that total cost will decrease at higher frequencies because of a decreasing number of write-offs and no-sales.

Table 7.16 Cost overview of the most important simulation results for the SC for cheese and desserts.

			SCENARIO		
Performance indicator	2_3	**2**	3	4	5
Outlet					
Order generation	101	**100**	128	149	160
Inventory	123	**100**	93	82	89
Goods receipt / filling shelves	101	**100**	102	102	103
Total cost	102	**100**	103	105	107
Distribution centre					
Order processing	100	**100**	150	200	250
Goods receipt	100	**100**	150	200	250
Transportation	100	**100**	150	200	250
Total cost	100	**100**	150	200	250
Producer					
Order processing	101	**100**	128	149	160
Inventory end-products	128	**100**	101	101	101
Order picking	101	**100**	131	156	172
Transportation	100	**100**	150	200	250
Total cost	103	**100**	134	164	189
Supply Chain					
Total cost	102	**100**	112	123	133

The project team assumed that all process costs at the *RDC* depend on the number of orders and secondary unit loads (see Table 7.16). Overall, these numbers will hardly change when the frequency is increased, causing the RDC cost to increase linearly with the increasing number of deliveries.

Because of the manual labour required to process orders, the *producer's* cost increases significantly when *FREQ* increases. Furthermore, the order picking cost depends mainly on the number of order lines and this number increases as *FREQ* increases. Since the producer pays a fixed amount for each delivery, the transportation cost increases linearly. The utilisation degree of the truck will change slightly since the number of secondary unit loads decreases a bit. Only the larger retail outlets will see a change from two containers to just one at each delivery. And as may be expected, the utilisation degree of the containers shrinks (see Figure 7.31), giving room for new distribution concepts. For example, it might be interesting to shift the order picking process per outlet to the RDC and only give the aggregate outlet orders to the producer. This will allow the producer to supply the goods on several pallets that can be order picked and cross-docked at the RDC. This will certainly decrease the producer's transportation cost.

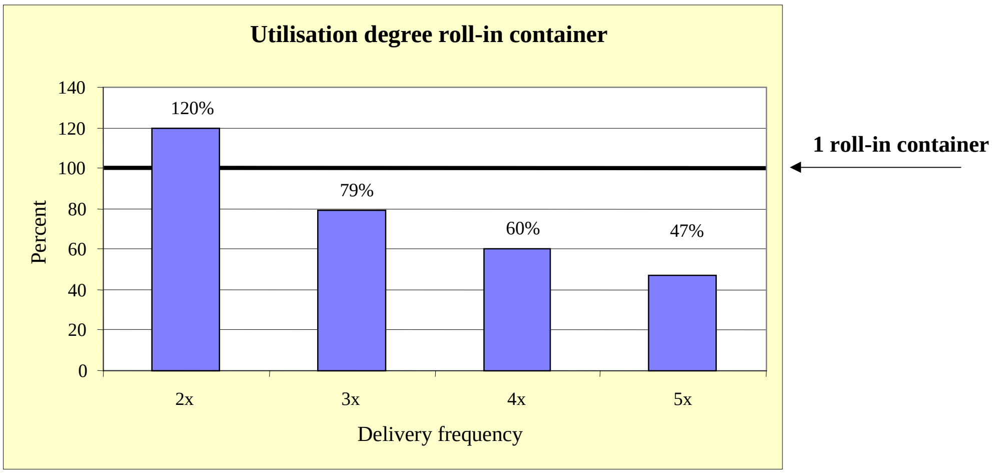


Figure 7.31 Average utilisation degrees of roll-in containers per delivery.

Figure 7.32 presents the relative portion of each business process in the total cost per stage in order to evaluate the absolute differences between performances of SC scenarios in Table 7.16. It shows that 48% of the producer's total process cost is caused by order picking (because of the cross-docking principle). The RDC's biggest cost involves transportation (67% of total RDC costs); and for the outlet, receiving goods and filling shelves are most expensive (87% of total outlet costs!). From a cost perspective, inventory reduction is not the most interesting aspect. However, inventory reduction gives more room for expansions in product assortment, which is one of the main strategic objectives. Furthermore, low inventories enhance low throughput times, resulting in high product freshness.

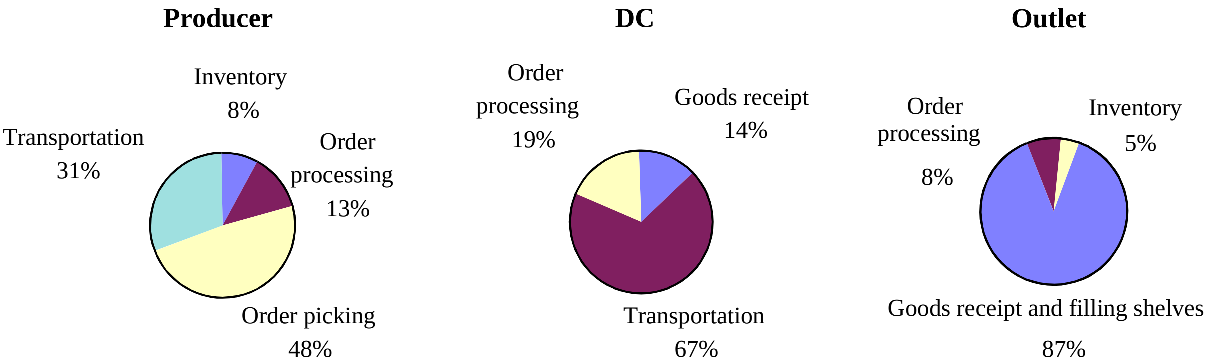


Figure 7.32 Distribution of costs in percents per business process in scenario 2 for each SC stage.

When a trade-off is made between SC scenarios, investigating potential inventory reductions, increase of product freshness and additional costs incurred, the project team suggested scenario 3 performs best. Increasing the frequency to 4 times a week will reduce the inventory for fast movers a bit further, but this does not compensate for the extra SC cost. However, this might change if other order policies are introduced.

Order policy

Simulation results showed that the implementation of a forecast-driven ordering system in retail outlets could further reduce inventory levels, if the right parameters concerning the validation of historical POS data are chosen (See Figure 7.33). The procedure used is comparable to the one used in the SC for chilled salads. That is, the forecasted demand for a certain ordering day is computed by taking consumer demand of the last four weeks (and weighting it by respectively 40%, 30%, 20% and 10%) for the weekdays related to the order sales period. Because consumer demand showed less variability in the input data of this SC model, the order forecast policy provided us with good insights. These results indicate that order forecasting could provide extra benefits, but identifying the exact benefits takes much more analyses and depends very much on the product-market characteristics. In scenario 5 stock levels of fast movers could be further reduced by 23%.

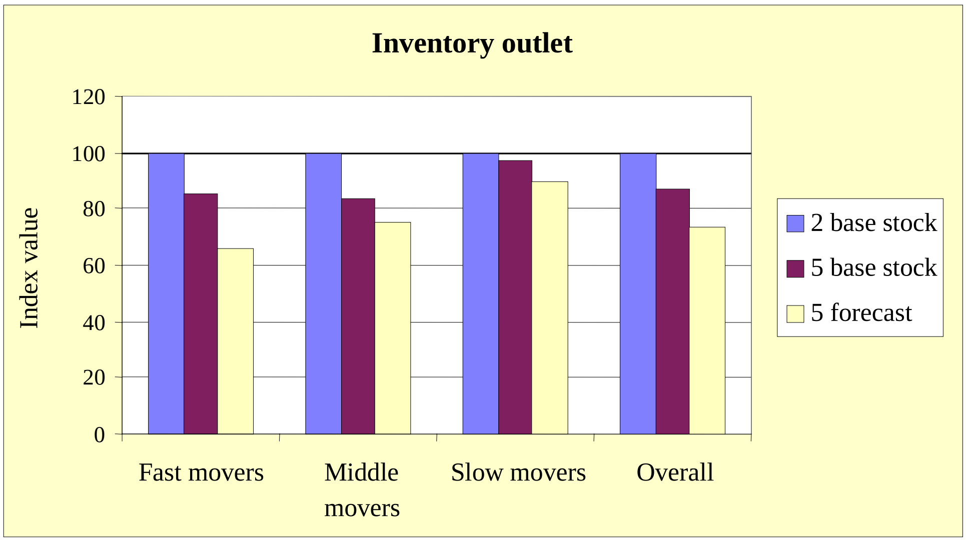


Figure 7.33 Additional reductions in stock levels in retail outlets when an order forecast policy is used.

Distribution unit size

The final redesign variable we would like to discuss is the distribution unit size. Just as in the SC for chilled salads, we found in this SC that current distribution unit sizes restrict benefits at higher order and delivery frequencies. When they are reduced to one individual consumer product (batch size one) for each product, the simulation of such SC scenarios shows that these settings may result in additional improvements in inventory levels and product freshness for fast movers.

Figure 7.34 shows the stock levels for two scenarios; scenario 5 with standard distribution unit sizes, and scenario 5 with the distribution unit sizes reduced to one (scenario 5-DE). In scenario 5-DE, fast movers' inventories decrease further by 20%, middle movers' inventories by 23% and slow movers' inventories by 50%! Note that process cost related to handling distribution units such as order picking and filling shelves will increase significantly.

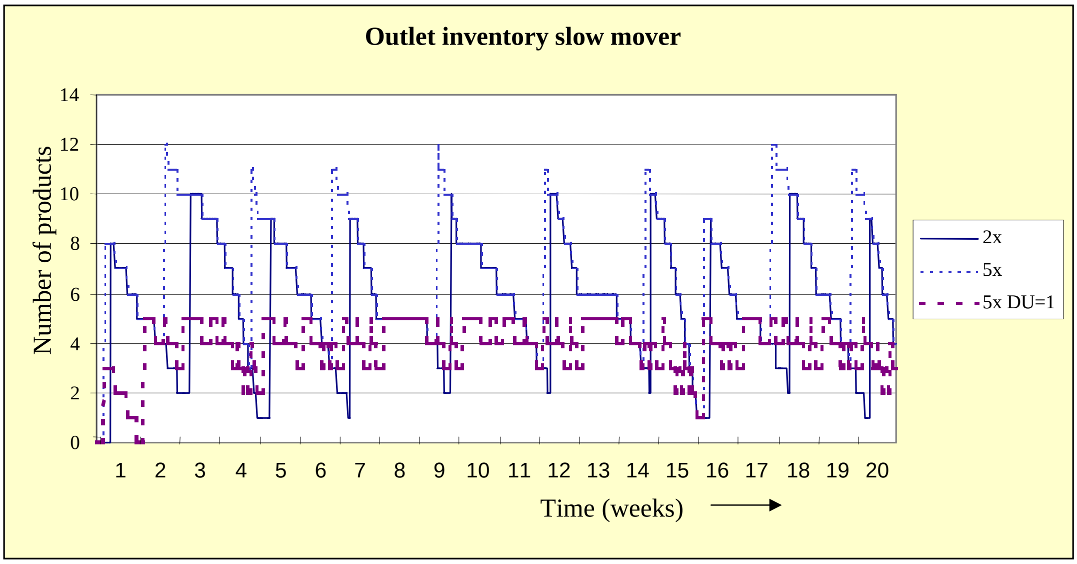
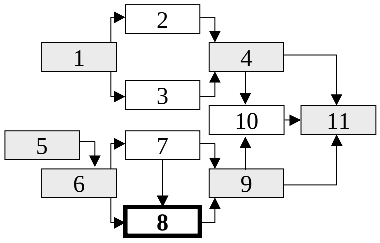


Figure 7.34 Outlet inventory levels when all distribution units are reduced to one product (DU=1).



7.4.2.4 Sensitivity analysis

The obtained results are sensitive to some of the parameters and input data of the model. *Sensitivity analyses* need to be performed to evaluate the robustness of scenario 3 to changes in input data. That is, will scenario 3 still perform best if realistic changes to these data are made? And how big can the changes be in order to imply a scenario shift? Analogous to case IIA, we performed sensitivity analyses on consumer demand data, week distribution functions, delivery days, inherent uncertainty in the RDC lead time, the calibration process to 0% no-sales and, finally, cost definitions. In this section only the main results will be presented; details can be found in Appendix L.

Consumer demand

When demand variability is decreased better results are obtained. Since demand peaks are smoothed, safety stocks can be further reduced. However, the differences between the scenarios are less significant. In all cases scenario 3 performed best.

Week demand distribution function

The week demand distribution function in the outlet influences the results of the simulated SC scenarios. As we found in case IIA, the benefits of extra ordering days are mainly determined by the combination of the days chosen and the week demand distribution function. Only when the extra ordering day is used to level the order quantities are additional benefits realised. As long as the current demand distribution function approaches reality and fluctuates in the week, the trade-off between the scenarios is robust.

Delivery days

The settings of the ordering and delivery days at retail outlets influence the exact benefits to be obtained in the SC (see Appendix K). When we simulated scenario 3 with other ordering days, different results were obtained. Appendix L also shows that when Saturday is included as a delivery day for the producer, additional benefits can be obtained.

From the findings we can also conclude that an automatic order forecasting system would improve the ordering process further if it incorporated the week demand pattern. That is, more products are sold on Friday and Saturday, hence required stock levels are higher on those days than during the rest of the week. Up to now safety stock levels have been based on the average week demand.

Inherent uncertainties in the SC

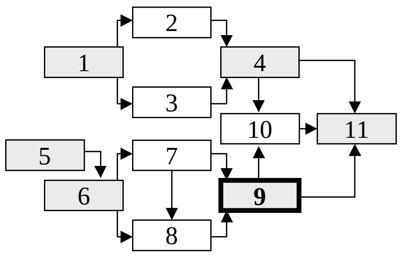
Simulation results in this SC are analogues to the results of case IIA. That is, stock outs at the producer have more impact on retail outlet stock outs at higher frequencies since all slack is removed from the system. On the other hand, as expected, the system recovers much faster after disturbances.

Calibration to 1% no-sales in retail outlets

In accordance with the findings in case IIA, outlet inventories drop significantly when SC scenarios are calibrated to 1% no-sales. On average the order-up-to level is lowered by 20%, resulting in (allowed) stock outs at demand peaks. Of course, the exact results depend heavily on the demand variability. We can conclude that these changes do not influence the ranking of the SC scenarios concerning inventory reductions and product freshness. However, they do significantly influence the absolute benefits to be obtained, which could lead to the conclusion that it costs too much to deliver more frequently. The model can provide estimated benefits if different delivery performances are compared. The key practitioners should decide on the trade-off between the benefits to be obtained and extra costs to be made in each SC scenario.

Cost definitions

The final aspect for the sensitivity analysis is the settings of the cost drivers used. Figure 7.32 showed that order picking is responsible for the largest part of the producer's total process cost, transportation for the RDC and filling shelves for the retail outlet. Hence, it is interesting to focus on the cost drivers of these processes. In general, simulation results showed that the trade-off between the SC scenarios never changes. In all cases, the number of roll-in containers changes when the frequency is increased. Hence, when the cost for handling these containers increases significantly, higher frequencies become less interesting. The number of distribution units handled per week is relatively constant in all SC scenarios since consumer demand is the same for all scenarios. We can conclude that the ranking of the scenarios is not sensitive to changes in cost (driver) definitions.

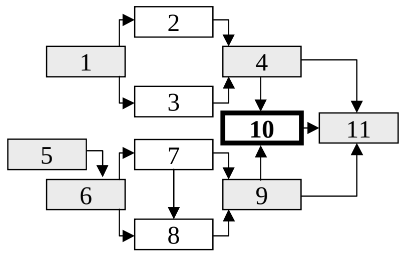


7.4.2.5 Conclusions simulation study

The project team concluded that scenario 3 performs best unless consumer demand increases significantly, distribution unit sizes are reduced or an automated ordering system is implemented that can differentiate between product types. Furthermore, better results can be obtained when the producer is able to pick products on Saturday too. The sensitivity analysis showed that the trade-off between the scenarios was relatively insensitive to changes in input data. The exact days on which to order and deliver depend to a high degree on the week demand distribution function in retail outlets (see Section 7.5). Finally, the higher the demand variability within a week, the fewer benefits will be obtained at higher frequencies.

The project team concluded that the model captured the relevant characteristics of the SC for cheese and desserts. It provided good insight into the benefits of various SC scenarios, and it could distinguish between the scenarios. Analogues to the simulation study in the SC for chilled salads, additional benefits can be identified that were not taken along in this study (see Section 7.3.2.5). Simple calculations show that when all aspects are taken along overall SC profits will certainly increase at higher ordering and delivery frequencies.

7.4.3 Model validation: field test results versus simulation results



Just as in case IIA this simulation model was validated in several ways. By comparing the results of the field test with the simulated scenarios (scenario 2_3 versus scenario 4 with order forecast), we are able to obtain an indication of the validity of the results of the simulation study. Table 7.17 presents the results.

Table 7.17 Comparing the results of the field test with the results of the simulated field test in the SC for cheese and desserts.

Performance indicator	*Product type*	*Field test*	*Simulation model*
Change in retail Outlet inventory	Fast mover	- 50% (from 4.7 to 2.3 days)	- 39% (from 3.2 to 2.1 days)
	Middle mover	+ 30% (from 1.4 to 1.8 days)[6]	- 38% (from 4.5 to 3.0 days)
	Slow mover	- 50% (from 11.4 to 5.6 days)	- 26% (from 8.1 to 6.2 days)
Change in product freshness for consumer	Fast mover	+ 2.3 days	+ 1.7 days
	Middle mover	+ 0.7 days	+ 1.9 days
	Slow mover	+ 2.6 days	+ 2.0 days

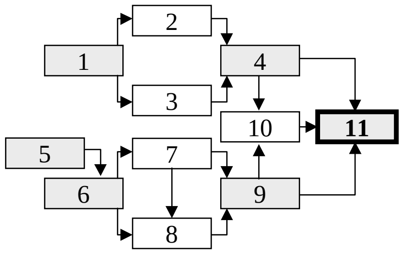
This table shows that the model approaches the benefits in the field test. The differences can be explained as follows:

- In the simulation study two "optimised" scenarios (both 0% stock outs) were compared, which (virtually) increased inventories. In practice, two "nearly optimised" situations are compared. The middle movers in particular revealed a lot of stock outs in the 0-index. This can also be seen in Table 7.17 since the outlet stock levels in the field test were much too low.
- The simulation model follows the order policies exactly. As we have seen, this was not the case in the field test; retail managers over-ordered slow movers at the start of the 0-index.
- The measurement periods should be extended to a much longer period to obtain more reliable figures that can be evaluated statistically.

Although the outcomes are not identical for the reasons given above, the experts concluded that the model could discriminate between different scenarios. They concluded that the model did predict probable trends and the order of magnitudes of benefits to be obtained. This was

6 Caused by wrong ordering patterns resulting in stock outs (see Section 7.4.1).

also due to the involvement of all participants in the development process of the simulation model; they were fully aware of all underlying assumptions.



7.4.4 Conclusions case IIIA

The project team concluded it is best to implement scenario 3 in the current situation. Increasing the frequency any further would create timing and capacity problems in all SC stages. The implementation of new ICT-systems is essential in overcoming these barriers. EDI and real-time control systems seem necessary as well as training and education on the other. Scenario 4 might become interesting when consumer demand increases

In accordance with case IIA this case study showed that a reduction of SC uncertainties (i.e. the presence of long lead times, low ordering frequencies, lack of insight into sales and inventory levels as described in Chapter 5) improves service levels significantly, although current SC configurations restrict possible benefits. Comparable trends in results were obtained in the field test and with simulation studies. Which scenario a SC should choose depends on the trade-off between service levels and total SC costs. Figure 7.35 depicts the distribution of extra process cost in the SC when the frequency is increased. It shows that the producer incurs relatively more costs than the retailer (DC and outlets) as the frequency increases.

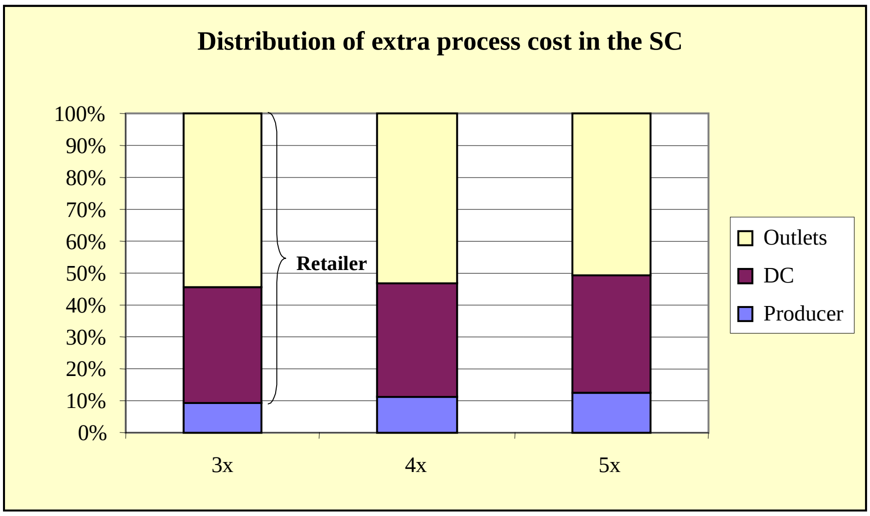


Figure 7.35 Distribution of total process cost in the SC in different SC scenarios.

7.5 Analytical approach to estimate SC performances

Another way to evaluate SC scenarios (or to validate the results of the simulation model) is to analyse the SC scenarios analytically. This might result in theoretical (upper or lower) bounds for the performance indicators in the simulation model. The sensitivity analyses of the models showed that the results were sensitive to the demand distribution functions and the presence of demand peaks. Analytical modelling can use these data to estimate the benefits to be obtained.

When the base stock order policy is used, the order-up-to level is equal to shelf capacity (Order = Shelf capacity – current stock – on order). And shelf capacity in turn is determined by the maximum number of products that needs to be stored in the shelf to suffice demand for an order sales period (see Section 5.7.1). At every ordering moment, the number of goods that were sold during the last order sales period are ordered to replenish stock. The larger the order sales period and the higher customer demand the more products that need to be stored. By using the week demand distribution function and weekly point-of-sale data, we can determine the required shelf capacity for each order in each SC scenario.

Table 7.18 shows the week demand distribution for retail outlets in the SC for chilled salads. Suppose outlet orders are placed on Tuesday and Friday morning with a lead time of 24 hours according to a base stock order policy. Then the order of Tuesday will be as large as total sales since the last ordering moment (the order sales period, see Section 5.7.1), i.e. the sum of sales on Friday, Saturday, and Monday (in this case 11 + 22 + 18 = 51% of week demand). In this case, the order on Friday accounts for 49%. Hence, in this scenario, in order to have no stock outs, the order-up-to level is set at the maximum percentage, i.e. in this case 51% of week demand. When we combine this with peak week demand we have the maximum number of products sold during one order sales period. For example, if peak week demand is set at 500 products, than the order-up-to level (shelf capacity) is set at 0.51 * 500 = 255 products. When the outlet orders are placed on other days the order-up-to level will change as Table 7.18 shows. When we compute these order-up-to levels for different SC scenarios and compare the findings, we can evaluate possible inventory reductions.

Table 7.18 Impact of delivery days on peak demand.

	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	MAX
% of week demand	18%	19%	19%	11%	11%	22%	
Ordering moments				*Order quantities*			
2x		51%			49%		51%
2x other days			70%		30%		70%
3x		51%		38%	11%		51%
3x other days	23%		37%		30%		37%

We calculated the required RDC order-up-to levels for the SC scenarios for the SC for chilled salads and indexed the results to scenario 2_3 (see Appendix I for the calculations). The results are summarised in Table 7.19 and compared to the order-up-to levels that were used in the simulation study for a fast moving article to realise 0% no-sales. Note that the week order demand distribution of the Mega-outlet changes as delivery frequencies to retail outlets increase (according to Table 7.3).

Table 7.19 RDC order-up-to levels in the SC for chilled salads (the results of the simulation model are based on a fast-moving product).

		Analytical results				**Simulation model results fast mover**			
		Frequency RDC-outlets				Frequency RDC-outlets			
		3x	*4x*	*5x*	*6x*	*3x*	*4x*	*5x*	*6x*
Delivery	*2x*	100				100			
frequency	*3x*	73	77	77	81	74	80	80	86
producer-	*4x*	73	77	77	81	74	80	80	86
RDC	*5x*	47	56	56	64	53	62	62	71

The analytic model presents slightly larger reductions in order-up-to levels compared to the simulated scenarios for the fast mover. This is caused by the dynamic aspects of the SC captured in the simulation model; for example, the impact of distribution unit sizes. We can conclude that both results show comparable trends. When the delivery frequency of the producer increases, inventory levels decrease. And when the delivery frequency of the RDC increases this results in a relative increase of RDC inventories.

When we do this exercise for the outlet order-up-to levels indexed to scenario 2_3 the results presented in Table 7.20 are found. The table shows that the overall results approach the analytical results. However, when we focus on the different product types, we see that slow movers especially differ significantly. Once again the distribution unit sizes hinder more frequent ordering in the simulation study. Also, fast movers show different results. The analytical approach assumes consumer demand is constant. But when the order sales period crosses over the weekend, the absolute values can change significantly if the new week shows peak demand. This is the case for fast movers that are ordered every time.

Table 7.20 Outlet order-up to levels in the SC for chilled salads.

Delivery frequency	**Analytical results**	**Simulation results** Overall	Fast movers	Middle movers	Slow movers
3x	100	100	100	100	100
4x	55	74	69	77	100
5x	51	74	69	77	100
6x	51	74	70	72	100

Comparable exercises were done for the SC for cheese and desserts. The results are presented in Table 7.21 indexed to scenario 2. We refer to Appendix K for the detailed calculations.

Table 7.21 Outlet order-up-to levels in the SC for cheese and desserts.

Delivery frequency	**Analytical results**	**Simulation results** Overall	Fast movers	Middle movers	Slow movers
2x	100	100	100	100	100
3x	78	85	90	78	94
4x	78	77	76	80	91
5x	78	79	78	78	98

We conclude this section by stating that it is not always better to develop complex models of a SC system in order to evaluate SC scenarios. Simple analytical models can provide great insights into the effects of changes (or provide theoretical bounds). The level of model detail depends on the SC objectives, hence, the performance indicators to be modelled, and the level of data detail available. Simulation is especially helpful when the dynamic behaviour of a complex system is studied, multiple performance measures are considered and the impact of SC uncertainties are evaluated.

7.6 Evaluation of the case studies

Now that the results of the case studies have been described, it is time to evaluate whether the aims formulated in Section 7.1 have been realised. We will first ask ourselves whether we have supported organisations in deciding whether or not to implement a new SC scenario. Second, the complementary character of the field test and the simulation study is discussed. We end this section with a discussion of the applicability of the modelling approach developed in Chapter 7.

7.6.1 Supporting SC decision makers

One of the aims in conducting these case studies was to support managers of the participating organisations in deciding whether or not to implement a new SC scenario, by quantifying the benefits and costs of new SC scenarios on pre-defined SC performance indicators. The evaluation of this objective is best done by answering the three main questions for each case study posed in Section 7.1. The answers to these questions are summarised in Table 7.22.

Table 7.22 Summary of case study results

Research question	*Case IIA: SC for chilled salads*			*Case IIIA: SC for cheese and desserts*		
What is the best practice SC scenario?	Delivery frequency producer 3x per week, delivery frequency RDC 4x per week, lead times within 24 hours, order forecast module			Delivery frequency producer and RDC 3x per week, lead time within 24 hours, order forecast module		
Did SC performances improve?	*Producer*:	*RDC*:	*Outlet*:	*Producer*:	*RDC*:	*Outlet*:
• Inventory reduction	-	- 35%	- 29%	-	-	- 34%
• Product freshness	-	-	+ 4 days	-	-	+ 3 days
• Process costs	+ 2%	+ 8%	+ 5%	+ 30%	+ 50%	+ 1%

Research question	Area	Restrictions
What are the organisational and infrastructural restrictions?	SC configuration	• Current sizes of the distribution units • Shelf capacities
	Control system	• Timing and capacity problems in the SC • Parallel interaction problems with other SCs
	Information system	• Current Information and Communication Technology systems; especially the lack of EDI, automated order forecast systems and real-time inventory management systems
	Organisation structure	• Education/motivation (of current decision-makers and those who execute business processes) • Different working hours at the SC stages (Saturdays not included by producers)

The case studies advocated implementing a SC scenario in which the delivery frequencies are increased by one time per week to further improve customer service. As discussed in the previous sections, further increasing the delivery frequencies makes no sense because of the sizes of the distribution units and the current demand variability throughout the week. Although process costs in the SC rise when the frequencies are increased, simple calculations showed that additional advantages in those scenarios cause overall SC profits to increase.

Differences between the SCs

The SC for cheese and desserts works with the concept of cross-docking, whereas the SC for chilled salads comprises a stock-holding RDC. Although cross-docking eliminates a lot of time in the SC, it does have some disadvantages. A request for shorter lead times places the producer under enormous pressure to perform all processes within a very short time period. Such systems can only work well when uncertainty in retail demand is low. Otherwise, huge inventories are required at the producer to cope with demand peaks, eliminating all SC benefits that are made downstream the SC. Another option would be for the producer to improve production flexibility by increasing the production frequency and decreasing production batch sizes. Furthermore, in the SC for chilled salads a CAO system was implemented. Unfortunately, this was not possible in the other SC since these systems still have difficulties with articles whose prices depend on the product's weight. Finally, the total process costs for the RDC and producer differ in both case studies because of different definitions of the cost drivers. Whether the cost driver for transportation is the number of transports or the number of secondary unit loads transported makes quite a difference.

Distribution of costs and benefits

What the model also provided was a thorough evaluation of the costs made and benefits obtained in each SC scenario. As we have seen, the extra costs and expected benefits are not distributed equally amongst the SC participants. Therefore, whether or not the advocated SC scenarios are actually implemented in the SC depends on the attitudes of the SC participants. One could think of a re-allocation of costs or giving the producer the possibility to introduce new products in retail outlets to fill up the vacant shelf space. Of course, these new products should be competitive compared to other possibilities. We also refer to Section 2.7 in which several criteria for successful partnerships are discussed. The factors summarised in Table 2.6 should be carefully evaluated before a decision is made. It is up to the managers of the participating SC organisations to place the results in the right context and to take appropriate action to improve customer service; also in relation to other suppliers and customers.

Conclusion

We can conclude that our approach did support the SC managers in deciding whether or not to implement new SC scenarios. In fact, the SC for cheese and desserts implemented the advocated SC scenario in their SC as a result of our research.

7.6.2 Complementarity of field test and simulation study

Another aim in conducting these case studies was to show the complementarity of the simulation study and a field test in identifying a best practise SC scenario. The best way to determine whether this aim has been fulfilled is by examining the results of the first case study in the SC for chilled salads. The field test identified the organisational and infrastructural restrictions for the SC scenario, whereas the simulation study evaluated the SC scenarios on multiple SC performance indicators. Although the simulation study results indicated that the managers should implement scenario 5_4, the field test results changed this advice to scenario 3_4[7]. Comparable results were found in the SC for cheese and desserts. This leads to the following proposition:

Proposition 7.1

Using only mathematical models without testing the scenarios in practice might result in scenarios that are not feasible because restrictions in reality are not included or foreseen.

[7] Although the standard outlets could not be taken along in the quantitative analysis because of data integrity issues, much (with respect to qualitative issues) could be learned from their way of working.

7.6.3 Applicability of the modelling approach and the modelling languages

The final aim in conducting the case studies was to test the applicability of the modelling approach developed in Chapter 6 to model the dynamic and complex character of food SCs. In both case studies project teams were established comprising key participants from SC stages. Both project teams concluded that the dynamic models:

- comprised the relevant information required to evaluate SC scenarios;
- predicted probable trends and the order of magnitude of changes in SC performance as new SC scenarios are implemented;
- allowed the project team to make a trade-off between SC scenarios since the model results proved to be very robust to changes in input data.

Table 7.23 typifies the models made by the typology presented in Section 2.4. It shows that our models include many more SC characteristics than the analytical models discussed in Section 2.4.

Table 7.23 Characteristics of the discrete event simulation models (compare with Table 2.5).

Model elements	*Included in the simulation models*
Scope of SC	SC (including part of the SC network)
Aspects considered	Multiple stages, Perishable goods
Demand process	Variability in consumer demand, inherent uncertainties
Information availability	All possibilities: refers to the chosen SC scenario
Type of SC control	All possibilities: centralised or decentralised SC control
Type of replenishment	Fixed or periodic inventory replenishment cycles, Order forecast modules, ship-all or variable size
Objective(s) of model	Minimising total SC cost of all business processes AND maximising product freshness and product availability for end-consumers in retail outlets
Methodology applied	Dynamic Discrete Event Simulation (DDES)

ExSpect and our Modelling Framework

We found that Petri Nets (see section 6.7) allow for a natural representation of discrete logistic processes. Modelling the flow of goods, means and information via tokens seems to be very natural and corresponds to the way processes are mapped in ODL and EPC diagrams. The fact that flows are represented graphically also makes the overall structure comprehensible and supports the communication between people from different backgrounds. When modelling a logistic system with ExSpect, we often have to choose between 'putting information in the net structure' and 'putting information in the value of a token'. The first results in a larger and more complex Petri Net. The latter results in more complex operations on the value of a token, and therefore, in a more complex description of the behaviour of some of the transitions. We have to balance continuously between the complexity of the net structure and the complexity of the token values (see also Van der Aalst, 1992). We found that ExSpect could grasp all constructs of our modelling framework (Figure 6.4) in one way or another. However, the following remarks need to be made:

- With ExSpect we were able to capture the dynamic behaviour of food SCs. The precedence relationships between business processes are easily modelled by the availability of tokens in places. However, validating the complete model especially concerning the timing of processes is complex. Because of the specific characteristics of Petri-Nets, the delay of one single process could cause the whole chain of processes to be executed at wrong times. We built a building block TIME TRIGGERING to facilitate the consistent timing of business processes.

- In ExSpect all (types of) business processes are modelled in the same way by processors. No explicit distinction is made between physical transformation processes, information transformation processes and decision making processes. Resources have to be modelled explicitly, i.e. constructed by using a process definition with channels and tokens. The availability of the resource can then be represented by an enabled token.
- The business entities could be modelled as defined. However, modelling the Best-Before-Date (indicating the remaining product shelf life) of products and clustering products in groups by their BBDs resulted in complex codes.
- ExSpect provided the required system hierarchy in the simulation model.
- All information and process steps required to calculate performance measures have to be modelled explicitly, requiring a lot of modelling time and effort. For example, an average inventory level is calculated with data explicitly collected at certain time points.
- It is difficult to separate the experiment (i.e. the list of design variables and its values) from the model reducing the visibility of the model. When the timing of processes is changed, one has to search through the model to find all related processes.

Arena and our Modelling Framework

We found that Arena could also grasp all constructs of our modelling framework in one way or another. Here, the following remarks need to be made:

- With Arena we were able to capture the dynamic behaviour of food SCs. The precedence relationships between business processes are easily modelled by linking the output of one process to the input of another process. Because the experiment and the model are separated, the tracking and tracing of process relationships is much easier than in ExSpect.
- The timing of business processes is arranged differently than in ExSpect. We can either use a loop and a delay or the starting time can depend on the availability of a resource. At the moment an entity is created in Arena, a time stamp is added, which allows us to monitor the period of time the entity exists. This is important in our analysis for representing product shelf lives.
- Arena possesses several standard SIMAN functions. The modelling process is done best when these standard functions are used as much as possible. However, these functions are mainly aimed at transitions of physical flows. Therefore, Arena is very good in modelling the goods flows and transformation processes. But when complex information processing and decision making processes need to be modelled, complex codes have to be used, reducing the applicability of Arena.
- The business entities were modelled slightly different than in ExSpect, since in Arena all entities remain in the model during the whole simulation period. Hence, a batch of products still comprises the individual products and their characteristics. This created difficulties, since running the simulation model with very large (realistic!) numbers of consumer demand proved to be impossible. On the other hand, this characteristic simplifies computations of performance indicators that are related to the creation moment of entities. For example, the computation of product throughput times in the SC.
- Hierarchy is not present in Arena version 3.0.1, resulting in very complex models with loss of clarity.

7.7 Conclusions

In this chapter we presented the results of two case studies in which alternative SC scenarios were modelled and evaluated. The case studies showed the applicability of the modelling approach developed in Chapter 6. With the simulation models developed in the case studies, the trends and order of magnitude of changes in SC performances of different SC scenarios could be predicted. The case studies also showed the complementarity of the field test to a simulation study. By using this approach, SC managers can be supported in deciding whether or not to implement a new SC scenario. Last but not least, the case studies showed the impact of SC uncertainties on SC performances. By decreasing the order forecast horizon and improving the replenishment frequencies, notable improvements were made. This once again gives quantitative support for our proposition in Chapter 1 that SC uncertainties hinder SC performance.

Both ExSpect and Arena proved to be promising tools for modelling SC scenarios. Petri nets (in ExSpect) provide useful models which capture the precedence relationships and structural interactions of stochastic, concurrent and asynchronous events. However, the lack of incorporated measurement systems and an output analyser in the tool increases the time required to model a SC system and reduces the variety in available output-results. ARENA, on the other hand, is very good for modelling goods flows, but modelling control structures requires more efforts.

Finally, we showed that quick insights can be obtained for small parts of SC problems using simple analytical models. Simulation is especially helpful when the dynamic behaviour of a complex system is studied, multiple performance measures are considered and the impact of SC uncertainties are evaluated.

Chapter 8

A Step-by-Step Approach to Generate, Model and Evaluate Supply Chain Scenarios

'If you don't design your supply chain,
don't worry. It will design itself!'
(Andersen Consulting)

8.1 Introduction

This chapter summarises the findings of this research project concerning the step-by-step approach to generate, model and evaluate SC scenarios. The development of this approach has been described in the previous chapters.

8.2 A Step-by-Step Approach to Generate, Model and Evaluate Supply Chain Scenarios

It is now possible to present a generic step-by-step approach to analyse food SCs and come to a best practice SC scenario that may be implemented in an existing SC (Figure 8.1). This approach departs from proposition 1.1, which states that to identify effective SC scenarios one should focus on the identification and management of the sources of uncertainties in SC decision making processes.

Step 1a. Define the boundaries of the SC to be investigated
The first step in analysing and redesigning a SC is to determine the organisations that are part of the SC under investigation[1]. We defined a SC as 'the series of (physical and decision-making) activities connected by material and information flows that cross organisational boundaries aimed at producing value in the hands of the ultimate consumer whilst satisfying other stakeholders in the SC'. Step 1a focuses on the extendedness of the SC horizontally (SC width) and vertically (SC length).

[1] Note that our approach departs from the presence of incentives for SC co-operation at the different SC organisations.

As we have seen, a SC is always part of a large SC network; an organisation markets multiple products via multiple distribution channels and is supplied by multiple suppliers. Therefore, one has to determine the degree of decomposition: what aspects of the SC network can be analysed separately without losing sight of reality? Our focus is on those SC organisations that aim to satisfy customers in one specific market. This is necessary since otherwise multiple SC objectives can be identified that might conflict.

Step 1b. Define SC objectives and identify SC Key Performance Indicators (SC KPIs)
Parallel to step 1a, the SC participants should start with jointly identifying order winners and satisfiers for the SC, because these provide the intended direction of control actions to improve SC performance. By analysing the goals of each individual organisation and by identifying market requirements, SC KPIs can be defined and norms established. A SWOT analysis (Strengths, Weaknesses, Opportunities and Threats) may be applied to rank the performance indicators and identify deficiencies. According to Johnson and Scholes (1997) a SWOT analysis can be a useful way to summarise the relationship between key environmental influences, the strategic capability of the organisation and hence the agenda for developing new strategies. The KPIs should satisfy the eight criteria to fully capture the essential characteristics of SC processes as listed in Table 3.3.

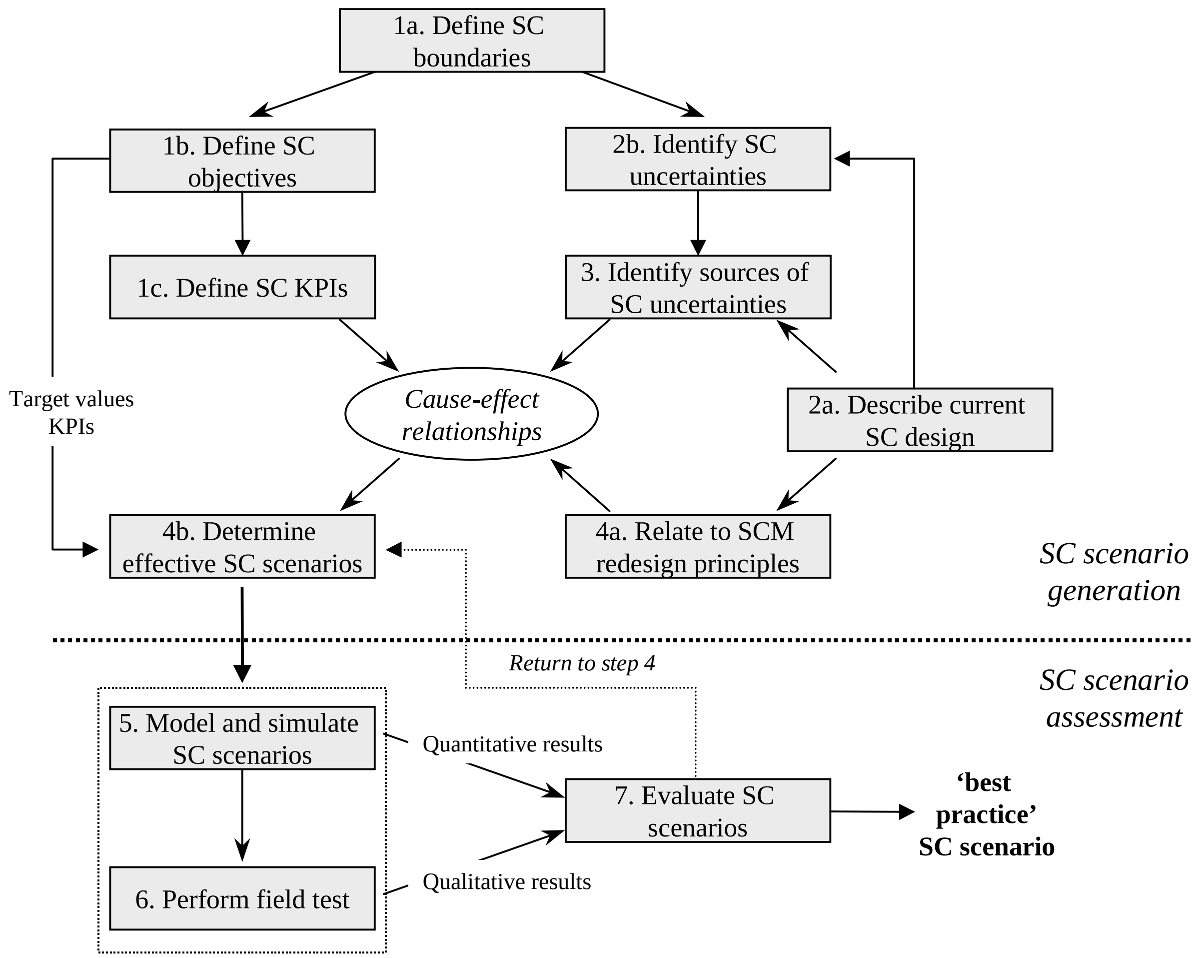


Figure 8.1 A step-by-step approach to generate and evaluate SC scenarios.

Step 2. Understand the current SC process and identify SC uncertainties.
The redesign of business processes must be based on a thorough analysis of the existing situation, taking qualitative as well as quantitative issues into account *(step 2a).* The conceptual framework developed in Chapter 3 can be used to analyse and describe SCs to facilitate the redesign process. When applied, the current SC scenario is described in detail concerning the managed, managing, and information systems and organisation structure in the SC. This process can be formalised by mapping all relevant business processes with ODL and EPC models.

In this process, decision-making situations in the SC can be identified (*step 2b*) in which the decision-maker has lack of effective control actions or is unable to accurately predict the impact of possible control actions on system behaviour because of a lack of:

- information (or understanding) of the environment or current SC state;
- a consistent model of the SC presenting the relationships between SC redesign variables and SC performance indicators.

The presence of these SC uncertainties can be recognised by the presence of safety buffers in time, capacity or inventory to prevent a bad SC performance.

Step 3. Identify the sources of SC uncertainty.
Via a process and customer complaints analysis a list of the main sources (the causes) of the SC uncertainties can be identified and typified (according to Table 4.2). Sources of SC uncertainty refer to inherent characteristics of the SC and characteristics of the managed system, managing system, information system and/or organisation structure that are present at a certain point in time and that generate SC uncertainty. The formulation of (estimated) cause-effect models will help in this process. The construction of these models should take place in close co-operation with the problem owners, i.e. the key decision-makers in the SC.

Step 4. Identify potentially effective SC scenarios.
By applying Table 5.17, a list of effective SCM redesign principles (see Section 5.7) can be identified that is likely to affect the main sources of SC uncertainty *(step 4a)*. Note that each principle should be transformed, according to the situational context, into effective SC redesign strategies. The ranking of these principles can be determined by evaluating the impact of each SCM redesign principle on the SC KPIs (which are formulated in *step 1*).

From the ranked list of SCM redesign principles a ranked list of SC redesign variables for this SC can be deduced (*step 4b*). The domain of the possible settings of each relevant SC redesign variable can be determined by investigating the theoretical or empirical boundaries together with the problem owners. Analytical modelling can aid in this process. A combination of settings of these main SC redesign variables constructs a SC scenario. Furthermore, the objective of the SC partners to obtain fast results in the short term or more drastic results in the longer term determines the choice of the SC scenarios to be investigated.

Step 5. Evaluate the SC scenarios quantitatively.
By applying the modelling framework developed in Chapter 6, we can capture the relevant aspects of the SC under consideration in a simulation model and simulate the dynamic behaviour of the SC in SC scenarios. The simulation study will assess the impact of alternative settings of the main SC redesign variables in SC scenarios on the key SC

performance indicators. The model should be validated by experts, partially on the basis of the SC mapping models constructed in *step 2*. Finally, the robustness of effective SC scenarios should be determined by performing a sensitivity analysis in which alternative settings of variables and input data are used in the simulation model.

Step 6. Evaluate the SC scenarios qualitatively.
By implementing an interesting SC scenario in a field test for several weeks, organisational and information technological constraints on new SC scenarios can be identified. Ideally, the field test SC scenario should be based on preliminary runs of the simulation model. On the other hand, it may test the SC system to its limit in that it chooses extreme settings for some relevant SC redesign variables. Within the project team the findings of the field test should be transposed to other possible SC scenarios.

Step 7. Identify and implement the 'best practice' scenario in practice.
The most effective SC scenario that also fulfils all requirements encountered in the field test is identified as the best practice SC scenario. However, the determination of what SC scenario is best is difficult since multiple performance measures should be considered by several organisations. Undoubtedly, a discussion about the distribution of additional costs and benefits will take place.

Furthermore, if the level of analysis in the research concentrated on a small part of the SC network, the results should be placed in the real context. In other words, is the SC scenario still 'optimal' when the other SCs in the SC network are included in the analysis? The necessity of this additional step depends to a large degree on the analysis done (*step 1a*) to determine the decomposition level and the interaction level of the different SCs.

Step 8. Monitor and evaluate the SC
If a new SC scenario is implemented, the SC should be monitored to determine to what extent the SC objectives are achieved. If the SC performance indicators (still) differ from target values new SC scenarios should be formulated and evaluated (*return to step 4*). When new partners enter the SC or when the environment requires a change in SC objectives *return to step 1*.

8.3 Conclusion

With the above described step-by-step approach to generate, model and evaluate supply chain scenarios, our search for a methodology for the generation and assessment of effective SC redesigns is concluded.

Chapter 9

Evaluation

'Some men see things as they are, and say, Why?
I dream of things that never were, and say, Why not?'
(George Bernard Shaw)

9.1 Introduction

At the start of this research project in 1994 little was known about SCM and its potential for SC performance improvement. This thesis aimed to fill in some of the gaps concerning the redesign process of SCM. The main questions individual food companies face are *whether, how,* and *with whom* they should start SCM activities. Food companies should be able to analyse what SCM can do for them and find out what the consequences might be if a SC view is taken together with one or more supplier(s) and/or customer(s). An extensive literature research did not reveal any integral method to generate, analyse and evaluate SC redesigns systematically. In this research, a redesign of the SC configuration and/or operational management and control is called a SC scenario. The objective of this research was to contribute to the body of knowledge on SCM by developing:

1. a research method to analyse a food SC and to generate a number of potential effective SC scenarios that are estimated to improve the current SC performance.
2. a research method to assess different SC scenarios and identify an effective 'best practice' SC scenario for a particular food SC.

These methods should assist the managers of food companies in evaluating their current position in a food SC and in deciding whether and how they should redesign the SC. In this final chapter we evaluate our research and examine the contribution we have made to the body of knowledge on SCM. Section 9.2 will summarise the results and determine whether we have fulfilled our research objectives. Section 9.3 discusses the relevance and limitations of the research. We conclude this thesis with recommendations for further research.

9.2 Summary of main findings

Chapter 2 began with a description of the environment in which SCM emerged. Definitions of SC and SCM were given and related concepts such as BPR and ECR were discussed. Furthermore, attention was paid to strategic partnering and, more important, criteria for successful partnerships. The following chapters focused on answering our three main research questions (see Section 1.4). We will discuss the main findings of our research by answering these three scientific questions formulated in Chapter 1.

9.2.1 What is the relationship between SC uncertainty and SC performance in food SCs?

In order to examine the relationship between SC uncertainty and SC performance we first defined both terms. In Chapter 3 we defined *SC performance* as the degree to which a SC fulfils end user requirements concerning the relevant performance indicators at any point in time, and at what total SC cost. Furthermore, we identified the main SC performance indicators for food SCs, based on a literature review and the characteristics of food SCs (see Section 1.2). The concept of *SC uncertainty* was discussed in Chapter 4. SC uncertainty is defined as decision making situations in the SC in which the decision-maker lacks effective control actions or is unable to accurately predict the impact of possible control actions on system behaviour because of a lack of:

- information (or understanding) of the environment or current SC state;
- a consistent model of the SC presenting the relationships between SC redesign variables and SC performance indicators.

In Chapter 3 it became clear that a SC is a very complex system comprising (multiple) actors, objectives, measures of performance, system hierarchy, connected subsystems and (value-added) processes, monitoring and control mechanisms, decision making procedures, resources, and so on. Applying SCM is basically searching for a means to reduce the complexity of the total system to make the SC more manageable and perform better. To assist in this process we:

(i) proposed focusing on the identification and management of the sources of decision making uncertainties in the SC to identify a number of potential effective SC scenarios;

(ii) defined a conceptual framework for SC analysis and redesign based on the systems approach. When each organisation in a SC is analysed according to the proposed framework, a detailed description emerges of the SC configuration and operational management and control structures in the SC.

The appropriateness of the proposition and the applicability of the conceptual framework was shown in three case studies discussed in Chapter 5. In all three case studies SC uncertainties were identified that hindered SC performances. Therefore, the answer to the first research question is as follows:

Answer research question 1

The presence of uncertainties in SC decision making situations results in the establishment of safety buffers in time, capacity or inventory to prevent a bad SC performance. These safety buffers initiate the existence of several non-value-adding activities that reduce the profitability of the SC. Reducing or eliminating the SC uncertainties will improve SC performance.

During the research one of the main obstacles to SCM became evident, i.e. the lack of consistent definitions of terms throughout the entire SC. Of course, such consistency is also important for our own research. Therefore, Table 9.1 lists the definitions that were developed for the main terms (next to SC performance and SC uncertainty) used in this research.

Table 9.1 Our definitions of the main terminology used in this research.

No.	*Term*	*Definition*
1.1	A 'best practice' SC scenario	A feasible SC configuration and operational management and control of all SC stages that achieves the best outcome for the whole system.
2.2	Supply chain (SC)	A series of (physical and decision making) activities connected by material and information flows that cross organisational boundaries.
2.3	Supply Chain Management	The integrated planning, co-ordination and control of all logistical business processes and activities in the SC to deliver superior consumer value at less cost to the SC as a whole whilst satisfying requirements of other stakeholders in the SC.
3.3	SC scenario	An internally consistent view of a possible instance of the logistical SC concept, i.e. the managed, managing, and information systems and organisation structures in the SC.
3.5	SC performance indicator	An operationalised process characteristic, which compares the efficiency and/or effectiveness of a (sub)system with a norm or target value.
3.8	SC redesign variable	A management decision variable that determines the setting of one specific part of the SC configuration or operational management and control.
4.2	Source of SC uncertainty	An inherent or system characteristic of the managed system, managing system, information system and/or organisation structure that are present at a certain point in time and that generate SC uncertainty.

9.2.2 How can we identify potential effective SC scenarios in a food SC?

The research method to identify effective SC scenarios was developed from the findings in Chapters 3 and 4, and was expanded and tested in Chapter 5. The complete step-by-step approach is presented in Chapter 8. The following results were obtained in the development process:

- SC redesign requires the detailed analysis of SC processes to describe and analyse the relationships between processes, and between processes and SC performance. *Two mapping techniques* were identified for modelling all the relevant characteristics of SC business processes we identified (Section 5.2): Organisation Description Language (ODL) for the static process description (Uijttenbroek et al., 1995) and Event Process Chain (EPC) modelling (Kim, 1995) for the description of process dynamics. These mapping techniques proved to be very helpful in discussions with key participants for identifying bottle-necks in the SC.
- The application of the step-by-step approach to generate SC scenarios in the case studies, which is described in Chapter 5, resulted in a *general list of sources of SC uncertainty*. This list provides us with a checklist for possible improvement areas in researched SCs.
- A *general list of SCM redesign principles* is constructed from literature that can be used to select relevant performance improvement options. Some of the principles relate to changes in the SC configuration, others to changes in the operational management and control (i.e. the control system, information system and organisation structure). The impact of each redesign principle on the main SC KPIs is assessed, which facilitates the ranking of the redesign strategies (related to the SC objectives).
- From the experiences in the explorative case studies, we were able to develop a valuable tool for SC redesign; i.e. a *table that relates the sources of SC uncertainty to effective SCM redesign principles* (Table 5.17). By applying this table the relevant SCM redesign principles can be identified that are likely to affect the identified sources of SC uncertainty. Note that each principle should be transformed, according to the situational context, into SC redesign strategies for that particular SC.

Thus, research question 2 can be answered as follows:

Answer research question 2
The application of our step-by-step approach for generating effective SC scenarios will result in a number of important SC redesign variables. The combination of different settings for these SC redesign variables establishes a number of potentially effective SC scenarios. The degree of effectiveness of these scenarios has to be determined in the evaluation phase (research question 3).

9.2.3 How can SC scenarios be evaluated with regard to SC performance for the SC participants?

Chapter 6 discussed the complementarity of a model study and a field test in evaluating the effectiveness of SC scenarios. It was concluded that in this research the combination of two methods should be applied to identify a best practice and feasible SC scenario. These are:

- to construct a mathematical (i.e. analytical or simulation) model that allows for realistic modelling of (part of) SC scenarios applicable in (food) SCs, which in turn allows for the assessment of the quantitative impact of those SC scenarios on relevant SC KPIs;
- to conduct a field test experiment in the SC, comprising one of the most promising SC scenarios (resulting from the model study), which allows for the identification of the practical and organisational restrictions (i.e. the feasibility) of SC scenarios.

In Chapter 6 several mathematical modelling methods were discussed and evaluated. We concluded that because of multiple performance and time-related process aspects that need to be taken into account when modelling SCs, and the need for credibility of the model in the eyes of the decision-makers, the use of simulation instead of analytical modelling is preferred in this research.

Chapter 6 further presented a framework for modelling the dynamic behaviour of food SCs. This framework was developed from literature search and empirical research. Our modelling framework can be used for strategic decision making by developing different simulation models for alternative SC scenarios and evaluating them while using the same set of input parameters. Comparison of the performance of alternative scenarios provides managers with information about the expected benefits of each alternative.

Both the modelling framework and the field test were used in two revisited case studies. Chapter 7 presented the results of these case studies in which SC scenarios were modelled and evaluated. Several observations led us to the conclusion that our modelling framework provided good support for the analysis and evaluation of new SC scenarios on predefined SC performance indicators. Experts acknowledged that the simulation models incorporated the relevant aspects of the SC system under consideration and that the model could be used to evaluate the behaviour of SC scenarios. The case studies also showed the complementarity of the field test with a simulation study. By using this evaluation approach SC managers can be supported in their decision of whether or not to implement a new SC scenario.

Simulation provides an effective pragmatic approach to detailed analysis and evaluation of SC scenarios. Timed Coloured Petri Nets and SIMAN are both promising languages for modelling and for the quantitative analysis of SC scenarios. Petri nets provide useful models that capture the precedence relationships and structural interactions of stochastic, concurrent and asynchronous events. However, the lack of an incorporated measurement systems and output analyser in the tool ExSpect increases the time required to model a SC system and reduces the variety in available output-results. ARENA, on the other hand, is very good for modelling goods flows, but modelling control structures requires greater efforts.

Answer research question 3

The impact of a SC scenario on SC performance should preferably be evaluated by using both a modelling (simulation) study and a field test experiment. In this way the new SC scenario is evaluated both quantitatively and qualitatively (i.e. considering the behavioural and organisational aspects). The modelling framework developed in this research provides a good means for capturing the dynamic behaviour of a food SC. The final decision of which SC scenario to implement depends on the trade-off between multiple SC performance indicators for each SC participant and the SC as a whole, and the feasibility of each SC scenario.

9.2.4 Conclusion

We can conclude that we were indeed successful in contributing to the body of knowledge on SCM by developing two research approaches. First of all, a research method to generate a number of potential effective SC scenarios for food SCs. And second, a research method to assess different SC scenarios and to identify an effective ‘best practice’ SC scenario for a particular food SC. The complete step-by-step approach developed in this thesis can be used to analyse, redesign and evaluate a SC more effectively and more efficiently, which enhances the competitive advantage of the SC. It enables the assessment of the impact of SC scenarios on SC performance, provides insight in SC functioning and works as a facilitator to rethink current SC business processes. Furthermore, we have made the following contributions to SCM theory:

- The term SCM has been clearly defined and operationalised by the development of a list of 22 generic SCM redesign principles.
- The step-by-step approach to SC redesign is the result of integrated research in the fields of Information Technology, Operational Research and management studies. This thesis aimed at crossing discipline boundaries and integrating views from all three areas.
- Most SC problems are either analysed from a quantitative point of view (see Section 2.4) or from a qualitative point of view (see Section 2.7 and 4.6). In this research we tried to integrate both views.

9.3 Discussion

Although the results we have obtained are useful to participating SC organisations and to researchers, our research is nevertheless subject to a number of limitations. We will discuss these limitations by means of the research design and the approach for modelling SCs. We will end this section by giving some remarks concerning the translation of our findings to actual practice.

9.3.1 Multiple Embedded Case Studies

This research aimed at theory building using multiple embedded case studies. According to Yin (1994) such case studies can be generalised for theoretical propositions, but not for populations or universes. Therefore, we focus on the degree of generalisation of our step-by-step SC redesign approach and not on the exact findings of the application of our approach in the case studies. Whether or not inventory levels can be reduced by, for example, 50% depends completely on the situational context of the SC.

By describing and discussing the relevant processes and variables in the SC using ODL and EPC models, we assume to have captured the critical variables in the SC within the demarcation area of our research. However, there might be additional variables in the SC field that could interfere with our variables. We will look closer at these variables by discussing the research demarcation areas.

Selected food SCs

Two types of food SCs were investigated in this thesis; a SC for daily fresh food products and two SCs for processed food products. Although we recognise that the specific findings in each case study might differ significantly if other SCs were investigated, we believe that the step-by-step approach to SC analysis and redesign need not be different. The definition of SC objectives, the identification of SC uncertainties via detailed process mappings, and the identification of effective SCM redesign strategies does not depend on the specific characteristics of the SC. However, it is possible that additional sources of SC uncertainty would be found that could be linked to our list of SCM redesign principles, thereby further completing our methodology.

SC network

The case studies reported in this thesis comprised multiple organisations. Case I comprised growers, auctions, an exporter and retail organisations. Case II comprised a salad producer and a retail organisation (comprising DC and outlets). Finally, case III comprised two suppliers of desserts, a producer and a retail organisation. We defined a SC as 'the series of (physical and decision making) activities connected by material and information flows that *cross organisational boundaries'* that aimed at producing value in the hands of the ultimate consumer *whilst satisfying requirements of other stakeholders in the SC*'. In evaluating our research, the following remarks can be made:

- In the case studies only parts of the total SC networks were investigated. We believe our approach to SC redesign is also applicable to larger SC networks in which SCs interact and more SC participants are incorporated. This is supported by some preliminary studies. However, in some cases a decomposition method is required to make the modelling approach feasible. Focusing on the SC network will give more insight in the functioning of SCs, since improvements made in one SC might result in a decline in other SCs.
- Requirements of other stakeholders in the SC, such as the government, environmental protection groups, and employees, are not explicitly considered in this research. These stakeholders are particularly important in the trade-off process between several SC scenarios. For example, the government may pass regulations that decrease the possibility to increase delivery frequencies or a firm may have employees that refuse to work on

Saturdays. The incorporation of all the stakeholders' requirements may result in a different outcome concerning the best practice SC scenario.

- Our research focused on the management of existing SCs. It could be that designing and establishing completely new SCs results in leaner SCs, since current practices might hinder the installation of optimal SC scenarios. However, the complexity of setting up completely new SCs is very high. Current practices have emerged through a process that took many years. Completely new SCs will be very prone to errors because of a lack of experience in co-operation.

We can conclude that the development of our approach to SC analysis and redesign is relatively independent of the choice of the case studies. Although, doing more case studies might make the generic lists used in our approach more comprehensive as additional perspectives are incorporated. According to Yin (1989) the quality of the research design can be evaluated using four criteria. Table 9.1 presents the results of such an evaluation indicating the suitability of our research design.

Table 9.1 Evaluation of the research design.

Criterion	*Definition*	*Main case study tactics used*
Construct validity	Establishing correct operational measures for the concepts being studied.	• Using multiple sources of evidence: literature, discussions with key participants and other researchers, observations.
Internal validity	Establishing causal relationships between research variables (certain conditions are shown to lead to other conditions).	• Constructing cause-effect models and discussing these with key SC participants. • Comparing empirically based relationships with predicted ones (customer claim analysis etc).
External validity	Establish the domain to which a study's findings can be generalised.	• Replication logic applied to multiple case studies.
Reliability	Demonstrating that the operations of a study can be repeated with the same results.	• Establishing a case study protocol that is used in each case study. Detailed reporting of all assumptions and relations identified and data used in the SC modelling process.

9.3.2 Generating Supply Chain Scenarios

The discussion should also be focused on the research steps in the case studies. The following remarks can be made:

- One of the major steps in our approach is mapping business processes in the SC. It is always difficult to demarcate the processes to be included in the analysis. In order to grasp all critical variables, the co-operation of key SC participants is essential. Also, doing a field test experiment is not always feasible. This too requires the co-operation of many people. And sometimes, as we have seen in our field tests, these people do not profit directly from the experiment itself, reducing the enthusiasm to participate.
- In this research we have chosen discrete-event simulation to analyse the impact of SC scenarios on SC performance. As discussed in Chapters 6 and 7 we believe that the combination of analytical approaches and simulation provides a good means for analysing and improving SCs. Analytical modelling should be applied to smaller and static SC problems and could provide upper and lower bounds for redesign variables that can be used in the simulation of the dynamic behaviour of the complete SC.

9.3.3 Modelling and Evaluating Supply Chain Scenarios

We can make the following remarks concerning the SC modelling process and the outcomes of the case studies:

- The outcomes concerning SC cost should be further refined. In the case studies the required investments of new SC scenarios have not been included. Furthermore, we included only a few product types, which were extrapolated to the total product assortment. In this process small round-off errors can make considerable differences at the bottom line. In our research we 'solved' this problem by letting the SC participants decide what multiplying factors should be used.
- As expected, the availability of data at the required aggregation level was a problem. To decide on model input values assumptions had to be made.
- The current information and goods flows of promotional products are not explicitly incorporated in the simulation model. We assumed that as delivery frequencies increase these flows will be incorporated in the traditional flows. However, this is only the case in SC scenarios that have a high delivery frequency.
- In the current simulation model environmental restrictions are not considered. When, for example, the environmental burden of SC scenarios is incorporated, higher delivery frequencies may not be stimulated (c.f. requirements of other stakeholders).

The field tests provided thorough insight into the organisational and infrastructural consequences of the new SC scenario and they also gave an indication of the benefits to be obtained. However, if field experiences are to be used more extensively for validation purposes, much longer measurement periods and more outlets should be incorporated. The it would also be possible to evaluate the field test results statistically.

The best practice SC scenarios identified in the case studies all focused on a reduction of the use of slack in the SC (concerning inventory, capacity or time). As was already mentioned in Chapter 7 one of the participants already *felt* increased reliance on the performance of the supplier. The question is whether SC stages are willing to sacrifice part of their span of control for the sake of SC performance improvement, especially when additional profits are mainly made elsewhere in the SC.

9.3.4 Using the step-by-step approach in practice

One of the questions that remains is whether a best practice SC scenario, resulting from the application of our approach, will actually be implemented in the SC. Section 3.5 discusses two types of SC control: centralised (the SC cockpit) or decentralised. Up to now both views assume a (bounded) rational decision making approach. Cox (1999) states (see also box 9.1):

'There are chains in which companies are able to construct strategies that allow them to obtain dominant control over particular supply chain resources. Once this is established, this ownership allows them to satisfice rather than delight customers, and also to aggressively leverage their suppliers so as to allow for a maximum appropriation of value for themselves. Companies like Microsoft, major supermarket chains, and companies with unique brands are in this position' (Cox, 1999).

Cox continues: 'only by understanding the power struggle over value appropriation between buyers and suppliers around particular supply chain resources, as well as the horizontal competition between direct competitors, is it possible to understand the real strategic and operational environment within which companies and entrepreneurs have to operate'. This implies that the SC cockpit view will not always result in an optimised SC. The key to success is to understand the particular circumstances in which the organisation is operating and to consider how these circumstances are likely to change over time. We refer to Section 2.7 which discusses additional factors that influence this process, such as trust.

Box 9.1 ICT systems: enablers of SCM?
Often new ICT systems are seen as enablers for SCM. However, recently five major car manufacturers presented an example of the opposite. DaimlerChrysler, General Motors, Ford, Renault, and Nissan announced the establishment of a new internet site on which suppliers of raw materials are played off against each other. Not the real SCM spirit!

(source: Volkskrant, 28 February 2000)

9.3.5 Concluding remark

We acknowledge that our step-by-step approach to generate, model and evaluate SC scenarios should be considered as only the first step towards a generic toolbox that can be used to improve SC performances. The discussed limitations of the research will be used the next section to help formulate directions for further research.

9.4 Recommendations for further research

SCM research should focus on the construction of a toolbox comprising theories, methods and techniques and even working applications to analyse and improve the management of the SC. With this objective as a starting point, we can identify the following ways to elaborate on our research.

Refinement of the list of SCM redesign principles and sources of SC uncertainty
The list of SCM redesign principles evolved during a review of Information Technology, Operational Research, management studies, and some marketing literature. Although we expect that our list is relatively complete, additional principles might be found in related research areas, such as Strategic Management, Quality Management, etc. Furthermore, some of the SCM redesign principles are related to each other and some can be further detailed.

The list of sources of SC uncertainties is the result of our case studies. By checking this list in other SCs and, probably even more interesting, in other industries, extensions can possibly be made. This will make our step-by-step approach for SC redesign more generically applicable and useful in SC redesign projects.

Refinement of the modelling approach
When evaluating the modelling approach the following suggestions for further research can be formulated:

- This research showed that simulation is a helpful tool for supporting decision makers in making SC decisions. On the other hand, we discussed some analytical tools to aid decision makers. We state that both types of tools can be used in the SC improvement process. However, it is not clear at the moment in which situations and for what purposes which type of tool should be used. Swaminathan et al. (1998) present an interesting multi-agent approach to model SC dynamics, in which a combination of analytical and simulation models is used. Also, the use of different types of simulation tools should be evaluated. For example, Petrovic et al. (1998) model a SC using fuzzy modelling and simulation; they find fuzzy sets a usable tool to represent uncertainty in system parameters. Further research into the applicability of different types of quantitative methods combined with a typology of SC decision situations will help in constructing a toolbox for SC decision makers (see also Section 9.3.2).
- The building of SC simulation models will be greatly facilitated by constructing generic building blocks. In this research, building blocks were constructed at a high model level (SC stages) and for some of the detailed model elements (e.g. the process that triggers business processes at fixed times). By constructing a library of generic building blocks on the level of individual business processes, efficient and effective modelling of SCs can be facilitated. A start in this process has been made in Msc-projects for modelling food SCs in ExSpect (Olieman, 1997) as well as Arena (Van Dijk, 1999).

SC partner selection

Our approach was developed from the situation in which SC participants are gathered at a table discussing ways to improve their performance. However, the first question is how to get the SC participants together at one table. We refer to the work of Migchels (2000), who has focussed on the SC partner selection process and gives a comprehensive literature review on the subject. Maybe our approach can be extended to assist in the identification of minimum requirements for the selection of new SC partners.

Adopting a SC network perspective

In order to evaluate SC scenarios for all SC participants and related stakeholders, SCs should be investigated from a network perspective focusing on parallel interaction problems. In doing so, new SC scenarios might evolve, for example, the concept of shared distribution. This concept aims at the co-operation of organisations within parallel SCs. By establishing a shared distribution centre from which products of both SCs can be delivered to customers, costs can be decreased. In fact these are functions that are fulfilled by logistics service providers and that make use of economies of scale.

One of the assumptions in the simulation study was that when retail outlets are delivered to more frequently, products can be transported together with other product groups that are already delivered more frequently. Analysing SCs from a network perspective can test this assumption.

Facilitating information transparency and SC planning

Market dynamism has increased significantly in the last decade. A good example is the recent price war Dutch retailers have been engaged in (Food Management, 2000). This dynamism requires producers to be responsive to these changes in order to satisfy customer demands. Frequent and fast planning seems essential in this process, resulting in an increased demand for SC decision support systems to assist planning in and over SC stages. Suppliers of ERP packages are working to superimpose Advanced Planning Systems (APS) on top of the ERP systems to facilitate integrated planning (De Kimpe and Van Breedam, 2000). For example, the APS available-to-promise module provides information on the availability of goods in the near future. The result is based, among other things, on real-time data from production and inventory control in all (incorporated) SC stages. The implementation of such systems requires the availability of all relevant management information. Performance indicators should be uniquely identified and should be followed in time.

Definition of unique and integrated performance measures
Some authors call for more integrated performance measures, which involve measurement of an entire process or series of processes across functional areas (Caplice and Sheffi, 1994). Integrated measures offer more control over the SC since key managers have measures reflecting actions across a number of functional areas. Without integrated measurement information, SC members have little incentive to work with other members. The only concern is to perform well on their own measures even if that performance is at the expense of other supply chain members (Bechtel and Jayaram, 1997). These performance measures should be uniquely identified throughout the SC to eliminate translation problems.

The trade-off between performance indicators can be facilitated by weighing each performance goal (see Section 6.2). De Boer (1998) gives an extended overview of all techniques that can be used to assign weights to performance indicators.

Green Supply Chains
In recent times, changing environmental awareness has also influenced SCM research. For example, Bloemhof-Ruwaard et al. (1995) cite factors that might influence the future direction of SCM: legal requirements or consumer pressure to reduce waste, green SCM to include waste treatment, reuse of materials and packaging, recovery of products, adaptation of new materials, product redesign, process changes. As already posed in the discussion, these issues provide additional elements to be incorporated in the design of a toolbox for SC analysis and redesign. In Hameri and Paatela (1995) a multidimensional simulation tool is presented for modelling SC systems related to the chemical industry, incorporating environmental assessment. Also important in relation to this, especially in food SCs, are tracking and tracing issues to guarantee food safety (Beulens et al., 1999).

Crossing discipline boundaries
SCM integrates the different research fields. For example, retail inventory management and consumer choice behaviour have been largely isolated areas of investigation within academic literature. Retailers have become aware of the importance of co-ordinating assortment and inventory management decisions and they now pursue Category Management programs. Understanding precisely how choice behaviour (product substitution effect) can be incorporated in inventory models and what impact it has on assortment decisions and operating performance are the main research challenges in this area (Mahajan and Van Ryzin, 1999).

Finally, an important research field lies in the combination of technological disciplines and operations management, especially now that the introduction of new process and information technologies (see Chapter 1) facilitates new ways of management.

Epilogue

'A shared language precedes mutual trust
and leads to a professional partnership'
(SC participant in case II, 1998)

At the start of this research little operational knowledge was available on SCM, especially with respect to the SCM redesign options available to a company. By reporting and discussing the findings of this research in international journals and congress proceedings during the last five years (Van der Vorst et al. 1996-2000) we hope to have contributed to the body of knowledge on SCM.

When we revisited our case study companies recently, we found that they had achieved positive results. All companies emphasised that a much better insight was obtained in the collaboration project with suppliers and/or customers. It was astonishing to find that current practices in the SC are often the result of agreements made a long time ago, and that these practices are not adjusted to later changes in the strategic and operational management and control in SC stages. Often, good descriptions of current practices were never made. At the moment, all companies are working on the reduction of SC uncertainties. The producers are focusing on the incorporation of their suppliers, thereby extending their SC; the retailers are focusing on the implementation of new ICT systems. The advocated best practice SC scenario for the SC for cheese and desserts has been implemented in practice. However, an ex post analysis of total SC costs and benefits has not yet been made.

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Glossary

'The basic tool for the manipulation of reality
is the manipulation of words'
(Philip Dick)

Activity Based Costing (ABC)
A management accounting technique that recognises that it is activities which cause cost and not products. The key to ABC is to seek out the 'cost drivers' along the logistics pipeline that cause costs because they consume resources. (Cooper and Kaplan, 1991)

Actor
A stage in the supply chain performing certain processes and supplying goods or services to its customers.

Back order
Materials requested by a customer that are unavailable for shipment at the same time as the remainder of the order. They can be shipped when available. (Johnson and Wood, 1996)

Balanced Scorecard.
A scorecard with KPIs that provides ongoing guidance on those critical areas where action may be needed to ensure the achievement of those goals. It encompasses a number of KPIs that will provide management with a better means of meeting strategic goals than the more traditional financially oriented measures, such as customer loyalty and employee satisfaction. (Kaplan and Norton, 1992)

Benchmarking
The process of comparing and measuring an organisation's business process performance against either the performance of business leaders or other companies to determine best practices.

Best-Before-Date (BBD)
The minimum date up to which a product is still fit for consumption.

Best practice
Doing things in the most effective manner, usually focusing upon a specific activity or operation (a critical success factor) such as inventory management, customer service, and so on. (Gattorna and Walters, 1996)

Best practice SC scenario
A 'best practice' SC scenario refers to a feasible SC configuration and operational management and control of all SC stages that achieves the best outcome for the whole system.

Business Process Redesign (BPR)

The fundamental rethinking and radical redesign of business processes to achieve dramatic improvements in critical, contemporary measures of performance, such as cost, quality, service and speed. (Hammer and Champy, 1993)

Category Management (CM)

A management approach focusing on product categories for the optimisation of assortments, product introductions and promotions.

Chain Integration

The co-ordination of logistical activities between separate links in the chain in order to plan, control and execute the logistic processes as one integrated system supported by an integrated information system, with the aim of improving the logistic performance of the complete system. (Boorma and Van Noord, 1994)

Co-makership

The development of long-term relationships with a limited number of suppliers on the basis of mutual confidence. (Christopher, 1998)

Co-ordination

The additional information processing performed when multiple, connected actors pursue goals that a single actor pursuing the same goals would not perform. (Malone, 1987)

Cross-docking

Immediately moving cargo as it is being received at a warehouse to a loading dock where it is loaded aboard outbound trucks.

Customer Order Decoupling Point (CODP)

A stock point that separates the part of the organisation oriented towards customer orders form the part of the organisation based on planning. Downstream of the CODP the material flow is controlled by customer orders and focus is on customer lead-time and flexibility. Upstream towards suppliers, the material flow is controlled by forecasting and planning and the focus is on efficiency (usually employing large batch sizes).

Decision Process

A set of actions and dynamic factors that begins with the identification of a stimulus for action and ends with the specific commitment to action. (Mintzberg et al., 1976)

Distribution Requirements Planning (DRP-I)

A system of determining demands for inventory at distribution centres, consolidating the demand information backwards, and acting as input to the production and materials system. (Lambert and Stock, 1993)

Distribution Resource Planning (DRP-II)

Extends DRP-I to include the planning of key resources in a distribution system.

Echelon stock

The inventory of the component plus the entire inventory of downstream items that use or require the component (e.g., subassemblies or end items). (De Bodt and Graves, 1985)

Efficient Replenishment (ER)

Changing the way of operational co-operation in the SC supported by a free flow of accurate and timely information, integrated with the flow of product, throughout the grocery SC. ER consists of secondary improvement concepts which implemented together should result in responsive, flexible, customer-order driven SCs. (Coopers & Lybrand, 1996)

Electronic Data Interchange (EDI)

Buyers and sellers are linked by computers and use computers to exchange orders and other routine information.

Extended Enterprise

A network of organisations characterised by a dominating company that extends its view and scope of operation and takes the lead and sets the pace. The relationships in the network are well structured and guarded by formal agreements.

First-in-first-out (FIFO)

A scheduling rule whereby the oldest item in line gets processed first.

Globalisation

The world-wide reduction of trade barriers and development of regional, multi-country economic zones.

Glocalisation

The global sourcing of raw materials combined with local marketing. (Lubbers, 1998)

Installation stock

The inventory of the component neglecting all downstream inventories. (De Bodt and Graves, 1985)

Lead time

The time that elapses from the moment an order is placed to the point in time when ordered goods are received.

Logistical (SC) concept

A description of the current SC by characterising four elements, i.e. the managed, managing, and information systems and organisation structures in the SC.

Logistics

That part of the supply chain process that plans, implements and controls the efficient, effective flow and storage of goods, services and related information from the point-of-origin to the point-of-consumption in order to meet customer requirements.

Logistic Control Concept

See Managing System.

Logistics Management

The process of planning, implementing and controlling the efficient, cost-effective flow and storage of raw materials, in-process inventory, finished goods, and related information from point-of-origin to point-of-consumption for the purpose of confirming to customer requirements. (Lambert and Stock, 1993)

Managed System

See SC configuration

Managing System

The managing system plans, controls and co-ordinates business processes in the SC while aiming at realising logistical objectives within the restrictions set by the SC configuration and strategic SC objectives. It can be described by four elements: hierarchy in decision levels, type of decision making, position of the CODPs and level of co-ordination.

Marketing Channel

An orchestrated network of interdependent organisations that creates value for end-customers by generating form, possession, time and place utilities. (Stern et al., 1996)

Mass-individualisation

The fact that buying behaviour of consumers is changing constantly, is unpredictable and differs per individual creating fragmented markets.

Mathematical Models

A representation of a system in terms of logical and quantitative relationships that are then manipulated and changed to see how the real system would react. (Law and Kelton, 1991)

Model

An external and explicit representation of part of reality as seen by the people who wish to use that model to understand, change, manage, and control that part of reality in some way. (Pidd, 1999)

Material Requirements Planning (MRP-I)

A computer-based production and inventory control system that attempts to minimise inventories yet maintain adequate materials for the production process. (Lambert and Stock, 1993)

Manufacturing Resource Planning (MRP-II)

A set of computer modules that allows a from to evaluate manufacturing action plans from a resource (labor, plant capacity) point of view, manage and control these plans, and review their financial implications. (Lambert and Stock, 1993)

Order cycle

Elapsed time between when a customer places an order and when the goods are received.

Order forecast horizon

The time period between placing an order and the receipt of goods of the next order.

Order picking

The selection of specific items to fill a complete customer order in a warehouse.

Order sales period

The time period between two successive deliveries.

Partnership

An ongoing relationship between two organisations which involves a commitment over an extended time period, and a mutual sharing of the risks and rewards of the relationship. (Ellram, 1991)

Performance indicator (PI)
A process characteristic, which compares the efficiency and/or effectiveness of a system with a norm or target value.

Postponed production
Delaying as much as possible that moment in a production process at which different product versions assume their unique identity, thereby gaining the greatest possible flexibility in responding to changing consumer demands. (Van Hoek, 1998)

Power
The ability of one channel member to get another channel member to do what it otherwise would not have done. (Stern et al, 1996)

Process
A structured measured set of activities designed to produce a specified output for a particular customer or market. (Davenport, 1993)

Quick Response (QR)
A partnership strategy in which retailer and supplier work together to respond more quickly to consumer needs by sharing information on POS activity with the aim to jointly forecast future demand for replenishable items and to continually monitor trends to detect opportunities for new items. (Fisher, 1997)

Redesign variable
A SC redesign variable is a management decision variable at strategic, tactical or operational level that determines the setting of one of the descriptive elements of the managed, managing, or information system or organisation structure.

Roll-in container
Container on wheels that is used in DCs as well as retail outlets for transporting goods.

Serial Inventory Systems
SCs in which each firm has only one supplier and/or customer.

Shelf life
The remaining time, i.e. number of days, a product is still fresh enough for consumption.

Simulation
The process of designing a mathematical or logical model of a real system and then conducting computer-based experiments with the model to describe, explain, and predict the behaviour of the real system. (Hoover and Perry, 1989)

Stock-keeping unit (SKU)
Each separate type of item that is accounted for in an inventory.

Sources of supply chain uncertainties
Inherent characteristics of the SC and characteristics of the managed system, managing system, information system and/or organisation structure that are present at a certain point in time that generate SC uncertainty.

Supply chain (SC)

The series of (physical and decision-making) activities connected by material and information flows that cross organisational boundaries aimed at producing value in the hands of the ultimate consumer whilst satisfying requirements of other stakeholders in the SC.

Supply chain configuration

The SC configuration refers to the set of participants with specified roles in the SC and required infrastructures (Beulens, 1996) defined at three levels: network design, facility design, and resource design.

Supply Chain Costing

Cost calculation method that provides a mechanism for developing cost-based performance measures for the activities comprising the key processes within a complete supply chain. (Lalonde and Pohlen, 1996)

Supply Chain Management (SCM)

SCM is the integrated planning, co-ordination and control of all logistical business processes and activities in the SC to deliver superior consumer value at less cost to the SC as a whole whilst satisfying other stakeholders in the SC.

Supply Chain Management redesign principle (SCM-RP)

Changes in the logistical concept that aim at improving the performance of a certain SC KPI.

Supply chain performance

The degree to which a SC fulfils end user requirements at any point in time concerning the relevant performance indicators and at what total SC cost.

Supply chain scenario

A SC scenario is an internally consistent view of a possible instance of the logistical SC concept, i.e. the managed, managing, and information systems and organisation structures in the SC.

Supply chain uncertainty

Decision making situations in the SC in which the decision-maker is unable to accurately predict the impact of control actions on system behaviour because of a lack of:

- information (or understanding) of the environment or current SC state;
- a consistent model of the SC presenting the relationships between SC redesign variables and SC performance indicators.

Stock out

Absence of an item at the same time there is a willing buyer for it.

Stock out cost

Cost to seller when it is not possible to supply an item to a customer who is prepared to buy it.

System

A structured set of objects and/or attributes together with the relationships between them in its environment.

System Analysis

Analysis in which the importance of each aspect of a situation is recognised, along with the relationship of each part to all other aspects of the situation. (Johnson and Wood, 1996)

Total Cost of Ownership (TCO)
Cost calculation method that attempts to identify the total acquisition price by including the costs of purchasing, holding, poor quality, and delivery failure. (Ellram, 1995)

Uncertainty
A decision making situation in which a decision-maker does not know how to act because the outcomes of possible actions are not precisely known.

Value
The amount buyers are willing to pay for what a company provides, measured by total revenue. (Stern et al. 1996)

Value-Adding Logistics (VAL)
See postponed production.

Value-Adding Partnership (VAP)
A set of independent companies that work closely together to manage the flow of goods and services along the entire value-added chain.

Value chain
The system of dependent activities in an organisation with relationships that impacts the costs or effectiveness of the system. (Porter, 1985)

Value Chain Analysis (VCA)
A method for identifying ways to create more customer value based on Porter’s value chain concept. In a VCA the firm’s costs and performance are evaluated in each value-creating activity to identify improvement options. (Kotler, 1988)

Value Stream
The specific parts of the firms that actually add value to the specific product or service under consideration. (Hines and Rich, 1997)

Value System
The total system of value chains of suppliers, customers and the organisation itself. (Porter 1985)

Vendor Managed Inventory (VMI)
A management concept in which the supplier manages the inventory at the customer’s location.

Virtual Enterprise
A network of organisations characterised by complementary contributions from a number of different companies in which one company plays the role of a broker. The virtual enterprise looks for new markets and can organise itself to satisfy the market, even though it currently lacks the necessary capabilities.

Appendices

- A Pitfalls of SCM and their opportunities.
- B The Supply Chain Council's integrated SC metric framework.
- C Process mapping tools.
- D ODL-description of process number 4 in the SC for fresh produce.
- E Overview of all sources of SC uncertainty and corresponding SC redesign options in case IIA.
- F Overview of all sources of SC uncertainty and corresponding SC redesign options in case IIIA.
- G A typology of sources of SC uncertainty identified in the case studies.
- H The relationship between the order forecast horizon, lead time and delivery frequency
- I Delivery days in the SC for chilled salads (case IIA).
- J Sensitivity analysis of the model results in case IIA.
- K Delivery days in the SC for cheese and desserts (case IIIA).
- L Sensitivity analysis of the model results in case IIIA.
- M The impact of a higher delivery frequency on stock levels

Appendix A Pitfalls of Supply Chain Inventory Management and corresponding SC opportunities according to Lee and Billington (1992).

Problem related to	Pitfalls	Symptoms	SC opportunities
Information definition and SC management	1. No SC metrics	• Independent and disconnected individual sites • Incomplete metrics • Performance measures not tracked • No attention to measures tracked	• Define SC objectives • Install and monitor SC performance measures • Metrics must be oriented to customer satisfaction (responsiveness)
	2. Inadequate definition of customer service	• Inadequate of line-item fill rate measure • No measures for response times, lateness and/or backorder profile	• Measure delivery performance in terms of completed orders (and not per product line) • Measure total response time and average lateness
	3. Inaccurate delivery status data	• Delays in providing delivery information • Inaccurate delivery information	• Provide customers with timely and accurate updates on the status of late orders
	4. Inefficient information systems	• Inadequate linkage among databases at different sites • Proliferation of operation systems for the same functions at different sites • Delays and inaccuracies of data transfer	• Eliminate delays in information retrieval and transmission • Use the same operating systems for the same functional tasks at different sites
Operational problems	5. Ignoring the impact of uncertainties	• No documentation or tracking of key sources of uncertainties • Partial information on sources of uncertainty	• Documentation and tracking of key sources of uncertainties • Tracking of root causes of uncertainties
	6. Simplistic inventory holding policies	• Stocking policies independent of magnitudes of uncertainties • Static stocking policies • Generic and subjective stocking policies	• Make stocking policies dependent of magnitudes of uncertainties • Dynamic stocking policies • Make product specific stocking policies
	7. Discrimination against internal customers	• No service measures of internal customers • Low priority for internal orders • Inappropriate incentive systems • Jockeying for priority among different internal divisions.	• Create service measures for internal customers • Create appropriate incentive systems
	8. Poor co-ordination between different supplying divisions	• No co-ordination among supplying divisions to complete an order • No system information among multiple supplying divisions • Independent shipment plans	• Co-ordination among supplying divisions to complete an order • Global system information among multiple supplying divisions • Dependent shipment plans
	9. Incomplete shipment methods analysis	• No consideration of inventory and response time effects	• Trade-off inventory and response time effects to mode and cost of transportation

Appendix A Continued

Strategic and design related problems	10. Incorrect assessment of inventory costs	• Omission of obsolescence and cost of rework • No quantitative basis for inventory holding cost assessments	• Include obsolescence and cost of rework • Use quantitative basis for inventory holding cost assessments
	11. Organisational barriers	• Independent performance measures and incentive systems at different sites • Barriers between manufacturing and distribution	• Create dependent performance measures and incentive systems at different sites and at different functional units
	12. Product-process design without SC consideration	• No consideration of manufacturing and distribution in product-process design • No consideration in design for customisation and localisation • Organisational barriers between design and the SC	• Consideration of manufacturing and distribution in product-process design • Consideration in design for customisation and localisation
	13. Separation of SC design from operational decisions	• Chain decisions without consideration of inventory and response time efficiencies	• Chain decisions with consideration of inventory and response time efficiencies
	14. Incomplete SC view	• Focus on internal operations only • Inadequate understanding of operational environment and needs of immediate and ultimate customers	• Focus on external operations • Understand operational environment and needs of immediate and ultimate customers • Share status information in the SC

Appendix B The Supply Chain Council's integrated SC metric framework

In November 1996, the Supply Chain Council introduced its Supply Chain Operations Reference (SCOR) model. Member companies, including diverse industry leaders such as Dow Chemical, Compaq, Texas Instruments, and Federal Express, worked together for over six months to develop the model. They defined common SCM processes, matched these processes against 'best practice' examples, and benchmarked performance data as well as optimal software applications. The end result was a tool for:

(1) measuring both SC performance and the effectiveness of SC re-engineering (see Table B.1: each composite metric is defined in detail by a number of metrics, see www.supply-chain.org.);
(2) testing and planning for future process improvements.

SCOR comprises a four-level pyramid that provides a guide for SC members to follow on the road to integrative process improvements:

- Level 1 defines the four key SC process types (i.e. plan, source, make, and deliver) and the point at which SC competitive objectives are established;
- Level 2 defines 26 core SC process categories established by the Supply Chain Council with which SC partners can jointly configure their ideal or actual operating structure;
- Level 3 provides partners with information useful in planning and setting goals for SC process improvements;
- Level 4 implements SC process improvement efforts.

The model was tested both in a mock SC situation and internally at Rockwell Semiconductor Systems with highly positive results. The main improvement was that various departments are now talking the same language (Handsfield and Nichols, 1999).

Table B.1 Supply Chain Council's integrated SC metric framework (Bowersox, 1996).

Metric type	*Outcomes*	*Diagnostics*
Customer satisfaction/ Quality	1. Perfect Order Fulfilment 2. Customer Satisfaction 3. Product quality	9. Delivery to commit date 10. Warranty costs, returns and allowances 11. Customer inquiry response time
Time	4. Order fulfilment lead time	12. Source/make cycle time 13. Supply chain response time 14. Production plan achievement
Costs	5. Total supply-chain costs	15. Value added productivity
Assets	6. Cash-to-cash cycle time 7. Inventory days of supply 8. Asset performance	16. Forecast accuracy 17. Inventory obsolescence 18. Capacity utilisation

Appendix C Process Mapping Tools

One of the process redesign methods mentioned by Davenport (1993) is the process value analysis. *Process value analysis* is a fairly straightforward approach that involves studying process components and activities to understand process flow. Taking the current process as a point of departure, it documents elapsed time and expense for each activity. Requirements of customers, both internal and external, are solicited and used to test the value of each activity. Activities that add no value to a process output (in the eyes of the customer) become candidate for elimination. However, a shortcoming is that the tool is not described in a usable format.

Hines and Rich (1997) describe seven other value stream mapping tools that can be used (in combination) to redesign and improve current supply chains. They evaluate the usefulness of each tool in the identification and elimination process of JIT wastes (overproduction, waiting, transport, inappropriate processing, excess stock, unnecessary motion and correction of mistakes (Shingo, 1989)). The seven value stream mapping tools are (Hines and Rich, 1997):

- *Process activity mapping*: describing and categorising each activity in terms of activity types (operations, transport, inspection and storage). The machine or area used for each of these activities is recorded, together with the distance moved, time taken and number of people involved. The basis of this approach is to try to eliminate activities that are unnecessary, simplify others, combine yet others and seek sequence changes that will reduce waste.
- *Supply chain response matrix* (or time-based process mapping): portraying in a simple diagram the critical lead time constraints for a particular process. The supply chain response time for new products to arrive at the market is the sum of the cumulative inventory in the value stream in days and the cumulative lead time.
- *Production variety funnel*: analysing the structure of the supply chain (divergence, convergence, etc.) and typifying the complexity to be managed in the supply chain. It maps the number of product variances against the lead time.
- *Quality filter mapping*: identifying quality problems in the supply chain by mapping three types of defects latitudinally along the supply chain.
- *Demand amplification mapping*: mapping actual consumer sales and orders placed upstream in the supply chain to show how demand changes along the supply chain in varying time buckets (‘Forrester effect’; see Section 4.4).
- *Decision point analysis*: identifying the customer order decoupling point and assessing the processes to ensure that they are aligned with the relevant push or pull philosophy and evaluate ‘what if’ scenarios.
- *Physical structure mapping*: the volume structure is visualised by mapping all firms involved in the supply chains of a focal firm, with the area of each part of the diagram proportional to the number of firms in each set. Cost structure mapping does the same thing but then the area of the diagram is linked to the value added by the corresponding firm.

According to Hines and Rich (1997) the relevant mapping tools can be chosen by identifying the various wastes (see the Just-in-Time concept; Ohno, 1988) that exist in the value stream (see Table C.1). Interviewing managers in the value stream to ascertain the individual importance weighting of the seven wastes accomplishes this. The supply chain response matrix tool is closely related to another mapping tool, namely *strategic lead time management* (Gattorna and Walters, 1996). This involves tracking the length of the time inventories of raw materials, components and finished goods spend in the pipeline until they are sold to end users. All members of the pipeline must know where the product is at any time, regardless of its ownership. Strategic lead time management focuses on the resource aspect of time and attaches a value that may be measured (Turner, 1994).

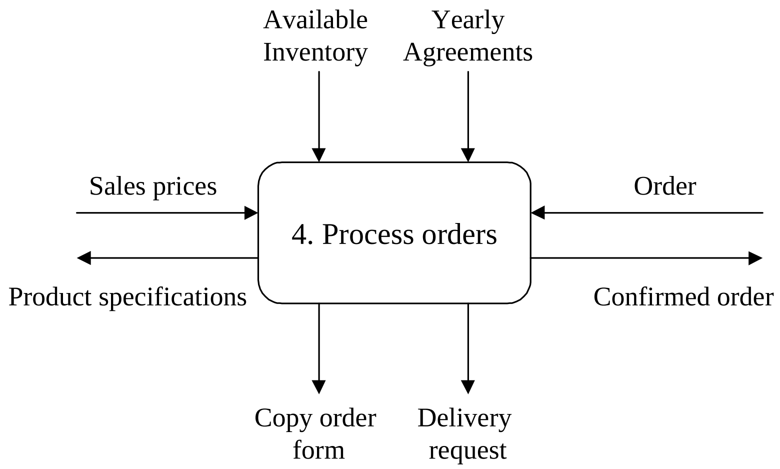
Table C.1 Value stream mapping tools (Hines and Rich, 1997).

Wastes	*Process activity mapping*	*Supply chain response matrix*	*Production variety funnel*	*Quality filter mapping*	*Demand amplification mapping*	*Decision point analysis*	*Physical structure mapping*
Over-production	L	M		L	M	M	
Waiting	H	H	L		M	M	
Transport	H						L
Inappropriate processing	H		M	L		L	
Unnecessary inventory	M	H	M		H	M	L
Unnecessary motion	H	L					
Defects	L			H			
Overall structure	L	L	M	L	H	M	H

Key: H = High correlation and usefulness
M = Medium correlation and usefulness
L = Low correlation and usefulness

Appendix D ODL description of process number 4 in the SC for fresh produce

Process map



Process text

Process name:
Process orders

Process objective:
Sales persons process incoming customer orders into delivery requests within the yearly agreements and according to calculated sales prices.

Relations:

- Yearly Agreements is input from 'Strategic process'
- Incoming Order is input from 'Customer'
- Confirmed Order is output to 'Customer'
- Delivery Request is output to 'Plan distribution'
- Copy Order form is output to 'Invoicing' and 'Plan purchasing specifications'
- Product Specifications is output to 'Plan purchasing specifications'
- Sales Prices is input from 'Plan purchasing specifications'
- Inventory Levels is input from 'Inventory control'

Entities:

Product Specifications:	Number of unit loads of Product-Size.
Product Size:	Unique code referring to a product type, quality class, and packaging material.
Incoming Order:	Request for delivery products with several order-lines comprising Product Specifications and delivery date/time.
Confirmed Order:	A confirmation of order delivery with sales prices.
Yearly Agreement:	Restrictions for ordering and delivery per customer comprising lead times and price agreements.
Delivery Request:	Request for expediting Incoming Order according to order specifications.
Inventory:	Product Specifications per location.
Sales Person:	Communicates with customers and knows product- and price developments in Europe.
Data Typist:	Processes Incoming Orders into the Information System.

Process transitions:

- Sales Person:
  - Receives Incoming Order per fax or telephone
  - Checks Yearly Agreement with Customer
  - Checks availability of Product Specifications by Requesting Inventory
  - Accepts Incoming Order and hands over Copy Order Form to Data Typist
- Sales Person sends Purchasing Specifications to ‘Plan purchasing specifications’and ‘Invoicing’
- Sales Person:
  - Receives Sales prices from ‘Plan purchasing specifications’
  - Confirms Order with Customer

Responsibilities related to the process:

Sales person is responsible for accepting all Incoming Orders and offering Promotions to Customers in order to obtain high Sales.

Appendix E Overview of all sources of SC uncertainty and corresponding SC redesign options in case II.

Inherent sources of SC uncertainty		***SC redesign strategy***
❑ Variable raw material quality impacting supply quantity and production time. ❑ Variable production yield. ❑ Raw materials require defrosting time. • Peak in sales on Friday and Saturday or peak in demand due to weather. • Traffic congestion.		• Demand Management.
Managed system	***SCM redesign principles***	***SC redesign strategy***
SCM-RP 1. Redesign the roles and processes in the SC. ® No personnel available to accept goods or fill shelves. ❑ Machine downtime. ❑ Product loss due to inaccuracy in production/DC. ❑ Time for quality check required before raw materials are released. • Too much inventory in SC. • Product damaged during handling. • Quality decay due to long storage at retailer DC. • Shelf capacity shortages due to expanding product assortment.	a) Change or reduce the number of parties involved in the SC. b) Change the location of facilities. c) Re-allocate the roles actors perform in the SC and related processes. d) Eliminate non-value-adding activities in the SC.	❑ Do quality check at certified / contracted suppliers. • Eliminate the DC as storing facility and ordering partner; apply cross docking. • Make supplier responsible for inventory levels at retailer (VMI). • Expand shelf capacity by expanding storage space. • Reduce the need for filling shelves; introduce standard containers to be used also in the store.
Managing system	***SCM redesign principles***	***SC redesign strategy***
SCM-RP 2. Reduce customer order lead times ® Wrong order forecast due to long order forecast horizon. ® Long processing times due to batch order processing. ® Waiting times to add supplied goods to stock. ❑ Waiting times due to shortage of raw materials. ❑ Orders are sent by fax or phoned in, which requires extra time for them to be entered into the system. ❑ Long production runs. • Order pick forms are not printed according to the route plan; they have to be sorted afterwards. • Long supplier lead times in case of product shortages. • Orders are sent too late. • Waiting times before printing pick lists.	a) Change position of CODP. b) Implement ICT systems for information exchange and decision support. c) Reduce waiting times. d) Create parallel administrative and logistical processes. e) Increase manufacturing flexibility. f) Improve the reliability of supply and production quantity and quality.	Reduce forecast horizon by decreasing order lead time facilitated by: • implement EDI for order exchange. • implement real-time order processing system. • reduce waiting and processing times by automating order entry and aligning SC systems. • perform processes parallel. • reduce set-up times of packaging lines. • co-ordinate activities in the SC (see SCM-RP 5). ® change position of CODP: introduce cross docking principle at retailer DC. ❑ decrease supplier lead times.
SCM-RP 3. Synchronise all logistical processes to consumer demand ® Stock outs due to time window for refilling shelves. ❑ Long production runs result in long production throughput times. ❑ Fixed production schedule. • Long forecast horizon resulting in large safety buffers in the SC.	a) Increase the number of events per time unit (frequency) for all SC processes. b) Decrease the lot sizes applied in SC.	® Increase the frequency of filling shelves. ❑ Increase the production frequency and decrease production batch sizes. • Increase the ordering and delivery frequency and decrease order batch sizes.

Appendix E Continued

Managing system	***SCM redesign principles***	***SC redesign strategy***
SCM-RP 4. Co-ordinate and simplify logistical decisions.		
® Orders arriving after printing pick lists have more chance of facing stock outs. ® Order picking uses sticky labels that sometimes fall off. ® Many people are authorised to adjust inventory levels leading to little data integrity. ❑ Supplied goods not accorded by quality control but still administrative added to stock. ❑ Orders to suppliers are in kg and not measured correctly (a 10% variation in quantity accepted). ❑ Orders are picked according to loading list; the last customer receives most shortages. ❑ Products stored too long: FIFO not applied or wrong forecast. ❑ Too much inventory due to fixed production batch sizes or wrong demand forecast. ❑ Yield differs from production plan; scrap factors incorporated in BOM not correct. ❑ Shortages in supply due to too low safety stock levels. ❑ Products are allocated to a customer who is to be supplied later on whilst rush orders cannot be delivered immediately. ❑ Shortages during picking are written down on forms that get lost resulting in extensive searches and discussions. • Forrester effect due to human interacted order policy at DC. • Too many products ordered due to data errors or minimal order batch quantity. • Forward buying of products during promotion weeks at lower product prices.	a) Co-ordinate and redesign policies. b) Eliminate or reduce subjective human decision making. c) Differentiate to products, systems and processes. d) Simplify structures, systems, processes and products.	® Automate order procedure in retail outlets and use demand forecasting modules. ® Eliminate order processing policy at retailer DC. ® Adjust authorisation codes concerning inventory control. ❑ Establish long term contracts with suppliers based on short lead times and frequent deliveries. ❑ Adjust scrap factors constantly. ❑ Implement integral information system that gives insight into coming orders and goods at all times. ❑ Reduce the number of suppliers. ❑ Eliminate the presence of shortages at order picking by checking real-time inventory levels before generating order forms. • Introduce rationing policy at order picking in which shortages are divided amongst all customers. • Improve labelling at order picking or introduce Radio Frequency (FIFO) order picking. • Improve inventory control policies; use other forms or automate activities. • Decrease lot sizes in the SC. • In calculating safety stock levels differentiate the formula per product type. • Eliminate forward buying by co-ordinating consequences of actions.

Appendix E Continued

Information system	***SCM redesign principles***	***SC redesign strategy***
SCM-RP 5. Create information transparency in the SC ® No insight in sales during the day. ® Product shelf stickers not correct. ® Scanning problems result in missing products in outlet. ® No shelf life information available of stocked products in the DC. ® Batch processing inventory management system. ® Eliminated products from assortment are not removed from article list. ❑ Shortages are not mentioned on shipment note to customer. ❑ The information system provides no link between planning and operational progress. ❑ Inventory levels are never up to date; because production output usually differs from planning. ❑ Tracking product flaws in process not possible per batch resulting in large losses. ❑ Shortages assumed but stock levels not up to date. ❑ The corrected order pick form (with shortages and so on) is used as shipping list to DC but is prone to errors. ❑ Forrester effect due to no insight into inventory levels at retailer DC and into demand pattern retail outlets. • Too much exchange of data by paperwork prone to errors. • Data errors in order entry process by phone. • Data not usable due to aggregation level. • Retailer and the producer use different article numbers.	a) Establish an information exchange infrastructure in the SC. b) Exchange demand, supply, inventory or work-in-progress information. c) Increase information timeliness by implementing real-time information systems. d) Develop a common database and standardise bar-coding.	❑ Eliminate shipment notes to customers; inform customer via EDI on coming shipments. ❑ Implement integral information system; supplying WIP information at all times with possibility to track products per batch. • Implement digital shelf stickers to be adjusted automatically and centrally. • Standardise and agree on bar-coding. • Implement real-time inventory management system. • Exchange inventory and sales information to partners upstream in the SC. • Co-ordinate the type of data that needs to be exchanged in the SC in order to be usable.
Organisation structure	***SCM redesign principles***	***SC redesign strategy***
SCM-RP 6. Jointly define SC objectives and KPIs ® Students fill shelves but do not apply FIFO-principle. ® Product batches with little remaining shelf lives are not reported to Sales department. ❑ Quality perception raw materials of producer and suppliers differs. • Supply delivery performance disagreement because of different definitions for metrics.	a) Jointly define logistical SC objectives and corresponding SC performance indicators. b) Agree on how to measure logistical performances in the SC. c) Align employee's incentives with SC objectives.	• Jointly define SC objectives and corresponding performance indicators (including measurement). • Educate personnel as to the defined SC objectives and the impact of their actions on the realisation of those objectives; reward them accordingly. • Standardise quality perceptions in SC.

Appendix F Overview of all sources of SC uncertainty and corresponding SC redesign options in Case III.

Inherent sources of SC uncertainty		***SC redesign strategy***
® 50% of weekly demand is placed on Friday and Saturday. ® Promotion products influence demand for regular products. ❑ Desserts are delivered with 23 days shelf life left. ❑ Variable production yield / scrap rates. • Delivery time overdue because of traffic congestion.		• Product promotions just on weekdays. • Reduce number of promotions in SC.
Managed system	***SCM redesign principles***	***SC redesign strategy***
SCM-RP 1. Redesign the roles and processes in the SC. ® No personnel available to accept goods or fill shelves. ® Retail outlets cannot be delivered at all times due to regulations concerning noise pollution in city centres. ® Product loss at DC because of accidents. ❑ Additional decay during unconditioned storage or transportation. ❑ Production flexibility restricted due to fixed product/line combinations / Packaging line downtime. • Products are stored too long or under the wrong conditions.	a) Change or reduce the number of parties involved in the SC. b) Change the location of facilities. c) Re-allocate the roles actors perform in the SC and related processes. d) Eliminate non-value-adding activities in the SC.	® Reallocate the stores; place larger stores at the edge of the city with more shelf capacity. ❑ Invest in new production lines. • Reduce the need for filling shelves; introduce containers to be used also in the store. • Use Integral Quality Control in the SC. • Provide enough air-conditioned storage capacity. • Standardise the unit loads in the SC.
Managing system	***SCM redesign principles***	***SC redesign strategy***
SCM-RP 2. Reduce customer order lead times ® Wrong forecast due to a long forecast horizon. ® Producer supplies too late because of delays. ® A lot of time 'wasted' on refilling shelves. ❑ Too little time to pick ordered products. ❑ Long set up times of the packaging lines. ❑ Waiting times before plans are made. • Long process throughput times in the SC. • Waiting times for entering orders into the information system. • Entering orders into the information system takes two hours at the DC as wells as at producer.	a) Change position of CODP. b) Implement ICT systems for information exchange and decision support. c) Reduce waiting times. d) Create parallel administrative and logistical processes. e) Increase manufacturing flexibility. f) Improve the reliability of supply and production quantity and quality.	Reduce forecast horizon by decreasing order lead time: • Implement EDI for order exchange. • Reduce waiting and processing times by automating order entry and aligning SC systems. • Create parallel processes. • Reduce set-up times of packaging lines. • Co-ordinate activities in the SC (see SCM-RP 5). ❑ Decrease supplier lead times. ❑ Buy flexible packaging equipment. • Change cross-docking principle: order picking on outlet level at the retailer DC. •
SCM-RP 3. Synchronise all logistical processes to consumer demand ® Wrong forecast due to a long forecast horizon. ® A lot of time 'wasted' on refilling shelves. ❑ Fixed production schedule; little flexibility. ❑ Long production runs. • Too much inventory.	a) Increase the number of events per time unit (frequency) for all SC processes. b) Decrease the lot sizes applied in SC.	❑ Decrease length of production runs; decrease batch sizes. ❑ Increase production frequency. ❑ Increase supplier delivery frequency. • Reduce forecast horizon by increasing ordering and delivery frequency.

Appendix F Continued

Managing system	*SCM redesign principles*	*SC redesign strategy*
SCM-RP 4. Co-ordinate and simplify logistical decisions.		
® Too many products ordered due to wrong forecasts. ® Orders are sent too late to the producer. ® Goods received at retail outlets are often not checked (mainly because the supplier reports # of kilos delivered and not # of pieces) or checked after shelves are filled which is hardly feasible. ® When shortages are observed the supplier is directly contacted instead of the DC resulting in wrong invoices. ® Other supplier is too late at DC causing delay in truck departure. ® Truck is not available; has not returned from previous route. ® Loading papers are not ready. ❑ Promotional activities are not co-ordinated with Production department; one assumes they can produce all orders. ❑ Too few desserts delivered and not reported in advance. ❑ Working order sequences are changed by personnel. • Products stored too long because: - FIFO-principle not applied at order picking; - too many products ordered due to minimal order batch sizes, a not optimal order procedure, or forward buying.	a) Co-ordinate and redesign policies. b) Eliminate or reduce subjective human decision making. c) Differentiate to products, systems and processes. d) Simplify structures, systems, processes and products.	® Automate ordering procedure in retail outlets and use demand forecasting module. ® Reduce the number of suppliers; higher chance that all suppliers will then be on time at DC. ❑ Change content of shipment papers in accordance with wishes of retailer. ❑ Co-ordinate promotions with Production department. ❑ Introduce automated support for order picking to automatically pick according to FIFO-principle. • Determine optimal stock levels in SC. • Co-ordinate time windows of activities in SC and explain necessity. • Eliminate checking activities by eliminating shipment papers; the supplier registers what has been sent and credits accordingly (trust!). • Make clear communication lines in the SC or notify retail outlets of shortages beforehand. • Educate personnel. • Eliminate forward buying: SC co-ordination.

Information system	*SCM redesign principles*	*SC redesign strategy*
SCM-RP 5. Create information transparency in the SC		
® Problems with article bar-coding in outlets (unreadable, unknown). ® Systems give no insight in sales during the day. ❑ Batch processing inventory management systems: at night the inventories are up dated. ❑ No WIP information and process throughput times available. ❑ Errors when entering order data into the system because the product array on the fax does not correspond to the array in the system. • Product freshness in stock not known.	a) Establish an information exchange infrastructure in the SC. b) Exchange demand, supply, inventory or work-in-progress information. c) Increase information timeliness by implementing real-time information systems. d) Develop a common database and standardise bar-coding.	❑ Implement a batch registration system (i.e. knowing product type – shelf life – quantity). • Implement real-time systems for inventory management adapting to sales and supplies. • Implement an integral system providing information on WIP. • Unify bar-coding. • Co-ordinate product arrays in systems.

Appendix F Continued

Organisation structure	*SCM redesign principles*	*SC redesign strategy*
SCM-RP 6. Jointly define SC objectives and PIs ® Students fill shelves and do not apply the FIFO principle. ® Empty shelves due to inattention of personnel who fill shelves. ® Inventory checks on product tenability only take place once a week whilst two is required (takes a lot of time). ❑ Capacity shortages at order picking; personnel used to unload arriving truck. • Supply delivery performance disagreement because of different measures. • Forward buying by purchasing personnel of retailer.	a) Jointly define logistical SC objectives and corresponding SC performance indicators; b) Agree on how to measure logistical performances in the SC. c) Align employee's incentives with SC objectives.	• Jointly define SC objectives: eliminate forward buying. • Educate personnel: make SC objectives known to all personnel. • Reward behaviour/actions of personnel aimed at achieving these SC objectives. • Align tasks of personnel to SC objectives.

Appendix G Typology of sources of SC uncertainty identified in the case studies

General sources of SC uncertainty	*Examples of sources of SC uncertainty from cases* **I, II, and III**
Inherent characteristics	
1. Product characteristics	• Product quality decay influences shelf life. • Raw materials require defrosting time before they can be used.
2. Demand characteristics	• Peak in sales at Friday and Saturday. • Peak in demand due to weather changes. • Promotion products influence demand for regular products.
3. Process characteristics	• Variable production yield / scrap rates. • Machine downtime.
4. Supply characteristics	• Delivery time overdue because of traffic congestion. • Variable raw material quality. • Time for quality check required before raw materials are released.
Managed system	
5. SC infrastructure	• Products are bought at auction far away. • Products have to be picked up at more auctions. • Exotic products are not held on stock but are bought from importers.
6. Parallel interaction	• Because of the competitive nature of purchasing, too few products could be bought at the auction. • Other supplier is too late at DC causing delay in truck departure. • Truck is not available; did not return on time from previous route.
7. SC facilities	• Products are stored or transported under not-optimal conditions (wrong temperature or product mix) / shortage of air-conditioned storage capacity. • Production flexibility restricted due to fixed product/line combinations. • Long set up times of the packaging lines. • Shelf capacity shortages due to expanding product assortment.
Managing system	
8. Long information lead time and decision process time	• Customer orders are phoned in too late. • Entering orders into the information system takes two hours. • Loading papers are not ready. • Processing orders takes a long time. • Production planning is done manually.
9. Long supply, manufacturing and distribution lead time	• Waiting times between successive processes. • Products are supplied much too late: long process throughput times. • Too little time to perform activities. • Long production runs.
10. Long order sales period	• Low ordering and delivery frequency. • Wrong forecast due to a long forecast horizon. • Waiting times for entering orders into the information system. • Long forecast horizon resulting in large safety buffers in the SC.
11. Administrative and Decision Procedure	• Demand amplification due to human interacted order policy. • Too many products ordered due to minimal order batch sizes, a not optimal order procedure, or forward buying. • FIFO-principle not applied at order picking. • Orders arriving after printing pick lists have more chance of stock-outs. • Products are allocated to a customer who is to be supplied later on whilst rush orders can not be delivered immediately. • Too much inventory due to fixed production batch sizes.
12. Decision complexity	• Promotional activities are not co-ordinated with Production; one assumes they can produce all orders. • Orders contain up to 50 different product types with different lead times.

Information system	
13. Data timeliness	• Batch processing inventory management systems: at night the inventories are up dated.
14. Data & definition accuracy	• Errors when entering order data into the system because the product array on the fax does not correspond to the array in the system. • Shortages during picking are written down on forms that get lost resulting in extensive searches and discussions. • Order specifications by phone misunderstood. • Too much exchange of data by paperwork prone to errors. • The corrected order pick form (with shortages and so on) is used as shipping list to DC prone to errors. • Products in stock not correctly specified.
15. Data applicability	• Purchasing buys products on aggregated orders; hence it is not familiar with specific product quality requested by the customer. • Retailer and the producer use different article numbers. • Data not usable due to aggregation level.
16. Information availability	• No shelf life information available of stocked products in the DC. • No WIP information and process throughput times available. • Ultimate supply delivery time not known. • 75% of the customer orders are unknown at the time of auctioning. • Urgency of packing order not co-ordinated with planner. • Demand amplification due to lack of insight into inventory levels and consumer demand pattern. • Systems give no insight into sales during the day.
Organisation	
17. Regulations	• Retail outlets cannot be delivered at all times due to regulations concerning noise pollution in city centres.
18. Authority and responsibilities	• Goods received at retail outlets are often not checked or are checked after shelves are filled which is hardly feasible. • Many people are authorised to adjust inventory levels. • Supplied goods not accorded by quality control but still administratively added to stock. • Purchasers have the authority and means to change parameters in customer orders. • Working order sequences are changed by personnel. • Sales persons are overruled by the director who accepts all orders.
19. Human behaviour	• Product loss due to inaccuracy in production/DC. • Forward buying of products during promotion weeks at lower product prices. • Customer ordered too much and wants to be relieved of the surplus. • Differences in quality perception. • Students fill shelves and do not apply the FIFO principle. • Empty shelves due to inattention of personnel who fill shelves. • Supply delivery performance disagreement because of different definitions for metrics.

Appendix H The relationship between the order forecast horizon, lead time and delivery frequency

One of the major obstacles for performance improvement identified in the food SCs was demand uncertainty caused by a long order forecast horizon (see Chapter 5). Next to the implementation of real-time management systems, the two most important redesign variables to decrease the order forecast horizon are delivery frequency and lead time.

Figure H.1 depicts the relationship between demand uncertainty (expressed in the number of days that need to be forecasted), lead time and delivery frequency. Increasing the delivery frequency whilst leaving the lead time 3 days could result in a situation in which a new order should be placed whilst the former order is not yet delivered. This complicates the ordering process and is therefore not recommended. Therefore, in case IIA as well as case IIIA the order lead time is reduced to 1 day in all new SC scenarios.

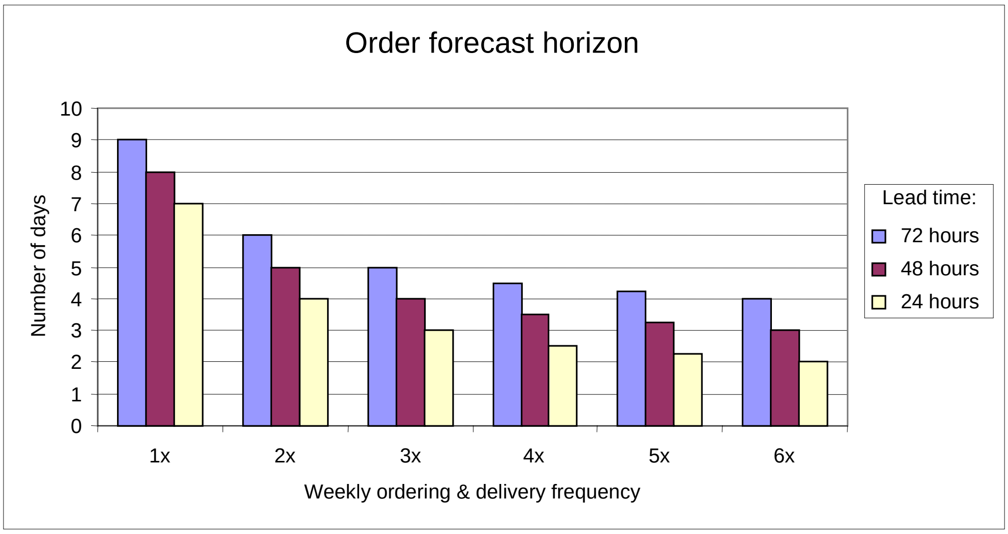


Figure H.1 Order forecast horizons (in number of days to be forecasted) for different frequencies and lead times.

Appendix I Delivery days in the SC for chilled salads

Table I.1 gives the order and delivery days used for the simulated scenarios. In each scenario the retail outlets order at 10:00 hrs and receive their goods at about 8:00 the following morning. The retailer distribution centre (RDC) orders at 12 noon and is delivered to at 4:00 in the morning. All these scenarios refer to a lead time of about 24 hours.

Table I.1 The settings for the order and delivery days used in the simulated scenarios (changed or additional order and delivery days in a new SC scenario are presented in italics).

Scenario	Order days RDC	Delivery days producer	Order days test outlet[1]	Delivery days DC
2_3	Wednesday Friday	Thursday Monday	Tuesday Thursday Saturday	Wednesday Friday Monday
3_4	*Tuesday* *Thursday* Friday	*Wednesday* *Friday* Monday	Tuesday Thursday *Friday* Saturday	Wednesday Friday *Saturday* Monday
4_5	Tuesday *Wednesday* Thursday Friday	Wednesday *Thursday* Friday Monday	Tuesday *Wednesday* Thursday Friday Saturday	Wednesday *Thursday* Friday Saturday Monday
5_6	*Monday* Tuesday Wednesday Thursday Friday	*Tuesday* Wednesday Thursday Friday Monday	*Monday* Tuesday Wednesday Thursday Friday Saturday	*Tuesday* Wednesday Thursday Friday Saturday Monday

These settings of ordering and delivery days combined with the week demand distributions (see Tables 7.3 and 7.4) determine the peaks in demand. Consider, for example, scenario 2_3. When we follow the time windows used in the simulation model, the RDC order on Friday is based on all Outlet orders that were received on Thursday and Wednesday (Friday's orders have not yet been processed according to the time schedule). Hence, we have to add the week demand percentage of the Outlets for Thursday and Wednesday (given by the week demand distribution function) to find the percentage of demand that is related to that ordering moment. When the RDC orders up to that number of products, no stock outs will occur.

Table I.2 RDC order-up-to-levels for different producer delivery frequencies (the week order distribution of the Mega-outlet is set at delivery frequency 3x; see Table 7.4).

	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	MAX
% of demand	18	19	19	11	11	22	
Ordering moments	*Order quantities*						
2x			70%		30%		70%
3x		51%		38%	11%		51%
4x		51%	19%	19%	11%		51%
5x	33%	18%	19%	19%	11%		33%

Comparable exercises are done for the other week order distribution functions of the Mega-outlet (for frequencies 4x/5x and 6x). Table I.3 depicts the results.

[1] Note that these days refer to the order days of the modelled test outlet. Other retail outlets have other order days. Hence, the RDC receives outlet orders every day of the week.

Table I.3 RDC order-up-to levels in the SC for chilled salads (the results of the simulation model are based on a fast-moving product).

		Percentages				**Indexed values to scenario 2_3**			
		Frequency DC-outlets				Frequency DC-outlets			
Frequency		*3x*	*4x*	*5x*	*6x*	*3x*	*4x*	*5x*	*6x*
Producer-	*2x*	0.70	0.70	0.70	0.71	100	100	100	101
DC	*3x*	0.51	0.54	0.54	0.57	73	77	77	81
	4x	0.51	0.54	0.54	0.57	73	77	77	81
	5x	0.33	0.39	0.39	0.45	47	56	56	64

Appendix J Sensitivity analysis of the model results in case study IIA (SC for chilled salads)

This appendix describes some of the results of the sensitivity analyses to changes in the input data in more detail concerning the SC for chilled salads.

Consumer demand

Figure J.1 shows the consumer demand pattern of the test outlet used. It shows that there are some significant fluctuations in consumer demand, especially for fast movers, which have an impact on the results obtained. The fact that we calibrate the model to 0% no-sales indicates that the model settings depend on peak demand. Shelves should be large enough to cope with this peak demand. Hence it is interesting to evaluate the system behaviour for constant consumer demand.

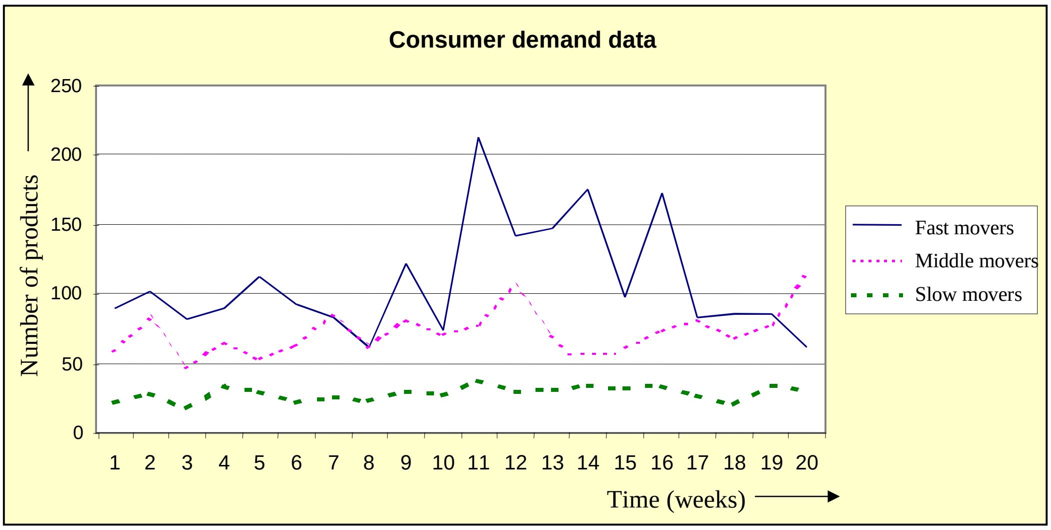


Figure J.1 Overview of real-life consumer demand data used in the simulation model.

The relevant SC scenarios were simulated again but now with a constant consumer demand in retail outlets, i.e. all demand variability was eliminated. The constant value was set at the average consumer demand for all products. The results are comparable to Table 7.6. That is, scenario 5_4 still performs best following the same reasoning explained earlier. However, the differences between the scenarios are less significant. Furthermore, in absolute terms much better results are obtained (see Figure J.2). Since peaks are smoothed, inventory levels can be further reduced by 50% compared to the same scenarios with peak demand.

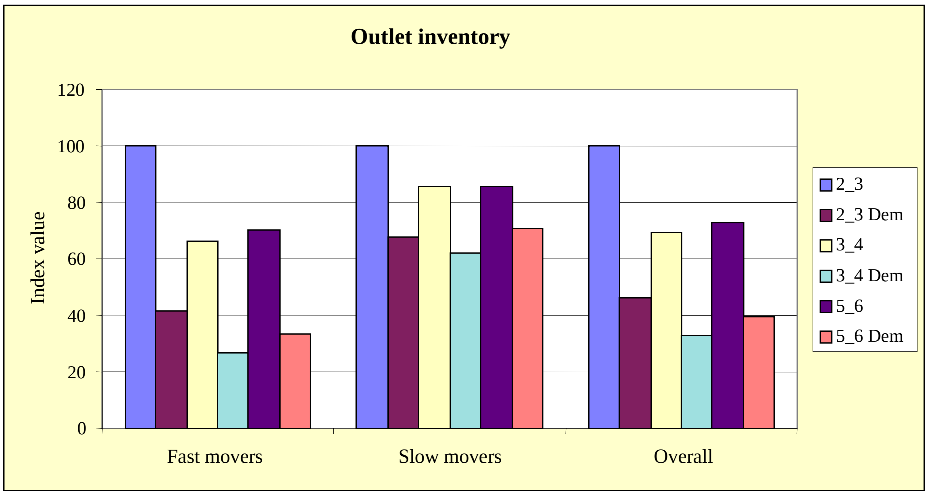


Figure J.2 Outlet inventories when consumer demand is levelled (Dem).

Week order distribution function Mega-outlet

Using scenario 5_3 as a starting point, Figure J.4 shows the simulation results when the week order distribution function of the Mega-outlet is kept the same for all scenarios (i.e. Monday 18%, Tuesday 19%, Wednesday 19%, Thursday 11%, Friday 11%, and Saturday 22%). The impact of the week order distribution function in the Mega-outlet can be clearly seen. When this function changes as delivery frequencies to outlets increase (left histogram in Figure J.4), DC inventories increase significantly, thereby eliminating the benefits of the increased delivery frequency of the producer. But when the week order distribution function is constant for all scenarios (right histogram), no changes in DC inventory are noticed. Thus an increase in delivery frequency to retail outlets impacts average inventory levels at the DC by the week order distribution function.

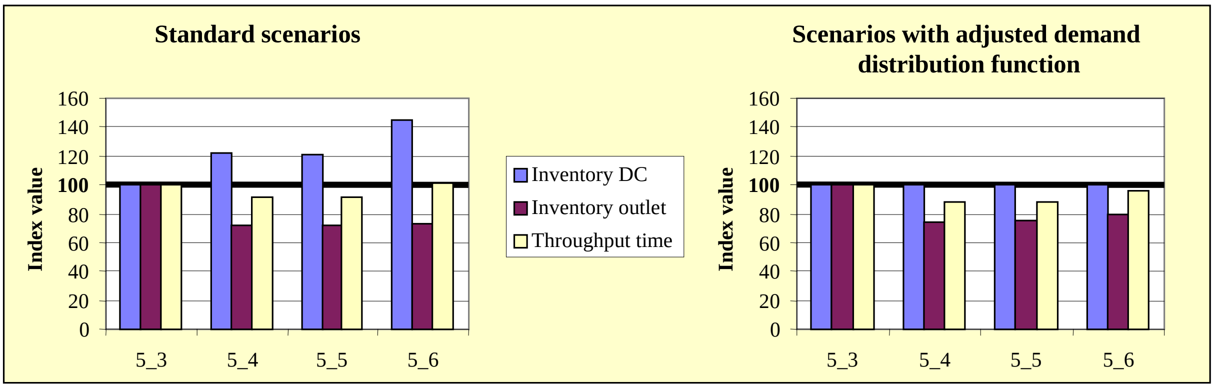


Figure J.4 Impact of the week order distribution function on DC inventory.

Order and delivery days

We simulated scenario 2_3-3 with other delivery days in the SC. This resulted in a 20% DC inventory increase, a 10% outlet inventory increase and half a day loss of product freshness compared to the standard scenario 2_3-3. Scenario 5_6 gives no change in results since each available weekday is already used as a delivery day. When we use the optimal delivery days in each scenario in both stages of the SC, scenario 5_4 performs best under the current restrictions.

Inherent uncertainties in the SC

We ran scenarios in which delays of 24 hours were simulated using a uniform distribution; in α % of the cases a complete outlet order is delayed at the DC and delivered to the outlet the next day. Table J.1 shows the impact on delivery performance of possible delays in deliveries to retail outlets for the calibrated scenarios 2_3 and 3_4 with constant consumer demand data. Each scenario is replicated 20 times to obtain reliable results. The delivery performance calculation is based on the total data.

Table J.1 Estimated outlet delivery performance when delays of 24 hrs in deliveries are simulated.

FREQ(dc,o) Chance of delayed order	3x per week	4x per week
α = 5%	99.99%	99.29%
α = 10%	99.98%	98.41%
α = 20%	99.97%	96.84%

When we simulate a complete non-delivery of the producer we find that the impact is much more intense at lower frequencies. The DC delivery performance in that week drops to about 60%, and consecutively the outlet delivery performance to customers drops to 80%. The impact is even worse when such a non-delivery occurs in a week with peak demand. Hence, we can conclude that although the system is much more sensitive to disturbances at higher frequencies, problems are solved much quicker.

Cost definitions

Figure 7.18 showed that transportation is responsible for the largest part of the producer's total process cost, order picking for the DC and filling shelves for the retail outlet. Hence, it is interesting to focus on the cost drivers of these processes.

Changing the producer's transportation cost

Since the number of secondary unit loads that is transported by the producer at different frequencies hardly increases, a cost increase makes hardly any difference. Of course, this changes when the cost driver is changed into the number of deliveries.

Changing the DC's order picking cost

When the order picking costs are decreased, higher frequencies result in less additional cost. Under no circumstances will a shift occur in the ranking of the scenarios. However, the absolute cost differences can become relatively small. But this does require a significant change in cost. For example, with a 30% cost reduction per picked good, total cost still rises on average by 8% with each extra delivery.

Changing the cost for filling shelves in the outlets

Higher frequencies would become more relevant if a cheaper working force could be obtained for filling shelves. But here again, significant changes are needed to obtain a shift in the ranking of the scenarios.

Appendix K Delivery days in the SC for cheese and desserts

Table K.1 gives the order and delivery days for the simulated scenarios with a lead time of one day. The retail outlets order at 08:00 hrs and receive the ordered goods at about 6:00 the following morning. The retailer distribution centre (RDC) transfers the orders at 11:00 hrs to the producer. The producer picks the products at 14:00 hrs and delivers them at 18:00 hrs that same day. Finally, the DC delivers the products to the retail outlets the next morning at 06:00 hrs.

Table K.1 The order and delivery days for the simulated scenarios.

Delivery frequency	Order days Outlet	Delivery days DC
2 times per week	Tuesday	Wednesday
	Friday	Saturday
3 times per week	Monday	Tuesday
	Wednesday	Thursday
	Friday	Saturday
4 times per week	Monday	Tuesday
	Wednesday	Thursday
	Thursday	Friday
	Friday	Saturday
5 times per week	Monday	Tuesday
	Tuesday	Wednesday
	Wednesday	Thursday
	Thursday	Friday
	Friday	Saturday

As already discussed in the SC for chilled salads, the settings of ordering and delivery days determine the peaks in demand. Consider, for example, scenario 2 (delivery frequency = 2 times per week). When we follow the time windows used in the simulation model the outlet order on Friday is based on sales on Thursday, Wednesday and Tuesday (because the order on Tuesday is placed in the morning). Hence, we have to add the demand percentage of the outlets for Tuesday to Thursday to find the percentage of demand that is related to that ordering moment. When the outlet orders up to that number of products, no stock outs will occur. Table K.2 presents the results of this exercise.

Table K.2 Outlet order-up-to levels in the SC for cheese and desserts.

	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	MAX
% of demand[2]	11%	13%	15%	21%	19%	21%	
Ordering moments	*Order quantities*						
2x		51%			49%		51%
3x	40%		24%		36%		40%
4x	40%		24%	15%	21%		40%
5x	40%	11%	13%	15%	21%		40%

Table K.2 shows that there are no additional profits when the order frequency is increased from 3 to 4 or 5 times a week. In all these scenarios Monday has the largest percentage of week demand. Hence, inventory levels cannot decrease. Higher frequencies are not interesting since Saturday is never included as an ordering day. On Saturday 21% of total week demand is sold and this is now replenished in the outlet on Tuesday (with the order of Monday).

[2] This refers to the week demand distribution function displayed in Table 7.12.

Saturday as an extra order day would give much benefits. Comparable exercises were done for the producer. Table K.3 depicts the results.

Table K.3 Inventory reduction in the SC for cheese and desserts.

	Outlet		**Producer**	
Scenario	*Max. orders*	*Index value*	*Max. orders*	*Index value*
2	51%	100	60%	100
3	40%	78	40%	67
4	40%	78	32%	53
5	40%	78	32%	53

Appendix L Sensitivity analysis of the model results in case study IIIA (SC for cheese and desserts)

This appendix will give some additional information on the sensitivity analyses to changes in the input data in more detail concerning the SC for cheese and desserts.

Consumer demand
Figure L.1 shows the consumer demand pattern of the input data used. It shows that there are some fluctuations in consumer demand in this SC too, which have an impact on the results obtained. However, the fluctuations are much less than in the SC for chilled salads.

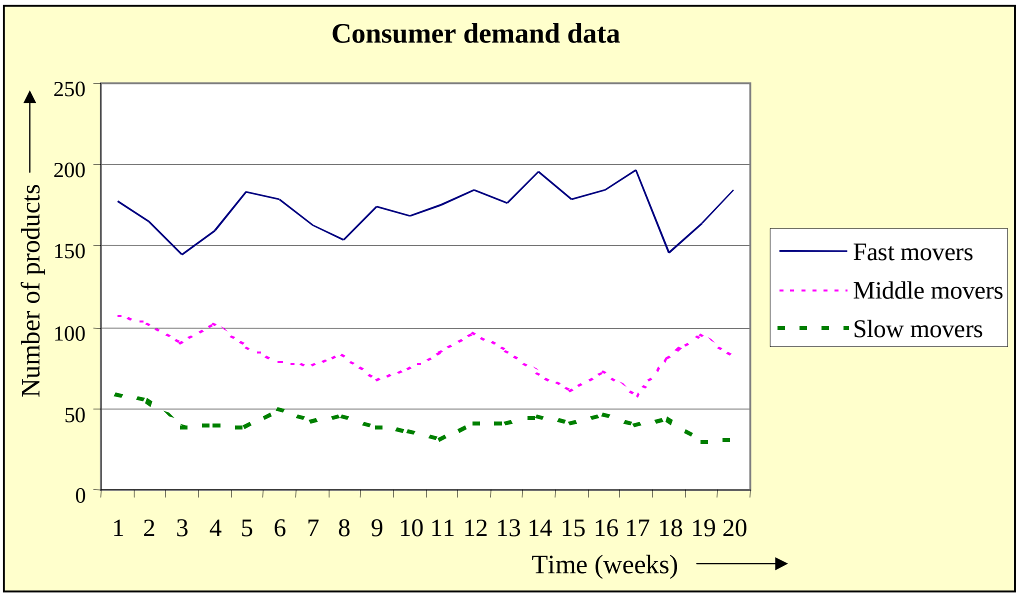


Figure L.1 Overview of real-life consumer demand data used in the simulation model.

The relevant SC scenarios were simulated again but now with a constant consumer demand in retail outlets, i.e. all week demand uncertainty was eliminated. The constant value was set at the average consumer demand for all products. For this input data too scenario 3 performs best. However, the differences between the scenarios are less significant. Furthermore, in absolute terms better results are obtained. Since demand peaks are smoothed, safety stocks can be further reduced.

Delivery days
When we simulated scenario 3 with outlet ordering days Monday-Wednesday-Friday and Monday-Wednesday-Thursday, the first scenario showed much better results (Figure L.2).

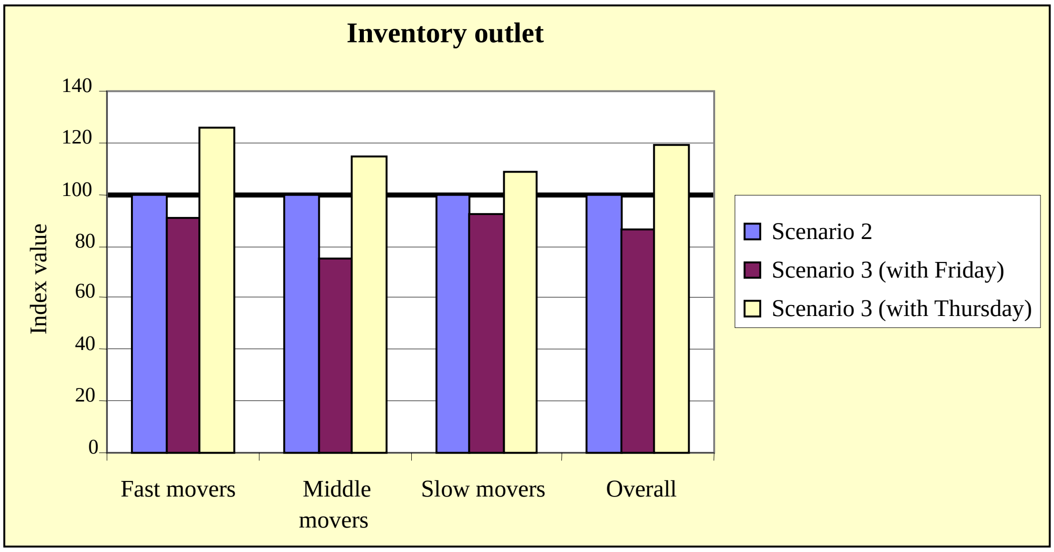


Figure L.2 Differences in benefits of SC scenarios when other ordering days are used.

Appendix M The impact of a higher delivery frequency on stock levels

Figure M.1 depicts an example of an inventory pattern for a fast-moving article. It shows that the extra delivery on Tuesday in scenario 5 increases inventory levels unnecessarily compared to scenario 4. In both scenarios no stock outs occur.

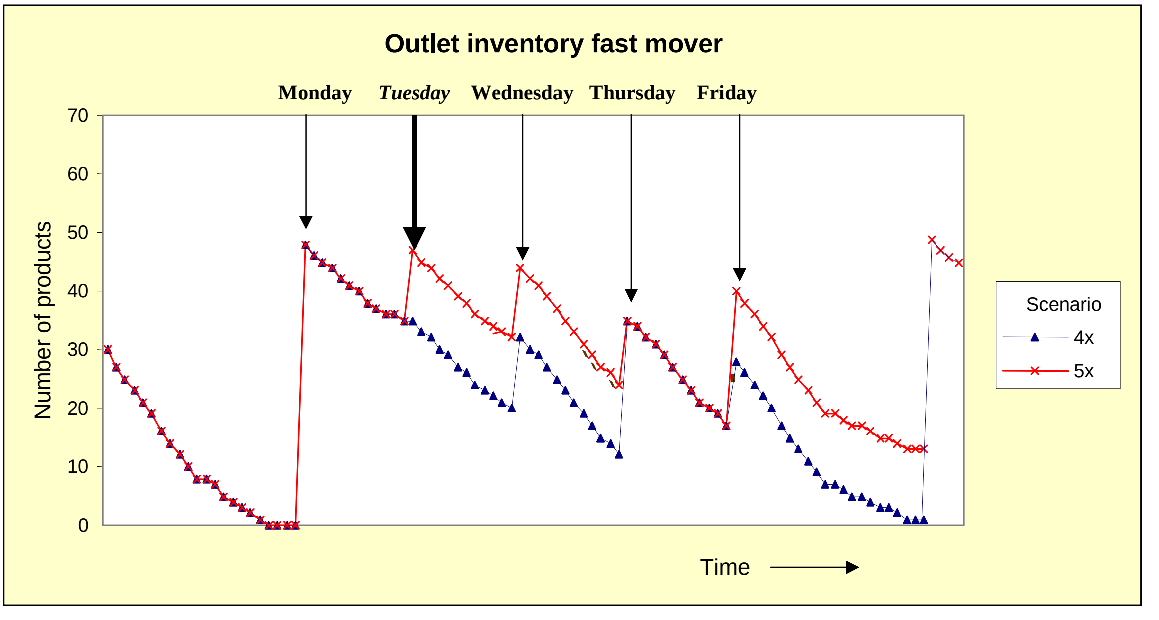


Figure M.1 Inventory pattern for a fast mover at delivery frequency 4 and 5 times per week.

Samenvatting (summary in Dutch)

Supply Chain Management (SCM) is een concept dat sedert het begin van de jaren negentig veel aandacht heeft gekregen van wetenschappers en de praktijk. Alhoewel de basisgedachten van SCM door een ieder wordt onderkend, is tot op heden de uitwerking ervan niet eenduidig vastgelegd. Dit maakt de bruikbaarheid en toepasbaarheid van het ketenconcept voor managers van (voedingsmiddelen)bedrijven onduidelijk. Zij zijn juist geïnteresseerd in *of, hoe* en *met wie* zij eventuele ketenactiviteiten moeten ontplooien om hun (keten)prestatie te verbeteren. Zij willen in staat zijn te analyseren of ketenmanagement iets voor hun bedrijf kan betekenen. Dit leidde tot een tweeledige doelstelling van het onderzoek beschreven in dit proefschrift. Ten eerste moest het onderzoek het concept SCM operationaliseren vanuit een logistiek oogpunt. Ten tweede zou het onderzoek moeten resulteren in een methode waarmee ketens kunnen worden geanalyseerd en herontworpen met verbetering van de ketenprestatie.

Door middel van een multidisciplinair literatuuronderzoek is *Supply Chain Management* in dit proefschrift gedefinieerd als het geïntegreerd plannen, coördineren en beheersen van alle logistieke bedrijfsvoeringprocessen en activiteiten in de keten. Het doel van SCM is tegen de laagste totale ketenkosten producten met de hoogste toegevoegde waarde te leveren aan de eindgebruiker terwijl voldaan wordt aan de eisen van andere belanghebbenden in de keten. Hierbij is een *keten* gedefinieerd als een serie van (fysieke en besluitvormings-) activiteiten, verbonden middels goederen- en informatiestromen, die organisatiegrenzen overschrijden. Daarnaast is via de operationalisering van SCM en enkele gevalstudies een stapsgewijze methode voor ketenanalyse en –herontwerp ontwikkeld, bestaande uit:

① Een methode waarmee (voedingsmiddelen)ketens kunnen worden geanalyseerd en effectieve verbetervoorstellen kunnen worden geïdentificeerd.
② Een methode waarmee de invloed van verbetervoorstellen op de logistieke ketenprestatie en het functioneren van de keten kan worden geëvalueerd zodat een ‘best practice’ ketenscenario kan worden vastgesteld.

Een *ketenscenario* is gedefinieerd als een intern consistent beeld van de logistieke inrichting en besturing in een reeks van samenwerkende bedrijven binnen het ketennetwerk. Een *‘best practice’ ketenscenario* is gedefinieerd als een praktisch haalbaar ketenscenario wat volgens alle ketendeelnemers leidt tot de beste prestatie voor het hele systeem met betrekking tot te voren gedefinieerde prestatie-indicatoren.

Het gebruik van deze integrale aanpak moet managers van voedingsmiddelenbedrijven ondersteunen in het evalueren van de huidige positie in de keten(s) en in de besluitvorming al dan niet tot ketenherontwerp over te gaan. In de volgende paragrafen zal het onderzoek in meer detail worden besproken.

Aanleiding tot het onderzoek

In hoofdstuk 1 is de aanleiding van het onderzoek naar SCM in voedingsmiddelenketens beschreven door in te gaan op recente ontwikkelingen. Demografische en sociaal-economische ontwikkelingen, zoals bijvoorbeeld de vergrijzing en de toename van huishoudens met tweeverdieners, hebben geleid tot een vraag naar versere producten op de winkelschappen en producten met een hogere toegevoegde waarde (bijvoorbeeld kant-en-klaar maaltijden). Daarnaast hebben ontwikkelingen als globalisering, de Europese eenwording en strengere eisen vanuit de overheid ten aanzien van voedselveiligheid en milieu geleid tot veranderende eisen ten aanzien van het functioneren van bedrijven. Ook is men gaan inzien dat suboptimalisatie in de keten plaats kan vinden als men zich uitsluitend richt op de eigen resultaten in plaats van op de ketendoelen. Vooral in voedingsmiddelenketens ervaart men dat andere bedrijven in de afzetketen de inspanningen, om bijvoorbeeld een hoge kwaliteit te garanderen, teniet kunnen doen. Concurrentie vindt steeds meer plaats tussen ketens in plaats van tussen individuele bedrijven. SCM, oftewel ketenmanagement, wordt dan ook gezien als *de* aanpak ter verbetering van de logistieke ketenprestatie. De ontplooiing van dergelijke activiteiten wordt mede mogelijk gemaakt door recente ontwikkelingen in de Informatie en Communicatie Technologie. Een uitgebreide multidisciplinaire literatuurstudie leverde geen bestaande integrale logistieke methode op waarmee managers hun ketens kunnen analyseren en herontwerpen.

Onderzoeksvragen

De genoemde ontwikkelingen creëren de noodzaak tot ketencoördinatie. Zij hebben ertoe geleid dat managers snel besluiten in complexere situaties moeten nemen wat een verhoging van de besluitvormingsonzekerheid in de keten tot gevolg heeft. Door de aanwezige muren tussen actoren in de keten af te breken, kunnen deze besluitvormingsonzekerheden worden gereduceerd. De uitwerking van deze gedachten leidde tot de volgende basishypothese voor het onderzoek:

Om effectieve ketenscenario's te identificeren moet men zich richten op de identificatie, beheersing en reductie van de bronnen van besluitvormingsonzekerheid in de keten.

Vertrekkende vanuit deze basishypothese zijn de volgende onderzoeksvragen geformuleerd:

① Wat is de relatie tussen onzekerheid in besluitvormingssituaties en de ketenprestatie in voedingsmiddelenketens?

② Hoe kunnen potentiële effectieve ketenscenario's geïdentificeerd worden voor een specifieke voedingsmiddelenketen? (validatie van de basishypothese)

③ Hoe kan een 'best practice' ketenscenario worden vastgesteld?

Onderzoeksontwerp

Het onderzoek volgde de inductieve/deductieve onderzoekscyclus waarin literatuur en drie *gevalstudies* zijn gebruikt voor het ontwikkelen van een onderzoeksmethode voor ketenanalyse en herontwerp. Gevalstudie I is uitgevoerd in een vers product keten bestaande uit telers, veilingen, een groenten en fruit exporteur en buitenlandse afnemers (met name supermarktketens). Gevalstudie II betrof een keten bestaande uit een producent van slaatjes en een supermarktketen (met distributiecentrum en vele winkels). Tenslotte had gevalstudie III betrekking op een keten bestaande uit twee producenten van desserts die leveren aan een kaasproducent (tevens desserthandelaar) welke vervolgens producten aan een supermarktketen levert. Deze drie gevalstudies zijn op twee manieren gebruikt:

- Alle gevalstudies zijn gebruikt voor theorievorming betreffende onderzoeksvraag ①, de relatie onzekerheid versus ketenprestatie, en ②, de identificatie van potentiële effectieve ketenscenario's;
- De twee laatste gevalstudies zijn verder uitgewerkt om een methodiek te vinden waarmee de invloed van ketenscenario's op de logistieke ketenprestatie kan worden geëvalueerd (onderzoeksvraag ③)

Operationalisering van kernbegrippen

In hoofdstuk 2 is ingegaan op SCM en gerelateerde concepten zoals Efficient Consumer Response (ECR) en Business Process Redesign (BPR). Vertrekkende vanuit de besturingsbenadering van De Leeuw (1988) is in hoofdstuk 3 geconcludeerd dat een *keten(scenario)* gedetailleerd kan worden beschreven aan de hand van vier elementen: het bestuurde systeem, het besturende systeem, het informatiesysteem en de organisatiestructuur van bedrijven in de keten. Binnen elk van deze vier elementen zijn *ketenherontwerpvariabelen* te onderkennen; dit zijn variabelen op strategisch, tactisch of operationeel niveau die bepalend zijn voor de inrichting en besturing van de keten. Wanneer de instelling van één van deze variabelen verandert (bijvoorbeeld de leverancierskeuze binnen het bestuurde systeem of de leverfrequentie naar een afnemer binnen het besturende systeem), verandert dus ook het ketenscenario. In hoofdstuk 3 zijn verder de belangrijkste *ketenprestatie-indicatoren* (Key Performance Indicators; KPIs) geïdentificeerd voor voedingsmiddelenketens. Deze zijn benodigd voor het bepalen van de effectiviteit van een alternatief ketenscenario, dat wil zeggen het niveau tot waarop de ketendoelen zijn behaald. Onze ketenbenadering is geïntegreerd weergegeven in een conceptueel raamwerk dat gebruikt kan worden voor het gedetailleerd beschrijven en analyseren van een keten ter ondersteuning van het ketenherontwerp proces.

Methode voor het genereren van ketenscenario's

In hoofdstuk 4 is een aanzet tot een methode voor het genereren van mogelijk effectieve ketenscenario's gepresenteerd. De methode vertrekt vanuit onze basishypothese: de identificatie van bronnen van onzekerheid in besluitvormingssituaties in de keten die de logistieke ketenprestatie begrenzen. De definitie van *ketenonzekerheid* is gebaseerd op de vijf algemene voorwaarden voor effectieve besturing van De Leeuw (1988):

Ketenonzekerheid betreft besluitvormingssituaties in een keten in welke een besluitvormer ① een tekort heeft aan effectieve sturingsmogelijkheden, of ② de invloed van een mogelijk besluit op het ketengedrag niet goed kan voorspellen door een tekort aan:

- *informatie (of begrip) over de omgeving of de huidige ketentoestand;*
- *een consistent model van de keten betreffende de relatie tussen keten herontwerpvariabelen en keten KPIs.*

Ketenonzekerheid wordt veroorzaakt door zogenaamde *bronnen van ketenonzekerheid.* Dit zijn specifieke kenmerken van de inrichting en besturing van de keten; het zijn inherente keteneigenschappen (zoals variatie in kwaliteit van aangevoerde grondstoffen) en kenmerken van de bestuurde, besturende en informatie systemen en organisatiestructuren in de keten. Door die bronnen van onzekerheid in de keten te identificeren die beperkend zijn voor de voornaamste KPIs, worden belangrijke verbetermogelijkheden onderkend. Om dit proces verder te structureren is een uitgebreide studie verricht naar de mogelijkheden van SCM in Logistiek Management, BPR, SCM en Operationele Research literatuur. Dit heeft geleid tot een algemene lijst van 22 *ketenverbeterprincipes*, waarvan verwacht wordt dat ze de prestatie van de keten op minimaal één van de keten KPIs verbetert. Elk ketenverbeterprincipe verwijst naar een alternatieve instelling van één of meer van de ketenherontwerpvariabelen en dus het ketenscenario. Door nu elk van deze verbeterprincipes te relateren aan mogelijke bronnen van onzekerheid die in een keten geïdentificeerd kunnen worden, is een middel gevonden om belangrijke herontwerpvariabelen in een keten te onderkennen. Die bronnen van ketenonzekerheid die de meeste invloed hebben op de keten KPIs zijn de eerste kandidaten voor het herontwerp proces. Deze aanpak is getest en verder ontwikkeld in hoofdstuk 5 waarin de resultaten zijn besproken van drie gevalstudies.

Generatie van ketenscenario's in gevalstudies

In elke gevalstudie is een gedetailleerd beeld verkregen van het ontwerp en besturing van de betreffende keten door het toepassen van het ontwikkelde raamwerk voor ketenanalyse en herontwerp. Daarbij zijn twee beschrijvingstechnieken gebruikt (Organisation Description Language (ODL) en Event Process Chain (EPC) modellering), die ketenprocessen transparant maken voor alle actoren in de keten. Hiermee werd het mogelijk discussies over het ketenscenario te voeren met belangrijke managers in de keten, waarbij de onderkenning van ketenonzekerheden en bronnen van onzekerheid centraal stonden. Door de gevonden bronnen vervolgens te relateren aan de algemene lijst van ketenverbeterprincipes en de invloed van iedere bron op de keten KPIs kwalitatief te analyseren, zijn in alle gevalstudies relevante ketenverbetervariabelen (en dus potentiële ketenscenario's) geïdentificeerd.

Alle drie gevalstudies hebben geleid tot een gedetailleerde lijst van bronnen van onzekerheid die in de betreffende keten werden onderkend. Door deze drie lijsten samen te nemen ontstaat een meer algemene lijst van bronnen van onzekerheid die in voedingsmiddelenketens kunnen voorkomen. Door deze bronnen vervolgens te relateren aan de 22 algemene ketenverbeterprincipes ontstaat een waardevol instrument voor ketenherontwerp; het toont relevante verbeterprincipes in een keten wanneer gestuit wordt op bepaalde bronnen van ketenonzekerheid.

Modelleren en evalueren van ketenscenario's

Nadat relevante ketenscenario's zijn onderkend is het zaak deze scenario's te evalueren op hun invloed op de ketenprestatie zodat een 'best practice' ketenscenario kan worden bepaald. In hoofdstuk 6 is geconcludeerd dat dit plaats zou moeten vinden volgens twee methoden:

- Via een *wiskundig model van de keten* kan de invloed van een ketenscenario op de keten KPIs kwantitatief worden geëvalueerd. Aangezien meerdere KPIs meegenomen dienen te worden en processen in de tijd aan elkaar gerelateerd zijn, is gekozen voor discrete-event simulatie.
- Daarnaast zou één veelbelovend ketenscenario als *experiment op kleine schaal* in de keten geïmplementeerd dienen te worden gedurende een korte periode. Dit verschaft namelijk inzicht in organisatorische, culturele en infrastructurele beperkingen van ketenscenario's en dus in de praktische haalbaarheid van dergelijke ontwerpen.

In hoofdstuk 6 is een raamwerk ontwikkeld voor het modelleren van het dynamisch gedrag van voedingsmiddelenketens. Met dit raamwerk worden alle van belang zijnde aspecten van het ketensysteem gevangen in een model, zodat ketenscenario's kunnen worden gesimuleerd. De voornaamste componenten van het raamwerk zijn: bedrijfsvoeringprocessen en -entiteiten, databases, capaciteiten, prestatie-indicatoren en ketenherontwerpvariabelen. Het raamwerk is gebaseerd op een aantal aannamen, zoals de aanwezigheid van systeem hiërarchie en de mogelijkheid een keten te representeren als (a) een netwerk van processen met volgorderelaties die gebruik maken van capaciteiten en (b) als een dynamisch systeem met veranderende performance karakteristieken in de tijd. Tenslotte zijn twee simulatiepakketten geïntroduceerd, ExSpect en Arena, die in de gevalstudies zijn gebruikt.

Evaluatie van ketenscenario's in de gevalstudies

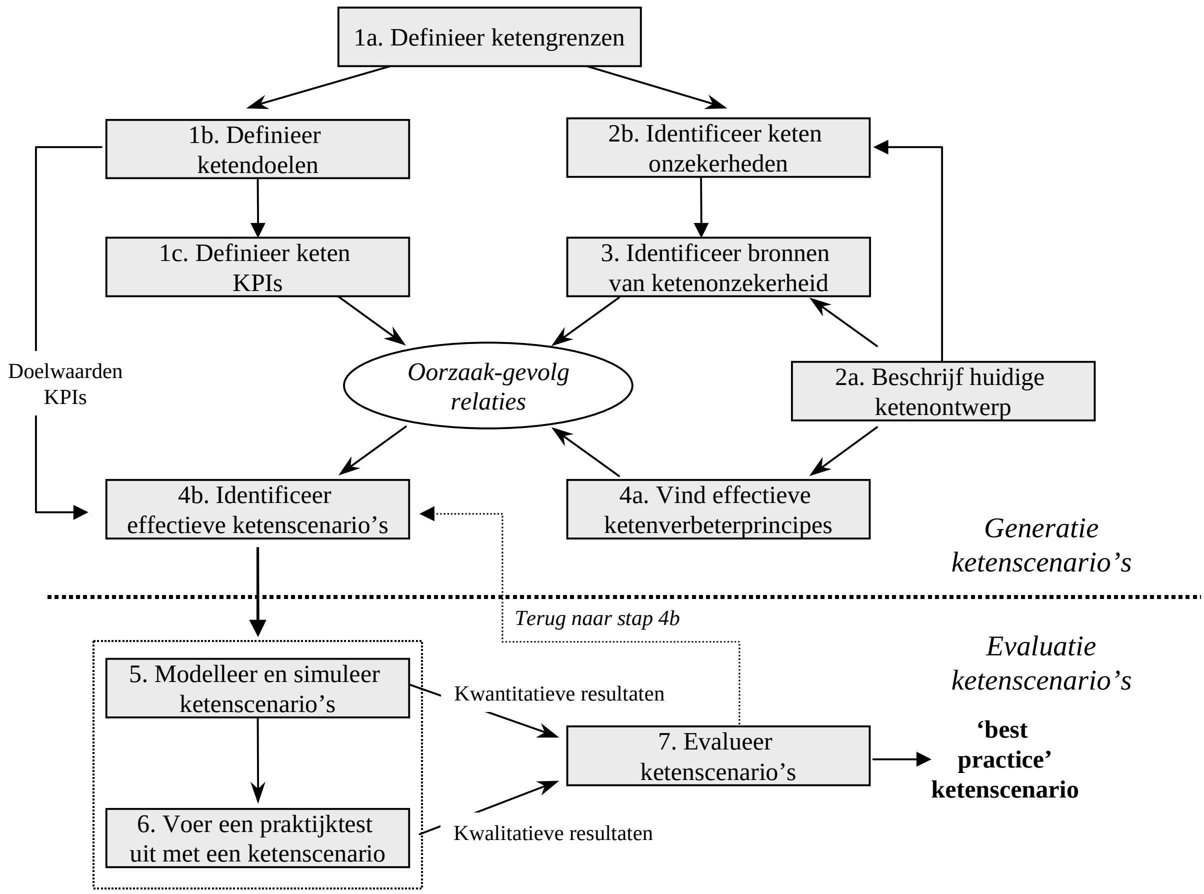
De bruikbaarheid van het modelleringsraamwerk is aangetoond in de twee gevalstudies (hoofdstuk 7) waarin het raamwerk is gebruikt om ketenscenario's te modelleren en de consequenties op de keten KPIs door te rekenen. De resultaten van de simulatiestudie, geverifieerd door managers van de deelnemende bedrijven (expert validatie), toonden de trends en de orde van grootte van veranderingen in ketenprestatie voor de verschillende scenario's. Zowel ExSpect als Arena bleken veelbelovende omgevingen voor ketenmodellering alhoewel beide pakketten ook enkele nadelen hebben.

De gevalstudies toonden ook de complementariteit aan van een veldexperiment ten opzichte van een simulatiestudie. Zo is in één gevalstudie scenario X aangedragen als 'optimaal' ketenscenario vanuit de simulatiestudie. Maar naar aanleiding van bevindingen in het veldexperiment is dit advies veranderd in scenario Y. Door gebruik te maken van deze duale aanpak kunnen ketenmanagers ondersteund worden in hun beslissing al dan niet een ander ketenscenario te implementeren. In beide gevalstudies is een alternatief ketenscenario voorgesteld waarvan aangetoond is dat het aanmerkelijk beter zal presteren op de keten KPIs dan het huidige scenario.

Tenslotte is in hoofdstuk 7 een analytische benadering voorgesteld voor kleinere ketenvraagstukken en voor de validatie van simulatiemodellen.

Een stapsgewijze benadering om ketenscenario's te genereren, modelleren en evalueren

In hoofdstuk 8 is de volledige stapsgewijze benadering voor ketenanalyse en -herontwerp, leidend tot een 'best practice' ketenscenario, samengevat (figuur 1).



Figuur 1. Een stapsgewijze benadering om ketenscenario's te genereren, modelleren en evalueren

Stap 1 betreft de afbakening van de ketengrenzen en het gezamenlijk definiëren van de ketendoelen en keten KPIs. In *stap 2* worden de elementaire ketenprocessen in detail beschreven (met behulp van de beschrijvingstechnieken ODL en EPC-modellering) wat leidt tot de identificatie van onzekerheden in de besluitvormingsprocessen in de keten. Oorzaak-gevolg diagrammen, gecombineerd met discussies met werknemers, leiden vervolgens tot de respectievelijke bronnen van onzekerheid (*stap 3)*. In *stap 4* worden effectieve ketenscenario's geïdentificeerd door de belangrijkste bronnen van onzekerheid te relateren aan de lijst van ketenherontwerpprincipes. Potentiële ketenscenario's worden vervolgens kwantitatief en kwalitatief geëvalueerd door middel van, respectievelijk, een modelstudie (*stap 5*) en een veld experiment (*stap 6*). De methode wordt afgesloten met *stap 7* waarin de resultaten worden gecombineerd en een 'best practice' ketenscenario wordt geïdentificeerd.

Conclusies

In hoofdstuk 9 zijn tenslotte de belangrijkste bevindingen samengevat door antwoord te geven op de drie onderzoeksvragen. In het kort zijn de antwoorden als volgt:

① *Wat is de relatie tussen onzekerheid in besluitvormingssituaties en de ketenprestatie in voedingsmiddelenketens?*

De gevalstudies toonden aan dat de aanwezigheid van besluitvormingsonzekerheid in de keten als gevolg heeft dat er veiligheidsbuffers in tijd, capaciteit en/of voorraad worden aangehouden om een slechte ketenprestatie te voorkomen. De aanwezigheid van deze buffers resulteren in het bestaan van meerdere niet-waarde-toevoegende activiteiten die de winstgevendheid van de keten beperken. Het reduceren of zelfs elimineren van de ketenonzekerheden zal de ketenprestatie verhogen.

② *Hoe kunnen potentiële effectieve ketenscenario's geïdentificeerd worden voor een specifieke voedingsmiddelenketen? (validatie van de basishypothese)*

Door gebruik te maken van de stapsgewijze benadering voor het genereren van effectieve ketenscenario's kunnen de belangrijkste keten herontwerpvariabelen worden geïdentificeerd in een specifieke keten. Ketenscenario's zijn vervolgens het gevolg van combinaties van verschillende instellingen voor deze variabelen.

③ *Hoe kan een 'best practice' ketenscenario worden vastgesteld?*

De invloed van een ketenscenario op de ketenprestatie kan goed worden geëvalueerd door gebruik te maken van zowel een modelstudie (gebruik makend van het ketenmodelleringsraamwerk) als een veldexperiment. Zodoende komen kwantitatieve elementen als wel kwalitatieve evaluatiecriteria aan bod. De uiteindelijke beslissing welk ketenscenario in de praktijk te implementeren hangt af van de afweging tussen verschillende keten KPIs voor elke participant en de keten als geheel en de haalbaarheid van elk scenario.

Wij denken met deze resultaten een bijdrage te hebben geleverd aan het kennisdomein van SCM. De stapsgewijze benadering (inclusief de voorgestelde technieken) kan worden gebruikt om ketens efficiënt en effectief te analyseren en te herontwerpen, hetgeen zal leiden tot een toenemende concurrentiekracht van de keten. De benadering verschaft managers inzicht in het functioneren van de eigen keten, laat managers de eigen processen kritisch beschouwen en maakt het managers mogelijk ketenscenario's te identificeren en te evalueren.

Aanbevelingen voor verder onderzoek

Ketenonderzoek zou zich moeten richten op de ontwikkeling van een gereedschapskist met daarin theorieën, methoden en technieken en operationele toepassingen, waarmee ketens kunnen worden geanalyseerd en verbeterd. We onderkennen dat onze stapsgewijze benadering gezien moet worden als een eerste belangrijke stap naar een dergelijke gereedschapskist. Uit het onderzoek zijn een aantal interessante mogelijkheden voor vervolgonderzoek naar voren gekomen. De belangrijkste aanbevelingen zijn (in willekeurige volgorde):

- Verdere detaillering en eventueel uitbreiding van de lijsten van keten herontwerpprincipes en bronnen van ketenonzekerheid door literatuur in andere disciplines te onderzoeken en door gevalstudies te doen in andere industrieën.
- Het aannemen van een ketennetwerk perspectief binnen het ketenonderzoek waarin de nadruk wordt gelegd op de interactie tussen ketens.
- Het definiëren van unieke en geïntegreerde keten prestatie-indicatoren, inclusief de meetmethoden, waarmee keten(prestatie)s kunnen worden vergeleken.
- Bepaling van de bruikbaarheid van het scala aan kwantitatieve methoden in verschillende typen besluitvormingssituaties in ketens.
- Het uitbouwen en verbeteren van de ontologie voor ketenmodellering en gebaseerd daarop het construeren van bibliotheken van gestandaardiseerde procesblokken in een simulatieomgeving waarmee efficiënt en effectief ketens kunnen worden gemodelleerd.
- Het ontwikkelen van een besluitvormingsondersteunend systeem, gebruik makend van de stapsgewijze methode en de bevindingen in de gevalstudies, waarmee automatisch ketenscenario's kunnen worden gegenereerd.
- Het incorporeren van de eisen van andere belanghebbenden in de keten en ketenomgeving in de ketenanalyse, zoals de overheid, milieugroeperingen en werknemersverenigingen.

About the author

Jacobus Gerardus Adrianus Johannes (Jack) van der Vorst was born in Terheijden, the Netherlands, on September 20 1970. In 1988 he received his high school diploma at the pre-university educational level (VWO-β) from the 'Newman College' in Breda, after which he started his study Agrocultural Systems Science with specialisation Agro-logistics at Wageningen University. He received his masters degree with honour in June 1994.

After having completed his studies, he started as a PhD student at Wageningen University, Management Studies Group. As from September 1996, the author is employed at the Management Studies Group at Wageningen University as Assistant Professor. In this function, he co-ordinates, develops and conducts courses on Production and Operations Management, Efficient Consumer Response and Supply Chain Management in regular MSc as well as MBA courses.

His current research includes Logistics Management, Supply Chain Management, performance measurement and evaluation, and simulation studies. His research was published in several journals (amongst which, the European Journal of Operational Research) and at international conferences in the United States, United Kingdom, Ireland, Sweden, Austria, Italy, Belgium, and the Netherlands.