Business Process Modelling in Demand-Driven Agri-Food Supply Chains

A Reference Framework

C.N. Verdouw

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C.N. Verdouw

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Woord vooraf

Toen ik in 2004 een idee voor een innovatieproject bij het LEI indiende, had ik nooit kunnen denken dat dit zou uitmonden in het proefschrift dat nu voor u ligt. Er hebben veel mensen aan bijgedragen dat het zover is gekomen. Een promotieonderzoek is een intensief sociaal proces, hoewel het ook vaak momenten van eenzaam doorbijten kent. Ik wil allen die direct of indirect hebben bijgedragen aan de totstandkoming van deze dissertatie hartelijk bedanken! Het is onmogelijk allen bij naam te noemen, maar graag bedank ik een aantal van hen in het bijzonder.

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"Onpeilbaar diep zijn Gods gedachten;
Daar Zijn verstand, nooit af te meten,
Ver overtreft al wat wij weten." [1]

Cor Verdouw
Veenendaal, augustus 2010

[1] Bijbel, Boek der Psalmen, berijming 1773 in opdracht van de Staten-Generaal der Verenigde Nederlanden, fragment uit psalm 147: 3

Table of Contents

Chapter 1. General introduction

1.1 Context

Agri-food companies operate in a complex and dynamic environment. The driving forces are diverse, and include:

- Increasing consumer concerns about food safety, and as a consequence fast changing food safety legislation and stringent quality requirements;
- Public concerns on effects of bio-industrial production;
- Increasing unpredictability of consumer demand;
- Globalisation and liberalisation of markets and as a consequence intensification of competition;
- Fast advances in (information) technology;
- High pace of agri-food innovations resulting in shorter product life cycles.

These developments result in increasing volatility and diversity of demand, which urge agri-food supply chains to become more demand-driven (Kinsey, 2001, van der Vorst *et al.*, 2001, Trienekens *et al.*, 2003, Taylor and Fearne, 2006, Canever *et al.*, 2008, van Donk *et al.*, 2008, Verdouw, 2008b). Demand-driven supply chains are often advocated as an alternative of supply chains that efficiently push products to the marketplace. They aim for rapid and customised response to uncertain demand, instead of anticipatory supply of standard products in high volumes (Fisher, 1997, Christopher, 2000). Consequently, a demand-driven chain can be defined as a supply chain[2] in which all involved actors are sensitive and responsive to demand information of the ultimate consumer and aim to meet those varied and variable demands in a timely and cost-effective manner (based on Kohli and Jaworski, 1990, Vollmann *et al.*, 2000, Cecere *et al.*, 2004). In agri-food supply chains, also responsiveness to supply information is required to deal with a high supply uncertainty (Lee, 2002). Agri-food industry is concerned with living products and biological production processes, which make supply chains vulnerable to decay, weather conditions, pests and other factors that are difficult to control (van der Vorst *et al.*, 2001, van der Vorst and Beulens, 2002, Taylor and Fearne, 2006, van Donk *et al.*, 2008).

Implementation of dynamic demand-driven supply chains is a complex task (Selen and Soliman, 2002). It requires a shift from lean supply chains that focus on efficiency and standardisation to agile supply chains that focus on responsiveness and customisation (Fisher, 1997, Christopher, 2000). This puts the emphasis on the supply chains ability of continuously matching products and business processes, including the network of producers and distributors, to changing demand requirements (Day, 1994, Prahalad and Ramaswamy, 2000, De Treville *et al.*, 2004). Consequently, demand-driven supply chains are highly dynamic networks of changing participants with different allocations of business processes, and different modes of control and coordination. In other words, they are characterised by a high

[2] A supply chain is defined as a connected series of business processes performed by a network of autonomous companies working together to provide products, services, and information for end customers (adapted from Stevens 1989, Lambert and Cooper 2000, and Christopher 2005).

variety and variability of supply chain configurations[3]. Companies must be able to take part in different supply chain configurations concurrently and to switch to new or adjusted configurations.

Information systems are important enablers of such dynamic, demand-driven supply chains. They make it possible to share supply chain information timely and subsequently to alert the firms early in order to respond quickly to changes in demand or supply (Lee and Whang, 2000, Li *et al.*, 2007). To do this in the dynamic context of demand-driven supply chains, it must be possible to connect and disconnect the information systems of the involved actors and hence to set-up and change integrations ('pick, plug and play'). This leads to great demands on, in particular, the interoperability and agility of supporting information systems. Interoperability is the ability for two systems to understand one another and to use one another's functionality (Chen *et al.*, 2008). Information system agility can be defined as the ability to identify needed changes in information processing functionalities and to implement changes quickly and efficiently (Lui and Piccoli, 2007).

Key management capabilities in accomplishing the implementation challenges introduced above include the design of customised supply chains and subsequently the engineering of enabling information systems (Lambert *et al.*, 1998, Fine, 2000, Cooper and Tracey, 2005). Supply chain design guides managers in developing and managing supply chains. It comprises mapping, analysis, and (re)design of the network of contributors, the business processes and the level of process integration and management (Lambert and Cooper, 2000). Information system engineering comprises the modelling and implementation of information architecture (Martin, 1989, Sommerville, 2006). Business processes models have a central role in both activities (see Figure 1).

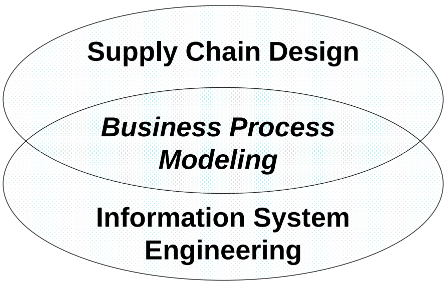

Figure 1 Management efforts in implementation of demand-driven supply chains

Business process models are an important part of enterprise and supply chain architectures. Architecture can be defined as the fundamental organisation of a system embodied in its components, their relationships to each other, and to the environment, and the principles guiding its design and evolution (IEEE 1471:2000). Enterprise and supply chain architectures are complex, since they consist of many

[3] A supply chain configuration is defined in this thesis as a specific set of business processes, control systems and coordination mechanisms, performed by a specific network of contributors who together produce and deliver a product or service with distinct value for the ultimate customer.

different components and many different relationships. Conceptual models are important to make this complexity manageable, by providing systematic representations (visualisation, description) of architectures from different viewpoints and at various levels of abstraction. There are different types of conceptual models for different purposes of usage by different stakeholders, including business process models.

Business process models represent specific ordering of work activities across time and place, including clearly identified inputs and outputs (Davenport, 1993, p.5). They are important means to ensure smooth translation of supply chain designs to information system architecture. Models of supply chain processes can function as linking pins that are on the one hand understandable for supply chain managers and on the other hand interpretable by information systems. In supply chain design, process models help to structure, integrate and redesign the activities among members of a supply chain. In information systems engineering, business process models are increasingly used to guide the workflow in run-time information systems. In particular in Service-Oriented Architecture (SOA), they are leading in routing event data amongst multiple software components that are packaged as interoperable web services (Erl, 2005). Consequently, new or adapted business processes can be supported without changing applications and the underlying infrastructure. Moreover, information systems can be quickly connected to new partners.

The leading role of business processes puts the emphasis on process models as central means for achieving the required interoperability and agility. As a consequence, it must be possible to design and instantiate new or adjusted business process models rapidly and at low costs. The main challenge in achieving this is to combine flexible customisation with efficient standardisation. Mass customisation is broadly advocated as a core approach to balance these seemingly contradictory notions (Davis 1989; Pine *et al.* 1993; Kotha 1995). It is a modular strategy that is intended to accomplish efficiency by reusing standardised components, while achieving distinctiveness through customer-specific assembly of modules (Lampel and Mintzberg, 1996, Duray *et al.*, 2000). Hence, predefined components for design and implementation of customised supply chain configurations should be available in a repository of standard building blocks. Reference process models are an important part of such a repository.

Reference process models can be used as a ‘frame of reference’ (*i.e.* blueprint, template) for the construction of other process models (Thomas, 2006). They improve the speed, efficiency and quality of modelling because of knowledge reuse and enhance shared understanding by providing a common language. The present thesis focuses on how reference process models can enhance the design of demand-driven supply chains and implementation of the enabling information systems.

1.2 Problem statement

Business process modelling has been an important subject of research for a long time (Aguilar-Saven, 2004). Initially, process models were used for quality management and business process redesign in order to overcome fragmentation between organisational units (functional silos) and between systems within companies (Raisinghani *et al.*, 2005, Kock *et al.*, 2009). Moreover, process models were used as a basis for software development and implementation of standard packaged software, in particular ERP systems (Curtis *et al.*, 1992, Barjis, 2008). In the late 1990s the scope has expanded towards the supply chain level, induced by the growing attention for supply chain cooperation and the emergence of internet. In the literature on supply chain modelling, models for information systems engineering were acknowledged to be an important category, besides the then dominant quantitative approaches (Min and Zhou, 2002). And also in the business community, new business process models for supply chain management emerged. The Supply Chain Operations Reference-model (SCOR) of the Supply-Chain Council (SCC, 2008c) is acknowledged as the most comprehensive of these models (Huan *et al.*, 2004, Lambert *et al.*, 2005).

In supply chain design, it has long been acknowledged that supply chain strategy should match to the nature of demand (Fisher, 1997, Childerhouse *et al.*, 2002, Lee, 2002). More recently, it has also been suggested that the design of business processes should reflect specific demand requirements at a more operational level in order to achieve customised response (Aitken *et al.*, 2005, Li and Kumar, 2005, Collin *et al.*, 2009). However, to the best of our knowledge, it has not yet been researched how supply chain process models must be setup to support the design of multiple customised process variants.

We hypothesise that reference process models can be valuable means for design and implementation of demand-driven agri-food supply chains. As discussed in the previous section, in demand-driven supply chains, companies must manage a high variety and variability of supply chain configurations in order to fulfil the demand requirements of their customers. Business process models should therefore support the design of customised supply chain configurations and subsequently the engineering of enabling information systems. To do so, three basic requirements to reference process models are identified in this thesis:

1. They must be setup to enable rapid instantiation of various specific supply chain configurations (instead of dictating a single blueprint);
2. They must support a seamless translation of high-level supply chain designs to detailed information engineering models;
3. They must be sector-specific *i.e.* contain domain-specific knowledge.

First, a rapid instantiation of various specific supply chain configurations can be achieved using a mass customisation approach. Application of mass customisation to reference process models implies that there cannot be one dominant design, but customised models are configured from a repository of standard building blocks *i.e.* predefined generic model components. However, current reference models do not support such an approach. They mostly are setup as strict blueprints (one-size-fits-all) or as models that represent multiple possible variants. The latter are complex models, particularly in case of a high diversity of variants, and consequently difficult to implement. Recently, configurable reference process models are proposed as a solution direction to solve this problem (Dreiling *et al.*, 2006, van der Aalst *et al.*, 2006, Rosemann and van der Aalst, 2007, Gottschalk *et al.*, 2008). However, configuration in this approach is the selection of the most appropriate process variant by skipping or blocking irrelevant options in the reference model. We have not found any literature about reference processes models that are configurable from generic components according to a mass customisation approach.

Second, a seamless translation of supply chain design to information engineering demands a modelling approach that combines high-level supply chain models, which visualise the actors, processes and management of specific supply chain configurations, with detailed process models that depict the information flows among activities and that are interpretable by information systems guiding the workflow. Existing supply chain models only support high-level decompositions of main business processes (Lambert *et al.*, 2005). They do not visualise the interaction among their activities and specific differences in the management of various supply chain configurations are not reflected. On the other hand, although information systems engineering research increasingly studied business process modelling, especially in the SOA field, available process models for information systems engineering so far focused on single enterprises or were designed from a pure technological point of view (Demirkan *et al.*, 2008). The architectural knowledge required to specify services and to configure business processes as a sequence of services is still missing (Papazoglou *et al.*, 2007). In sum, it can be concluded that reference models that link supply chain design and information systems engineering are not yet available.

Third, reference process models in the agri-food industry must include agri-food inherent characteristics and they must address the diversity of supply chain configuration as apparent in agri-food industry. Reference process modelling has been an important subject in agri-food for a long time. In particular, the INSP project can be mentioned, which was commissioned by the Dutch government in the 1980s. It developed detailed process and data models of different agricultural branches, including cattle farming, pig farming, poultry, horticulture under glass, arable farming, fruit and vegetable production and tree nursery (see among others Bos, 1987, Selman *et al.*, 1987, van Tilburg *et al.*, 1987, Graumans, 1988, ATC, 1994, Heslenfeld and Oosterhof, 1994, Stormink and Dijkstra, 1994). However, these models can be characterised as isolated models. They were developed for requirement definition and software design, but the models were not used to guide the workflow in run-time information systems. Furthermore, if implemented models were adapted, it was mostly done without taking into account the overall coherence and consistency as specified in the reference model. This resulted in a lack of active usage of reference models and, after some time, they were no longer maintained (Graumans, 2004, Wolfert *et al.*, 2010). Currently, to the best of our knowledge, there is no active example of a reference process model for agri-food supply chains.

In sum, reference process models can be valuable means for design and implementation of demand-driven agri-food supply chains. However, existing models, if available, are not sufficient for this purpose. Current supply chain process models are too high-level, while process models for information systems engineering are technology-oriented or focus on single enterprises. Furthermore, existing reference process models are setup as blueprints (one size fits all), which do not match with a mass customisation approach. Last, there are no supply chain process models available for the agri-food industry. Next section elaborates how our research aims to bridge these three gaps.

1.3 Research questions, objectives and demarcation

The previous section argues that existing reference process models do not support specific requirements for design of demand-driven supply chains and the implementation of enabling information systems in the agri-food industry. The present research aims to bridge identified gaps by the design of a reference framework for business process modelling that i) is setup to enable the instantiation of various specific supply chain configurations, ii) supports a seamless translation of high-level supply chain designs to detailed information engineering models, and iii) is sector-specific *i.e.* contains domain-specific knowledge for the agri-food sector.

The research addresses the following main research question:

How can reference process models be designed that enable the modelling of demand-driven agri-food supply chains and the implementation of supporting information systems?

This main question is split up into the following sub-questions:

a. What are the characteristics of demand-driven supply chains?
b. What are the requirements on reference process models to enable the modelling of demand-driven supply chains and the implementation of supporting information systems?
c. To what extent do existing reference process models meet the requirements of demand-driven supply chains?
d. How can reference process models be designed that meet the requirements of demand-driven supply chains?
e. How can reference process models of demand-driven supply chains be applied to the agri-food industry?

From these research questions, it follows that the main objective of the research is to propose a reference framework for business process modelling in demand-driven agri-food supply chains. Frameworks constitute theoretical propositions concerning a part of empirical reality (Porter, 1991). Our framework should capture all relevant concepts needed to design adequate reference process models for the purpose of this research. It is intended to comprise three main parts:

i) *Object system definition (result of question a)*: a conceptual view with respect to the field of interest, including typologies of the main concepts;
ii) *Modelling toolbox (result of question d)*: defines process models at different levels of abstraction and includes a knowledgebase for the configuration of these models from a repository of modelling building blocks;
iii) *Application of the framework to agri-food supply chains (result of question e)*: reusable sector-specific models, based on case studies, which comprise specific model building blocks for agri-food supply chains and a set of sector-specific templates.

The research focuses on the connection of supply chain design and information systems engineering (see Figure 1).

From a supply chain design perspective, the scope is limited to the business processes for execution and operational management of demand fulfilment in supply chains, in particular distribution, production and management of sales and procurement. These processes match supply chain capabilities to demand requirements from the point of origin to the point of consumption (Day, 1994, Lambert and Cooper, 2000). As a consequence of these scope choices, other business processes including product development, relation management, governance and strategic management, as well as return processes have been left out of consideration.

From a information systems engineering perspective, one can distinguish four different types of integration: technical connectivity, data sharing, application software interoperability and process coordination (Giachetti, 2004). The focus of this research is on the process level, *i.e.* modelling coordinated business process as a basis for application software and data integration.

1.4 Research method

1.4.1 Design-oriented research

The research used a design-oriented methodology to answer the defined research questions. Design-oriented research has its roots in engineering and the sciences of the artificial (Simon, 1969). It is typically involved with “how” questions, *i.e.* how to design a model or system that solves a certain problem (Van Aken, 2004). A case study strategy fits best in case of complex phenomena that cannot be studied outside its rich, real-world context (Benbasat *et al.*, 1987, Meredith, 1998, Voss *et al.*, 2002, Yin, 2002, Eisenhardt and Graebner, 2007). This often characterises design-oriented research, in particular in management studies, because it focuses on artefacts intended for real-life problems that are influenced by many factors (Van Aken, 2004).

Design-oriented research focuses on building purposeful artefacts that address heretofore unsolved problems and that are evaluated with respect to the utility provided in solving those problems (March and Smith, 1995, Hevner *et al.*, 2004). Artefacts may include four types of designs (March and Smith, 1995): i) constructs *i.e.* the language in which problems and solutions are defined and communicated, ii) models, which represent a real world situation; iii) methods that provide guidance on how to implement the models, and iv) instantiations showing that constructs, models or methods can be implemented in a working system. The generic design artefact developed in the present thesis is a reference process framework that includes constructs, models and methods for modelling business processes in demand-driven supply chains.

1.4.2 Research design

Starting point of design-oriented research is the selection and analysis of a certain 'problem class' (Hevner *et al.*, 2004, van Aken, 2004, van Eijnatten, 2006). In this analysis, the purpose of usage is specified in design requirements. Then, the research typically consists of a constructive part that builds an artefact and a part that evaluates the designed artefact (March and Smith, 1995). The research started with the definition of basic design requirements based on literature review and subsequently existing reference models were assessed on these requirements. Based on this assessment and the reviewed literature, a generic framework was constructed. This generic framework was applied in three different case studies. Consequently, the research was organised as visualised in Figure 2.

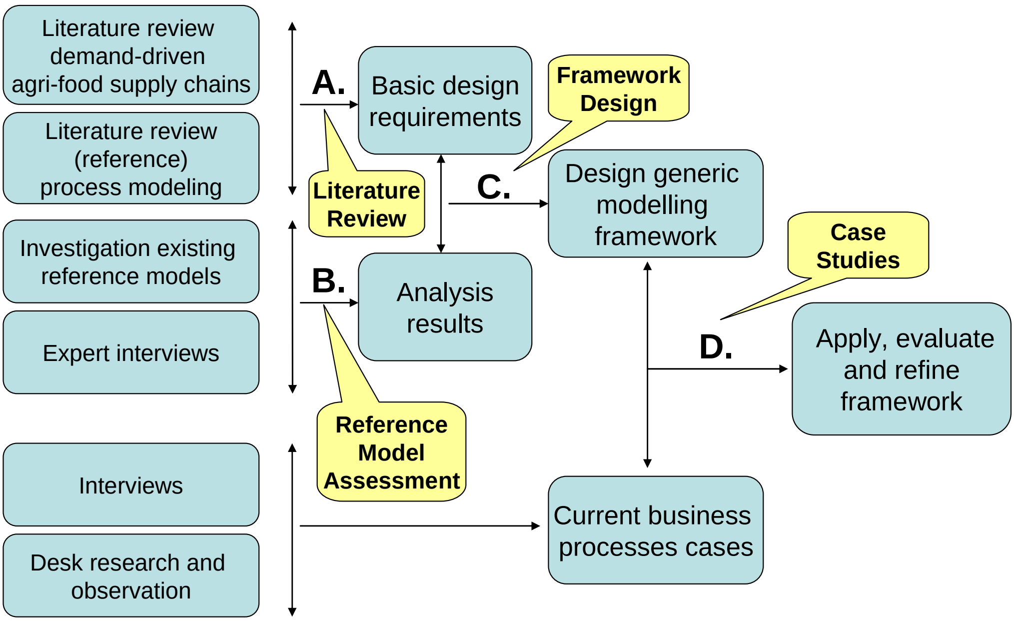

Figure 2 Conceptual design of the research (based on Verschuren and Doorewaard 2005, and van Eijnatten 2006)

The figure shows that the research consisted of four main phases (A-D). These phases followed the sequence of the defined sub research questions (see Table 1, next page).

Table 1 Research questions per research phase (X: main focus; *: additional)

Research Questions **Research Phase** *(see A-D in Figure 2)*	a. What are the characteristics of demand-driven supply chains?	b. What are the requirements on reference process models to enable design of demand-driven supply chains and implementation of the enabling information systems?	c. To what extent do existing reference process models meet the requirements of demand-driven supply chains?	d. How can a business processes be modelled in order to meet the requirements of demand-driven supply chains?	e. How can the designed reference process model of demand-driven supply chains be applied to agri-food industry?
A. Literature Review	X	X			
B. Reference Model Assessment		X	X		
C. Framework Design				X	
D.1 Case Study Modelling Framework				X	*
D.2 Case Study Agri-Food Application				*	X
D.3 Case Study Information Systems Architecture				X	*

First, in research phase A, the problem context was analysed in more detail in a review of the literature on supply chain design and information systems engineering. At this, we defined the object system conceptually based in Supply Chain Management literature. We described supply chains from a systems perspective, because this provides a basis for consistently modelling interactions between processes. Furthermore, in order to define the diversity of configurations as apparent in demand-driven supply chains, we developed typologies of three main concepts: business processes, control systems and coordination mechanisms. Next, basic design requirements to reference process models in demand-driven supply chains were defined. By doing this, the first and second sub research questions were answered.

Second step was an assessment of existing reference process models on these requirements. As Thomas (2006) argues, user-side acceptance is an important characteristic of reference models. Therefore the analysis focused on reference models, which are widely acknowledged and applied in business community. These models were selected from existing surveys (van Belle, 2002, Fettke and Loos, 2003, Fettke *et al.*, 2005) and additional literature search. The investigation was done by desk study and 15 in-depth expert interviews with reference model developers and implementation consultants. The results were used to assess how close existing reference models meet the addressed requirements in demand-driven supply chains. By doing this, the third sub research question was answered.

Third, building on the literature review, a generic framework for modelling business process in demand-driven supply chains was designed. The SCOR-model was chosen as a basis for this design (SCC, 2008c). SCOR is acknowledged as the most comprehensive supply chain process model and as a widely accepted common language in supply chain design (Huan *et al.*, 2004, Lambert *et al.*, 2005). The framework design provided the answer of the fourth sub research question.

Fourth, the last sub research question was addressed by applying the designed modelling framework in three case studies. The case studies all followed a reflective design cycle (see figure below).

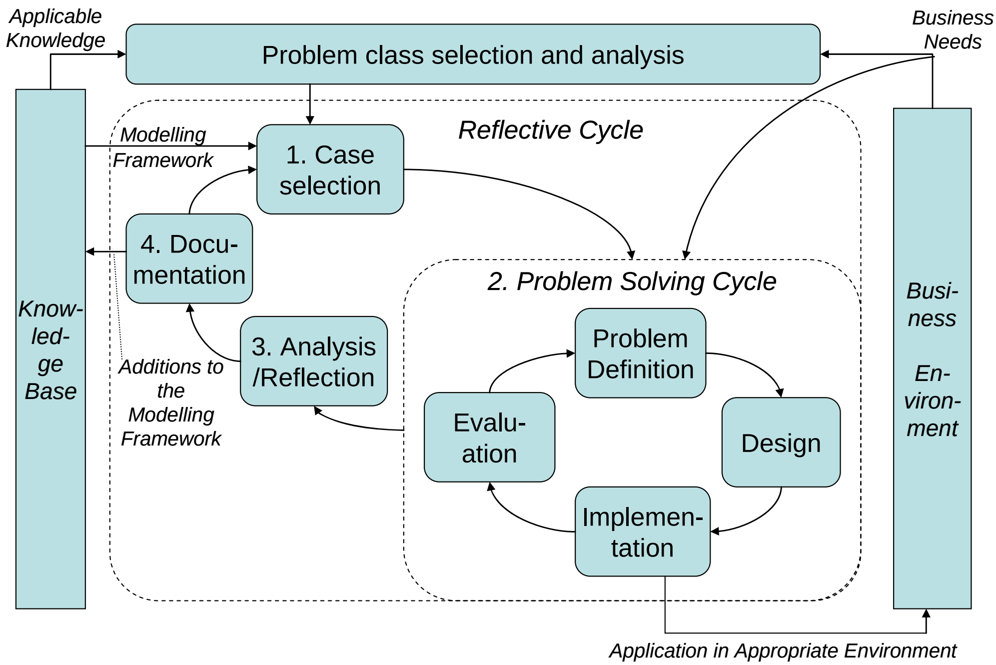

Figure 3 Reflective design cycle (adaped from van Aken 1994, van Aken 2004, Hevner et al. 2004, van Eijnatten 2006)

The input of each reflective design cycle was twofold (see top-left in Figure 3). First, the objective and scope were defined by a selection and analysis of the 'problem class' as described previously in this chapter. Second, the available version of the modelling framework served as the starting point for every case study. Based on the problem class selection and the preliminary framework design, the first step of a reflective design cycle was the case selection. As usual in case study research (Eisenhardt, 1989, Yin, 2002), the choice of the cases was based on theoretical replication logic rather than statistical sampling logic. Next, each case study followed a problem solving cycle of problem definition, design, implementation and evaluation, see bottom-right in Figure 3 (van Aken, 1994, Wolfert, 2002, van Aken, 2004, van Eijnatten, 2006). After every regulative cycle, the case study results were abstracted to reusable models (analysis/reflection) and incorporated in the framework (documentation). As such, the generic design served as a theoretical basis for abstracting replicable knowledge from the case study findings (Yin, 2002, p. 47).

1.4.3 Setup of the cases studies

The iterative design cycle described above was repeated for three different case studies. They focused on different elements of designed framework, successively: i) the object system definition and generic modelling toolbox, ii) the application to agri-food supply chains, and iii) the enabling information systems architecture.

Case study 1 applied the designed framework in an explorative multiple case study in the Dutch flower industry, which faces a high variety and variability of supply chain configurations. In this branch typically trade relations are changing frequently, growers are participating in different distribution channels, product variety is high and production processes are relatively uncertain, especially due to the dependency on living materials. The research investigated supply chain configurations in in-depth interviews with managers of five producers, one auction and two traders. Based on the identified configurations of each case firm, three typical supply chain configurations were defined and modelled by applying the framework. Finally, the evaluation was done by verifying whether the applied framework meets the defined requirements and by checking the conceptual validity of the framework. Conceptual validation is closely related to verification and evaluates whether the model concepts that have been used correspond to the concepts recognizable in the system that is being studied in reality (Wolfert, 2002, Sargent, 2005). In the case study, this was done comparing the framework, including a conceptual model of the object system based on literature, with supply chain configurations as found in the investigated cases.

Case study 2 applied the framework to fruit supply chains in an in-depth multiple case study. The fruit industry is characterised by typical agri-food features such as long production lead times, seasonable production, quality variations between producers and between lots, short required delivery time due to product freshness, and special packaging demands. In total, 8 cases were analysed in 4 European countries (Spain, Greece, Poland and The Netherlands). Data collection was done in 28 in-depth semi-structured interviews with key informants of the selected case firms and additional document reviewing. The cases were analysed using the hierarchical method combined with triangulation of researchers, which implies that separate cases are examined independently by different researchers after which these results are analysed in a comparative analysis (Verschuren and Doorewaard 2005). Subsequently, a fruit-specific reference process model was designed by application of the generic framework to fruit supply chains based on the case study investigation results. Finally, like in the first case study, the applied framework was verified and conceptually validated. Furthermore, also the face validity was evaluated. Face validation judges whether the design appears to be reasonable to people knowledgeable about the system, for example by confronting experts with the model outcomes and ask them if they are reasonable (Harrison, 1991, Wolfert, 2002). In the case study, this was done in a review by seven industry experts. Finally, the case study results were abstracted to reusable models by updating the framework with the preconfigured models of typical fruit supply chain configurations.

Case study 3 focussed on implementation of the framework in configurable process models. Based on the analysis of existing reference models, the case study assessed the application of configuration software for combined product and process configuration as a basis for planning and control of fulfilment. Because of the explorative nature of the research, an in-depth single case study research was chosen. This research was conducted in the Dutch flower industry at a firm that was characterised by high uncertainty of demand and supply. Based on a review of configuration literature, first a typology of dependence between product and process configuration was defined. Next, the case-study firm was investigated in semi-structured open interviews with managers and employees of the case company, and additional desk research. The typology was used to identify the design requirements for information systems enabling the coordination of these dependencies at the case firm. Subsequently, we designed a conceptual architecture and obtained a Proof of Feasibility. At this, it was demonstrated to what extent the defined requirements can be satisfied with a commercially available configurator tool. Evaluation was done by verification of the identified requirements and discussion about the utility with the management of the case study firm and the configurator vendor. Based on this evaluation, general development strategies were identified and the framework was updated with the developed typology and architecture.

Finally, it should be noticed that the research phases were not performed chronologically. As figure 3 shows, the research consists of iterative design cycles organised around the case studies. In particular the literature review and framework design were updated during the entire research process.

1.5 Thesis outline

The remainder of this thesis describes the research results and concludes with a discussion. The results are presented in the next four chapters (see figure 4).

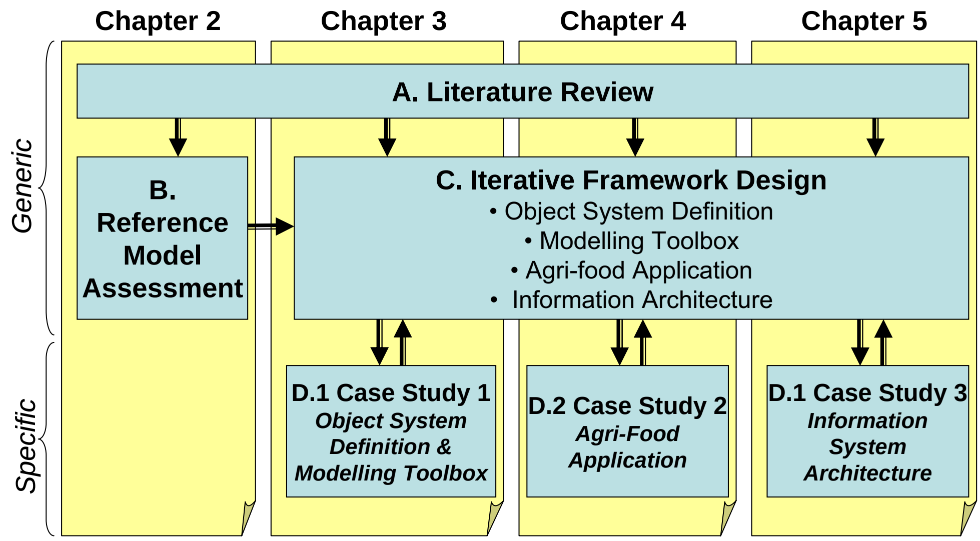

Figure 4 Thesis outline related to the research phases

First, chapter 2 assesses existing reference models for production and supply chain management. It is argued that in demand-driven supply chains reference models should support an ICT mass customisation approach. Based on literature study, requirements on reference models for enhancement of ICT mass customisation are defined and it is assessed to what extent existing reference models meet these requirements.

In the next chapters, different elements of the designed framework are developed, each based on literature review and each supported by a case study research.

Chapter 3 proposes a generic framework for modelling business process in demand-driven supply chains. It defines the object system of this thesis and develops an accompanying modelling toolbox. Building on the terminology and process definitions provided by the Supply Chain Operations Reference (SCOR) model, it models supply chain configurations as specific sets of business processes, control systems and coordination mechanisms. Therefore it identifies modelling building blocks (reference components), a method to instantiate the model to specific cases (configuration tree) and preconfigured diagrams of typical supply chain configurations (reference templates).The designed modelling framework is applied in a multiple case study in the Dutch flower industry.

Chapter 4 presents an application of the framework to fruit supply chains. Based on a multiple case study in four European countries, it extends the modelling toolbox with model building blocks for fruit supply chains and a set of fruit-specific process model templates. Furthermore, it includes a specific type of process models that visualise the product flow in a supply chain configuration, including different units of aggregation.

Chapter 5 focuses on a conceptual architecture of enabling information systems by exploring how configurators can be used for combined product and process configuration in order to support mastering high uncertainty of both supply and demand. Therefore, it first defines the dependence between product and process configuration in a typology of interdependencies. Next, a conceptual architecture is proposed for coordination of these interdependencies based on a single case study in the Dutch flower industry.

Finally, chapter 6 discusses the overall results, draws conclusions and addresses remaining challenges for further research and development.

Chapter 2. Towards dynamic reference information models: Readiness for ICT mass customisation [4]

Abstract
Current dynamic demand-driven networks make great demands on, in particular, the interoperability and agility of information systems. This chapter investigates how reference information models can be used to meet these demands by enhancing ICT mass customisation. It was found that reference models for Production and Supply Chain Management do not yet sufficiently meet the requirements of a mass customisation approach. They have developed from isolated models based on pure standardisation and tailored customisation strategies, towards static repository-based models founded on segmented standardisation strategies. Existing models provide valuable knowledge for developing towards more dynamic reference information models, including the progress made by ERP vendors to make their reference models configurable. Important remaining challenges are setting reference information models up as generic models that define classes of architectures, and incorporating user-friendly means that guide users through the process of configuring specific information models.

Keywords: Reference models, Information systems, Mass customisation, Production and supply chain management

2.1 Introduction

In response to today's increasingly volatile business environment, supply chains are in transition from chains pushing products efficiently to the marketplace, towards agile networks that sense and react dynamically to demand information. This makes great demands on, in particular, the interoperability and agility of supporting information systems (Li *et al.*, 2007, Swafford *et al.*, 2008). Interoperability is the ability for two systems to understand one another and to use one another's functionality (Chen *et al.*, 2008). ICT agility is the ability to identify needed changes in the information processing functionalities and to implement them quickly and efficiently (Lui and Piccoli, 2007).

The main challenge in meeting these demands is combining flexible customisation with efficient standardisation. In business literature, mass customisation is broadly advocated as a core approach to balance these seemingly contradictory notions (Davis, 1989, Pine *et al.*, 1993). Mass customisation relates the ability to provide customised products or services through flexible processes to the ability to produce in high volumes at reasonable costs (Da Silveira *et al.*, 2001). This is by fabricating parts of the product in volume as standard components, while achieving distinctiveness through customer-specific assembly of modules (Duray *et al.*, 2000).

Recent developments in ICT, particularly Service-Oriented Architecture (SOA), enable the application of mass customisation principles to information systems (Dietrich *et al.*, 2007). ICT mass customisation combines the advantages of standard

[4] C.N. Verdouw, A.J.M. Beulens, J.H. Trienekens, T. Verwaart (in press). Towards dynamic reference information models: Readiness for ICT mass customization. Computers in Industry, special issue on Trends and Challenges in Production and Supply Chain Management, doi:10.1016/j.compind.2010.07.008

and customised software. It enables on-demand configuration of information systems from standard components with standardised interfaces.

Information models (*e.g.* process and data models) support ICT configuration tasks since they provide systematic representations of the complex architectures to be configured. Specific information models could be developed from scratch for each configuration, but this would result in high costs and long lead-times. An alternative approach would be to use available ‘best practices’ captured in reference information models as a ‘frame of reference’ (*i.e.* blueprint, template).

The objective of this chapter is to assess how reference information models can be used to enhance ICT mass customisation. Therefore, it respectively aims to: i) identify the requirements to reference information models in an ICT mass customisation approach, ii) investigate the extent to which existing reference models, in the domain of Production and Supply Chain Management, are useful for ICT mass customisation, and iii) to explore trends in the development towards dynamic models.

The research started with a literature study to identify the requirements on reference information models in an ICT mass customisation approach. Therefore, a three-stage funnel approach was followed. First, the generic concept of mass customisation and the requirements on systems, enabling such an approach, were defined. Secondly, the approach and identified requirements were applied to mass customisation of information systems. Thirdly, the analysis concentrated on the role of reference information models in mass-customisable ICT.

After literature review, existing reference information models were investigated. Because user acceptance is an important characteristic of reference models, the investigation focussed on reference models that are widely acknowledged and applied in the business community. The scope of our analysis was the domain of Production and Supply Chain Management, implying that reference information models which mainly focus on eCommerce processes (ordering, invoicing, catalogue exchange, etc.) and sector-specific reference models were not assessed.

The investigation was carried out through desk study and in-depth expert interviews with reference model developers, implementation consultants and managers (67%, 53% and 33% respectively, multiple roles possible). In total, 15 experts were interviewed (9 persons from 7 software vendors and 6 people from 5 service providers) in-depth, based on a structured three-part questionnaire: i) content and technology, ii) model development, and iii) implementation and usage (see Appendix A).

The structure of this chapter follows the research approach. Section 2.2 defines the concept of mass customisation, the requirements on systems enabling such an approach, and applies this to information systems. Section 2.3 elaborates on the role of reference models and the requirements on such models for the enhancement of ICT mass customisation. Section 2.4 provides an overview of existing reference models for Production and Supply Chain Management and describes the extent to which these models meet the identified requirements. The chapter concludes by describing trends towards dynamic reference information models and addressing future challenges.

2.2 Towards mass-customisable ICT

This section discusses the characteristics of a mass customisation approach, and identifies the requirements when such an approach is applied to ICT.

2.2.1 What is mass customisation?

The term 'mass customisation' was coined by Davis (1989). It was initially promoted as a broad visionary concept, putting together seemingly contradictory notions: customisation to produce tailored products or services through flexible processes versus standardised mass production to produce in high volumes at reasonable costs (Davis, 1989, Pine *et al.*, 1993). Around the turn of the century, mass customisation was mentioned in the debate about agility versus leanness as a core concept to bridge the gap between both approaches. Agile strategies focus on flexibility and customisation, while lean strategies focus on efficiency and standardisation. From the debate it emerged that leanness and agility are not mutually exclusive strategies, and that a hybrid strategy of both agile and lean approaches is required to meet the requirements of responsiveness (Naylor *et al.*, 1999). In such 'leagile' approaches, the positioning of Customer Order Decoupling Points (CODPs) plays a central role. The CODP separates that part of the supply chain geared towards directly satisfying customers' orders from that part of the supply chain anticipating future demand (Hoekstra and Romme, 1992). Downstream products are differentiated to specific customers or markets, while upstream products are standardised based on demand forecasts.

Based on the CODP position, a continuum of control strategies is proposed in literature, varying from strategies in which all processes are driven by customer order, to full anticipatory control in which all processes are based on demand forecasts. The main configurations are engineer-to-order (ETO), make-to-order (MTO), assemble-to-order (ATO) and make-to-stock (MTS). These strategies involve different levels of product differentiation, from fully customised in engineer-to-order (ETO) to fully standardised in make-to-stock (MTS).

Lampel and Mintzberg (1996) argue that there is a dominant trend from both ends of the continuum toward the middle, namely towards mass customisation, or as they name it: 'customised standardisation'. Such a strategy offers the buyers the option of selecting their own set of components. Customers get their own product configuration but constrained by the range of available components. A mass customisation strategy is enabled by an Assemble-to-Order (ATO) production strategy, in which customer-specific products are assembled to customer order from standardised components that are fabricated to forecast.

Several authors stress that mass customisation imposes high demands on the enabling business systems. Pine *et al.* (1993) argue that modularity and a linkage system are key factors to achieve mass customisation. Modularity allows parts of the product to be made in volume as standard modules, with product distinctiveness achieved through specific combinations of the modules (Duray *et al.*, 2000). A linkage system permits components to integrate rapidly in the best combinations or sequence required to tailor products or services (Pine *et al.*, 1993). Duray *et al.* (2000) add that besides modularity, customer involvement in specifying the product is a key characteristic. Zipkin (2001) states that mass customisation requires unique operational capabilities. He addresses four key capabilities: i) a mechanism for interacting with the customer and obtaining specific information (elicitation); ii) flexible processes that fabricate the product according to this information; iii) the logistics to deliver the right product to the right customer; and iv) powerful communications links that integrate these elements into a seamless whole. Tseng (2001) identifies three basic requirements in design for mass customisation: i) common building blocks that can be reused maximally, ii) unified product architecture providing a structure of the defined building blocks that represent the capability of the enterprise to fulfil customers' needs in a unified manner; and iii) a platform for meta level integration of the product realisation process. Huang *et al.* (2005) focus on product platforms as a common success factor in achieving mass customisation, which encompass four strategies *i.e.* commonality, modularity, scalability and postponement.

Synthesized from this literature, five key requirements for mass customisation systems are addressed:

a. *Generic product model*: mass customisation does not imply providing limitless choice, but it is restricted to available options. For quick product assembly, it must be clear what these possibilities are. Thus a product model is required that provides a standardised taxonomy representing different product variants and the underpinning structure (Tseng, 2001). Traditionally, product models are developed for every product or variant, which results in high complexity and component redundancy. Therefore, Hegge & Wortmann (1991) introduced a generic product model that represents the set of all variants of a particular product family. It depicts all possible configuration options of product instances and the interdependencies that exist between components or features.
b. *Modularity*: products in a mass customisation approach consist of distinctive, autonomous and loosely coupled modules. These are independent components, each with its own single function and concentrated purpose (Sanchez and Mahoney, 1996). These components can be used as black boxes, *i.e.* in order to use them, it is not necessary to know their inner structure, and changes in one component do not impact the integrity of other components. Full product modularity also requires modularity of the enabling business processes and the network of producers and distributors.
c. *Integration platform*: modularity must go along with seamless integration in order to enable rapid and flexible assembly of customised products and services. Therefore, a platform is required that provides the production technology and communication infrastructure for flexible integration of product components. This platform assembles and interconnects the modules and coordinates the realisation of customised end products, according to given specifications including interface standards.
d. *Configuration support*: mass customisation is only possible if specific customer needs can be elicited rapidly and without error, while considering the possible options (Zipkin, 2001). Furthermore, the identified requirements must be translated into the product information needed for procurement and manufacturing. This requires adequate systems for configuration, *i.e.* configurators. These are tools that guide users interactively through the product

specification process. They show the available product range and provide possible selections based on the defined generic product model (Sabin and Weigel, 1998).

e. *Component availability*: in a mass customisation approach, products are assembled from an inventory of standard available components when specific customer orders appear. In order to meet short order-to-delivery lead times, it is evident that the components with the right functionality must be available if customers demand a specific configuration.

2.2.2 Mass customisation of information systems

ICT mass customisation combines the seemingly contradictory notions of efficient standard software and flexible customised software. It enables customer-specific assembly of information systems from a repository of standard components. As such, mass-customisable ICT can be positioned in the middle of a continuum of standard packaged software and customised software. Software developers pre-design and realise modules based on forecasted functionality. Customers get their own ICT configuration, but constrained by the range of available components, as defined in reference models for the configuration of systems. These components could be supplied by different software vendors, which allows for using best-of-breed solutions in selecting and designing systems.

Following the identified requirements for mass customisation systems, the requirements for mass-customisable information systems are:

a. *Generic information model:* like product architectures in a mass customisation approach, information models should be set up as generic models, which define the class of architectures that can be assembled. Additional complexity of generic information models is that they comprise different interrelated model types including process, data and application models.
b. *Modular software:* modules in an ICT mass customisation approach are application-independent services, in which policy, input and output data, and interfaces are well defined (product modularity). They should not impose technical constraints on development of other modules (process modularity). Furthermore, it should be easy to replace a software module of provider A by a module of provider B, and it must be possible to combine modules of different vendors (network modularity).
c. *Information integration platform*: a software platform is required that the modules can easily be plugged into, that can enact the execution of modules upon the occurrence of external or internal events, and that enables the exchange of information between the modules. Contrary to mass-customisable products, this platform has a virtual nature. It is not tied to one place. Especially internet-based techniques enable integration of modules that are located all over the world.
d. *Configuration support:* configuration of ICT elicits the required functionality of specific instantiations of information systems building upon a generic information model. Since information systems are composed of many interacting components, ICT configuration must be done for different levels of abstraction and different types of subsystems. Consequently, configuring information systems includes many partial configuration tasks that occur at different moments by different

people. The dependencies between these different tasks must be well coordinated.

e. *Component availability:* the availability of software modules that, together, provide the desired functionality, including a specification of the interfaces. A specific characteristic of ICT components is again the virtual nature. This implies that components can be duplicated very quickly and at a negligible cost. On the other hand, availability is dependent on service providers, because users have access to the modules via an often complex information infrastructure.

During the last decades, much progress has been made in making ICT meet these requirements. Although it is not the purpose of this chapter to analyse in detail technical implementations of ICT mass customisation, five important lines of developments can be distinguished: evolvement of modular software, shift from data-oriented to process-driven software, evolvement of Enterprise Application Integration (EAI), focus on architecture (model-driven software) and isolation of business logic in formalised rules. Service-Oriented Architecture (SOA) combines these advances into one integrated approach. SOA consists of three layers (Erl, 2005):

- *A business process management layer, coordinating the execution of business services*: this is a functional integration layer that groups services from the underlying business service layer into business processes. The process services are typically implemented through generic enactment engines, that execute workflows defined in languages such as BPEL or BPML. Following the workflow specifications, the enactment engines invoke services in the next layer. Services in the process layer can be rapidly configured or reconfigured using Business Process Management (BPM) tools.
- *A business services layer, delivering information services to the business processes*. The business services implement the information-processing functions of the actual business processes. Business services may be either straightforward data registration or reporting services, or complex services based on extensive business logic. They may implement these functions directly, for instance by applying business rules, or use application services that connect the business services to (legacy) information processing application systems.
- *A business application layer, executing the application logic and data storage*. Applications are wrapped in application services, offering a standard web service interface to the business services, thus enabling enterprise application integration (EAI).

The technological advances towards SOA have helped to meet, in particular, requirements b. and c. for mass-customisable information systems, *i.e.* software modularity and information integration platform. Moreover, it enables rapid system configuration by providing standards like Service Component Architecture that specify technical aspects of the interfacing and service assembly. However, SOA does not include the knowledge required to specify services and to configure business processes as a sequence of services. Furthermore, the required software components must be available packaged as application-independent web services. Nonetheless, many current legacy systems are traditional monolithic ERP systems, which especially lack the required modularity (Akkermans *et al.*, 2003, Rettig, 2007).

So, even if a company applies SOA, important remaining challenges include the development of: i) generic information models that specify families of business processes and services, and ii) tools that support configuration of specific business process and service architectures. Reference models play an important role in meeting these requirements, as we will elaborate further in next section.

2.3 Role of reference models to enhance mass-customisable ICT

This section discusses the role of reference information models in mass-customisable ICT, and addresses the requirements to enhance such an approach.

2.3.1 What are reference information models?

Information modelling is an essential task in the analysis and development of information systems. Information models depict the architecture of mostly enterprise or supply chain systems. Architecture can be defined as the fundamental organisation of a system embodied in its components, their relationships to each other, and to the environment, and the principles guiding its design and evolution (IEEE 1471:2000). As such, architecture is about how specific products, systems or organisations are divided into sub-systems and what the relationship is between these components (structural arrangement). Architectures of information systems are complex, since they consist of many different components and many different relationships. Information models are important in terms of making this complexity manageable, by providing systematic representations (visualisation, description) of architectures from different viewpoints and at various levels of abstraction. As such, information models support different stages of software development: requirements definition, design specification and implementation description.

Reference models have played an important role in information modelling for a long time, in particular in software engineering projects and implementation of standard packaged systems. For the purpose of this chapter, reference information models should be distinguished from architectural frameworks. An architectural framework provides a systematic taxonomy of concepts of how to organise the structure of information models (Sowa and Zachman, 1992). They depict the required information model types in different views and at various levels of abstraction, and show how these are related.

This chapter deals with reference information models as conceptual models of information systems that formalise recommended practices for a certain class of domains (Fettke and Loos, 2003). Reference information models are used as a 'frame of reference' (*i.e.* blueprint, template) to construct company-specific information models and, as such, they improve quality, costs and lead-times of information modelling processes. Reference information models can contain different model types, depending on the purpose of usage specified in architectural frameworks. Most common are process and data models (including master data).

2.3.2 Continuum of reference information model strategies

Reference models are used in different ways in the ICT agility continuum, varying from pure standardisation to pure customisation. Below we describe the different use of reference models in these strategies, illustrated by a simplified example of configuring a business process model (in BPMN notation) for the order fulfilment process of a discrete manufacturer that produces to customer order.

In a *pure standardisation approach,* standard packaged software is based on one standard reference information model, *i.e.* a ’dominant’ design targeted to the broadest possible group of buyers. This standard model represents in detail forecasted functional requirements and accompanying characteristics of the system design. It is the starting-point in software development. Implementing the software implies that the underlying standard reference information model is implemented, often implicitly. A company adopts the reference process model that is best suited to its characteristics. It is not possible to customise the reference model. Consequently, the instanced model is identical to the reference model.

Also, reference information models in a *segmented standardisation* strategy specify in detail the anticipated functional requirements as a basis to develop standard software. However, contrary to pure standardisation, there is not one dominant design, but reference models in this strategy cover multiple variants for different clusters of buyers. These reference models are used for selecting applicable functionalities and specification of the right parameters. A typical example of this strategy is ERP software that is segmented to different types of companies in different branches.

Figure 5 (next page) shows that, in this strategy, the reference model contains all allowed process variants present in this illustrative case: Make-to-Stock (MTS) and three types of Make-to-Order (MTO): discrete, continuous and batch production. Implementation implies selection of the most appropriate variant by skipping or blocking irrelevant options in the model. Subsequently, the instanced model is a stripped version of the reference model.

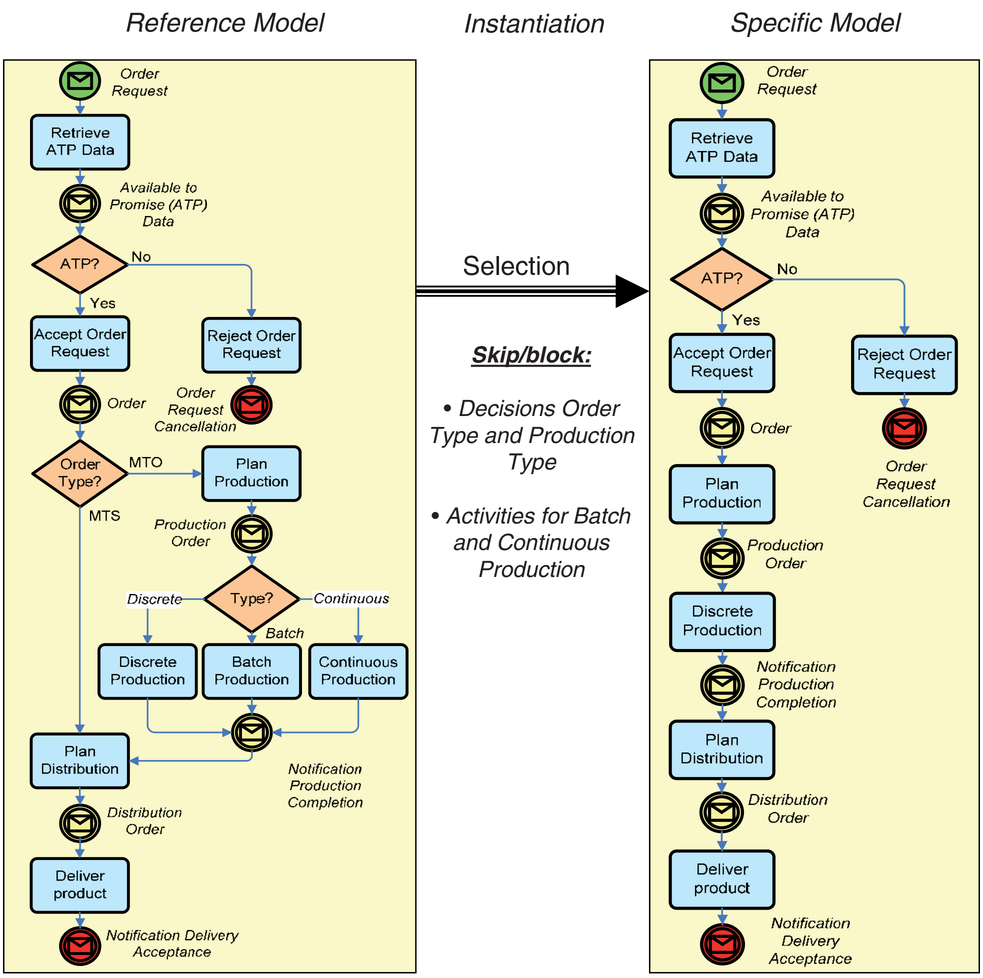

Figure 5 Illustrative application of reference models in a segmented standardisation strategy

In a *customised standardisation (=mass customisation)* strategy, reference information models are generic models that specify the available components, possible features, and the permitted choices and combinations of components. The models are used both for design and development of software components and for guiding the configuration of customer-specific information systems.

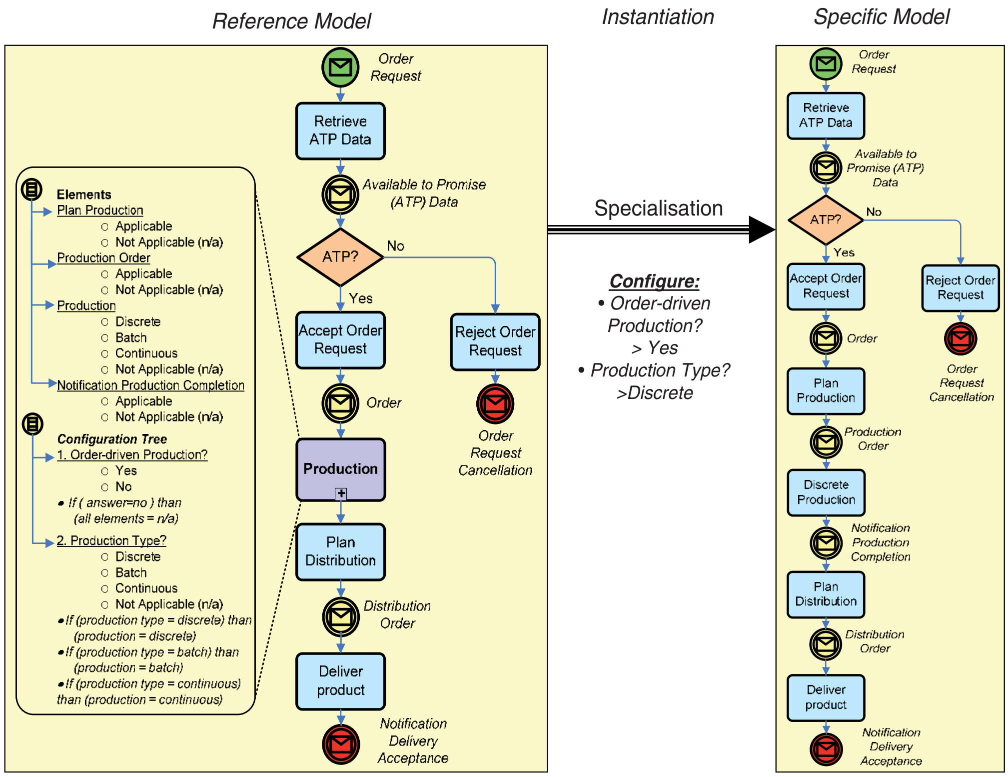

Figure 6 Illustrative application of reference models in a mass customisation strategy

Figure 6 shows that reference models in a mass customisation strategy depict generic building blocks that can be configured for specific situations. In this example, ‘Production’ is set up as a generic activity. All possible elements of this activity are defined, including the attributes and possible values. In this simplified example, two activities and two intermediate messages are available. Additionally, the reference model includes a tree of configuration choices and accompanying constraints. Configuration of the reference model implies configuration of specific instances by following a configuration tree. In this illustrative example, two choices are made. The production is order-driven, which implies that all elements are applicable. The production type is discrete, which implies that the activity Discrete Production is chosen. Based on the configuration choices, the values of the reference elements are specified. Thus, the instanced model is a specialised version of the reference model.

In a *tailored customisation* strategy, the starting point is a standard reference information model that specifies system design (just like in a pure standardisation strategy). At implementation, this reference model is modified for particular customer wishes. The customised reference model is used to develop a fully customer-specific software system, as far as possible reusing existing software components.

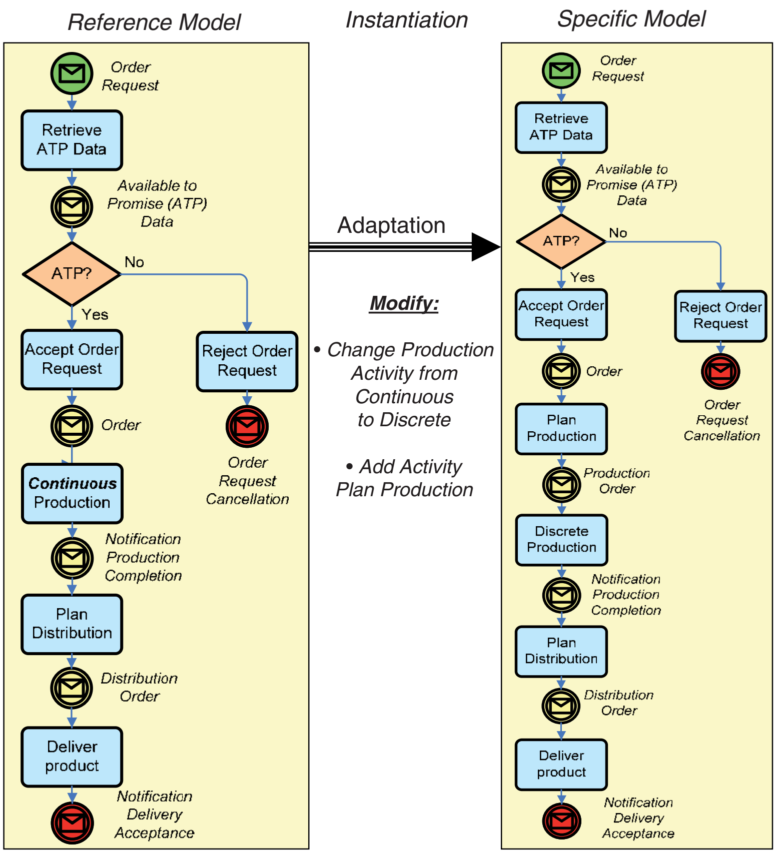

Figure 7 Illustrative application of reference models in a tailored customisation strategy

Figure 7 shows that in this approach companies adapt reference models until the customised model fully meets the user's specific requirements. In this example, adaptation of the reference model is achieved by inserting a missing activity (Plan Production), and changing an activity (Continuous Production into Discrete Production). Subsequently, the instanced model is a modified version of the reference model.

Lastly, in *pure customisation,* strategy information systems are fully customised, without reusing existing designs and software modules. This implies that information modelling is done from scratch, fully according to customer specification, and reference information models are not used.

Overall, it can be concluded that reference models in these strategies mainly differ in the extent to which they can be customised to specific requirements. In pure standardisation, reference models are strict blueprints that must be taken as they are ('one size fits all'). In a segmented standardisation strategy, users can choose a specific variant that best suits their requirements, constrained by the available variants in the reference model. In a mass customisation strategy, users can specify their own configuration, but this is constrained by the available generic components and the rules that define permitted choices. In a tailored customisation strategy, users are free to modify the reference model to their specific requirements. However, it is important to notice that reference models are often used in a combination of strategies. For example: selection of the most appropriate variant from a segmented standardised reference model and than adaptation of this to the specific situation (tailored customisation). Also, different strategies can be applied at different abstraction levels.

In this chapter, we focus on reference models used in an ICT mass customisation approach. Therefore, below we discuss further development of the characteristics demanded of such models.

2.3.3 Requirements of reference models for mass-customisable ICT

In accordance with the requirements for ICT mass customisation as developed in section 2.2.2, the requirements for reference information models are:

a. *Generic model setup*: the most important requirement is that reference information models in a mass customisation strategy must be set up as generic models. They must specify the generic components of the supported information architectures, and define permitted choices and combinations in explicit configuration rules. Reference models must neither be single structures, as is the case in a pure standardisation and tailored customisation strategy, nor detailed specifications covering all possible variants, as is the case in a segmented standardisation strategy.
b. *Supporting software modularity*: in a mass customisation strategy, a reference model instance must be the design of a component-based information system. This requires that it provides precise definitions of the supported application services, including specifications of input and output data, policy, standardised interfaces, and possible sequences of services.
c. *Executable*: in mass customised systems, tailored functionality is provided by customised execution of standardised services. This is achieved by using the configured models in the run-time system for service orchestration, *i.e.* routing event data amongst multiple services. Therefore, the information models that support implementation must be machine-interpretable in the chosen software platform. In order to configure such models, reference information models must support a format that is executable. If reference information models are reused in different software environments, machine-interpretability requires that the reference model is represented in a standard notation.
d. *Configuration support*: the configuration of reference information models in a mass configuration approach is a complex task, especially in the domain of Production and Supply Chain Management. Therefore, there should be tools in place providing user-friendly means of leading users through the process of configuring specific information models. These tools must be able to inherit configuration choices, from requirements definition to implementation models.
e. *Content availability*: reference models must provide domain-specific knowledge required to specify services and to configure business processes as a sequence

of services in specific areas of application. For example, dependent on the specific purpose of usage, in the domain of Production and Supply Chain Management this might imply that the model includes: i) both manufacturing, logistics, engineering, commercial and supporting processes including finance and quality management, and ii) discrete, continuous and batch production, and iii) different forms of forecast-driven and order-driven control (for example: material management with MRP, kanban and CONWIP), and iv) both intra and inter enterprise integration.

2.4 Reference information models for production and supply chain management

Reference information models are important means to enable an ICT mass customisation approach, if they meet the requirements developed in the previous section. This section summarises the investigational results by providing an overview of existing reference information models and assessing the extent to which these models fit within a mass customisation approach.

2.4.1 Overview of existing reference information models

In the domain of Production and Supply Chain Management**,** widely acknowledged and applied reference models are SCOR, the GSCF Framework, VRM, the CPFR model of VICS, the MIT Process Handbook Y-CIM, ISA95, STEP, and the ERP reference models of SAP and Baan. Appendix B provides an introduction to these reference models. The models support different stages of information system development.

The MIT Process Handbook and the Supply Chain Management reference models, *i.e.* SCOR, VRM, and the GSCF framework, provide business knowledge that can be used to define information system *requirements*. The MIT Process Handbook focuses on a systematic repository of business knowledge of both single enterprise and supply chain processes (Malone *et al.*, 1999). The Supply Chain Operations Reference model (SCOR) aims to provide a reference model of supply chain processes (SCC, 2008c). Therefore, it includes process models of single enterprises (plan, source, make, deliver, return) and describes how these processes can be integrated in supply chains. The Value Reference Model (VRM, formerly VCOR) (VCG, 2007) and the framework of the Global Supply Chain Forum (GSCF) Lambert *et al.* (1998) have the same focus, although their scope is broader because they also support non-logistics processes such as marketing.

ISA95, Y-CIM, STEP and the CPFR model of VICS are focused on specification of functional *design*. ISA95 is a standard for integration of enterprise and manufacturing control systems (ISA, 2008). It includes interfaces between ERP and MES functions specified in XML. Y-CIM (Scheer, 1994) aims at design of systems that integrate logistics, including production, and product engineering. STEP (Pratt, 2001) is a standard including a reference data model for electronic exchange of product data. The CPFR model of VICS focuses on integration of retailers with manufacturers. It provides models for the collaborative aspects of planning, forecasting and replenishment processes and includes message specifications in XML (VICS, 2004).

The ERP models of SAP (Curran and Ladd, 1999) and Baan (TriArch, 1998, Verbeek, 1998) focus on *implementation* of their specific ERP software and, therefore, incorporate very detailed system-specific models. These models are mainly focussed on single enterprises, and from that perspective they also support the interface processes, such as ordering, contracting, and integration of planning.

2.4.2 Usefulness of existing reference information models

Table 2 summarises the analysis of the extent to which the investigated reference information models meet the requirements for ICT mass customisation. It indicates that none of the investigated models sufficiently meet all of the defined requirements. Overall, in particular a generic model setup and adequate configuration support are missing. Most of the investigated models are based on a combination of (segmented or pure) standardisation and tailored customisation. An exception is the MIT Process Handbook, but this model lacks rules that define interrelationships between processes, and it focuses on textual knowledge that can be used in requirements definition. Furthermore, the ERP vendors, especially SAP, have performed valuable work in making their reference models configurable. Below, we elaborate further on the analysis of the different requirements.

Table 2 Summarised overview of the extent to which existing reference models meet the identified requirement for ICT mass customisation

Category	Reference model	Requirements				
		Generic model setup	*Supporting software modularity*	*Executable*	*Configuration support*	*Content availability*
Requirements	SCOR	-	n/a	n/a	-	+
	GSCF Framework	-	n/a	n/a	-	+
	VRM	-	n/a	n/a	-	+
	MIT Process Handbook	+/-	n/a	n/a	+/-	+
Design	CPFR-model of VICS	-	+/-	+/-	-	+
	Y-CIM	-	+	+/-	-	+
	ISA95	-	+/-	+/-	-	+
	STEP	-	+/-	+/-	-	+
Implementation	SAP	+/-	+	+	+/-	+
	Baan	+/-	+	+	+/-	+

a. Generic model setup

Most of the assessed reference information models are either single structures, as is the case in a pure standardisation and tailored customisation strategy; or detailed

specifications covering all possible variants, as is the case in a segmented standardisation strategy.
An exception is the MIT Process Handbook, in which specialisation of processes is a core element (Malone *et al.*, 1999, Wyner and Lee, 2003). In this handbook, processes are described as generic entities for which possible variants and attributes are defined. Companies that use the handbook to map their business processes, specify which variants are relevant to them, plus the company-specific values of the attributes. As such, the underlying concept fits well with a mass customisation approach. However, the handbook does not contain rules that specify interrelationships between processes. Furthermore, the focus is on providing a comprehensive repository of mainly textual business knowledge.

ERP vendors have incorporated elements of a mass customisation strategy in order to manage the enormous complexity of their detailed reference models covering all possible implementation variants.

In the Baan reference models, the detailed business process diagrams are linked to generic business functions by four possible types of rules (Verbeek, 1998). Transformation rules specify which process is relevant for a certain business function. Static conditions can activate or de-activate parts of the linked processes. Parameter rules specify the settings of specific parameters. Consistency rules check the interdependencies between rules. However, this functionality has not often been used, mainly because users perceive it to be too complex.

SAP has conducted comprehensive research into the development, formalisation and testing of configurable reference modelling (Rosemann and van der Aalst, 2007). In this research, the EPC process modelling language is extended to configurable EPCs (cEPC). cEPC includes a notation for configurable functions that can be blocked or skipped during configuration, and configurable connectors that can be made more specific during configuration. Moreover, interrelations within configurable models can be defined in the form of configuration requirements that constrain permitted choices, and configuration guidelines that define recommendations.

However, the reference models of SAP and Baan are still mainly based on a segmented standardisation strategy. They represent all possible implementation variants in detail. The configuration rules focus on selection of the appropriate variant by removing non-applicable variants and do not guide specialisation of generic models, as is the case in a mass customisation strategy.

b. Supporting software modularity

The assessed ERP reference models include process models that specify which components of their software are used in which activities. Furthermore, these models are integrated with SOA-based integration platforms, NetWeaver for SAP and Infor Open SOA for the Baan models. This is also the case for the Y-CIM model, since it is modelled in the ARIS toolset which is well integrated with NetWeaver and other SOA platforms.
STEP, ISA95 and CPFR/VICS have specified XML interface standards and thus these models partly enhance different applications to interoperate as modules. The

MIT Process Handbook, SCOR, VRM, and the GSCF framework do not support software design and, thus, do not directly support software modularity.

c. Executable

The ERP reference models are well integrated with the applicable ERP systems. For example, Baan process models can be used both for dynamic generation of user-specific menus and for execution in the Baan workflow module. Furthermore, the models are compatible with SOA and, therefore, also executable by other systems. Y-CIM, STEP, ISA95 and CPFR/VICS do not focus primarily on implementation. Subsequently they do not comprise executable models. However, STEP, ISA95 and CPFR/VICS include standard specifications in common computer-interpretable form (mainly XML). Furthermore, Y-CIM model is compatible with different ERP systems and SOA platforms, including NetWeaver, because of the use of the ARIS toolset. The MIT Process Handbook, SCOR, VRM, and the GSCF framework only support business requirements definitions and, therefore, they are not executable.

d. Configuration support

The MIT Process Handbook offers users an internet tool to browse through the models and to zoom in from generic processes to specialized variants. However, only the ERP reference models of both SAP and Baan provide functionality for guiding users through the model configuration process based on explicit configuration rules.

Building upon the SAP research into configurable EPCs (cEPC), La Rosa *et al.* (2007) propose a questionnaire-driven approach to guide a user interactively through the configuration of cEPCs by asking them questions, in natural language, and then linking the answers to the configuration choices defined in cECPs. This approach is supported by tools for questionnaire specification and answering, definition of mappings between cEPCs and questionnaires, and generation of configured cEPCs. Together, these tools very nearly form a configurator for mass-customisable reference process models. However, an essential difference is that the input reference process models in cEPC notation are based on a segmented standardisation strategy that represents all possible variants in detail. This implies that the tools support selection of the appropriate variant and not specialisation from a generic model, as is the case in a customisation strategy.

In the Baan software, model wizards can be specified that guide users through selection of the right business process variant and through the setting of specific parameters (Verbeek, 1998). These wizards can be added to business functions, and are based on the defined business rules. However, the Baan reference models do not contain predefined wizards. Furthermore, as discussed previously, the configuration rules were not often used, mainly because users perceived these to be too complex. Therefore, Baan experimented with the application of its software for product configuration to DEM process models, but due to the decline of the Baan Company at the end of the 1990s, this has not resulted in an operational system.

e. Content availability

The assessed models all have their own focus, but together they cover the main business processes for production and supply chain management. The ERP models focus on implementation of their specific ERP software and, thus, they provide very detailed and system-specific models. ISA95, CPFR and STEP focus on system-independent design of software interfaces, while Y-CIM aims at the design of platform-independent CIM systems. The MIT Process Handbook and the SCM models provide generic business knowledge that can be used to define information system requirements.

2.5 Outlook and conclusions

2.5.1 Evolution of reference information models

If the investigated models are placed in a historical perspective, the following trend in development of reference information models can be distinguished as visualised, in a somewhat simplified manner, in Figure 8.

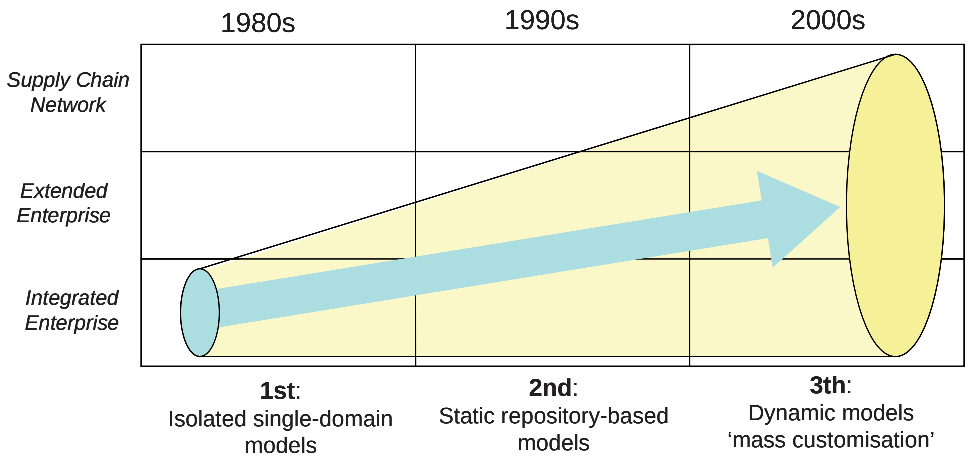

Figure 8 Evolution of reference information models

First generation: isolated single-domain models
Since the 1980s, reference information models have grown in popularity in the business community. There was a growing sense that software should be developed on the basis of architecture. Several architectural frameworks were developed. Subsequently, reference information models were developed. The emphasis was on isolated enterprise models in single domains, *i.e.* strict blueprints for specific industries ('one size fits all'). These models were used in the requirements definition and design phase of standard (standardisation strategy) or customised software (tailored customisation strategy). After having used the models intensively in setting-up software applications, the models were not integrated in the operational information systems. This resulted in a lack of active usage of the applied model and implementation experiences were mostly not incorporated into the reference models.

Second generation: static repository-based models
As from the mid 1990s, the standard software industry has developed reference models to accelerate implementation processes. Especially in the rising ERP

industry, much effort was put into reference modelling, in particular by SAP and Baan. These models contained repositories of model variants that cover multiple domains (segmented standardisation strategy). During implementation, the relevant model variants were selected from the repository, and customised if necessary. Thereafter, the instantiated models were used for setting company-specific parameters and ultimately these were used in the run-time ERP systems. However, these second generation ERP reference models did not contain configuration logic. The rules for company-specific selection of model variants and parameter setting were implicit in the minds of implementation consultants.

In the late 1990s, eBusiness gained popularity, which put the emphasis on inter-enterprise processes. Enterprise reference models were expanded with architectures enabling integration with customers and suppliers, and these models started to become XML compliant. Furthermore, new models for supply chain management were developed, including the GSCF framework and SCOR.

Third generation: dynamic models (mass customisation)
From the middle of the first decade of the century, there was a growing demand for mass-customisable information systems resulting in a renewed interest in reference models as a basis of information systems. Important driving forces included the new realism following the burst of the e-Business bubble, which resulted in a strong emphasis on the returns from ICT, and the rise of the Service-Oriented Architecture (SOA) approach that combines technological progress made at different lines of ICT development. Also the ERP industry has embraced SOA and commenced to modularize their systems (Møller, 2005). In addition, eBusiness developed beyond single B2C transactions, towards the support of different types of interactions in complex Supply Chain Networks (SCNs).

As a result of these developments, reference models are increasingly becoming compatible with SOA standards (such as BPEL) and made available in SOA-based integration platforms (such as NetWeaver for SAP). Moreover, ERP vendors, especially SAP, started to make their reference models configurable. On the other hand, in the SOA field the emphasis is shifting from technology towards business aspects, including architectural challenges such as business semantics for service definition, design methodologies for service engineering and business-oriented service composition (Papazoglou *et al.*, 2007, Demirkan *et al.*, 2008). Developing dynamic reference models that support a mass customisation strategy would be a valuable contribution towards accomplishing these developments.

2.5.2 Future challenges

The foremost remaining challenges for development towards third-generation models are setting up reference information models as generic models and incorporating configuration support. Existing models provide valuable knowledge, especially the progress accomplished by ERP suppliers to make their reference models configurable. However, current ERP reference models are complex because they represent all possible implementation variants in detail. Extending these models with explicit configuration logic will further increase the complexity of the reference models. Therefore, one of the key issues is to set up configurable reference models in a manageable and user-friendly way. This might be achieved by application of proven product and sales configurator software. At this, solutions must be found to deal with the redundancy of configuration logic in reference models and hard-coded in legacy systems.

Other important challenges are implementation-related. Despite the technological advances regarding SOA, systems today run on different technology and many current software applications are monolithic, non-modular systems. Replacing current systems with new flexible solutions is no realistic option for many companies, among others because of the significant investments in legacy and the risks of loosing stability. Therefore, an important precondition of dynamic reference models is the implementation of a SOA-based technical infrastructure that enables modularization and integration of existing information systems. Next, the incorporation of reference model configuration into systems execution will impact systems performance, in particular if the reference models are distributed among multiple organizations. In the latter case, also security will be an issue.

2.5.3 Conclusions

The objective of this chapter was to assess how reference information models can be used to enhance ICT mass customisation. Therefore, it respectively aimed: i) to identify the requirements to reference information models in an ICT mass customisation approach, ii) to investigate the extent to which existing reference models, in the domain of Production and Supply Chain Management, are useful for ICT mass customisation, and iii) to explore the trends in development towards dynamic models.

ICT mass customisation combines the seemingly contradictory notions of efficient standard software and flexible customised software. It assembles customer-specific information systems from a repository of standard components. An important enabler is the availability of information models, which define the class of architectures that can be assembled. However, not all reference information models are appropriate for ICT mass customisation. Five requirements have been identified. The most important requirement is that they must be set up as generic models, which specify the generic components for configuration of specific information architectures, and that define permitted choices and combinations in explicit configuration rules. The reference models must support software modularity by precise definitions of the supported application services, including data specifications, interface standards and possible sequences of services. Furthermore, it must be possible to use the configured models in the run-time system for service orchestration. Also, the reference models have to include user-friendly means that guide users through the process of configuring specific information models. Lastly, the content reference models must provide domain-specific knowledge required in specific areas of application.

In an investigation of reference information models for Production and Supply Chain Management, it is found that none of the investigated models completely satisfy the defined requirements. Overall, particularly a generic model setup and sufficient configuration support are missing. Most of the investigated models are based on a combination of (segmented or pure) standardisation and tailored customisation. An exception is the MIT Process Handbook, but this model lacks rules that define interrelationships between processes, and focuses on textual knowledge that can be used in requirements definition. Furthermore, the ERP vendors, especially SAP, have done valuable work in making their reference models configurable. However, these models still represent all possible implementation variants in detail. Their configuration functionality is focused on selection of the appropriate variant and does not guide specialisation of generic models, as is the case in a mass customisation strategy.

When placing this analysis into a historical perspective, it emerges that reference information models have developed from isolated models for single enterprises, into static repository models for extended enterprises. At the moment there is growing demand for more dynamic reference information models, amongst other reasons because of the rise of the Service-Oriented Architecture (SOA) approach. Existing models provide valuable knowledge for that. The foremost remaining challenges are setting up reference information models as generic models, and developing user-friendly configuration support.

Chapter 3. A framework for modelling business processes in demand-driven supply chains [5]

Abstract
Demand-driven supply chains are highly dynamic networks of different participants with different allocations of business processes and different modes of control and coordination. Companies must be able to take part in multiple supply chain configurations concurrently and to switch rapidly to new or adjusted configurations. This imposes stringent demands on information systems and requires a modelling approach that i) combines high-level models for supply chain design with detailed models for engineering the accompanying information systems and ii) enables rapid instantiation of specific supply chain configurations from a repository of standard building blocks. The present chapter designs a process modelling framework that enhances such an approach. Building on the terminology and process definitions provided by the Supply Chain Operations Reference (SCOR) model, it models supply chain configurations as specific sets of transformations, control systems and coordination mechanisms. The designed modelling framework is applied in a case study in Dutch Flower industry.

Keywords: demand-driven supply chains; business process modelling, coordination, control, configuration, SCOR

3.1 Introduction

Demand-driven supply chains are often advocated as an alternative to supply chains that efficiently push products to the marketplace. They aim at a rapid and customised response to volatile demand, rather than anticipatory supply of standard products in high volumes (Fisher, 1997, Christopher, 2000). Consequently, a demand-driven chain can be defined as a supply chain[6] in which all actors involved are sensitive and responsive to demand information of the end customer and meet those varied and variable demands in a timely and cost-effective manner (based on Kohli and Jaworski, 1990, Vollmann *et al.*, 2000, Cecere *et al.*, 2004). Supply chain information is shared timely throughout the entire supply chain, enabling the early alerted firms to respond quickly to changes in demand or supply (Lee and Whang, 2000, Li *et al.*, 2007).

Although the concept of demand-driven supply chains sounds relatively simple, implementation is much more complex (Selen and Soliman, 2002). It requires the ability to continuously match products and business processes, including the network of producers and distributors, to changing demand requirements (Day, 1994, Prahalad and Ramaswamy, 2000, De Treville *et al.*, 2004). Consequently, demand-driven supply chains are highly dynamic networks of different participants with different allocations of business processes and different modes of control and

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[5] C.N. Verdouw, A.J.M. Beulens, J.H. Trienekens, J.G.A.J. van der Vorst (in press). A framework for modelling business processes in demand-driven supply chains. Production Planning and Control, doi:10.1080/09537287.2010.486384

[6] A supply chain is defined as a connected series of business processes performed by a network of autonomous companies working together to provide products or services for end customers (adapted from Stevens 1989, Lambert and Cooper 2000, and Christopher 2005).

coordination. In other words, they are characterised by high variety and variability of supply chain configurations[7].

In supply chain design, it has long been acknowledged that supply chain strategy should be matched to the nature of demand (Fisher, 1997, Childerhouse *et al.*, 2002, Lee, 2002). More recently, it has also been suggested that the design of business processes should reflect specific demand requirements at a more operational level, in order to achieve customised response (Aitken *et al.*, 2005, Li and Kumar, 2005, Collin *et al.*, 2009). However, to the best of our knowledge the implication to supply chain modelling has not yet been researched.

In demand-driven supply chains, companies must manage a high variety and variability of supply chain configurations in order to fulfil the demand requirements of their customers. Business process models should therefore support rapid design and flexible implementation of customised supply chain configurations. To do so, business process models must i) support a seamless translation of high-level supply chain designs to detailed information engineering models and ii) they must be setup to enable rapid instantiation of various specific supply chain configurations (rather than dictating a single blueprint).

Firstly, a seamless translation demands a modelling approach that combines high-level models for supply chain design with implementation models that detail the information flows among activities in an executable notation. Existing supply chain models only support high-level decompositions of business processes (Lambert *et al.*, 2005; chapter 2 of this thesis). They cannot visualise the control and coordination of these business processes or the sequence and interaction among their activities. Although information systems engineering research has increasingly studied business process modelling, particularly in the field of Service-Oriented Architecture (SOA), available process models for information systems engineering focus on single enterprises or are designed from a pure technological point of view (Demirkan *et al.*, 2008; chapter 2 of this thesis). The architectural knowledge required to specify services and configure business processes as a sequence of services is not yet available (Papazoglou *et al.*, 2007). Consequently, process models that link supply chain design and information systems engineering are not yet available.

Secondly, rapid instantiation of specific supply chain configurations can be achieved using a mass customisation approach. This is a modular strategy that is intented to accomplish efficiency by reusing standardised components while achieving distinctiveness through customer-specific assembly of modules (Pine, 1993, Duray *et al.*, 2000). Application of mass customisation to supply chain modelling implies that there cannot be one dominant design, but customised models are configured from a repository of standard building blocks *i.e.* predefined model components. Configuration of business process models is a relatively new area of research. Research in this field focuses on formalisation of configurable modelling techniques (Dreiling *et al.*, 2006, La Rosa *et al.*, 2007, Rosemann and van der Aalst, 2007). In our literature review, no applications to supply chain modelling were found.

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[7] A supply chain configuration is defined in this chapter as a specific set of business processes, control systems and coordination mechanisms, performed by a specific network of contributors who together produce and deliver a product or service with distinct value for the ultimate customer.

This chapter aims to contribute to the development of business process models that bridge these two gaps. The main objective is to design a process modelling framework that enables rapid design and implementation of demand-driven supply chains. The framework consists of a conceptual view with respect to the field of interest and a toolbox for modelling supply chain processes from a repository of standard building blocks.

The chapter is organised as follows. Firstly, in section 3.2 we describe the applied research method. Subsequently, the designed framework is introduced in the third and fourth section. Section 3.3 provides a conceptual definition of main elements of supply chain configurations. In section 3.4, we describe the toolbox for modelling these supply chain configurations. The case study results are then presented in section 3.5 to show the applicability of the framework. The chapter concludes by summarising the main findings, discussing the main contribution to literature and addressing future challenges.

3.2 Research method

The research used a design-oriented methodology, which has its roots in engineering and has increasingly been applied to management sciences inspired by Simon (1969). Design-oriented research is typically involved with 'how' questions, *i.e.* how to solve a certain problem by the construction of a new artefact (Van Aken, 2004, March and Storey, 2008). A case study strategy fits best for this type of questions, because case studies deal with complex phenomena that cannot be studied outside its rich, real-world context (Benbasat *et al.*, 1987, Meredith, 1998, Voss *et al.*, 2002, Yin, 2002, Eisenhardt and Graebner, 2007).

Design-oriented research consists of a constructive part that builds an artefact and a testing part that evaluates the designed artefact (March and Smith, 1995, Hevner *et al.*, 2004). Artefacts may include four types of designs (March and Smith, 1995): i) constructs *i.e.* the language in which problems and solutions are defined and communicated, ii) models, which represent a real world situation; iii) methods that provide guidance on how to implement the models, and iv) instantiations showing that constructs, models or methods can be implemented in a working system. The generic design artefact developed in the present chapter is a framework that includes constructs, models and methods for modelling business processes in demand-driven supply chains. Figure 9 (next page) visualises the main elements of this framework.

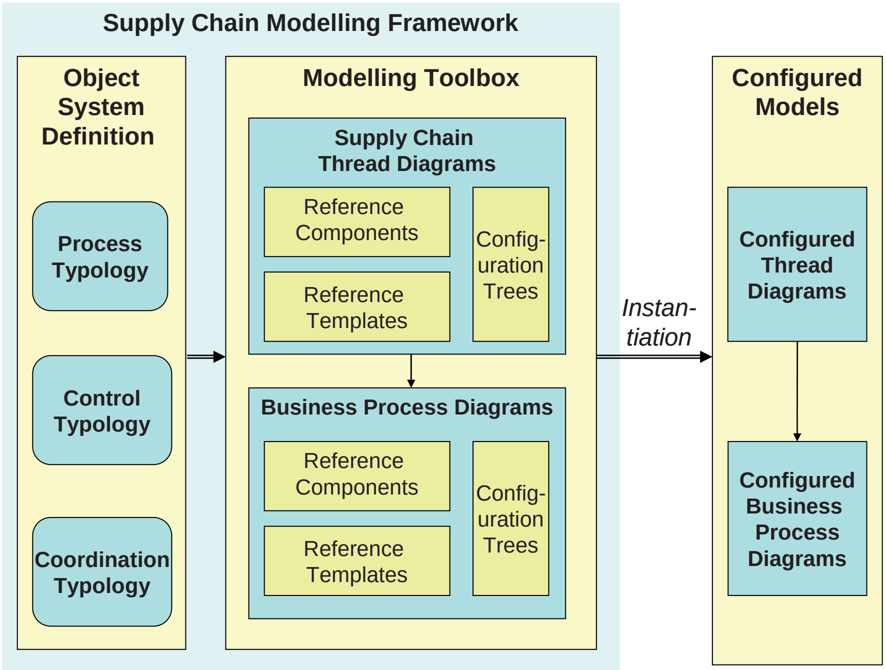

Figure 9 Main elements of the framework for modelling business processes in demand-driven supply chains

The modelling framework consists of two main parts: an object system definition and a generic modelling toolbox. The object system definition is a conceptual view of the modelling object: business processes in demand-driven supply chains. It defines the key elements and relationships of supply chain configurations and describes how specific configurations are composed. Subsequently, based on the object system definition, a generic toolbox for process modelling in demand-driven supply chains is designed. The toolbox contains design knowledge for modelling process diagrams that integrate the design of specific supply chain configurations (Supply Chain Thread Diagrams) with the engineering of enabling information systems (Business Process Diagrams). For these two types of process models, the toolbox identifies the modelling building blocks (reference components), a method to instantiate the model to specific cases (configuration tree) and preconfigured diagrams of typical supply chain configurations (reference templates).

The research was organised in three steps: i) object system definition, ii) toolkit design, iii) test of the designed framework in a multiple case study.
In the first research phase, the object system was defined conceptually. Supply Chain Management literature was reviewed to define supply chains and to identify main elements of supply chain systems. We described supply chains from a systems perspective, as this provides a basis for consistently modelling interactions between processes. Central to systems thinking is that the whole system is more than the sum of its parts (Jackson, 1992). As such, any system is approached as a `whole' of interrelated elements and viewed in terms of its environment (Trienekens and

Beulens, 2001). Such a systems perspective is the core philosophy of business process management approaches like Total Quality Management (Soin, 1992) and Business Process Redesign (Hammer, 1990, Davenport, 1993).

Furthermore, in order to define the diversity of configurations as apparent in demand-driven supply chains, we developed typologies of three main concepts: business processes, control systems and coordination mechanisms. Here we focussed on operational business processes for demand fulfilment, in other words: the business processes that match supply chain capabilities to demand requirements from the point of origin to the point of consumption (Day, 1994, Lambert and Cooper, 2000).

In the second research phase, a toolkit for modelling the defined object system was designed. Building on a previous study (chapter 2 of this thesis), we chose the Supply Chain Operations Reference (SCOR) model as a basis for this design. SCOR is a practice-based model that was developed and endorsed by the Supply-Chain Council (SCC) as the cross-industry standard for supply chain management (SCC, 2008c, SCC, 2008a, SCC, 2008b). At the moment, almost 1000 companies are members of SCC. The model is acknowledged as the most comprehensive supply chain process model and a widely accepted common language in supply chain design (Huan *et al.*, 2004, Lambert *et al.*, 2005). However, SCOR does not support implementation and it focuses on production and logistics, excluding commercial processes and product development.[8]

The SCOR model contains standard process descriptions, performance and best practice descriptions. It provides definitions of business processes at three aggregation levels. The first level defines the processes plan, source, make, deliver and return. The second level addresses different process categories per main processes (see below in Table 4). The third process level defines detailed activities per process category. SCOR recognises two types of process models: Thread Diagrams that visualise the main interactions among process categories (level 2) in a supply chain and Process Diagrams that depict the interaction among detailed processes (level 3 or beyond).

The design of the toolbox started with an assessement of the extent to what SCOR provides the representation power required to depict the defined object system. The analysis showed that SCOR provides an appropriate repository of generic process building blocks, but it also adressed some important limitations (see section 3.4). In order to overcome these limitations, we introduced an alternative way

[8] After a debate about the limited scope of SCOR, the SCC decided to develop other models to support commercial processes, including CRM and product development, namely the Customer Chain Operations Reference Model (CCOR) and the Design Chain Operations Reference Model (DCOR). The debate also resulted in the foundation of the Value-Chain Group, which introduced the Value Reference Model (VRM formerly VCOR). VRM is similar to SCOR, but it covers the complete scope of SCOR, CCOR and DCOR (VCG, 2008). Our choice for SCOR was because it's wide acceptance, this in contrast to VRM. We have included the interactions with the DCOR and CCOR processes, but because of our focus on demand fulfilment, we have not modelled these processes into much detail.

of modelling Thread Diagrams and we adopted the BPMN notation for modelling the Business Process Diagrams (OMG, 2010).[9]

The designed modelling framework was tested by applying it to a specific sector in an explorative multiple case study in the Dutch Flower industry. This sector is highly instructive for this purpose given that trade relations change frequently, growers participate in different distribution channels, product variety is high and production processes are relatively uncertain, particularly due to the dependency on living materials. In the case study, supply chain configurations were mapped from the perspective of focal companies as a unit of analysis. As usual in case study research (Eisenhardt, 1989, Yin, 2002), the choice of the cases was based on theoretical replication logic rather than statistical sampling logic. We searched for companies known for being market oriented and innovative, because the purpose was to assess the applicability of the framework in modelling a high variety of configurations as apparent in demand-driven supply chains. The other selection criteria were supply chain role, relative importance and accessibility for the researchers. In total, five producers, one auction and two traders were selected. Data were collected in in-depth interviews with key informants from the case firms and additional desk research. We chose interviewees with broad insight into the different business processes (sales, production and logistics) and the company's role in the supply chain. Most of those interviewed were managers (5 general managers, 4 operations managers and 2 commercial managers). The interviews followed a structured questionnaire for mapping supply chains according to network structure, business processes, coordination and control systems and information technology (based on Lambert and Cooper, 2000, van der Vorst *et al.*, 2005), see appendix C. Data analysis focussed on identifying the supply chain configurations in which each case company participates. Based on the findings, three typical existing supply chain configurations were defined and modelled by applying the developed framework. As such, the framework served as an analytical vehicle for theoretical generalisation of the case study findings (Yin, 2002). The resulting models were incorporated as reference templates in the designed framework (see Figure 9).

The remainder of the chapter introduces the results following the research steps as described above.

3.3 Object system definition: supply chain configurations

This section develops the first part of the modelling framework, *i.e.* a conceptual definition of the modelling object (see Figure 9). After defining supply chains from a systems perspective, the key elements of supply chain configurations are classified in a typology of business processes, control systems and coordination mechanisms. Finally, it is shown how these concepts interrelate in specific supply chain configurations.

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[9] The Business Process Modelling Notation (BPMN) has developed into the de facto standard for business process modelling in Service-Oriented Architectures (SOA) and includes a mapping to underlying web service execution languages, *i.e.* BPEL. See www.bpmn.org.

3.3.1 Supply chains from systems perspective

According to Lambert and Cooper (2000), supply chain systems comprise three main elements: i) the supply chain network structure of cooperating actors, ii) the supply chain business processes that are performed by these actors, and iii) the management of these processes. The management of supply chain processes can be further categorised by applying the Viable System Model (VSM) (Beer, 1981, Beer, 1984). This is a cybernetic model, which sets out to explain how systems are viable, that is capable of independent existence. The VSM is composed of five subsystems:

- *System 1 (implementation)*: network of subsystems each consisting of an operational part interacting with its environment (productive unit) and a management part ensuring steady-state (control);
- *System 2 (coordination)*: allows the primary activities of operational subsystems (system 1) to communicate and align control. Furthermore it enables System 3 to monitor the activities within System 1;
- *System 3 (regulation)*: establishes the rules, resources, rights and responsibilities of System 1 and provides an interface with Systems 4/5. In addition System 3* is a sporadic audit which bypasses system 2 for a greater flexibility and timeliness.
- *System 4 (intelligence)*: looks outwards in order to monitor how the organisation needs to be adapted to remain viable and accordingly innovates the system towards new equilibriums;
- System 5 (*policy*): makes overall decisions to balance demands from different parts of the organisation and steers the organisation as a whole.

The VSM can also be applied to supply chain systems.[10] Figure 10 (next page) represents a supply chain as a system of interacting viable organisations.

[10] A supply chain could also be represented as a viable system of the organisations involved (first recursion level) that are each modelled as viable systems in themselves (second recursion level). Such a way of modelling suggests that supply chain systems are managed centrally, with one central supply chain policy and innovating as one integrated unit. However, this is per definition not the case since a distinctive characteristic of supply chains is that they consist of different autonomous organisations. We have therefore chosen to depict the organisations involved as interacting viable systems at the same level of abstraction.

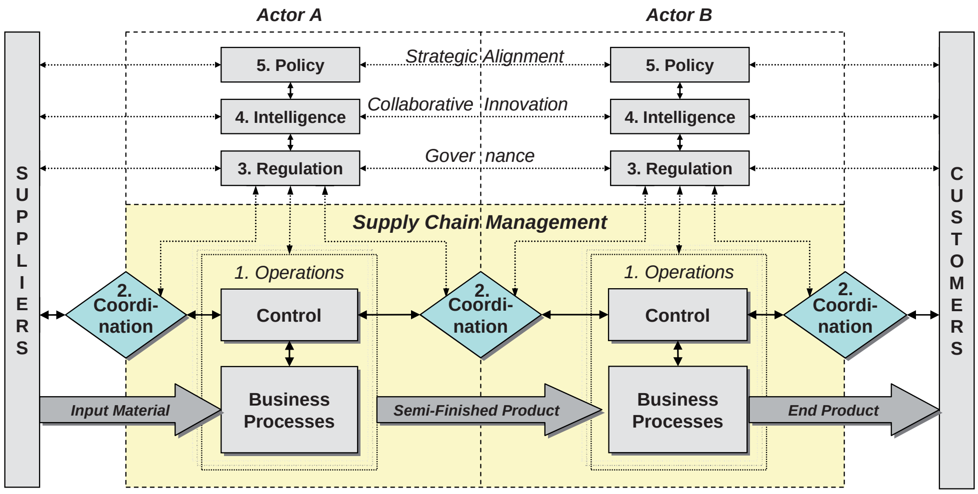

Figure 10 Simplified Viable System Model of a supply chain system (based on Beer 1981; Beer 1984)

Figure 10 shows that a supply chain is a connected series of business processes[11] performed by numerous autonomous companies. Supply Chain Management primarily focuses on the operational integration of business processes (systems 1 and 2). This implies that the participants coordinate the control of their business processes in order to improve the value delivered to the ultimate customers. Consequently, the main concepts of supply chain systems are business processes (performed by a network of firms), control and coordination. This is in line with the Supply Chain Management literature, for example:, Stevens (1989), Ballou *et al.* (2000), van der Vorst and Beulens (2002), Romano (2003) and Gibson *et al.* (2005).

In order to define the representation power needed to model the high diversity of configurations as apparent in demand-driven supply chains, more insight is needed into the possible variety of business processes, control systems and coordination mechanisms. Therefore these elements are further classified in the following sections.

3.3.2 Supply chain business processes

In systems thinking, a process is any open system that converts input into output in order to fulfil a function in its environment. A business process is a set of logically related tasks performed to achieve a defined business outcome (Davenport and Short, 1990). An important foundation of business process approaches was laid by Porter (1985), who introduced the term 'value chain'. A firm's value chain is a system of interlinked processes, each adding value to the product of service. Based on this principle, business processes can be subdivided into primary and supporting

[11] The VSM has been applied to business processes by Richard and Bititci et al. (1999). Bititci et al. (1999) modelled an enterprise as a viable system of business units (first recursion level) and subsequently each business unit as a viable system of business processes (second recursion level). We followed Richard (1998), who left out the business units and represented business processes at the first level of recursion, because business processes are cross-functional by nature.

business processes (Porter, 1985, Davenport, 1993). *Primary Business Processes* are those involved in the creation of the product, its marketing and delivery to the buyer (Porter, 1985). *Supporting Business Processes* facilitate the development, deployment and maintenance of resources required in primary processes. Managerial processes can also be identified as a separate category (Childe *et al.*, 1994, Bititci *et al.*, 1999), which can be further differentiated into multiple echelons with different time horizons (*e.g.* Armistead and Machin, 1997, Garvin, 1998).

Supply Chain Management focuses on primary and management processes from the point of origin to the point of consumption (Lambert and Cooper, 2000). From a supply chain perspective, both the creation of value in transformations and the transfer of value in transactions are important (Diederen and Jonkers, 2001). In supply chains, transformations are performed by numerous firms, especially if there is a high degree of specialisation. This requires that products are transferred between firms in exchange for money or something else, *i.e.* transactions take place. We have therefore found it useful to further classify primary business processes into transformation and transaction processes (based on among others Day, 1994, Diederen and Jonkers, 2001, In 't Veld, 2002). This distinction makes it possible to model the allocation of primary processes to the supply chain participants involved. *Transformation Process*es are primary processes that contribute directly to the creation and movement of products by a company such as engineering, production and distribution. *Transaction Processes* are primary processes that contribute directly to the establishment and conclusion of transactions between two actors, in particular, sales and purchasing. Consequently, the business processes of a supply chain consist of a sequence of transformation processes that add value to the product and transaction processes that connect transformations of the involved partners.

3.3.3 Supply chain control systems

The basic idea of control is the introduction of a controller that measures system behaviour and corrects if measurements are not compliant with system objectives (De Leeuw, 1997). Together with business processes, control systems form the network of subsystems of the Viable Systems Model (systems 1, see Figure 10). These subsystems are semi-autonomous units, which aim at maintaining a dynamic system equilibrium for given objectives (as set by the higher management echelons).

The level of detail of the sub systems to be considered is determined by the representation need. As argued in the previous section, business processes of a supply chain consist of a sequence of transformation and transaction processes. Supply chains are ‘in control’ if both transformation and transaction processes maintain a steady state. Therefore, the activities of these processes must include the cybernetic control functions necessary to demonstrate 'cybernetic validity'. Basically, this implies that they must have a feedback loop in which a standard, sensor, discriminator and effector are present (Beer, 1981, p.17). In 't Veld (2002) has developed a more complete typology of control functions in his Steady-State Model. This model distinguishes an Input, Intervention, Output and Requirements Zone (In 't Veld, 2002, Veeke, 2003). The *Input Zone* identifies, qualifies and quantifies input flows. This includes the following control functions: Input Coding, Input Filter, Feed Forward, Input Buffer and Safety Function (see definitions in Appendix D). If these functions are correctly fulfilled, systems only receive the proper input at the proper time and place. The *Intervention Zone* corrects disturbances in throughput and output and ensures service levels (including availability) of the required resources. This includes the following control functions: Internal Control Functions, Supporting Processes, Output Filter, Repair Function and Feedback (see definitions in Appendix D). The *Output Zone* qualifies, quantifies and identifies the output to be delivered to the environment. This includes the following control functions: Output Buffer, Safety Function and Decoding (see definitions in Appendix D). If these functions are correctly fulfilled, the function as a whole only delivers the proper output at the proper time and place. The *Requirements Zone* delivers the values of the requirements (objectives/norms/standards) for the input, intervention and output zone. This includes functions for initiation and evaluation of the control requirements.

We have applied the steady-state control model to transformation and transaction processes (see Appendix D). The control functions of transformation processes are related to the (physical) flow of input material to end products. The control functions of the transaction processes are related to the flow of order to accepted delivery. For example: coding the input of transformation processes involves receipt of physical material and translation into the format required for further processing, including repacking, putting products on proper carriers and adding product-related information. Coding the input of transaction processes particularly involves specification of customer requirements within possibilities and registration in the order-processing system that is complete and appropriate for further processing.

The defined control functions form the basic building blocks of control systems that may vary considerably among different supply chain configurations. A key factor that determines this variation is the position of the Customer Order Decoupling Point (CODP), also called order penetration point (Sharman, 1984, Wortmann *et al.*, 1997). The CODP separates that part of the supply chain geared towards directly satisfying customer orders from that part of the supply chain anticipating future demand (Hoekstra and Romme, 1992). It functions as a buffer between stable upstream processes and fluctuating downstream processes driven by customer orders (Naylor *et al.*, 1999). This buffer is filled by well scheduled, usually high volume, forecast-driven processes. If specific customer orders come in, products are taken from the buffer as input for order-driven processes.

Based on different CODP positions, different control strategies are proposed in literature, varying from strategies in which all processes are driven by customer order to fully anticipatory strategies in which all processes are based on demand forecasts. From a production perspective, the main strategies proposed in literature are engineer-to-order (ETO), make-to-order (MTO), assemble-to-order (ATO) and make-to-stock (MTS), based on Hoekstra and Romme (1992), Giesberts and van der Tang (1992), Wortmann *et al.* (1997) and Vollmann *et al.* (2005) amongst others. These control strategies particularly differ regarding the basis for production planning and engineering, the planning concept, structuring of product and process master data, and order entry/order promising (Table 3).

Table 3 Main differences between control systems, based on Wemmerlov (1984) and Giesberts and van der Tang (1992)

	MTS	ATO	MTO	ETO
Basis for production planning	Demand forecast	Forecast for components, Orders for end products	Customer orders	Customer orders
Basis for product engineering	Demand forecast	Demand forecast	Demand forecast	Demand forecast, Order backlog
Planning Concept	MPS and MRP	Two-level MPS and MRP, FAS	Project Planning	Project Planning
Product and Process Master Data	Standard BOM and routing	Generic/modular BOM and routing	Tailored BOM and routing	Fully order-specific BOM and routing
Order Entry	Select from catalogue	Configure from available components	Adapt existing product layouts	Develop customized products
Order Promising	Based on availability finished products, distribution capacity and distribution lead time	Based on component availability, capacity and lead times of assembly and distribution	Based on input material availability, capacity and lead times of fabrication, assembly and distribution	Based on input material availability, capacity and lead times of design, fabrication, assembly and distribution

3.3.4 Supply chain coordination mechanisms

Supply chains comprise multiple business processes performed by numerous interdependent organisations. The need to manage this complex of sub systems as a whole makes coordination a core issue in Supply Chain Management (Ballou *et al.*, 2000, Mentzer *et al.*, 2001, Sahin and Robinson, 2002, Danese *et al.*, 2004).

Coordination mechanisms are studied in depth in organisational science. Thompson (1967) distinguished three basic types of dependency: pooled, sequential and reciprocal interdependence, which require different types of coordination. Based on his work, which is refined by many others, three basic coordination modes can be defined (Thompson, 1967, Galbraith, 1977, Mintzberg, 1981):

- *Coordination by Standardisation*: specifies the necessary activities, output or skills in advance, which eliminate the need for further communication during execution;
- *Coordination by Plan (direct supervision):* central planning by a coordinating manager who takes responsibility for implementation by others, issuing instructions to them and monitoring their actions;
- *Coordination by Mutual Adjustment*: decentralised alignment through mutual feedback processes for joint problem solving and decision making, heavily relying on informal communication.

Initially, the focus was on coordination between organisational subunits. However, Malone and Crowston (1994) argue that the primary source of coordination problems is dependence among processes using resources. They have therefore developed a coordination theory from a business process perspective. Three basic types of dependencies are distinguished:

- *Flow dependencies* arise whenever one process produces a resource that is used by another process (precedence relation). Flow dependencies can be further elaborated into prerequisite ("right time"), accessibility ("right place") and usability ("right thing") precedence.
- *Sharing dependencies* occur whenever multiple processes use the same resource.
- *Fit dependencies* arise when multiple processes collectively produce a single resource.

Malone and Crowston (1994) and Malone *et al.* (1999) address different coordination mechanisms for managing these interdependencies. These can be categorised in the basic coordination modes of plan, standardisation and mutual adjustment.

So far the study of coordination mechanisms is concerned with single firms. In an extensive literature review, Arshinder *et al.* (2008) state that, although the need for coordination is broadly acknowledged, the study of supply chain coordination still appears to be in its infancy. Most research about coordination in supply chains has focussed on the specific mechanisms, without addressing the supply chain dependencies that they are intended to manage. We therefore define below the main dependences among business processes and address associated coordination mechanisms.

Supply Chain Management (SCM) is primarily concerned with coordination of flow dependencies: the business process output of one actor is the input of another actor's processes. Building upon previous sections, the main flows among supply chain business processes are:

- *Products:* the flow concerned with transformation processes that convert raw material from the point of origin to end products at the point of consumption;
- *Orders:* the flow concerned with transaction processes that convert customer orders into accepted fulfilment and that triggers responsive control;
- *Demand and supply information:* the flow of information that drives anticipatory control.

These flows result in the following classification of mechanisms to coordinate flow dependencies in supply chains.

Product precedence coordination: products produced by supplier companies are input for customer firms downstream in the supply chain (flow dependency). Therefore, input product (raw or semi-finished, packaging and handling unit for internal logistics) must have the appropriate characteristics, they must be in time and at the right place. Mechanisms to coordinate this include adopting product and logistics standards, negotiating product specifications, standard product delivery frequencies, distribution requirements planning and standard distribution network layouts.

Order precedence coordination: customer orders are conditional for execution of order-driven processes (flow dependency). Therefore, the customer requirements as specified in an order must match with the available supply chain capabilities. In other words, the requested products and associated service levels must be available to promise (ATP). Next, the order format must be appropriate for further processing. Mechanisms to coordinate this are adopting order standards, enforcement of order content and mutual adjustment until order information is complete. Furthermore, order information must be available in time at the right location. Mechanisms to coordinate this include standard order windows and planning of order submissions based on integrated planning systems.

Coordination of demand information precedence: demand information of customers is used as input for forecasting processes of suppliers upstream in the supply chain (flow dependency). Therefore, customers' demand information must be appropriate for suppliers' forecasting process (usability) and it must be available in time at the right place. Corresponding coordination mechanisms include agreeing on a standard frequency and format of exchanging Point of Sales (POS) and decentralised completion of demand information.

Coordination of supply information precedence: firms downstream in the supply chain use information about current and future availability of input products as a basis for planning and sales (flow dependency). Similar to demand information, supply information must also be appropriate for processing (usability) and it must be available in time at the right place.

Besides these flow dependencies, there are some key dependencies among multiple flows in a supply chain. These are related to the common usage of resources, *i.e.* material and capacity.

Coordination of material consumption: multiple processes all use the same input products which can be used only once (sharing dependency). Coordination of this dependency demands alignment of required input material for different end products. Coordination mechanisms include standard allocation rules (such as First-Come-First-Serve, market-like bidding or priority order), centralised material requirements planning or reservation by negotiation and informal communication.

Capacity-usage coordination: processes for multiple customer orders all use the same limited capacity (sharing dependency). Similar to material consumption, this dependency can be coordinated by standard reservation rules, centralised capacity requirements planning or reservation by mutual adjustment.

Capacity-precedence coordination: required capacity must be available for execution of (both order and forecast-driven) transformation processes. Therefore, capacity must meet the required service level. Important mechanisms to coordinate this are standard Service Level Agreements (including standards service and maintenance windows) and centralised or synchronised resource planning.

3.3.5 Basic setup of operational supply chain configurations

Above we identified the basic operational elements of supply chain systems, *i.e.* business processes, control systems and coordination mechanisms. A supply chain configuration is composed of a specific set of these elements. It is an internally consistent instance of a specific supply chain system that delivers value for a specific customer or customer segment (adapted from van der Vorst and Beulens, 2002). Based on the defintions developed above, a supply chain configuration can be defined more precisely as a specific set of business processes, control systems and coordination mechanisms, performed by a specific network of contributors who together produce and deliver a product or service with distinct value for the ultimate customer. Figure 11 shows the baseline setup of a supply chain configuration from the perspective of a single firm, zooming in on the systems 1 and 2 of actor A in Figure 10.

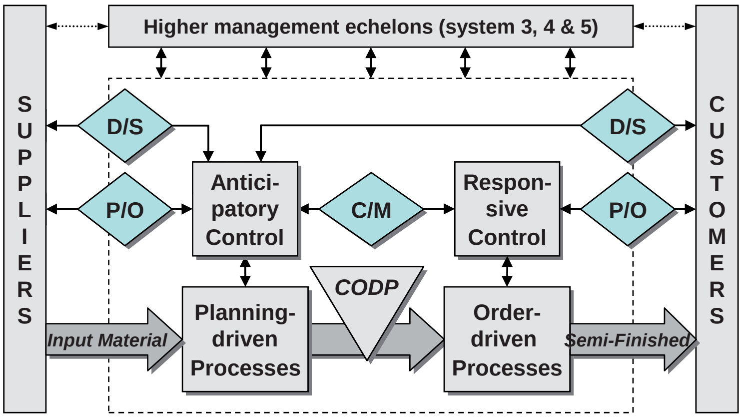

Figure 11 Baseline supply chain configuration from a single firm perspective

The starting point is a set of planning-driven and order-driven processes, including a specific position of the CODP. For example: sourcing of input material and production of components is done to forecast, while assembly and distribution of end products is done to order. The CODP position determines the specific balance between anticipatory and responsive control, *i.e.* the basic control strategy (see Table 3).

The dependencies among control of multiple business processes are managed by coordination mechanisms. Coordination of Product and Order precedences (P/O) occur at every interface of two basic supply chain roles, *i.e.* when products are passed on from one actor to another according to agreements about the requirements (order). Coordination of capacity usage, capacity precedence and material consumption (C/M) manages the dependencies among different business processes per actor. The last type of coordination (D/S) manages the exchange of planning-related information: demand information of customers (D) and information about expected input material of suppliers (S).

In order to visualise a complete supply chain configuration, the diagrams of different supply chain members could simply be linked. In such a diagram, every actor has a CODP and the responsive control systems of suppliers are connected via coordination mechanisms with the anticipatory control systems of customers. However, Figure 12 (next page) illustrates that a supply chain is more than just a linked set of single firms.

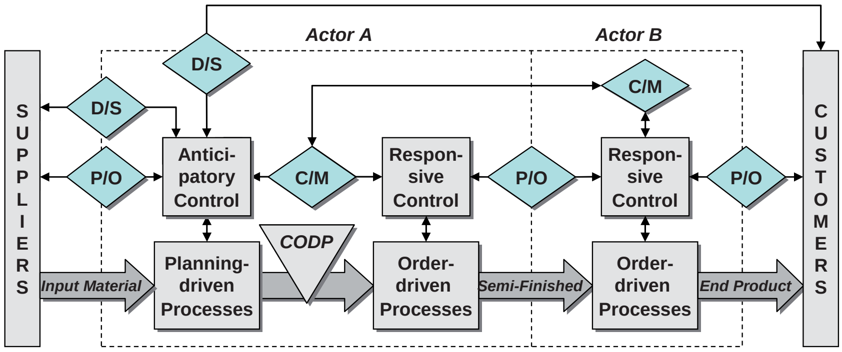

Figure 12 Conceptual model of an illustrative supply chain configuration (abstracted from the higher management echelons)

In this figure, in addition to Figure 11, actor B is also visualised. If this actor receives an order from the end customer, he purchases the required semi-finished products to order from actor A. Consequently, in this illustrative configuration all the business processes of actor B are order-driven and his CODP is moved to actor A. Furthermore, the demand forecast of actor A is based on the sales information of the end customer, who conversely uses supply information of actor A for promotion planning.

In this section we have developed a conceptual definition of the modelling object. Supply chain configurations are defined as specific sets of business processes, control systems and coordination mechanisms. These elements are further classified in order to help identify the possible variety of configurations that a company must manage in order to fulfil the different demand requirements of their customers.

Business process models in demand-driven supply chains should reflect the object system defined in this section. Therefore, they must explicitly visualise how order-driven and forecast-driven processes are decoupled and how interdependences between processes are coordinated. Furthermore, as argued in the introduction, process models should link between supply chain design and information systems engineering and enable rapid instantiation of specific supply chain configurations from a repository of standard building blocks. In the next section, we propose a toolbox that supports this.

3.4 Toolbox for modelling business processes of demand-driven supply chains

Based on the object system definition of the previous section, a toolbox for modelling business processes in demand-driven supply chains is designed (see Figure 9). The toolbox is based on terminology and process definitions provided by SCOR and contains design knowledge for modelling process diagrams that integrate the design of specific supply chain configurations (Supply Chain Thread Diagrams) with the engineering of enabling information systems (Business Process Diagrams). For these two types of process models, the toolbox identifies the modelling building blocks (reference components), a method to instantiate the model to specific cases (configuration tree) and preconfigured diagrams of typical supply chain configurations (reference templates).

In this section, we first introduce the setup of Thread and Process Diagrams and define their reference components. Next, we describe the related configuration trees. The designed reference templates are based on the case study and will be introduced in the next section.

3.4.1 Thread Diagrams

Business process modelling of supply chain configurations starts with depicting a diagram of the complete configuration in scope. Following SCOR, we use the term Thread Diagram for such a model. Figure 13 illustrates the modelling technique advised in SCOR (SCC, 2008a).

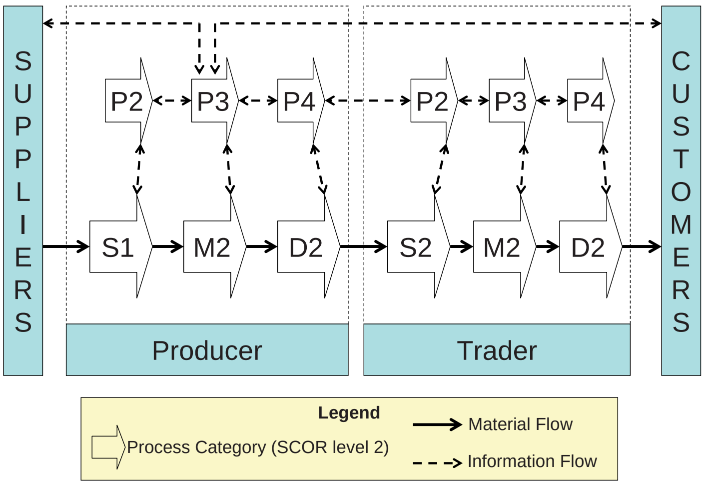

Figure 13 Example of a SCOR Thread Diagram

The figure shows that SCOR Thread Diagrams connect the different process categories (at the second level of abstraction) in a specific supply chain via material and information flows. The identified categories are implicitly based on different CODP positions and cover most of the control configurations as defined in this chapter (section 3.3.3). However, the technique for modelling Thread Diagrams suggested in SCOR does not explicitly visualise how order-driven and forecast-driven processes are decoupled and it does not show how interdependences between processes are coordinated. Furthermore, there is much redundancy in SCOR's process categories. For example: the make configurations Make-to-Stock (M1), Make-to-Order (M2) and Engineer-to-Order (M3) have exactly the same activities, except one activity for finalising engineering.

Consequently, it can be concluded that the SCOR model currently does not have sufficient representation power for modelling supply chain configurations as defined in the previous section, *i.e.* as specific sets of business processes, control systems and coordination mechanisms. We therefore propose an alternative way of modelling supply chain Thread Diagrams as shown in Figure 14.

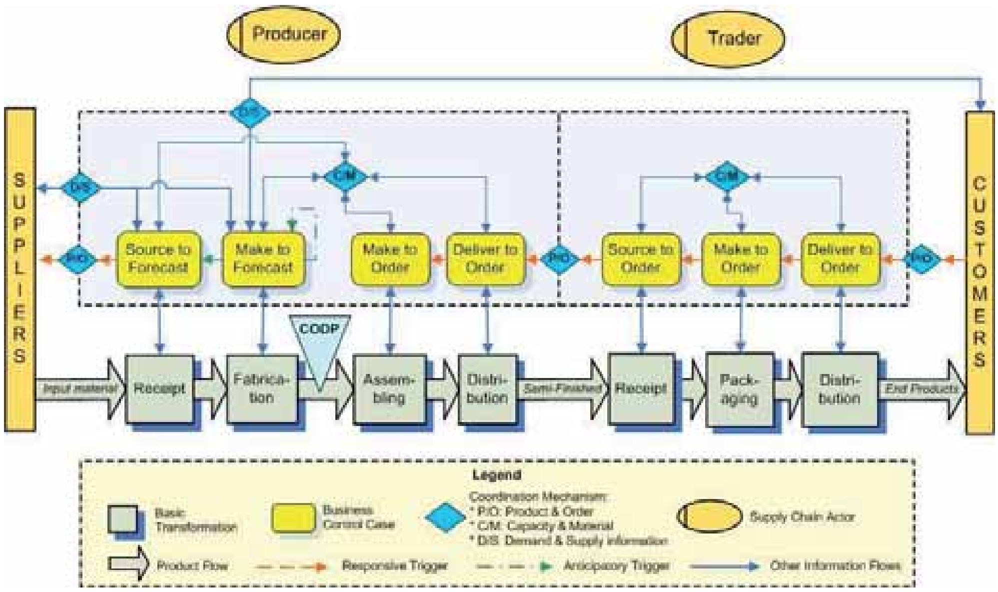

Figure 14 Thread Diagram of an illustrative supply chain configuration

Figure 14 depicts the supply chain configuration of Figure 12 as a Thread Model. The contributors involved, *i.e.* producers and traders, are presented at the top of Figure 14. At the bottom, the basic processes that transform input material into end products are visualised. The CODP indicates the extent to which these transformations are order-driven. Next, the centre of the diagram depicts a network of business control cases (the rounded rectangles) and coordination mechanisms (the diamonds).

A business control case represents a sequenced group of business processes that follow the same control strategy. They are defined at SCOR level 1: source, make or deliver (return is beyond the scope of this chapter). As argued in section 3.3.3, control strategies differ in the extent to which processes are responsive (to order) or anticipatory (to forecast), which is determined by the position of the Customer Order Decoupling Point (CODP). Consequently, we identified the following Business Control Cases: Source-to-Order, Source-to-Forecast, Make-to-Order, Make-to-Forecast, Deliver-to-Order and Deliver-to-Forecast. In addition, Engineer-to-Order and Engineer-to-Forecast were included in order to ensure the interactions with the product development processes.

A coordination mechanism manages the interdependencies among business control cases. Coordination of Product and Order precedences (P/O) occur at every interface of two basic supply chain roles, *i.e.* when products are passed on from one actor to another according to an agreement about the requirements (order). Coordination of capacity usage, capacity precedence and material consumption (C/M) manages the dependencies among multiple control cases per actor. C/M coordination is directly related to the SCOR plan process. However, the term ‘Plan’ suggests coordination based on direct supervision, which excludes mutual adjustment or standardisation. Lastly, the exchange of Demand and Supply information (D/S) connects anticipatory control cases of a supplier with responsive control cases of a customer.

3.4.2 Business Process Diagrams

Business process diagrams depict the sequence of activities and information flows of specific business control cases and coordination mechanisms. They can be used for information systems engineering purposes. The level 3 processes of SCOR can be used as the basic building blocks of these diagrams (see SCC, 2008b, SCC, 2008c). We analysed to what extent these processes cover the control functions and coordination mechanisms as identified in section 3.3. For example: the control function 'Input Filter' of the product flow is part of the SCOR process 'Verify Product'. The analysis shows that SCOR covers most of the identified control functions and coordination mechanisms.[12] We therefore adopted the level 3 processes of SCOR as the reference components for modelling Business Process Diagrams, although some refinements were implemented.[13]

Next, graphical Business process Diagrams can be modelled by using the reference components as activities. Although SCOR does not prescribe a specific technique for modelling process diagrams, it includes a brief guideline that suggest the modelling technique as illustrated in Figure 15 (SCC, 2008a).

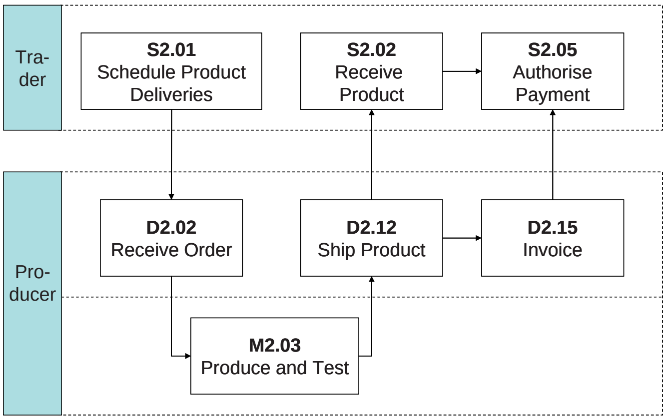

Figure 15 Example of a SCOR Process Diagram

A SCOR process diagram depicts the interactions between level 3 processes of the supply chain actors involved. The consistency of these interactions with the material and information flows in SCOR Thread Diagrams is unclear. Furthermore, it is an

[12] A cross-reference of the control functions and coordination mechanisms as defined in this chapter versus the level 3 processes of SCOR can be obtained on request from the corresponding author.
[13] These refinements are:

- The counterpart of the first deliver activities (order management) are included in source, *i.e.* we added Prepare and Submit Purchase Order (S1.0) and Prepare, Configure and Approve Purchase Order (S2.0).
- The deliver configuration for retail (D4) includes sourcing activities (D4.1 until D4.4); we moved these to a new source category for retail Source Retail Product (S4).
- The definitions of some available activities are extended, e.g. order closure is added to the invoice activities (D1.15, D2.15 and D3.15).

informal notation, which cannot be interpreted by information systems. Therefore, the framework developed in the present chapter does not use the process modelling technique suggested by SCOR, but it adopted the BPMN notation (OMG, 2010). Figure 16 shows an illustrative example, which zooms in on the ‘Deliver to Order’ control case of the producer, as depicted in the Thread Diagram of Figure 14.

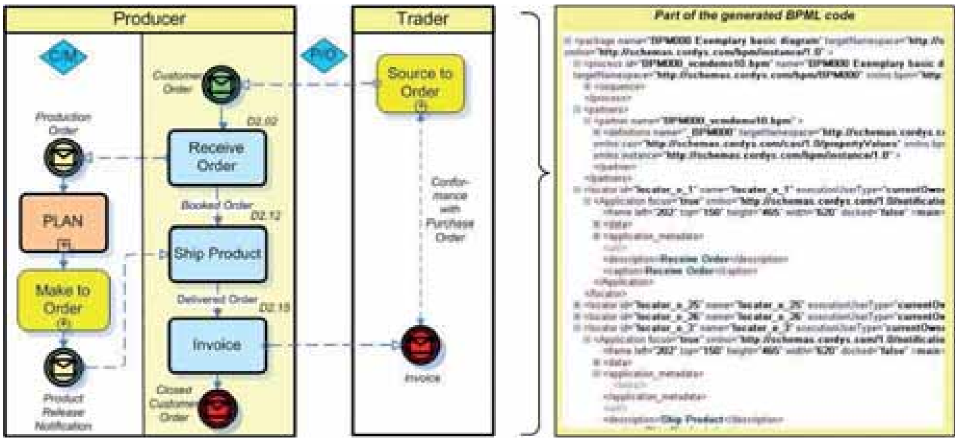

Figure 16 Simplified example of a Business Process Diagram in BPMN notation

The model comprises three vertical swim lanes, *i.e.* separate visual categories that illustrate different functional capabilities or responsibilities (White, 2005). The middle lane is an instantiation of the ‘Deliver to Order’ business control case performed by the producer. This lane is the core of the process diagram and depicts the sequence of the deliver activities (SCOR level 3 processes), the trigger (customer order) and the information flows among the activities. The other lanes show the adjacent business control cases at the same level of abstraction as the Thread Diagram, *i.e.* the make-to-order control case performed by the same producing role and the source-to-order control case performed by the customer (trader). Including these lanes makes it possible to visualise the information flows between these business control cases and the specific activities. In this example, the interaction with other control cases comprises exchange of customer order (trigger), production orders, information about released products and invoices.

3.4.3 Configurable Thread and Process Diagrams

In the introduction, we argued that a configuration-based approach is most suitable for modelling the business processes of demand-driven supply chains. In such an approach, process models are configured from generic model components, constrained by rules that define permitted combinations (chapter 2 of this thesis). The configuration process follows a tree of configuration choices. This is a kind of wizard, in which each decision is fed by the output of previous steps.

Thread Diagrams can be configured in four steps. First, the specific requirements about product and service level (including order-to-delivery time and required delivery location) have to be specified per customer or customer segment. This could be the result of a separate product configuration process. Second, the sequence of basic transformations required to deliver the end-products have to be defined and it should be determined which actors perform these. Third, it must be defined how far these transformations are order-driven. Important constraint is that process lead-times must be equal or less than the required order-to-delivery times. Finally, for forecast-driven processes, the source of demand and supply information should be specified. Based on these configuration choices, Thread Diagrams of specific supply chain configurations can be configured.

The business process diagrams are the result of a configuration process that also follows a tree of configuration choices, constrained by configuration rules. This process is started when zooming into a specific business control case out of a configured supply chain Thread Diagram. Information from this model about executing actors and interactions with other control cases is used as input. Next, a Business Process Diagram is configured in three steps. First, the relevant SCOR process category must be determined. For each business control case, there are one or more possible categories (see Table 4). Second, the relevant activities should be defined. Some activities are obligatory, others are optional and some activities are not permitted in specific cases. For example, in a deliver-to-forecast control case, the first two activities of D1 are not applicable ("Process Inquiry & Quote" and "Receive, Enter & Validate Order"). Last, the sequence of the selected activities must be specified. Possible sequences are constrained by configuration rules, since not all sequences are allowed. For example: it is obvious that products cannot be packed before they are picked and shipments must first be routed before products can actually be shipped. Based on these configuration choices, specific Business Process Diagrams can be configured.

Table 4 Business control cases and SCOR process categories (level 2, excluding Return)

	To order	***To forecast***
Deliver	D1 Deliver Stocked Product D2 Deliver Make-to-Order D3 Deliver Engineer-to-Order Product D4 Deliver Retail Product	D1 Deliver Stocked Product (excluding first two activities)
Make	M2 Make-to-Order M3 Engineer-to-Order (excluding first activity "Finalise Engineering")	M1 Make-to-Stock
Source	S1 Source Stocked Product S2 Source Make-to-Order Product S3 Source Engineer-to-Order Product S4 Source Retail Product	S1 Source Stocked Product S2 Source Make-to-Order Product S3 Source Engineer-to-Order Product S4 Source Retail Product
Engineer	M3 Engineer-to-Order (only first activity "Finalise Engineering")	DCOR

Above, we introduced a framework for modelling business processes in demand-driven supply chains. It comprises a consistent set of process models that intermediates between supply chain design and information systems engineering. The framework does not prescribe a strict blueprint of the 'best' supply chain design (no one size fits all), but it supplies managers with a toolkit for the design and implementation of their specific supply chain configurations from a repository of standard building blocks. The next section presents the application of the framework by means of an explorative multiple case study in the Dutch Flower industry.

3.5 Modelling demand-driven chains in the Dutch flower industry

3.5.1 Structure of the Dutch flower supply chains

The flower industry in The Netherlands comprises of cut flowers and pot plants production, mainly in greenhouses. Particularly the growing of pot plants has many similarities with manufacturing and is characterised by high product and process variety, The case study therefore focused on pot plant supply chains.

The Dutch pot plants industry is traditionally a strong and innovative sector with a leading international competitive position and a great contribution to the national economy. It is internationally renowned as a strong cluster (Porter, 1998). In 2004, its European market share was 44% (Splinter *et al.*, 2006). The main actors are (van der Vorst *et al.*, 2008):

- *Growers*: about 1360 Dutch growers that produce about 500 different sorts of pot plants on a total area of 1930 hectares (Splinter et al., 2006);
- *Auctions*: one major auction, recently formed from a merger between two big local auctions, provides trading facilities at seven locations in the Netherlands;
- About 1200 *traders* that can be split up into three groups: wholesalers, exporters and importers. Transport between two links is often outsourced to logistic service providers. In some cases, these providers perform additional activities like quality control, handling and packaging;
- Different *outlet channels* in national and international marketplaces: florists, supermarkets, discounters, garden and Do-It-Yourselve (DIY) centres, and market and street trade.

In the case study we applied the framework, developed in previous section, to the pot plants sector. Therefore, the supply chain structure of the involved cases was investigated in interviews with a total of five producers, one auction and two traders. The main findings of this investigation are as follows.

Firstly, chain roles are allocated differently among actors. For example, auctions traditionally have a strong position in mediating between production and the market. The role of traders has become more important and growers increasingly sell directly to retail channels.

Secondly, the extent to which processes are order-driven differs considerably. An important distinction is between daily spot market sales and network-coordinated sales, usually based on long-term contracts. For the spot market, products are made to stock and distribution is either to order (usually via traders) or anticipatory (usually via auctions). For network-coordinated sales, a wide variety of configurations is found. Often, plants are produced to forecast, while assembling (of plants, flowerpots and decorations), labelling and packaging are to customer order. In the case of sales promotions by retailers, production and sometimes even product development are to order, based on long-term contracts. On the distribution side, both traditional DC deliveries, cross-docking, direct deliveries and Vendor Management Inventory concepts are found.

Lastly, demand forecasts are mainly based on own estimations using generic market information. Only one interviewed trader analysed POS data for forecasting and replenishment purposes. No example of integrated Supply Chain Planning was found.

To summarise, the investigated companies participate in many different supply chain configurations comprising different sets of business processes, control systems and coordination mechanisms and performed by different networks of contributors. The next section describes how the framework is applied to model the basic variety of these configurations.

3.5.2 Modelling demand-driven pot plants supply chains

The investigation results show that configurations of pot plants supply chains can be positioned in a continuum from fully anticipatory (push) to fully order-driven (pull). We modelled three typical supply chain configurations as template instantiations of the modelling framework developed in this chapter. Two of these configurations are at both ends of the continuum, *i.e.* push and pull oriented, while the third is a mixed form that balances pull and push elements. The typical push-based configuration is a supply chain in which growers deliver standard products via the auction for the spot market. This configuration has been dominant for decades and is still widespread. The typical pull-based configuration is a supply chain in which production of pot plants is order-driven based on long-term contracts with retailers. Growers and retailers exchange demand and supply information and use this information to select and develop new varieties, to optimise production, replenish stores and plan consumer promotions. This configuration is currently developing and occasionally found, particularly among large growers. Lastly, the typical mixed form is a supply chain in which growers assemble plants, flowerpots and decorations, label and package to order via traders for network-coordinated sales. This configuration has emerged recently and is rapidly becoming common practice. Below, we describe configuration of a Thread and a Process Diagram of the last typical configuration (mixed form) to show the applicability of the modelling framework.

3.5.3 Configurable supply chain Thread Diagrams

As described in section 3.4.3, Thread Diagrams can be configured in four steps: i) specification of the customer requirements, ii) determining the sequence of basic transformations of the actors involved, iii) defining how far these transformations are order-driven and iv) identifying the source of demand and supply information for anticipatory processes. Consider for example a supply chain configuration in which garden centres are supplied by traders with pot plants assembled to order by growers (mixed push and pull configuration).

In this example, the customer is a local garden centre that demands specific decorations, packaging and labels and the required delivery time is a maximum of two days.

Next, the basic transformations are as follows. The pot plants are packed, labelled and distributed to the trader’s distribution centre. Here, the plants are transhipped via cross-docking and delivered directly to the local garden centres. These shops replenish their shelves and finally, consumers pick the plants they want and checkout.

Thirdly, for this example, replenishment at the garden centre is anticipatory (economic order quantity) and check-out at POS is (consumer) order driven. Trading receives combined orders from all local stores and allocates these orders to growers of different product categories. Growers assemble, package, label and distribute the required pot plants to order. Production of pot plants is completely to forecast. Usually the summed lead-time of these processes is 1 day, so the required delivery time can be achieved.

Lastly, the trader has an important role in coordinating the exchange of demand and supply information among growers and retailers. POS data of local stores are grouped by the retailer's head office and sent to the trader. The trader translates this information to the level of specific growers. Vice versa, growers communicate the availability of their pot plants to the trader. The trader groups the supply information from multiple growers and sends it to the retailer.

Based on this information, the Thread Diagram of Figure 17 can be configured.

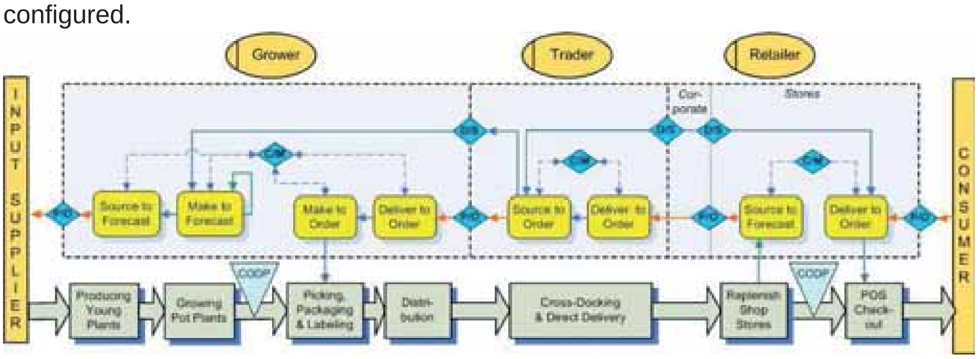

Figure 17 Example of a configured supply chain Thread Diagram for pot plants

The actors involved are presented at the top of the figure: growing/breeding, trading and retailing. Below the basic product flow is visualised: growers transform input material into young plants and young plants into end products. Both the actors involved and the basic product flow are defined in sector-specific terms that are as recognisable as possible for the users. The different CODPs positions are visualised in these transformations. Next, at the centre of the figure, the network of business control cases and coordination mechanisms is depicted.

3.5.4 Configurable Business Process Diagrams

Business Process Diagrams can be configured by zooming into a business control case or coordination mechanism of the supply chain Thread Diagram. For example, following the configuration tree as introduced in previous section, a Business Process Diagram of the control case "Deliver to Order" of the grower (see Figure 17) can be configured in three steps.

First, the relevant SCOR level 2 process category must be determined. In the example discussed, assembling (of plants, flowerpots and decorations), labelling and packaging are to order. So a make-to-order variant is chosen (D2, see Table 4).

Second, the relevant activities should be defined (see SCC, 2008b, SCC, 2008c). For this example, the following make-to-order (D2) activities are not applicable: Process Inquiry and Quote, Consolidate Orders (not planned), Build Loads (not planned), Select Carriers & Rate Shipments (own transportation) and Install Product.

Last, the sequence of the selected activities must be specified. In this case, we follow the sequence of activities as defined in SCOR, except routing of shipments which is done just before product loading and generating shipment documents. Based on these configuration choices, the Business Process Diagram of Figure 18 can be configured.

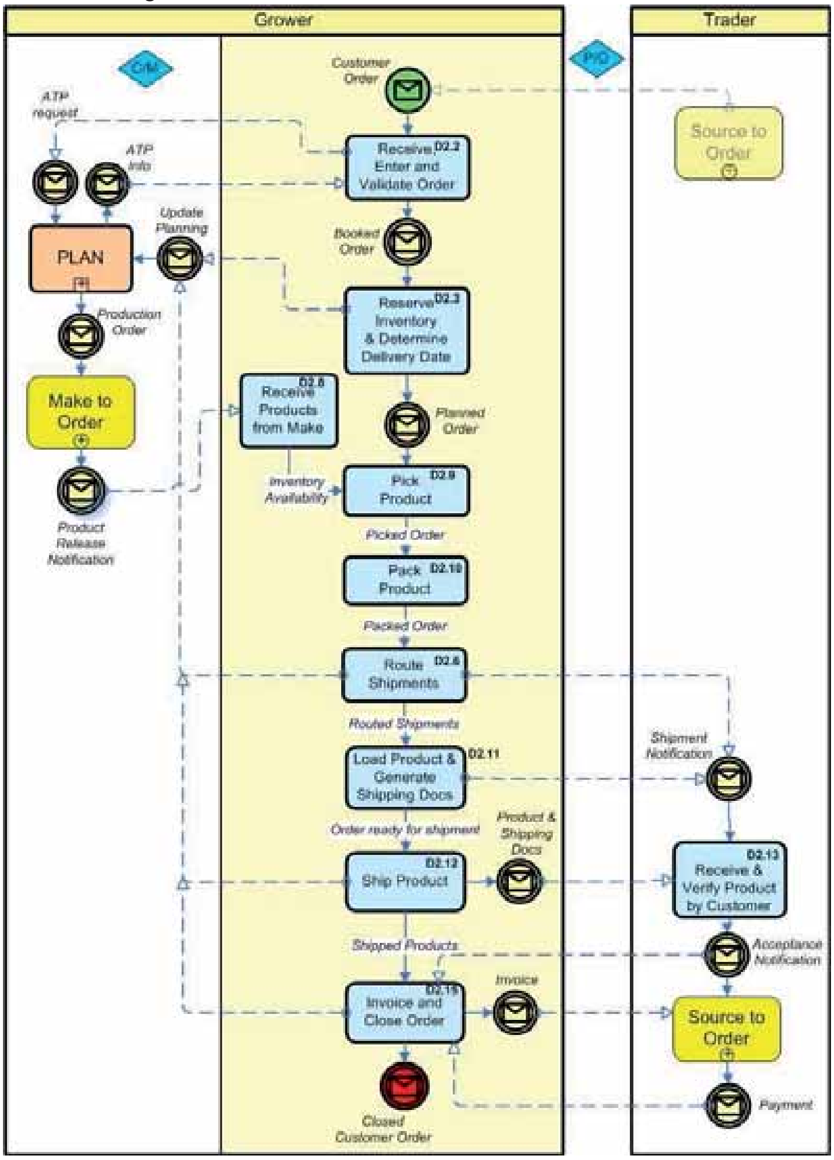

Figure 18 Example of a configured process model for Deliver to Order

The figure shows the Business Process Diagram of order-driven delivery by a grower to a trader in three interacting lanes. It is triggered by an order request from the trader, who sources to order. The process flow at the centre of the diagram depicts the activities for further processing, starting with order receipt. The activities correspond to the SCOR level 3 processes and incorporate the control functions developed in this chapter (see appendix D). The interactions with other processes are shown in the events with external business control cases. For example customer requirement update during order configuration or planning update during inventory reservation. The type of coordination of these interactions is visualised at the top of the lanes. These coordination mechanisms, as well as the connections to external business control cases, are compliant with the parent supply chain Thread Diagram.

To summarise the case study findings, the investigation shows that the case firms participate in many different supply chain configurations. The main variety of the investigated supply chain configurations emerges from the different allocation of basic transformations to the supply chain actors, and the different extents to which processes are order-driven. We applied the designed framework in order to model this basic diversity. Using the diagrams, building blocks and configuration methods as defined in the framework, the processes of three typical pot plants supply chains are modelled. The resulting process models represent the basic variety of business processes in pot plants supply chains and translate high-level supply chain designs into models that can be used as a basis for information systems engineering. This shows the applicability of our framework for systematic design and implementation of specific supply chain configurations from a repository of standard building blocks. The successful modelling of case-specific supply chain configurations from standard building blocks, using a generic framework, also suggests that the design can easily be extended to other cases and other sectors.

3.6 Concluding remarks

3.6.1 Discussion

In this chapter, we have presented a new framework for modelling business processes in demand-driven supply chains. It helps to map, in a timely, punctual and coherent way, the business processes of the supply chain configurations that a company must manage in order to fulfil the different demand requirements of their customers. Demand-driven supply chains aim to provide a rapid and customised response to volatile demand. We have argued that this imposes stringent demands on information systems and requires the ability to design and implement customised supply chain configurations rapidly. The designed process modelling framework enables this by supplying managers with concepts and a toolkit for modelling a wide variety of supply chain configurations from standard model components. As such, it enhances shared understanding and reuse of process knowledge in supply chain design and information systems engineering. Although the use of the framework is not limited to demand-driven supply chains, it is particularly useful in the case of a high variety and variability of supply chain configurations as apparent in demand-driven supply chains.

In the introduction we addressed two literature gaps regarding business process modelling in demand-driven supply chains. First, a seamless translation of high-level supply chain designs to detailed information engineering models is not yet available in literature. Existing process frameworks for supply chain design only support high level process modelling, while process models for information systems engineering are technology-oriented or focus on single enterprises. Second, existing supply chain process models are not setup to enable rapid instantiation of various specific supply chain configurations. Existing reference process models are setup as blueprints (one size fits all), which do not fit in with a mass customisation approach. The present chapter bridges these two gaps as follows.

In the first place, the designed framework provides a consistent set of process models that link between supply chain design and information systems engineering. Starting from high-level Thread Models of supply chain configurations it zooms into process diagrams that depict information flows among activities and that are modelled in a notation that can be interpreted by SOA-based information systems. More specifically, the Thread Diagrams in our framework explicitly visualise how order-driven and forecast-driven processes are decoupled and how interdependences between processes are coordinated, which existing frameworks lack.

In the second place, the framework is designed to enable rapid instantiation of specific supply chain configurations from a repository of standard components. Our framework provides a systematic classification of the building blocks that are necessary to model diverse supply chain configurations. Moreover, it includes a method that describes how specific configurations can be composed from these building blocks. As such, it contributes to the emerging field of process model configuration, which is a relatively new research area (van der Aalst *et al.*, 2006). Applications are in their infancy and are concerned with single enterprises (chapter 2 of this thesis). Our framework provides a first application in the field of Supply Chain Management.

SCOR is the supply chain framework that comes closest to our approach. Three key differences can be mentioned.

First, the processes of SCOR are decompositions and definitions of process components. We have adopted these as much as possible for our reference components. However, our framework goes further (see Figure 9). It adds: i) a conceptual definition of the modelling object, ii) a method to instantiate the model to specific cases (configuration tree) and iii) preconfigured diagrams of typical supply chain configurations (reference templates). Consequently, our framework enriches the knowledgebase of SCOR with reusable design and implementation knowledge.

Second, SCOR embraces a supply chain configuration approach by addressing different process variants for source, make, deliver and plan (see Table 4). However, the SCOR model does not make clear how these categories interrelate and what are essential differences in the underlying control systems and coordination mechanisms. Departing from a conceptual definition of supply chain systems, our framework introduces Supply Chain Thread Diagrams that model supply chain configurations as specific sets of transformations, control systems and coordination mechanisms. Our Thread Diagrams make also explicit how order-driven and forecast-driven processes are decoupled by visualising the CODP positions. Furthermore, our analysis of detailed control functions and coordination mechanisms resulted in some refinements of the SCOR level 3 processes, which are used as the building blocks of detailed Business Process Diagrams.

Third, the process diagrams suggested by SCOR are not fully consistent with SCOR Thread Diagrams and they are modelled in an informal notation, which cannot be interpreted by information systems. Consequently, SCOR process diagrams are not directly appropriate for information systems engineering. The framework developed in the present chapter uses the BPMN notation to ensure the smooth translation of supply chain designs to information systems architecture. Furthermore, our process diagrams are fully consistent with the parent Thread Diagrams and they include interactions with adjacent processes. The explicit modelling of these communication interactions is essential for information systems engineering since it defines the required system behaviour. Moreover, Kock *et al.* (2009) show that a communication flow orientation of business process models improves the success of business process redesign.

3.6.2 Conclusions and outlook

The main objective of this chapter was to design a process modelling framework that enhances the rapid design and implementation of demand-driven supply chains. The designed modelling framework consists of an object system definition and a generic modelling toolbox. The object system definition provides typologies of the main elements of supply chain configurations, *i.e.* business processes, control systems and coordination mechanisms, and describes how these concepts are related in supply chain configurations.

Next, building on these insights, a toolkit for modelling business processes in demand-driven supply chains was designed. Following SCOR, the framework identifies two types of process diagrams: Thread Diagrams and Process Diagrams. For both, the toolbox identifies the modelling building blocks (reference components), a method to instantiate the model to specific cases (configuration tree) and preconfigured diagrams of typical supply chain configurations (reference templates).

Last, the designed generic framework is applied in a multiple case study in the Dutch Flowers industry. The investigation showed that the case companies participate in many different supply chain configurations that can be positioned in a continuum from fully anticipatory (push) to fully order-driven (pull). Three typical configurations were modelled as template instantiations of the framework proposed in this chapter. The findings showed the applicability of the framework for systematic design and implementation of specific supply chain configurations from a repository of standard building blocks.

The case study applied the framework in an explorative analysis. Future research is needed to further develop, test and implement the designed modelling framework. An important remaining issue is the incorporation of in-depth implementation knowledge in the form of configuration rules and predefined configurations (template diagrams) for best practices and for specific industries. Moreover, implementation in Service-Oriented Architecture (SOA) platforms is an important topic to be further researched.

Chapter 4. Process modelling in demand-driven supply chains: A reference model for the fruit industry [14]

Abstract
The growing importance of health in consumption is expected to result in a significant increase of European fruit demand. However, the current fruit supply does not yet sufficiently meet demand requirements. This urges fruit supply chains to become more demand-driven, that is, able to continuously match supply capabilities to changing demand requirements. Realisation of such dynamic supply chains requires the design of customized supply chain configurations and subsequently the engineering of enabling information systems. Reference process models can be valuable means to support this. Based on a case study in four European countries, this chapter presents a reference model for designing business processes in demand-driven fruit supply chains. The model consists of a reference modelling framework and an application of the framework to fruit supply chains. The framework defines process models at different levels of abstraction and includes a method of how they can be composed from a repository of building blocks. The applied model comprises a definition of the model building blocks in fruit supply chains and a set of preconfigured models (templates). Together, they combine fruit-specific knowledge with the reuse of generic knowledge as captured in cross-industry standards. The developed reference model bridges the gap between supply chain design and information systems engineering by providing a consistent set of process models that are on the one hand understandable for business managers and on the other hand serve as a basis for information system implementation.

Keywords: Business process modelling, Supply chain management, Reference models, Fruit industry

4.1 Introduction

Fruit is an essential component of a healthy diet. The increasing awareness of consumers, combined with new lifestyles and higher income, is expected to result in a significant increase of European fruit demand (FAO/WHO, 2005). However, the relatively low fruit intake indicates that fruit supply often does not yet meet demand requirements including variety, quality, safety, convenience, and year-round supply of fresh produce (Hall, 2008, Trienekens *et al.*, 2008). This urges fruit supply chains to become more demand-driven, that is, being able to continuously match supply capabilities to changing demand requirements (Day, 1994, De Treville *et al.*, 2004). In a demand-driven supply chain, all actors involved are sensitive and responsive to demand information of the ultimate consumer and meet those varied and variable demands in a timely and cost-effective manner (Kohli and Jaworski, 1990, Vollmann *et al.*, 2000, Cecere *et al.*, 2004). As a consequence, information must be shared timely throughout the supply chain and the early alerted firms have to respond quickly to changes in demand or supply (Lee and Whang, 2000, Li *et al.*, 2007). This imposes stringent demands on the interoperability and flexibility of the enabling information systems.

Realisation of demand-driven supply chains is a complex task (Selen and Soliman, 2002). Any customer requirement may trigger the execution of a different set of business processes performed by a specific network of contributors (Prahalad

[14] C.N. Verdouw, A.J.M. Beulens, J.H. Trienekens, J. Wolfert (2010). Process modelling in demand-driven supply chains: A reference model for the fruit industry. Computers and Electronics in Agriculture, 73 (2), 174-187, doi:10.1016/j.compag.2010.05.005

and Ramaswamy, 2000). Consequently, supply chains must be highly dynamic networks having different modes of cooperation, control and coordination. Companies must be able to take part in different supply chain configurations concurrently and to switch rapidly to new or adjusted configurations. This requires the design of customised supply chain configurations and subsequently the engineering of enabling information systems (Fine, 2000, Lambert and Cooper, 2000, Cooper and Tracey, 2005). Fruit supply chains are facing additional complications due to some food-specific characteristics such as long production lead times, seasonable production, quality variations between producers and between lots, short required delivery time due to product freshness, and special packaging demands (van der Vorst *et al.*, 2001, Taylor and Fearne, 2006, van Donk *et al.*, 2008).

Reference process models can be valuable means to support the challenges in the design and implementation of demand-driven fruit supply chains. Process models represent specific ordering of work activities across time and place, including clearly identified inputs and outputs (Davenport, 1993, p.5). Reference process models are predefined models used for the construction of other process models (Thomas, 2006). They improve the speed and efficiency of modelling because of knowledge reuse and enhance shared understanding by providing a common language. Reference process models can also provide insight in the possible variety of supply chains processes and translate high-level supply chain designs into detailed information systems architecture. Additionally, they can support the rapid instantiation of specific supply chain configurations from a repository of standard building blocks, *i.e.* reusable model components.

Reference process modelling has been an important subject in agri-food since the emergence of architecture as a basis of software engineering (Zachman, 1987, Martin, 1989). For example, the Dutch INSP reference model included detailed process models of different agricultural branches, including fruit production (Bos, 1987). However, although the models were used intensively in the design of software applications, they were not used to guide the workflow in run-time information systems. Furthermore, if implemented models were adapted, it was mostly done without taking into account the overall coherence and consistency as specified in the reference model. This resulted in a lack of active usage of reference models and, after some time, they were no longer maintained (Wolfert *et al.*, 2010). Currently, to the best of our knowledge, there is no active example of a reference process model for fruit supply chains.

The present chapter aims to contribute to the development of reference process models in the fruit industry. It addresses the following research question: *"How can reference process models be designed that enable the modelling of demand-driven fruit supply chains and the implementation of supporting information systems?"* In order to answer this question, the objective is to propose a reference process model for fruit supply chains that consists of two main parts:

i) A reference modelling framework, which defines process models at different levels of abstraction and includes a method of how they can be composed from a repository of building blocks;

ii) An application of the framework to fruit supply chains, which comprises a definition of the model building blocks in fruit supply chains and a set of preconfigured models (templates).

The remainder of this chapter is organised as follows. In section 4.2, the applied research method is described. Subsequently, section 4.3 provides some conceptual background on reference process modelling and demand-driven supply chains. Section 4.4 maps the structure of the investigated fruit supply chains and defines the main fruit-specific process characteristics. Next, the research results are introduced. Section 4.5 introduces the designed reference modelling framework. Section 4.6 applies this framework to fruit supply chains. The chapter concludes by summarising the main results and discussing implications for future research.

4.2 Research method

The research followed a design-oriented methodology. Design-oriented research is typically involved with "how" questions, *i.e.* how to design a model or system that solves a certain problem (Hevner *et al.*, 2004, van Aken, 2004). We applied a design-testing approach, which is comparable with theory testing methods in traditional empirical science, *cf.* Eisenhardt (1989). In such an approach, generic design knowledge is developed based on deductive reasoning and after that the design is tested by applying it to specific cases. In this chapter is chosen for a multiple case study in European fruit industry.

The case data are collected within the project ISAFRUIT (www.isafruit.org). Data collection was done in in-depth structured interviews with key informants of the selected case firms and additional document reviewing (see Appendix E for the questionnaire). We chose interviewees with a broad insight into the different business processes (in particular sales, production, and logistics) and the company's role in the supply chain, *i.e.* 15 general managers, 7 operations managers and 6 commercial managers. The interview reports were reviewed and commented by the respondents. Table 5 summarises the key case study figures.

Table 5 Key case study figures

Country	Product	Type of production *(X main focus, * sideline activity)*		No. firms	No. inter-viewees
		Fresh	Prepared/ Processed		
Poland	1.Fresh Apple	X	*	3	3
	2.Organic Fruit	*	X	1	1
Greece	3.Fresh Apple	X		2	3
	4.Canned Fruit		X	2	2
Spain	5. Seedless Watermelon	X	*	3	3
	6. Fresh Stone Fruits	X	*	3	5
The Netherlands	7.Black Currant as Ingredient		X	4	5
	8. Fruit Salads		X	4	6
Total		***4***	***4***	***22***	***28***

The research was organised in four steps: i) literature review, ii) case investigation and analysis, iii) design and iv) review.

First, the literature on reference process modelling and supply chain management was reviewed. Based on the review the basic requirements to process modelling in demand-driven supply chains were identified and a conceptual supply chain model was developed for the case study investigation. The latter defines the elements and relations of a supply chain system, *i.e.* supply chain network, processes, management, resources (including information), and strategy and tactics (Verdouw, 2008a).

Second, the selected supply chains were investigated in interviews (see Table 5) and additional desk research. The structure of the questionnaire corresponds with the developed conceptual model. The data analysis started with aggregating the interview reports and desk material into mappings of the investigated supply chains following the structure of the conceptual supply chain model. Next, we identified the specific characteristics of business processes in fruit supply chains and the main factors that determine the differences among supply chain configurations within the fruit industry.

Third, a generic framework was designed for modelling business processes in demand-driven supply chains. The framework distinguishes three types of process models, Product Flow Models, Thread Diagrams and Business Process Diagrams, and includes a method how these diagrams can be composed from a repository of building blocks. The SCOR-model was chosen as a basis for this design (SCC, 2008c), because it has been acknowledged as the most comprehensive supply chain process model and as a widely accepted common language in supply chain design (Huan *et al.*, 2004, Lambert *et al.*, 2005). The framework of this chapter in particular adds the modelling of the allocation of basic transformations to supply chain actors in separate Product Flow Models.

Finally, a fruit-specific reference process model was designed. This was done by application of the generic framework to fruit supply chains based on the case study investigation results. The designed model was reviewed by in-depth interviews with experts of Frugicom, a Dutch Industry Platform for promoting standards for information sharing in fruits and vegetables supply chains (www.frugicom.nl). In total seven experts were interviewed: five industry representatives, a consultant of the involved standardisation organisation GS1 (www.gs1.com) and the Frugicom program manager. The results from these interviews were implemented in the final design that is presented in this chapter.

The remainder of the chapter introduces the results following the research steps as described above.

4.3 Reference process modelling in demand-driven supply chains

This section summarises results of the literature review on reference process modelling and supply chain management in order to provide some background on the theoretical positioning.

4.3.1 Reference information modelling

Reference process models have played an important role in information systems engineering since the start of the discussion in literature on architecture as a basis of software development (Zachman, 1987, Martin, 1989). Architecture can be defined as “the fundamental organisation of a system embodied in its components, their relationships to each other and the environment, and the principles governing its design and evolution” (IEEE 1471:2000). Architectures of information systems in supply chains are complex, since they consist of many different elements and many different relations. Information models, including process and data models, are important to make this complexity manageable by providing systematic representations (visualisation, description) of architectures from different viewpoints and at various levels of abstraction. Moreover, information models support different stages of information systems engineering: requirements definition, design specification and implementation description (Kosanke, 1995).

A reference information model is used as a ‘frame of reference’ (*i.e.* blueprint, template) to construct company-specific information models (Thomas, 2006). Reference information models can contain different kinds of sub-models, including process models. There are various notations for modelling business processes. They all graphically represent the sequence of activities, events and control decisions, but serve different types of users. Well-known standards are UML activity diagrams, EPC and BPMN. UML activity diagrams are part of the Unified Modelling Language (UML), an open method promoted by the Object Management Group (OMG) for software engineering driven by architecture (Rumbaugh *et al.*, 2004). The Event-driven Process Chains (EPCs) are introduced by SAP and IDS Scheer (Aris) and have become a popular notation for, in particular, business analysts (Scheer *et al.*, 2005). The Business Process Modelling Notation (BPMN) is especially used in service-oriented architectures (OMG, 2010). BPMN includes a mapping to the underlying web service execution languages, in particular BPEL (OASIS, 2007) and BPML (Arkin, 2002).

The emergence of Service-Oriented Architecture (SOA) has moved the emphasis in information modelling from a logical data orientation to a business process orientation. In a SOA approach, business process models are leading in routing event data amongst multiple software components that are packaged as interoperable services (Erl, 2005, Papazoglou *et al.*, 2007). Consequently, new or adapted business processes can be supported without changing applications and the underlying infrastructure and information systems can be connected quickly to new partners (Leymann *et al.*, 2002). The technological advances towards SOA have helped to accomplish software modularity and a common integration infrastructure. Moreover, it enables rapid system configuration by providing standards that specify technical aspects of the interfacing and service assembly. However, SOA does not include the knowledge required to specify services and to configure business processes as a sequence of services. Also the required software components must be available packaged as application-independent web services. In other words: SOA without content is just an empty shell. Therefore, in addition to SOA, the knowledge captured in reference process models is needed to achieve the required interoperability and agility of information systems (chapter 2 of this thesis).

4.3.2 Modelling in supply chain processes

Business process modelling has focused on single enterprises for a long time. Initially, a business process view was advocated to overcome fragmentation between organisational units (functional silos) and systems within companies (Davenport, 1993, Hammer and Champy, 2001). Especially, the quality management and business process (re)design movements are building heavily on process modelling approaches for single enterprises. Moreover, process models were used as a basis for software engineering and implementation of standard packaged software, in particular ERP systems.

Induced by the emergence of the internet in the late 1990s, the scope of business process modelling has expanded towards the supply chain level. In the literature on supply chain modelling, models for information systems engineering were acknowledged to be an important category besides the traditionally dominant quantitative simulation and optimisation approaches (Min and Zhou, 2002). In practice, new business process models for supply chain management emerged. Lambert *et al.* (2005) addressed two frameworks with sufficient level of detail for implementing business processes in supply chains, *i.e.* the Supply Chain Operations Reference-model (SCOR) of the Supply-Chain Council (SCC, 2008c) and the framework of the Global Supply Chain Forum (Lambert and Cooper, 2000). The GSCF-framework has a strategic perspective and focuses on integration via relation management. On the other hand, the SCOR-model is based on a more operational perspective and consequently focuses on information sharing and connecting with other members of the supply chain through transactional processes. It provides generic definitions of supply chain processes for production and logistics at three aggregation levels (SCC, 2008c). The first level defines the processes plan, source, make, deliver and return. The second level addresses different process categories per level 1 process. The third level defines detailed activities per process category. However, despite it has been acknowledged as the most comprehensive model (Huan *et al.*, 2004, Lambert *et al.*, 2005), SCOR still defines business processes at a high-level of abstraction, which is not sufficient for implementation.

4.3.3 Reference process modelling in demand-driven supply chains

The emergence of demand-driven supply chains in Supply Chain Management is reflected in the discipline of supply chain engineering. Initially, it was advocated to choose one dominant design that matches best to the nature of demand (Fisher, 1997, Childerhouse *et al.*, 2002). Only recently, it is addressed that the design of business processes should reflect specific demand requirements in order to achieve a much higher level of customised response to the different needs of different customers (Aitken *et al.*, 2005, Li and Kumar, 2005, Collin *et al.*, 2009). Major implication for process modelling is that there cannot be one dominant design, but models should precisely depict the variety of supply chain configurations.

Supply chains configurations comprise three main elements: i) the supply chain network structure of cooperating actors, ii) the supply chain business processes that are performed by these actors, and iii) the management of these processes (Lambert and Cooper, 2000). As a consequence, the basic variety of supply chain configurations is determined by the division of business processes among the involved actors and the way how these are managed. A key factor that determines the variation of management systems is the position of the Customer Order Decoupling Point (CODP), also called order penetration point (Sharman, 1984, Hoekstra and Romme, 1992, Wortmann *et al.*, 1997). The CODP separates that part of the supply chain geared towards directly satisfying customers' orders (responsive) from that part of the supply chain anticipating future demand (Hoekstra and Romme, 1992). Consequently, different positions of the CODP result in different control systems, in particular regarding to the basis for production planning and engineering, the planning concept, structuring of product and process master data, and order entry/order promising (Wemmerlov, 1984, Giesberts and van der Tang, 1992).

The CODP functions as a buffer between stable upstream processes and fluctuating downstream processes (Naylor *et al.*, 1999). As such, it decouples groups of relatively independently managed processes that follow different paces of time. Subsequently, the dependencies among these processes have to be managed properly, either by standardisation, central planning or decentralised mutual adjustment (Thompson, 1967).

Reference process models in demand-driven supply chains should represent supply chain configurations as defined above. In the literature review, no such models are found (see also previous section). Furthermore, in order to enable instantiation of specific supply chain configurations, reference models should be set-up as configurable models (chapter 2 of this thesis). Configuration of business process models is addressed only recently in research. Current research in this field focuses on formalisation of configurable modelling techniques (Dreiling *et al.*, 2006, Rosemann and van der Aalst, 2007). In our literature review, no applications to SOA and to the supply chain level were found.

In conclusion, the literature on supply chain design is traditionally dominated by quantitative modelling techniques. The available supply chain process models are at a high-level of abstraction. In information systems engineering, business process modelling has been researched increasingly, but from a technological point of view. In both disciplines there is a need for reference process models that on the one hand support supply chain managers in designing diverse supply chain configurations and that on the other hand are interpretable by information systems. In order to support demand-driven supply chains, these reference models should depict diverse supply chain configurations as series of order-driven and anticipatory processes connected by coordination mechanisms, and they should be setup as configurable models. Existing reference process models do not support this. Therefore, it can be concluded that currently reference process models do not provide the sufficient representation power for demand-driven supply chains.

4.4 Analysis of fruit supply chains

This section summarises the main findings of the case study investigation. It defines the specific characteristics of fruit processes and the diversity within the fruit industry that must be covered by the reference process model.

4.4.1 European fruit industry

The EU is a major fruit producer. The total EU production was almost 69 million tones in 2006 (CBI, 2008). The main fruits produced in Europe are apples, pears, citrus fruit and stone fruit (Freshfel, 2008). The majority of fruit production in Europe takes place in southern countries, *i.e.* Spain, Italy, France and Greece, where citrus fruits (especially oranges), grapes and peaches are dominating production. In northern countries, the emphasis is on apple production with Poland as the biggest producer having the highest share in the European apple production (Freshfel, 2008, Martinez-Palou and Rohner-Thielen, 2008).

The divide between northern and southern Europe is also apparent in consumption. The consumption per inhabitant is at least twice as much in southern countries. For example, the yearly consumption per person in 2006 was about 63 kg in the UK, 95 kg in The Netherlands and Poland, 180 kg in Spain and Italy and 280 kg in Greece (Freshfel, 2008). In total, Italy and Spain have the highest consumption rates. They together accounted for nearly 40% of the total EU market in 2006 (CBI, 2008). Germany and the UK have limited domestic production and rely heavily on imports. The Netherlands and Belgium are important fruit traders.

4.4.2 Supply chain structure of the investigated cases

The case studies were carried out in two southern European countries (Spain and Greece) and two northern countries (Poland and The Netherlands). Appendix F summarises the supply chain structure of the eight investigated cases. Overall, it is found that all analysed supply chains face some generic industry-inherent characteristics, but at the same time they consist of different supply chain configurations. Below, we elaborate on the generic fruit-specific characteristics and the main factors that determine diversity.

4.4.3 Generic fruit supply chain characteristics

The basic transformations in fruit supply chains are (see Figure 19):

- *Growing and Harvesting*: the production of ripened fruit from different types of inputs, in particular, fruit trees, soil, water, fertilizers, and pesticides. Growing includes activities such as planting, pruning, thinning, fertilization, irrigation, crop protection and crop maintenance. Harvesting consists of picking fruits from trees, mostly by hand. The moment of harvesting is an important factor determining fruit quality.
- *Processing*: transforms fresh fruits into food products. Main product categories are juices and fruit ingredients for the food industry, such as jams, ice creams or muesli. Processing techniques include preserving, juice extraction, microwave, slicing, freeze-chill and high pressure (Dauthy, 1995).

- *Washing, Sorting and Grading*. Fresh fruits are mostly washed just after harvesting in order to prevent damages. Important criteria for sorting and grading are size, weight, ripeness, damages, colour, shape and firmness. Measurement of these quality attributes is increasingly automated (Studman, 2001).
- *Packaging and Labelling*. Packing includes ensuring that the proper handling unit is used (*e.g.* putting fruits in crates and crates on pallets). Labelling includes adding product-related information that is needed for further processing such as article code, Bill of Material or ingredients, history information, country of origin and certificates.
- *Storage and Distribution*: receipt, warehousing, dispatching and transportation of fruit products. Three basic distribution modes can be distinguished: direct delivery, delivery via intermediate storage in a central distribution centre (DC) and cross-dock transhipment. Management of decay is a crucial factor in fruit logistics.
- *Retailing:* delivery to the final consumers via different outlet channels, including supermarket, specialised fruit and vegetables shops, market- and street trade, and food service providers including restaurants and caterers.

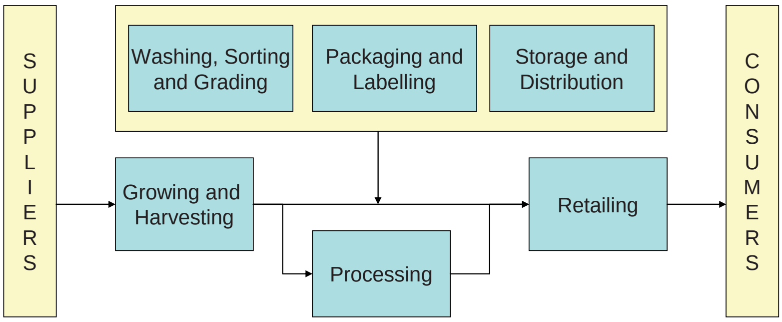

Figure 19 Basic transformations in fruit supply chains

Specific features of business processes in the fruit-industry in particular result from the fact that fruits are living products. This makes fruit supply chains vulnerable to decay, weather conditions, pests and other factors that are difficult to control. Appendix G further defines the identified specific characteristics of fruit production, processing and distribution, and its impact on supply chain processes.

4.4.4 Diversity of fruit supply chains

There are two distinctive characteristics that determine the main variety of the investigated supply chain configurations: i) the allocation of basic transformations to the supply chain actors, and ii) the extent to which fruit chains are order-driven.

i.) The allocation of basic transformations to the supply chain actors. Packaging, labelling, and distribution (including storage and transportation) are done either by fruit producers (or cooperatives of producers), processors, traders, retailers or specialised service providers. Fresh soft fruits are often packaged during harvesting in order to prevent damage. Sometimes the fruit producers also add consumer labels, but this is often postponed to the trader stage in order to prevent repacking. Fresh hard fruits are often packed and labelled by specialised packaging firms or traders.

Packaging of processed fruits is mostly done by the processor. Fruit processing is in some cases done by fruit producers as a sideline activity. Replenishment of the retail shops is in one case outsourced to a trader (Vendor Managed Inventory).

ii) The extent to which fruit chains are order-driven. The found configurations of fruit supply chains can be positioned in a continuum from anticipatory (push) to order-driven (pull). In particular, two factors emerged that determine the position in this continuum: i) the possible techniques for managing decay and ii) the availability of long-term agreements.

First, management of decay determines the extent to what order-driven post harvesting is possible. Techniques differ a lot between fresh, processed and prepared fruits. In fresh fruit supply chains, the emphasis has been on techniques for cooling and temperature monitoring along the entire supply chain. Moreover, the introduction of controlled atmosphere storage has had much impact, because with this technique especially hard fruits can be stored up to 12 months (Studman, 2001). In fruit processing, shelf live is drastically improved by adding preservatives, freezing, drying and/or canning fruits. In contrast, fruit preparation (especially cutting) decreases shelf live, which requires postponement of preparation and subsequently a rapid delivery.

Second, the availability of long-term agreements implies that the specific customer requirements are known a long time before delivery. This makes it possible to adapt also fruit production to specific customer orders. Furthermore, it was found that there often is an intensive exchange of demand and supply information in these supply chains with long-term and formalised relations.

Based on the case study analysis, a reference process model is designed that supports the identified fruit-specific features and the diversity of business processes in fruit supply chains.

4.5 Framework for process modelling in demand-driven supply chains

The designed reference model consists of a generic framework for process modelling in demand-driven supply chains and an application of the framework to fruit supply chains. This section elaborates on the framework. First, the basic requirements to the design are summarised from the literature review and the case study as presented previously. Then the different process model types of the framework are introduced.

4.5.1 Basic design requirements and overview of the designed framework

Reference process models can provide insight in the possible variety of business processes in fruit supply chains and translate high-level supply chain designs to detailed information systems architecture. To do so, they should meet the following basic requirements:

1. They must combine high-level models for supply chain design with implementation models that in detail depict the information flows among activities in an executable notation;

2. They must be setup as configurable models that enable instantiation of specific supply chain configurations from a repository of standard building blocks;
3. They must depict supply chain configurations as series of order-driven and anticipatory processes connected by coordination mechanisms;
4. They must be fruit-specific, that is: they must include fruit-inherent features and address the diversity of supply chain configuration as appears in fruit industry.

In order to meet these requirements, the framework identifies three types of process models at different levels of abstraction:

1. *Product Flow Models*: allocation of the basic transformations in the supply chain from input material to fresh or processed end products for the consumer;
2. *Thread Diagrams*: control and coordination of the basic transformations in specific supply chain configurations;
3. *Business Process Diagrams*: sequence and information flows among detailed control and coordination activities. These diagrams may consist of multiple levels of abstraction. One can zoom in from main processes to various levels of sub processes.

The following sections define the layout of these process models and how specific models can be composed from the identified building blocks.

4.5.2 Product Flow Modelling: allocation of basic transformations

The first step in modelling supply chain processes is to visualise the basic transformations, the actors and the related product flows from input material into end products in Product Flow Models. Transformations are business processes that contribute directly to the creation and movement of products by a company such as engineering, production and distribution. In a supply chain, transformations are performed by multiple firms, especially if there is a high degree of specialisation. Product Flow Models depict the allocation of transformations to the actors in a specific supply chain configuration.

The product flows among transformations comprise several levels of aggregation. Based on the GS1 Global Traceability Standard (Ryu and Taillard, 2007), four different units are distinguished:

1. *Shipping Unit (SU)*: an item or group of items delivered to one party's location at one moment in time, which undergoes the same dispatch and receipt processes. SUs can be identified with standard Shipment Identification Numbers (SIN).
2. *Logistics Unit (LU)*: an item of any composition established for transport and / or storage that needs to be managed through the supply chain. LUs can be identified with standard Serial Shipping Container Codes (SSCC).
3. *Trade Unit (TU)*: a product as it is traded before the point of sales in the supply chain. TUs can be identified with standard Global Trade Item Numbers (GTIN), in combination with a serial number (SGTIN) or with a batch / lot number.
4. *Consumer Unit (CU)*: a product as it is sold to end customers. CUs can be identified in the same way as TUs.

Product Flow Models are configured in four steps. First, the product-market combination of the supply chain configuration must be identified. Second, the sequence of basic transformations, required to deliver the end-products, has to be defined, including the input and output products. Third, it should be determined which actors perform the identified transformations. Finally, the levels of aggregation of the identified products must be defined.

4.5.3 Thread Diagram modelling: control and coordination of transformations

The next step in modelling supply chain processes is to design diagrams of the different configurations in scope. Following SCOR, the term Thread Diagram is used for such a model (SCC, 2008c). A Thread Diagram depicts a specific set of business processes, control systems and coordination mechanisms, performed by a specific network of contributors who together produce and deliver a product or service with distinct value for the ultimate customer. It extends a specific Product Flow Model with business control cases and coordination mechanisms. A *business control case* represents a sequenced group of business processes that follow the same control strategy. They are defined at SCOR level 1, source, make or deliver, and can be either responsive (to order) or anticipatory (to forecast). A Customer Order Decoupling Point (CODP) separates series of responsive and series of forecast-driven business control cases. A *coordination mechanism* manages the interdependencies among business control cases, either by standardisation, central planning or decentralised mutual adjustment (Thompson, 1967). The definition of the coordination mechanisms is based on Malone and Crowston (1994) and Malone *et al.* (1999). They are:

- *Product and Order coordination (P/O)* occurs at every interface of two supply actors, *i.e.* when products are passed on from one actor to another according to an agreement about the requirements (order). P/O coordination ensures that input products are appropriate for further processing and that the order requirements match with the available supply capabilities.
- *Capacity and Material coordination (C/M)* manages the common usage of scarce resources, *i.e.* material and capacity. It is directly related to the SCOR plan process. C/M coordination mechanisms align multiple control cases per single actor, which all use the same, limited, capacity and material.
- *Coordination of Demand and Supply information (D/S)* manages the exchange of information planning information among the participating actors. D/S coordination mechanisms connect anticipatory control cases of a supplier with responsive control cases of a customer.

Building on a configured Product Flow Model, Thread Diagrams can be configured in three steps. First, the specific requirements about product and service level (including order-to-delivery time and required delivery location) have to be specified. Second, it must be defined to what extent the transformations of the concerned Product Flow Model are order-driven. At this, an important constraint is that the process lead-times must be equal or less than the required order-to-delivery times. Finally, the source of demand and supply information should be specified for forecast-driven processes.

4.5.4 Business Process Diagram modelling: sequence and interaction of control and coordination activities

The last type of process models are Business Process Diagrams that are used for information systems engineering purposes. These process diagrams depict the sequence of activities and information flows of specific business control cases and coordination mechanisms. The BPMN notation was chosen in order to ensure a smooth connection to SOA-based information systems (see section 4.3.1 “Reference information modelling”). The framework distinguishes main and sub Business Process Diagrams. Main process diagrams can be configured by zooming in on a business control case or coordination mechanism of a supply chain Thread Diagram. The activities of main process diagrams are defined at SCOR level 3 (SCC, 2008c). Next, from the main processes one can zoom in on sub process diagrams.

Building on a configured Thread Diagram, Business Process Diagrams can be configured in three steps. First, the relevant SCOR process category must be determined. For each business control case, there are one or more possible categories (see Table 6). Second, the applicable activities of the selected category have to be determined. Some activities are obligatory, others are optional and some activities are not permitted in specific cases. Third, the sequence of the selected activities must be specified. Possible sequences are constrained by configuration rules, since not all sequences are allowed. For example: it is obvious that products cannot be packed before they are picked and shipments must first be routed before products actually can be shipped. Based on these configuration choices, specific Business Process Diagrams can be configured.

So far, we have introduced a framework for modelling business processes in demand-driven supply chains. The next section applies the framework to fruit supply chains.

4.6 Reference process model for fruit supply chains

The generic framework is applied to fruit supply chains based on the case study investigation. In addition to the framework, the applied model provides for each identified process model type:

1. The building blocks that are necessary for modelling business processes in fruit supply chains (*i.e.* reusable model components);
2. Pre-configured models (templates) that cover the basic variety of business processes in fruit supply chains.

4.6.1 Fruit Product Flow Models

The building blocks of Product Flow Models are transformations, the products flowing between these transformations, and actors. The model contains the following building blocks for fruit supply chains:

- *Actors*: fruit producers, fruit processors, traders (including importers and exporters), retailers and specialised service providers (*i.e.* packaging firms, transporters, and storage and transhipment firms).

- *Transformations*: growing and harvesting, processing, washing, sorting and grading, packaging and labelling, storage, distribution, and retailing (see section "4.4.4 Diversity of fruit supply chains" for a more detailed definition).
- *Products*: fruit trees, farm inputs (pesticides, fertilizers, etc.), ripened fruits, harvested fruits, shipped fruits, stored fruits, sorted fruits, packages, non-fruit ingredients, fruit products, pre-packed fruits, packaged fruit products, labelled replenished fruit products, sold fruit products. The products are defined at different units of aggregation:
    - Shipping Unit (SU): truck or vessel loads;
    - Logistics Unit (LU): pallets and containers;
    - Trade Unit (TU): crates, cartons, pallets or bulk lots (in weight or volume);
    - Consumer Unit (CU): single products (such as pieces of fresh fruit or bottles of juice), bags, and packages with a certain amount, volume or weight of fruits.

In the reference model, three template Product Flow Models are pre-configured:

1. Fresh hard fruits for fruit specialist shops, supplied via direct delivery;
2. Fresh soft fruits for supermarkets, supplied via traditional DC delivery;
3. Processed fruits for food service providers, supplied via cross-docking transhipment.

These templates cover the basic variety in allocations of the basic transformations to the supply chain actors, as emerged from the case study investigation (see section 4.4.4 Diversity of fruit supply chains). Figure 20 depicts the first template and visualises the production and delivery of pre-packed apples to a fruit specialist shop.

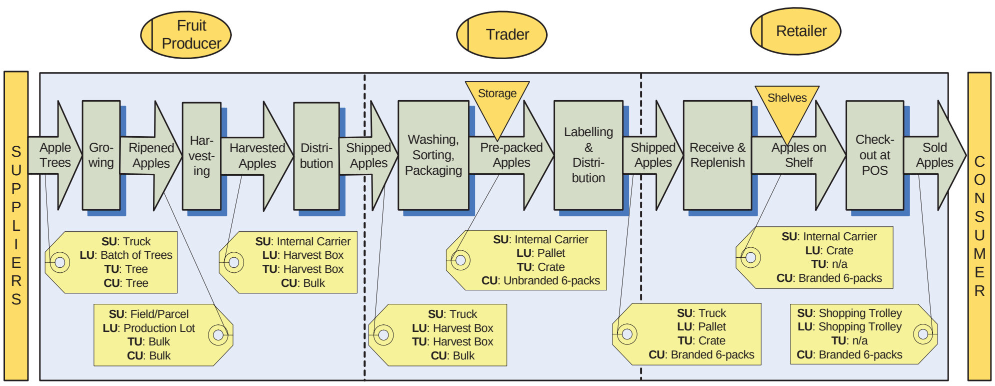

Figure 20 Template Product Flow Model fresh hard fruits for fruit specialist shops, supplied via direct delivery

In this Product Flow Model template, the fruit producer grows the apples, harvests ripened apples in cubic boxes, and ships the harvested apples to a trader. The trader washes, sorts and packs the apples in unbranded 6-packs. The pre-packed apples are stored until they can be delivered to a specific retailer. Then, the apples are labelled with the retailer's brand and shipped directly to local fruit specialist shops. The shop receives and replenishes the shelves. Finally, consumers pick the 6-packs from the shop shelves and check-out at the Point of Sales (POS). Figure 20 depicts these basic transformations, including the related product flows. The labels describe the logistics units of the product flows, *i.e.* the shipping units (SUs), logistic units (LUs), trading units (TUs) and consumer units (CUs).

4.6.2 Fruit Thread Diagrams

The building blocks of Thread Diagrams are, in addition to the accompanying Product Flow Model, business control cases and coordination mechanisms. The model adopts the SCOR level 1 processes Source, Make and Deliver in the definition of the business control cases. For each SCOR process, it identifies one responsive and one anticipatory business control case:

- Source to Order and Source to Forecast;
- Make to Order and Make to Forecast;
- Deliver to Order and Deliver to Forecast.

The coordination mechanisms, as described in the generic framework, are used: Product and Order coordination (P/O), Capacity and Material coordination (C/M), and coordination of Demand and Supply information (D/S).

The case study investigation shows that configurations of fruit supply chains can be positioned in a continuum from anticipatory (push) to order-driven (pull), *cf.* section 4.4.4 “Diversity of fruit supply chains”. In this continuum, two extreme forms are identified, *i.e.* a push and a pull oriented variant, and one mixed form that balances pull and push elements. Thread Diagrams are pre-configured both for fresh and processed/prepared supply chains. As a result, the reference model includes six template Thread Diagrams:

1. Anticipatory supply chain of fresh fruits;
2. Mixed-mode supply chain of fresh fruits;
3. Order-driven supply chain of fresh fruits;
4. Anticipatory supply chain of processed fruits;
5. Mixed-mode supply chain of processed fruits;
6. Order-driven supply chain of processed fruits.

Below, the diagrams of two contrasting templates are introduced to illustrate the concept: a traditional anticipatory supply chain of fresh fruits (first template) and an order-driven supply chain of processed fruits (last template).

Figure 21 shows the template Thread Diagram of a fresh fruit supply chain in which a fruit producer brings its harvest to an auction. The fruits are sold to a retailer that stores the fruits in a central Distribution Central (DC) until local supermarkets call them off.

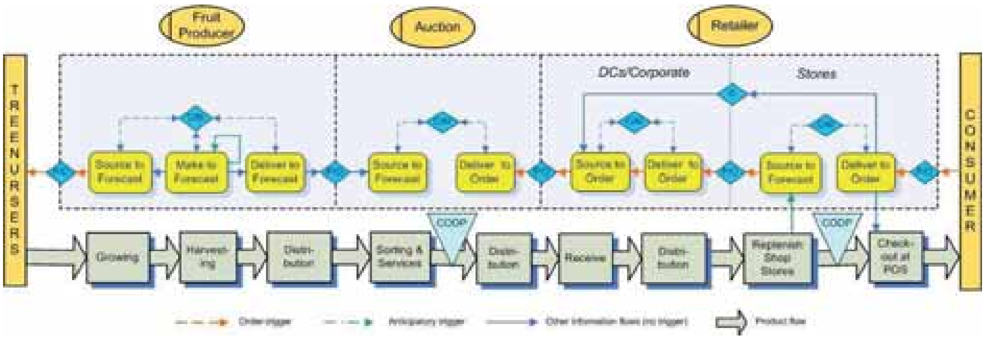

Figure 21 Thread Diagram Template of an anticipatory supply chain configuration for fresh fruits

The involved actors are presented at the top of the figure. At the bottom, the product flows are visualised. CODPs (the triangles) indicate to what extent the transformations are order-driven. Next, the centre of the diagram depicts a network of business control cases (the rounded rectangles) and coordination mechanisms (the diamonds). The figure shows that checkout at the Point of Sales is driven by consumer orders. The corporate purchasing department of the retailer combines the replenishment orders of all local stores and sources the requested fruits at the auction. The fruit grower is fully anticipatory, *i.e.* sourcing, production and distribution are all to forecast. The auction washes, sorts, grades and sells the fruit. Fruit that cannot directly be sold is stored in a controlled atmosphere warehouse. In this example, demand information is only exchanged within the retailer among local stores and the corporate departments.

A second template is shown in Figure 22. The diagram models a supply chain for processed fruits that is managed by a central orchestrator. This company has long-term contracts with all involved actors and is responsible for exchange of demand and supply information in the entire supply chain. Also replenishment of the shop stores is done by the orchestrator (VMI: Vendor Managed Inventory).

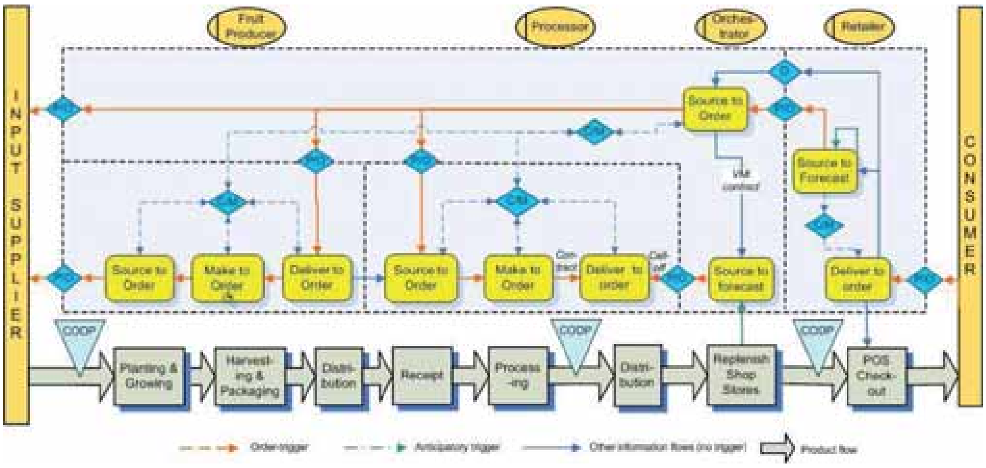

Figure 22 Thread Diagram Template of an order-driven supply chain configuration for processed fruits, supplied via Vendor Managed Inventory (VMI)

The orchestrator has a central role in this diagram. It concludes long-term contracts with growers that specify detailed requirements including the production techniques to be applied, the input material to be used and the packaging and labels to be added (deliver-, make- and source-to-order). The orchestrator also has similar contracts with a number of processors. Based on these contracts, the orchestrator aligns the planning of the fruit producers and processors (capacity and material coordination). The processors transform the fruits in products that can be stored for a long period of time. The orchestrator has a VMI contract with the retailer. This implies that the orchestrator has access to the retailer's inventory data and is responsible for maintaining the agreed inventory level.

4.6.3 Fruit Reference Business Process Diagrams

The basic building blocks of Main Business Process Diagrams are adopted from the level 3 processes of SCOR (SCC, 2008c) for modelling main processes, although some refinements were implemented. For example: the Make-to-Stock process variant of SCOR comprises the following level 3 activities: Schedule Production Activities, Issue Product, Produce and Test, Package, Stage Product, and Release Product to Deliver. The building blocks of Sub Business Process Diagrams are identified based on the case study analysis of specific process characteristics in fruit supply chains (see appendix G):

- *Fruit Production*: planting; monitoring tree, crop, weather and field condition; pruning; fertilizing; crop maintenance; irrigating; field maintenance; plant protection; harvesting; sorting and quality control;
- *Fruit Processing*: generate recipe and production order; receipt and quality control of fresh fruits and non-fruit ingredients; washing and sorting; pre-process treatment (such as peel, core, macerate, deseed, pulp and steam/blanch); produce dried fruits, canned fruits in syrup, jam, juice, prepared fruits; cool; and quality control processed fruits.

In the model, a Main Business Process Diagram of every business control case is pre-configured, *i.e.* one template per applicable SCOR process category (see Table 6). Next, template sub models are modelled for fruit production and fruit processing.

Table 6 Overview of the templates for Main Process Diagrams, based on SCOR (SCC, 2008c)

	To Order	*To Forecast*
Deliver	D1 Deliver Stocked Product D2 Deliver Make-to-Order D3 Deliver Engineer-to-Order Product D4 Deliver Retail Product	D1 Deliver Stocked Product (excluding first two activities)
Make	M2 Make-to-Order M3 Engineer-to-Order (excluding first activity)	M1 Make-to-Stock
Source	S1 Source Stocked Product S2 Source Make-to-Order Product S3 Source Engineer-to-Order Product S4 Source Retail Product	S1 Source Stocked Product S2 Source Make-to-Order Product S3 Source Engineer-to-Order Product S4 Source Retail Product

As an illustration, Figure 23 presents the template of a Main Business Process Diagram for Make to Order (M2) using the BPMN notation. It zooms in on the 'Make to Order' control case of the fruit producer (marked with a +-symbol in the Thread Diagram of Figure 22), showing how the different models are interlinked.

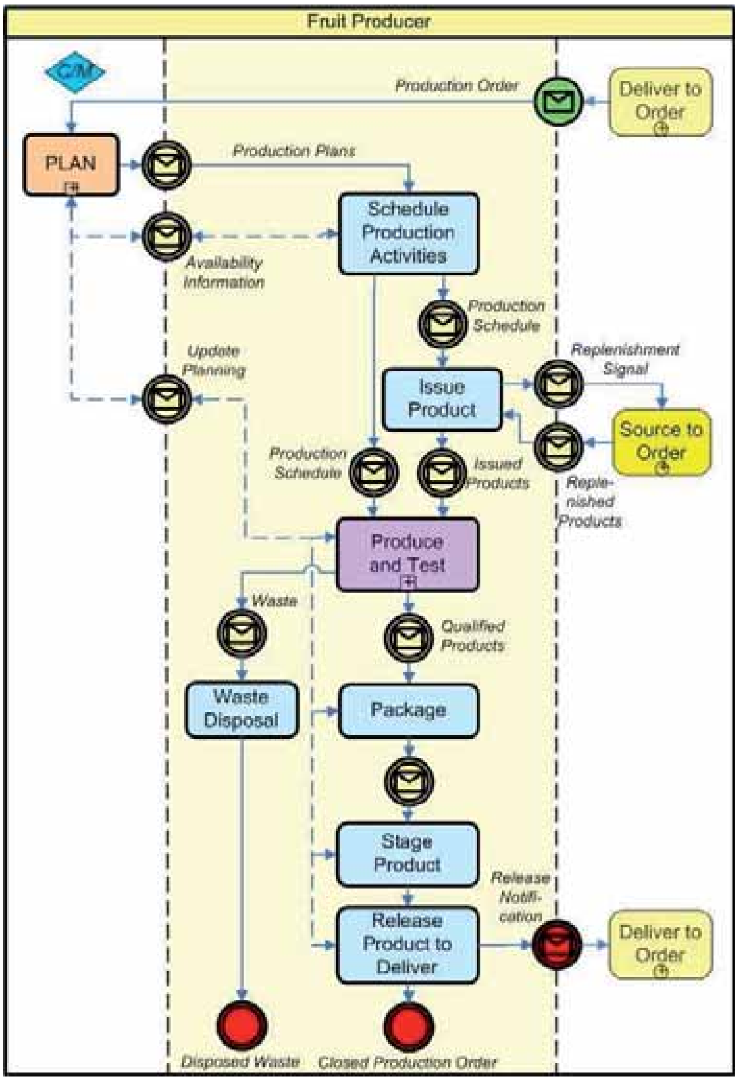

Figure 23 Main Process Model Template for Make to Order (in BPMN notation)

The main process model comprises three vertical swimlanes, *i.e.* separate visual categories that illustrate different functional capabilities or responsibilities (White, 2005). The middle lane is an instantiation of the 'Make to Order' business control case performed by the producer. It is the core of the diagram, and depicts the sequence of activities, the trigger (production order) and the information flows among activities (the message symbols). The activities correspond with the generic make-processes of SCOR (level 3). The other lanes show the adjacent business control cases and coordination mechanisms, as modelled in the parent Thread Diagram. In this template, these are performed by the same producing role, *i.e.* the deliver-to-order and source-to-order cases and the plan coordination mechanism (C/M: capacity and material). Including the different lanes makes it possible to visualise the information flows with control and coordination of related business processes. In this diagram, the interaction with other cases includes exchange of production order (trigger), production plans, and replenishment signals for products to be issued and release notifications of produced products.

One can zoom in from main Business Process Diagrams to various levels of sub process diagrams. Figure 24 illustrates this by showing the template of a sub Business Process Diagram for fruit production. It zooms in on the 'Produce and Test' activity of main process diagram discussed above (block with a +-symbol in middle of Figure 23).

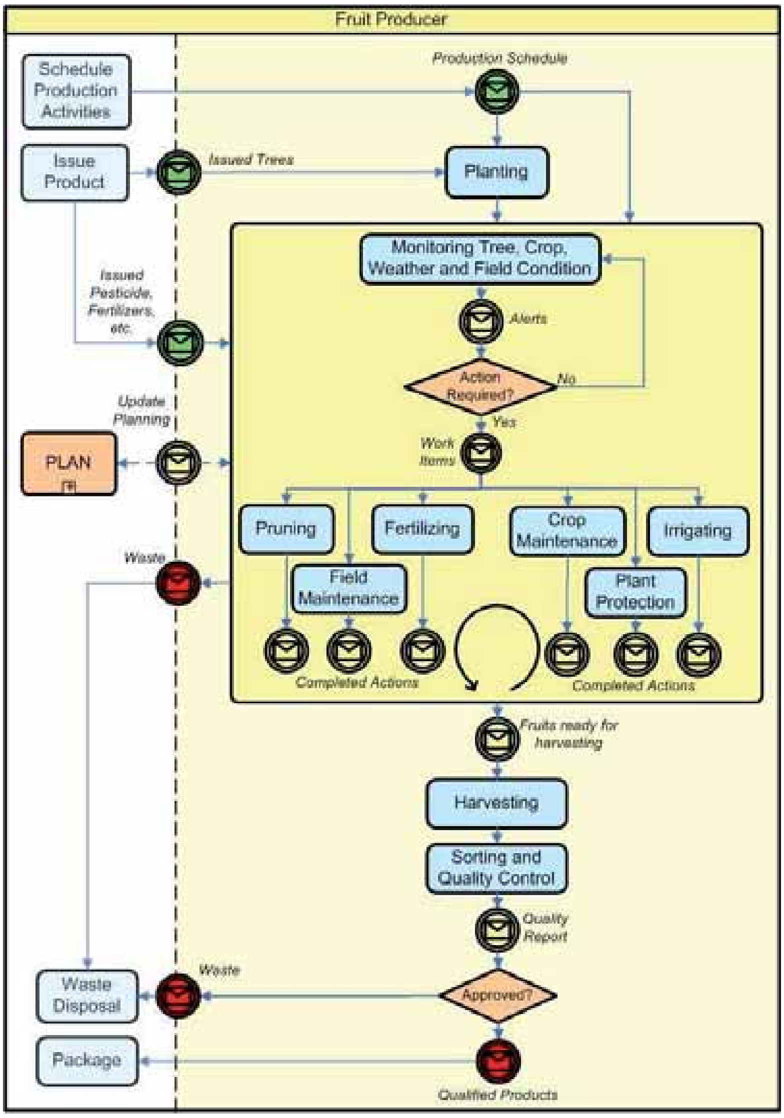

Figure 24 Sub Process Model Template for fruit production (in BPMN notation)

4.6.4 Fulfilment of the basic design requirements

In the previous sections, we introduced a reference process model for demand-driven supply chains. This model meets the requirements as addressed in section 4.5.1 as follows.

First, the reference model comprises a consistent set of process models that intermediate between supply chain design and information systems engineering. High-level Product Flow Models and Thread Diagrams are translated into Business Process Diagrams that in detail depict the information flows among activities in an executable notation (BPMN).

Second, the reference model defines the building blocks that are necessary to model the different process models, describes how specific models can be configured from these building blocks and provides templates of typical fruit configurations. Consequently, the reference model does not prescribe a strict blueprint of the ‘best’ supply chain design (one size fits all), but it supplies managers with a toolkit for the design and implementation of their specific supply chain configurations from a repository of standard building blocks.

Third, the reference model includes Thread Diagrams that depict supply chain configurations as series of order-driven and anticipatory processes connected by coordination mechanisms.

Finally, the reference model supports the fruit-specific features and the diversity of business processes in fruit supply chains as identified in the case study investigation. At the same time, it adopts cross-industry standards in order to reuse knowledge of other branches and to connect to common modelling languages. Table 7 shows how generic and fruit-specific elements are combined in the reference model.

Table 7 From generic to fruit-specific process models

Process Model Type	Framework	Building Blocks	Templates
1. Product Flow Model	Generic	Fruit-specific	Fruit-specific
2. Thread Diagram	Generic	Generic	Fruit-specific
3. Main Business Process Diagram	Generic	Generic	Fruit-specific
4. Sub Business Process Diagram	Generic	Fruit-specific	Fruit-specific

The model layout and configuration method as elaborated in the modelling framework are generic and adopt as much as possible international standards (in particular BPMN for the process diagrams). Moreover, the generic process elements of SCOR are adopted to identify the building blocks of Thread Diagrams and Main Business Process Diagrams. It is found that they fit well to fruit supply chains. The fruit-specific characteristics are covered by the building blocks of Product Flow Models and Sub Business Process Diagrams, and by the pre-configured models (templates).

4.7 Discussion and conclusions

In this section, we will discuss the designed model, identify opportunities for future development and research, and finally summarise the main conclusions.

4.7.1 Discussion

The aim of this chapter was to contribute to the development of reference process models in the fruit industry. Three main contributions of the research can be distinguished.

First, the chapter introduces a reference process model for fruit supply chains. To the best of our knowledge, such a model does not yet exist. The reference model combines fruit-specific knowledge with the reuse of knowledge provided by generic cross-industry standards. The sector-specific and generic knowledge is clearly separated in different reference model elements, which are then consistently integrated (*cf.* Table 7). As a result, the reference model can easily be extended to other sectors.

Second contribution to existing literature is that the designed reference model is setup to enable rapid instantiation of specific supply chain configurations from a repository of standard components. Our reference model provides a systematic classification of the building blocks that are necessary to model the high diversity of supply chain configurations in the fruit-industry. It introduces a new technique to represent supply chain configurations as series of order-driven and anticipatory processes connected by coordination mechanisms. Furthermore, it includes a method that describes how specific configurations can be composed from these building blocks and it contains pre-configured templates of typical configurations in fruit supply chains. We have chosen to model a limited number of templates of typical configurations that together address the basic variety as emerged from the case study. It would be unfeasible to predefine all possible situations in templates, because this would result in a highly complex and unmanageable reference model. At the same time, it must be noticed that a broad variety of configurations can be modelled with the current defined building blocks and users can easily configure own templates from the defined building blocks.

Contrary to most existing supply chain models (*cf.* section 4.3.2), our design does not prescribe a strict blueprint of the ‘best’ supply chain design (one size fits all), but it supports fruit companies in the design and implementation of their specific supply chain configurations. SCOR is the supply chain framework that comes most close to this approach. For modelling specific supply chain configurations, it addresses different process variants for source, make, deliver, plan and return. However, the SCOR model does not make clear how these categories interrelate and what are underlying control systems and coordination mechanisms. It also does not include a method for configuration of specific process models, nor preconfigured templates of typical supply chain configurations. Nonetheless, SCOR provides an authoritative common language for supply chain design that addresses most of the necessary generic process components. Therefore, we used it as a basis of our design.

Third, our model contributes to existing reference models by providing a consistent set of process models that are on the one hand understandable for business managers and on the other hand serve as a basis for information system implementation. As a result, our model intermediates between business process design and information systems engineering. Starting from high-level Product Flow

Models and Thread Diagrams of supply chain configurations, it zooms in on process diagrams that precisely depict the information flows among activities in a notation that can be interpreted by SOA-based information systems (BPMN). Existing supply chain models do only support high level process modelling (Lambert *et al.*, 2005). Also in information systems engineering research there is a growing need for process models that link business process design and systems implementation, especially in the SOA field. Here, the emphasis is shifting from technology towards business aspects, including architectural challenges such as business semantics for service definition, design methodologies for service engineering and business-oriented service composition (Papazoglou *et al.*, 2007, Demirkan *et al.*, 2008). The reference model developed in this chapter contributes to these challenges.

4.7.2 Future developments and research

The designed reference model is based on an extensive case study in four European countries and reviewed in-depth by industry experts. As a result, the research provides solid evidence that the designed model meets the specific requirements to reference process models in demand-driven fruit supply chains. Nevertheless, we foresee some important opportunities for future development and research.

The next step should be to embed the reference model in such a way that business-driven development is ensured while keeping the model manageable and robust. To achieve this, it is necessary that the present reference model functions as a basic design, which is further developed iteratively by pilots, based on business cases to provide proof of concepts (Wolfert *et al.*, 2010). By using the basic design as a starting point, consistency and robustness of single pilots, as well as the reuse of existing knowledge, is ensured. The main opportunities to work on in such an approach are implementation of the model in operational supply chain information systems and extension of the model’s scope.

In particular, two implementation-related issues can be mentioned. First, the developed model comprises process models in BPMN, which makes it a valuable starting-point for implementation of the designed process model in a Service Oriented Architecture (SOA) platform. Future research is needed to further assess how the framework can be used to integrate the information systems of multiple enterprises in a supply chain. Second, the reference model includes a description of the steps to configure specific process models. Ideally, users should be guided interactively through these steps in a wizard-like approach. Based on the resulting configuration choices, the process models should be generated automatically. However, implementation of such an approach is complex. To mention some difficulties: the constraints arising from the actual availability of the required resources should be taken into account, as well as the dependences between configuration choices; it must be possible to inherit configuration choices from the product requirement definition to detailed process diagrams; and configuration choices must be translated into graphical diagrams. Future research is needed to develop tool support for the configuration of process models.

Regarding the model’s scope, it could be researched how the designed reference model can be extended to other processes, such as strategic planning, product development, (collaborative) innovation and marketing. Furthermore, in this chapter, fruit supply chains have been modelled by applying a generic framework. This suggests that the design can easily be extended to other cases and other sectors, but further research is needed to provide evidence for this. Interesting additional questions are how agri-food specific knowledge can be reused in multiple agri-food branches and how the model should deal with connections between branches, for example the supply chain of a mixed fruit and milk drink.

Last but not least, a major future issue is how to institutionalise the model in order to ensure broad commitment and to organise model maintenance and further development. Firms in fruit supply chains could implement the reference model individually. However, there are some important disadvantages of such an individual approach: it is difficult to incorporate implementation experiences of other firms, the overall coherence and consistency as specified in the reference model can easily be lost and the maintenance costs are not shared. Moreover, ensuring the compliance with international standards and further development of the reference model might exceed the level of single firms. Therefore, industry-wide arrangements should be made to stimulate a successful adoption and application of the designed reference model. Local industry platforms are a natural starting point for this, but it should be researched how harmonisation in an international context could be achieved.

We strongly belief that accomplishing these organisational challenges should be the first next step in order to ensure business-driven development of the model and to keep the model manageable.

4.7.3 Conclusions

In this chapter, we have presented a new reference model for designing business processes in fruit supply chains. The model combines fruit-specific knowledge with the reuse of generic knowledge as captured in cross-industry standards. It bridges the gap between supply chain design and information systems engineering by providing a consistent set of process models that are on the one hand understandable for business managers and on the other hand serve as a basis for information system implementation. Contrary to most existing supply chain models, the reference model does not prescribe a strict blueprint of the ‘best’ supply chain design (one size fits all), but it supports fruit companies in design and implementation of their specific supply chain configurations.

Remaining future challenges are the further development and implementation of the designed model. This includes extending the scope to other business processes and sectors and implementation of the model in operational information systems. However, the first next step should be to embed the model in the fruit sector in order to ensure a broad commitment and to organise the model maintenance and further development.

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Chapter 5. Mastering demand and supply uncertainty with combined product and process configuration [15]

Abstract
Key challenge for mastering high uncertainty of both demand and supply is to attune products and business processes in the entire supply chain continuously to customer requirements. Product configurators have proven to be powerful tools for managing demand uncertainty. This chapter assesses how configurators can be used for combined product and process configuration in order to support mastering high uncertainty of both supply and demand. It defines the dependence between product and process configuration in a typology of interdependencies. The addressed dependences go beyond the definition phase, and also include the effects of unforeseen backend events during configuration and execution. Based on a case study in the Dutch flower industry, a conceptual architecture is proposed for coordination of these interdependencies and development strategies are identified.

Keywords: configuration, supply chain management, mass customisation, concurrent engineering, ERP, flower industry

5.1 Introduction

Mastering both demand and supply uncertainty is a key challenge for many companies. Markets are increasingly turbulent and also the vulnerability of production and logistics processes is growing. The management of uncertainty has been addressed as an essential task of supply chain management (among others by Davis, 1993). The well-known bullwhip effect shows that amplification of demand uncertainty can be reduced by supply chain coordination (Lee *et al.*, 1997). There are two main categories of supply chain uncertainties: i) inherent or high frequent uncertainties arising from mismatches of supply and demand, and ii) uncertainties arising from infrequent disruptions to normal activities such as natural disasters, strikes and economic disruptions (van der Vorst and Beulens, 2002, Kleindorfer and Saad, 2005, Oke and Gopalakrishnan, 2009). This chapter is concerned with the first category of uncertainties, which can either be demand or supply related (Lee, 2002).

For coping with the addressed uncertainties, Supply Chain Management (SCM) literature initially has focused on creating so-called lean supply chains that efficiently push products to the market. Lean supply chains build upon reduction of demand uncertainty, especially by product standardisation. Customers must choose from a fixed range of standard products that are made to forecast in high volumes. Business processes in lean supply chains can be highly automated by ERP systems (Davenport and Brooks, 2004).

In the late 1990s, the then dominant approach of leanness was criticised more and more. It was argued that in volatile markets it is impossible to remove uncertainty. Companies therefore should accept differentiation and unpredictability, and focus on better uncertainty management. Agility was proposed as an alternative approach that aims for rapid response to unpredictable demand in a timely and cost-

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effective manner (Fisher, 1997, Christopher, 2000). It is founded on a mass customisation approach that combines the seemingly contradictory notions of flexible customisation with efficient standardisation (Davis, 1989, Pine *et al.*, 1993, Chandra and Kamrani, 2004). This by fabricating parts of the product in volume as standard components, while achieving distinctiveness through customer-specific assembly of modules (Duray *et al.*, 2000).

Besides product modularity and flexible assembly systems (*cf.* Molina *et al.*, 2005), product configurators are addressed as important enabling technologies (Duray *et al.*, 2000, Zipkin, 2001, Forza and Salvador, 2002). Product configurators provide an interface for rapid and consistent translation of the customer's requirements into the product information needed for tendering and manufacturing (Sabin and Weigel, 1998, Forza and Salvador, 2002, Tseng and Chen, 2006, Reinhart *et al.*, 2009).

Until then, SCM focused on strategies for coping with demand uncertainty. Lee (2002) was one of the first who stressed the impact of supply uncertainty on supply chain design. Supply chains characterised by high supply uncertainty require the flexibility to deal with unexpected changes in the business processes. Disturbances of logistics, production or supply of materials should rapidly be observed and lead to process changes including re-planning and re-scheduling, purchasing new material, hiring alternative service providers, or negotiating new customer requirements. The rigid planning and scheduling systems of traditional ERP systems may cause problems in this type of supply chain (Akkermans *et al.*, 2003, Zhao and Fan, 2007). Modular software approaches, in particular Service-Oriented Architecture (SOA), have been proposed to overcome these limitations. In these approaches, process models guide the workflow planning and execution in run-time information systems. This puts the emphasis on process configuration to achieve the required backend flexibility. Process configuration supports a rapid and consistent specification of the workflow that is needed to fulfil specific customer orders (Schierholt, 2001, and others). For example, local deliveries from stock follow a different workflow than exports that are produced to order. Moreover, it supports reconfiguration of the workflow in case of unexpected supply events, *e.g.* components that were originally planned to be produced can be re-planned to be purchased.

Supply chains characterised by both uncertain demand and supply require a combination of responsiveness to changing demand and the flexibility to deal with unexpected changes in the business processes. Following Lee (2002), we use the term agility to characterise these types of supply chains. In agile supply chains, demand requirements and supply capabilities, *i.e.* products and processes including resources, should be continuously attuned. Therefore, both front-office and back-office systems need to be flexible and smoothly integrated. This chapter explores the application of configurators to both products and processes to achieve this.

The majority of the existing configuration research focuses either on product or process configuration. However, interdependence among product and process configuration is relatively under-researched (*cf.* Jiao *et al.*, 2007, Chandra and Grabis, 2009). A literature review, which is presented hereafter, shows that available literature on this subject focuses on the definition domain, *i.e.* translation of customer requirements to an integrated design of products and manufacturing processes (Jiao *et al.*, 2000, De Lit *et al.*, 2003, Jiao *et al.*, 2005, Bley and Zenner, 2006). However, the presence of supply uncertainty results in a high mutual dependence also after the definition phase. During configuration and execution, the effects of unforeseen backend events on the defined product and fulfilment processes must continuously be evaluated based on the actual state of the required resources. No research is found that provides an integrated consideration of the interdependences during definition, configuration and execution, neither that develops the corresponding information architecture for coordination of this interdependence using configurators.

The present research aims to contribute to this gap by assessing how configuration software can be used for combined product and process configuration to support mastering high uncertainty of both supply and demand. More specific, it aims to i) identify the interdependences between product and process configuration, ii) design an information architecture for coordination of this interdependence using configurators, and iii) identify configurator development strategies. Focus is on the order fulfilment cycle that starts with configuring orders in interaction with customers and ends with delivering the finished goods (Lin and Shaw, 1998, Croxton, 2003).

In the remainder of this chapter, we first give an account of the applied research method. Next, we introduce the problem context of the case study firm, which is a typical example of a company operating in agile supply chains. Subsequently, an overview is provided of the literature about the use of configurators for products and processes, and we define a typology of its interdependencies. The case-study results are then presented. The chapter concludes with addressing challenges for future development and summarising the main findings.

5.2 Research method

The research used a design-oriented case study method to answer the research question addressed in the introduction. Design-oriented research aims to develop a body of generic knowledge that can be used in designing solutions to management problems (Van Aken, 2004). It is a foundational methodology in information systems research (Hevner *et al.*, 2004). Design-oriented research is typically involved with ‘how’ questions, *i.e.* how to design a model or system that solves a certain problem. A case study strategy fits best for this type of questions, in particular in case of complex phenomena that cannot be studied outside its context (Benbasat *et al.*, 1987, Yin, 2002). This characterises the present research, because it focuses on the interdependences between product configuration, process configuration and the planning and control of fulfilment. Therefore, we have chosen for an in-depth explorative case study research that puts the different related topic areas into context. In such a case study, it makes sense to focus on an extreme situation that clearly highlights the process of interest (Eisenhardt, 1989, Yin, 2002). In present research, this is the existence of supply uncertainty in addition to demand uncertainty. Therefore, we searched within a sector that is inherently involved with high supply uncertainty, *i.e.* the Dutch flower industry. Firms in this sector face high supply uncertainty because of the dependence on the growth of living materials. Production processes are, therefore, vulnerable to weather conditions, pests and other uncontrollable factors. Next, we selected a firm within this sector that was characterised by high demand uncertainty. Additional criteria were product variety and practical reasons, in particular the firm's willingness to cooperate and the authors' familiarity in the domain.

Data collection is done in semi-structured open interviews with managers and employees of the case company, and additional desk research. In total, 14 persons have been interviewed in 9 interviews (5 managers and 9 employees). Division of roles:

- Management: Sales (1), Finance (1), Logistics (1), Production (1), CEO (1);
- Employees: Order Processing (1), Planning (2), Expedition (1), ICT (1), Production Seedlings (2), Production Cuttings (2).

The questionnaire comprises four main parts: supply chain structure, business processes, control and information management. Every section includes open questions both for mapping and evaluation (see appendix C). Three in-depth interviews were held covering the complete questionnaire. The subsequent interviews focused on specific business processes and were combined with observation of the company's operations and systems.

The research was organised as follows. First we defined the dependence between product and process configuration in a typology of interdependencies based on literature review. Second, the case-study firm was investigated in interviews and additional desk research. Next, the investigation results were matched with the developed theoretical framework to define the basic design requirements. The researchers then designed a conceptual information architecture for combined support of both product and process configuration. The designed architecture was tested in a Proof of Feasibility implementation at Sofon, a Dutch configurator vendor, and evaluated by the management of both the case-study firm and Sofon. Finally, general development strategies were abstracted from the case findings based of the developed theoretical framework.

5.3 Configuration in the Dutch flower industry

This section introduces the case firm and its need for product and process configuration.

5.3.1 Dutch flower industry

The Dutch flower industry is traditionally a strong and innovative sector with a leading international competitive position and a great impact on the national economy. It is internationally renowned as a strong cluster (Porter, 1998) that produces cut flowers and potted plants, mainly in greenhouses. Particularly production of potted plants has many similarities with manufacturing. It is also a form of discrete production, in which products are assembled from plants, flowerpots, decorations, labels and packaging. Fabrication of potted plants also has some features of continuous production, because of the process of continuous growth, but potted plants remain discrete units, traceable at single product level.

The extent to what processes are order-driven differs a lot, not only among different companies but also within firms. For the spot market, products are made to stock and distribution is either to order (usually via traders) or anticipatory (usually via auctions). For other cases, plants are often produced to forecast, while assembling, labelling and packaging are order-driven.

The flower industry is characterised by high uncertainty of both demand and supply. Supply uncertainty is high, because chains are vulnerable to product decay, weather conditions, pests, traffic congestion and other uncontrollable factors. Further, also demand uncertainty is high amongst others because of weather-dependent sales, changing consumer behaviour, and increasing global competition. This results in high variability of supply capabilities and demand requirements in terms of volume, time, service levels, quality and other product characteristics.

5.3.2 Case company profile

The case company is a global supplier of a wide range of young potted plants. It is a rapidly growing company, with 350 staff and with production locations in Holland, Brazil, Kenya, Israel and Zimbabwe. Annually, over 100 million young plants are delivered as input material to growers or wholesalers.

The firm is characterised by high product variety. It produces about 800 varieties in six main categories, including Begonia and Cyclamen. Besides, over 400 varieties are sourced from other producers to offer a complete assortment. Varieties differ, among others, in colour, shape, and growing characteristics. The firm propagates young plants in two basic ways: as seedlings or cuttings. Seedlings can be sold at different stages of the growing process. Cuttings can be sold rooted or unrooted; and in different sizes. All young plants can be delivered in different types of trays. Furthermore, delivery conditions vary. For example: due to product-inherent characteristics, some varieties can only be delivered in specific periods, and quality and prices are often time-dependent. Furthermore, royalties differ per variety and per continent.

Also process variety is high. Production differs between seedlings and cuttings. For seedlings, seeds are sourced from breeders, seeded in trays and budded. Budded seeds can be sold directly or grown further. Seedlings are mostly seeded to customer order, but also produced to forecast or sourced to order (especially for specific variety mixtures). Cuttings are mostly produced by the firm, but are also sourced from third parties. Production of cuttings starts with propagation and growing of parent plants, which is done in southern countries for reasons of climate and labour costs. After almost two years, cuttings can be harvested. They are shipped directly to customers, or transported to Holland for rooting. Unrooted cuttings can be stored for 10 days at the most, including 3 days for transportation. The company strives for order-driven harvesting and rooting of cuttings, but production to stock also occurs. Furthermore, logistics are complex, due to the global distribution of both production locations and customers, combined with high requirements concerning delivery lead-times and flexibility.

5.3.3 Need for combined product and process configuration

The interviews indicated that the case company is characterised by high uncertainty of both demand and supply. Demand requirements (about product features, quality and service levels) are diverse and difficult to predict. Also predictability of the demand amount and time is low, although basic seasonable patterns can be determined. Moreover, the lead-times, yields and qualities of production very much depend on the growth of living materials.

The company deals with this high uncertainty by providing variety in their product assortment and flexibility in meeting customer demands with respect to product specifications and delivery schedules. To date, it has relied heavily on improvisation by experienced employees. However, since the company is growing, they face problems in keeping this manageable, which set limits to further growth. As a consequence, the interviewees in particular stressed the lack of tools for customer requirement definition based on real-time information of the supply capabilities, as well as flexible back-office systems for (re)planning, (re)scheduling and monitoring of order fulfilment. The addressed most urgent bottlenecks are:

- Knowledge of production processes and options to reconfigure these processes is only implicitly available in the minds of some experienced staff members. This problem is manageable with the firm's current scale, but inhibits further growth.
- Information systems are fragmented and poorly integrated. They require a lot of manual data re-entry. Information inconsistency leads to larger safety buffers than strictly required, and many redundant data checks and duplicate registrations are performed.
- Mid-term planning is not coordinated with operational data, due to a lack of system integration.

The company's management assessed existing ERP systems for solving these problems, but evaluated them to lack the required flexibility. Therefore, the firm decided to consider implementation of configuration software for products and processes, in combination with an ERP system, as possible option to master uncertainty.

5.4 Role of configurators in supply chain management

This section provides some conceptual background about the use of configurators and defines the dependence between product and process configuration in a typology of interdependencies.

5.4.1 Product configurators in responsive supply chains

Configurators have emerged from the development of rule-based product design in the field of Artificial Intelligence. A well-known early application was R1, a product configurator for VAX computers (McDermott, 1981). A product configurator is a tool that guides users interactively through specification of customer-specific products (Sabin and Weigel, 1998, Forza and Salvador, 2002, Tseng and Chen, 2006, Reinhart *et al.*, 2009). Configurators generate specific product variants by combining sets of predefined components and specifying features according to permitted values. Next, they check the completeness and consistency of configured products based on rules that define the interdependencies between components or features. Product configurators are based on generic product models, which define the class of objects that can be configured (Hegge and Wortmann, 1991).

Currently, configurators play an important role in responsive supply chains, which are characterised by high demand uncertainty and low supply uncertainty (Lee, 2002). They are widely used for product configuration to enable rapid response to customer demands. In interaction with the user, the software generates consistent and complete specifications of customised products, taking into account both customer's requirements (*e.g.* functional specifications and delivery conditions) and feasibility of production, sourcing and delivery. Along with the product specification, current configurators can produce commercial offers and draft contracts, and schedules and contracts for support and maintenance of the product. The software can be designed for use either by a sales representative of the supplier, or by a customer, *e.g.* through the internet. In both cases the configuration process results in a quick and effective order specification that can directly be entered into the production planning and scheduling systems.

5.4.2 Configuration in agile supply chains

Next to demand uncertainty, agile supply chains are also characterised by high uncertainties at the supply-side (Lee, 2002). High supply uncertainty makes great demands on the flexibility of supporting information systems. The development of modular software approaches especially has been advocated for realizing this flexibility (for example Verwijmeren, 2004). Service-Oriented Architecture (SOA) is the latest development in software modularity (Wolfert *et al.*, 2010). In a SOA approach, business process models are leading in routing event data amongst multiple application components that are packaged as autonomous, platform-independent services (Erl, 2005, Papazoglou *et al.*, 2007). Consequently, new or adapted business processes can be supported without changing the underlying software. Induced by the emergence of Service-Oriented Architecture, also ERP vendors have commenced to modularise their software (Møller, 2005, Loh *et al.*, 2006).

The leading role of business processes in modular software approaches puts emphasis on rapid configuration of processes in achieving flexibility. The concept of process configuration is introduced by Schierholt (2001), who applied the principles of product configuration to support process planning. Rupprecht *et al.* (2001) and Zhou and Chen (2008) described approaches for automatic configuration of business process models for specific projects. Jiao *et al.* (2004) formalised the modelling of process configurations for given product configurations. Verdouw *et al.* (chapter 2 of this thesis) argue that reference process models should be set-up as dynamic configurable models to enable ICT mass customisation and they assess the readiness of existing models. Furthermore, the ERP vendor SAP has addressed process configuration to manage the complexity of their reference process models that are used as a basis for system implementation. They conducted extensive research to make these models configurable (Dreiling *et al.*, 2006, Rosemann and van der Aalst, 2007). Building upon this, La Rosa *et al.* (2007) proposed a questionnaire-driven approach to guide users interactively through process model configuration.

Nevertheless, the majority of existing literature focuses either on product or on process configuration. The mutual dependence between product and process configuration is relatively under-researched (*cf.* Jiao *et al.*, 2007, Chandra and Grabis, 2009). The papers, found in our literature review, all focus on the definition domain, *i.e.* translation of customer requirements to an integrated design of products and manufacturing processes. Jiao *et al. (2000)* put forward an integrated product and process model that unifies Bill-of-Materials and routings, called generic Bill-of-Materials-and-Operations. Jiao *et al.* (2005) proposed a product-process variety grid to unify product data and routing information. De Lit *et al.* (2003) introduced an integrated approach for product family and assembly system design. Bley and Zenner (2006) developed an approach to integrate product design and assembly planning.

As argued before, the presence of supply uncertainty results in a high mutual dependence also after the definition phase. During configuration and execution, the effects of unforeseen backend events on the defined product and fulfilment processes must continuously be evaluated based on the actual state of the required resources. However, no research is found that explicitly considers the interdependences during definition, configuration and execution, and that develops the corresponding information architecture for coordination of this interdependence using configurators. Therefore, in next section we first develop a typology of product and process interdependences based on organisational literature.

5.4.3 Typology of interdependences between product and process configuration

Dependence is a central notion of the General Systems Theory. This theory argues that the whole of a system is more than its parts, because of the existence of dependencies between their elements (Bertalanffy, 1950). Thompson (1967) was one of the first to apply this idea to organisational theory. He distinguished three basic types of dependency: pooled, sequential and reciprocal interdependence, which require different coordination modes: coordination by standardisation, by plan and by mutual adjustment. His work is refined by many others, all focusing on coordination of generic dependencies between organisational subunits. Malone and Crowston (1994) have introduced different types of dependencies between activities and resources. They distinguish between flow, sharing and fit dependencies (see also Malone *et al.*, 1999). Flow dependencies arise whenever one activity produces a resource that is used by another activity (precedence relation). Sharing dependencies occur whenever multiple activities all use the same resource. Fit dependencies arise when multiple activities collectively produce a single resource.

If we apply these interdependencies to product and process configuration, distinction should be made between different decision levels, *i.e.* definition, configuration and execution. First, in the *definition* phase designers predefine reference product and process models. These are generic models, or family models, which define the possible product and process components, and that include rules that define the possible combinations of components. A product reference model is constrained by the available business processes as defined in process reference models. Vice versa, a process reference model must contain the business processes that produce the variety of products as defined in product reference models. Second, the *configuration* phase starts when a customer order request comes in. A customised product is configured in interaction with the customer, and taking into account whether the enabling business process can be configured. Therefore, the required input products and capacity must be available to promise. The result is an accepted order, which triggers configuration of the business processes that fulfil the order. These might include distribution activities (Make to Stock), and production activities (Assemble / Make to Order), and engineering activities (Engineering to Order). Last, the *execution* phase comprises planning, scheduling and completion of the configured business processes. The progress is monitored continuously and if necessary the product and process configurations are updated.

Figure 25 more precisely defines the interdependence among product and process configuration in a typology of dependencies. This typology is an application of the categorisation of Malone and Crowston (1994) and Malone *et al.* (1999) as discussed above.

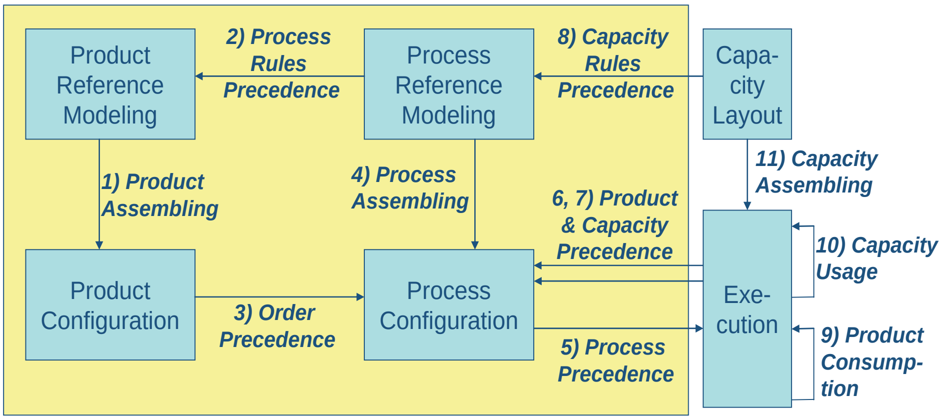

Figure 25 Interdependencies for combined product and process configuration

Product configurators are primarily means for coordination of fit dependencies: assembling consistent product variants that meet specific customer requirements from available components and options. Analogously, process configuration coordinates the assembly of consistent process variants from available activities or services. The alignment of product and process configuration requires coordination of precedence (flow) dependencies: process configuration is conditional for product configuration and vice versa. Furthermore, process configuration depends on operational execution because fulfilment of the configured process needs capacity and input products. More specific, the defined interdependencies are:

(1) *Product Assembling:* multiple product modules are required to produce a single product (fit dependency). Product configurators are primarily means for coordination of this dependency. They specify components, options, interfaces and interdependency rules in reference product models and guide customer-specific configuration of product variants.
(2) *Process Rules Precedence*: process properties set constraints to possible product configurations. Consequently, process reference models are a precondition for product reference models (flow dependency). This dependency is mostly coordinated by mutual adjustment of product and process models by designers, ideally supported by tools that ensure consistency of both model types.
(3) *Order Precedence*: specific product configurations (order information) are input for configuration of specific fulfilment processes (flow dependency). Therefore, order

information must be interpretable by back-office systems for production and distribution. This dependency can be coordinated by standardisation of order data in an executable form, including Bill-of-Materials.

(4) *Process Assembling*: multiple activities, *i.e.* process modules, are required to compose a single process (fit dependency). Process configuration is primarily a mechanism to coordinate this dependency. It specifies the activities, interfaces and interdependency rules in reference process models and guides configuration of order-specific processes.

(5) *Process Precedence*: the output of the process configuration task is conditional for the planning and scheduling of the fulfilment (flow dependency). Execution of a configured process consumes input products (raw material or semi-finished products) and uses capacity. This dependency can be coordinated by standardisation of configured processes in a model format that is interpretable by planning and scheduling systems.

(6) *Product Precedence*: for execution of a fulfilment process, the required input products must be available (flow dependency). This dependency can be coordinated by integration with planning and scheduling mechanisms.

(7) *Capacity Precedence*: for order-driven processes, the required capacity must be available (flow dependency). This can be coordinated by integration with planning and scheduling mechanisms.

(8) *Capacity Rules Precedence*: the characteristics of used capacity (*e.g.* machine setup, other facility layouts, and human resource competences) set constraints for the possibilities for process configuration (flow dependency). This can be coordinated similarly to Process Rules Dependencies: mutual adjustment of capacity layouts and process models by designers ideally supported by tools that ensure model consistency.

The last dependencies to be mentioned are related to operational execution of configured processes:

(9) *Product Consumption*: multiple configured processes all use the same input products (sharing dependency).

(10) *Capacity Usage*: configured processes for multiple orders all use the same capacity (sharing dependency).

(11) *Capacity Assembling*: multiple capacity units are required to set up specific layouts (fit dependency).

These last three dependencies are coordinated by planning and scheduling systems. They do not directly impact product and process configuration (only via product, capacity and process precedence's) and are thus beyond the scope of this chapter.

5.5 Information architecture for combined product and process configuration

This section describes a conceptual information architecture for combined support of both product and process configuration, including a Proof of Feasibility implementation in a configurator.

5.5.1 Basic design requirements

The uncertainty of both demand and supply of the case company is high, as section 5.3 demonstrates. Demand requirements (about product features, quality and service levels) are diverse and difficult to predict. Also predictability of the amount and time is low, although basic seasonable patterns can be determined. Moreover, the lead-times, yields and qualities of production very much depend on uncontrollable factors.

In order to make this variability manageable, the solution to be designed must support coordination of the high interdependence between the company's products and processes during:

- *Definition*: it must be possible to define integrated reference models, which cover the variety of the firm's products and enabling processes, and that take into account the constraints arising from its specific process characteristics;
- *Configuration*: it must be possible to configure customised products and the accompanying processes, in interaction with the customer and taking into account whether the required input products and capacity are available to promise;
- *Execution*: it must be possible to implement the configured business processes in the company's backend systems, to monitor its progress and update product and process configurations if necessary.

More specifically, these basis requirements imply that the design must support coordination of the dependences as developed in previous section. Table 8 identified these dependencies for the case company by matching the investigation results with the defined typology. The remainder of this section develops a corresponding information architecture, including a Proof of Feasibility implementation in the configurator Sofon.

Table 8 Important configuration-related dependencies of the case company that should be supported

Type (see Figure 25)	**Dependencies**
1) Product Assembling	• Possible size of cuttings depends on variety • Colour and growing characteristics differ per variety • Possible tray type depends on variety and maturity • Applicable category of the royalties depends on variety and customer country • Product information differs per variety (*e.g.* growing characteristics) and customer (*e.g.* barcode)
2) Process Rules Precedence	• Required delivery time must be equal to or more than the summed lead-times of order-driven processes (about 14 weeks for seedlings, 5-6 weeks for rooted cuttings, 10 days for unrooted cuttings) • Several varieties can only be delivered during a specific season • Price depends on delivery week because of seasonable production • Import regulations, including phytosanitary requirements, differ per country
3) Order Precedence	• Configured order for cuttings triggers configuration of the propagation process • Configured order for seedlings determines mixture of seeds to be sourced
4) Process Assembling	• Scope of activities for order fulfilment depend on the extent to which processes are order-driven • Type of production activities to be configured differs for seedlings and cuttings • Type of distribution activities to be configured depends on country of destination (for example: road, rail or air freight, and different requirement to shipping documentation) • Quality control and registration activities depend on required quality management certificate
5) Process Precedence	• Configured rooting process triggers greenhouse planning & scheduling • Transportation activities in the configured process determine types of logistical service provider to be reserved • Registration activities in the configured process guide data entry

Type (see Figure 25)	Dependencies
6) Product Precedence	• Seed availability of specific varieties constrains order-driven seeding • Condition of parent plants determines possibilities for order-driven rooting
7) Capacity Precedence	• Availability of greenhouse space determines possibilities for configuration of rooting activities in the cuttings order fulfilment • Availability of air freight capacity constrains configuration of transportation of harvested cuttings
8) Capacity Rules Precedence	• Location of greenhouse capacity determines location of rooting process • Availability of educated personnel determines possibility and location of production of unrooted cuttings
9) Product Consumption	• Available parent plants constrains the amount of cuttings that can be harvested • Available seed constrains the amount of seedlings that can be seeded
10) Capacity Usage	• Total greenhouse capacity constrains the amount of cuttings that can be rooted and seedlings that can be budded synchronously, consequently capacity shortage for an urgent order might result in rescheduling another order
11) Capacity Assembling	• Equipped personnel, machines and greenhouse space must interact effectively to execute configured processes

5.5.2 Information architecture for product configuration

Sofon Guided Selling is a model-based product configurator. It provides functionality for the definition of questionnaires that guide users interactively through requirements specification and translate this information to product configurations in the form of Bills-of-Materials, quotation calculations, visualisations and document generation. Most users utilise Sofon as a front-office system, in combination with an ERP system for the back-office. Figure 26 illustrates the underlying information architecture.

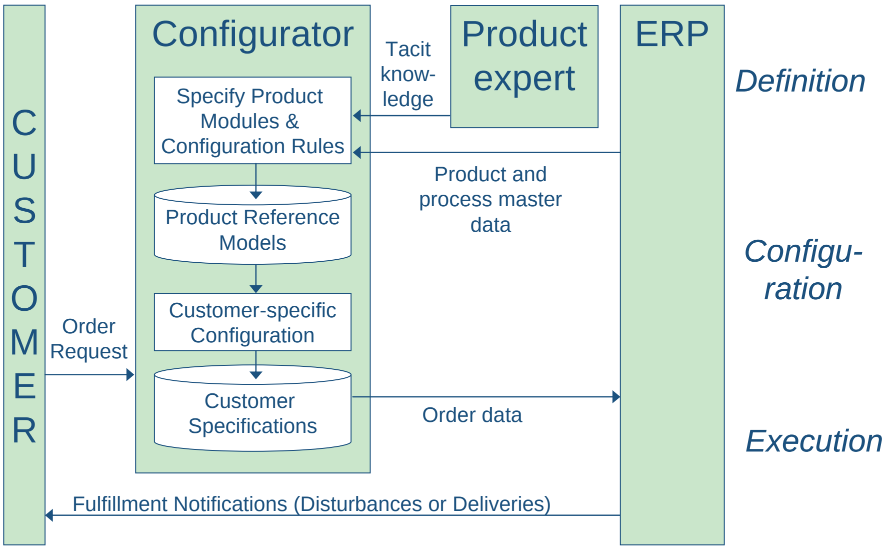

Figure 26 Product configuration in a responsive environment

The focus is on coordination of Product Assembling dependencies. Therefore, functionality is provided to specify the product range, possible features, and rules that define permitted selections in reference product models. Additionally, other order specifications such as delivery dates can be defined here. Product experts can enter configuration rules into the configurator's repository. Product data (Bill-of-Materials, part numbers, prices) and process data (routing, lead times, production cost) can be copied from ERP master data, to ensure that production orders will be in terms that can be interpreted by ERP systems (Process and Capacity Rules Precedence).

Questionnaires are then generated that guide configuration, either directly by the customer or through a sales representative. The configured product and other customer specifications (orders, Bill of Material) are generated in a format that can be executed by ERP systems (Order Precedence). Also, basic order-specific routings can be generated that serve as a basis for planning and scheduling (Process Precedence).

For the case firm, the reference product model includes product categories (including Begonia and Cyclamen), specific varieties and product features, such as budded seeds or grown up, cutting size, rooted or unrooted, possible tray types, delivery conditions and royalty types. Figure 27 presents a simplified example in Sofon.

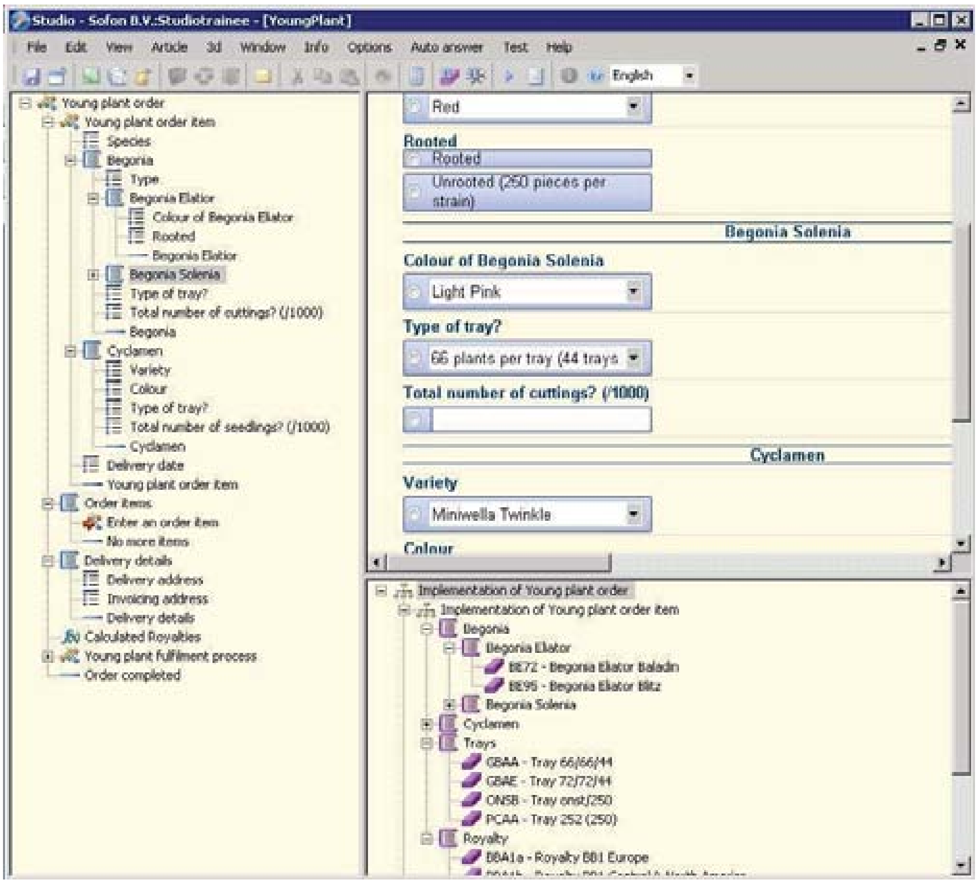

Figure 27 Illustrative case-firm implementation of product configuration

The figure shows that the generic model is defined in two ways. The main part is the definition of wizard-like questionnaires in the language of customers. The generic questionnaire is defined to the left of the screen and possible answers are shown to the top-right of the screen. At the bottom, the product model is specified as a generic Bill-of-Materials (BOM) that is executable by ERP systems. During configuration, selections made in the questions are specified automatically into this BOM. For example: based on the selection of the colour red, the variety ‘Begonia Elatior Baladin’ is defined (see figure 27: article code BE72).

5.5.3 Information architecture for combined product and process configuration

Currently, configurators such as Sofon focus on product configuration in the responsive segment. Agile supply chains require combined product and process configuration. Two essential differences can be distinguished: i) introduction of process configuration between product configurators and planning and scheduling systems, and ii) dynamic alignment of resulting interdependencies. In the case study, Sofon was used to develop an information architecture for this and to evaluate the feasibility of configurators. Figure 28 shows the resulting conceptual model.

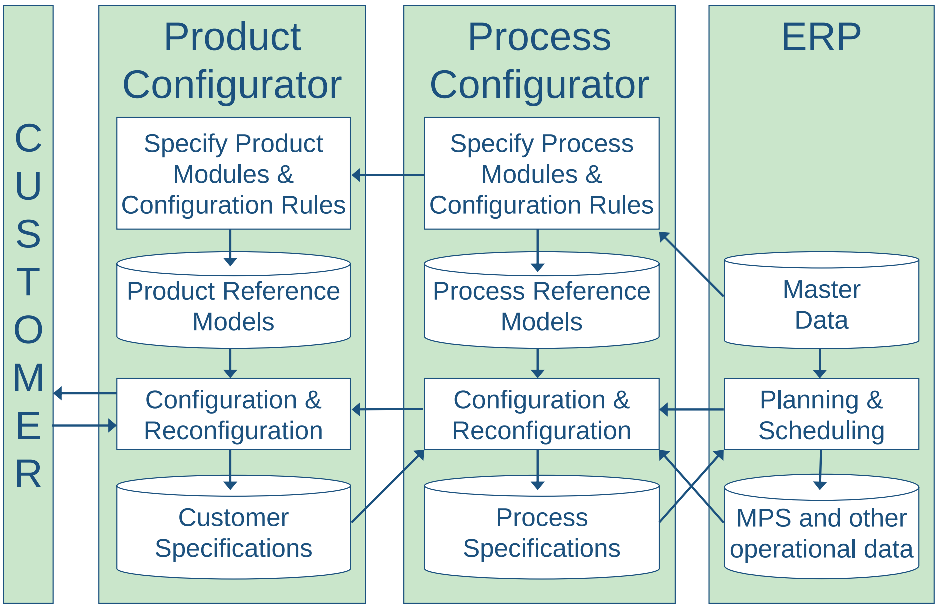

Figure 28 Combined product and process configuration in an agile environment

Analogous to product configuration, the focus of process configuration is on the coordination of Process Assembling dependencies, *i.e.* to assemble specific order fulfilment processes from multiple activities (process modules). Therefore, standard process models can be specified and the composition of customer-specific processes can be guided by configurator tools. However, the important difference with product configuration is that most information required for process configuration is available in the system. Two important information sources can be distinguished for process configuration: customer orders (output of product configuration) and availability of required input products and capacity (output of ERP back-office system). Neither of

these types of information needs to be specified manually during process configuration.
Although Sofon focuses on companies in the responsive segment that do not face high supply uncertainties, the tool can be applied to configure processes in the same way that it is used to configure products. Figure 29 presents an example for the case company using Sofon's existing functionality.

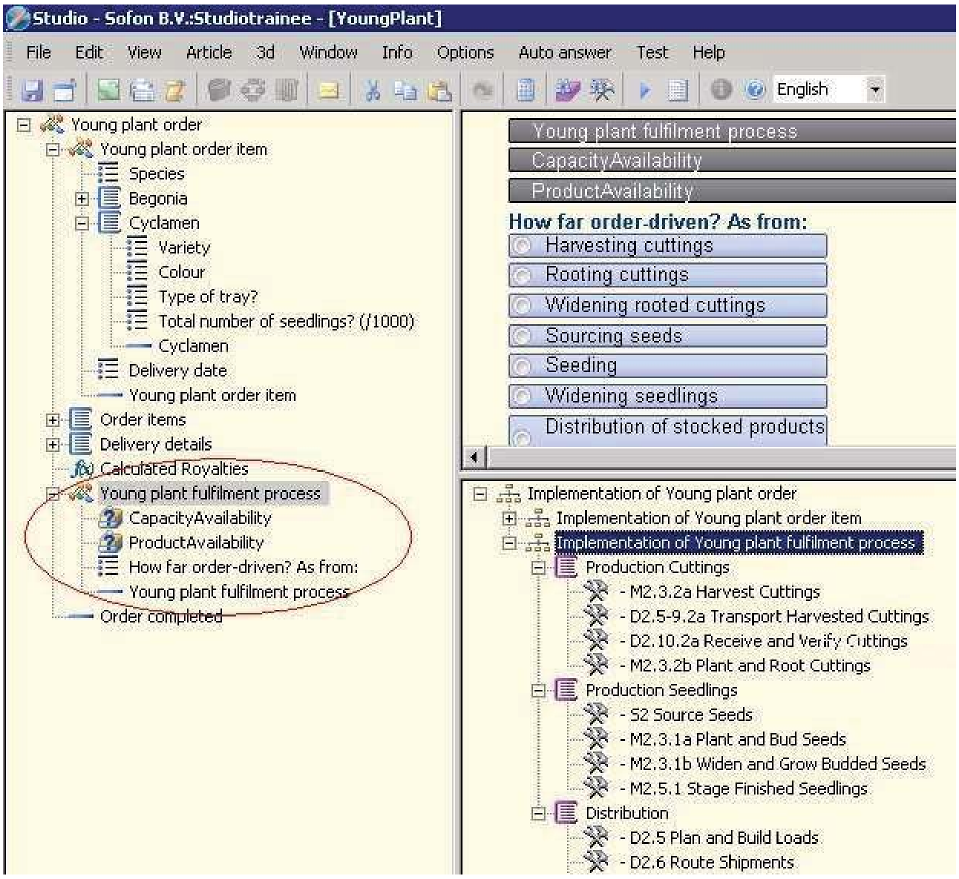

Figure 29 Illustrative case-firm implementation of process configuration

It shows that there are three additional questions for the configuration of the young plant order fulfilment processes, all of which are answered automatically. The questions concerning capacity and product availability are queries to ERP back-office systems. The question *"How far order-driven?"* is answered by an automatic calculation using the retrieved data about product and capacity availability and information about the required versus possible lead-time. The required delivery lead-time is as specified during product configuration. The possible lead-time is the sum of all order-driven fulfilment processes. The calculation result is input for activity specification in the generic routing (*i.e.* Bill of Activities) that is executable by ERP systems (see bottom-right of Figure 29).

Consider, for example, an illustrative order for Cyclamen. The customer specification, resulting from product configuration, shows that this is an order for 2000 budded 'Cyclamen Miniwella Twinkle blanc' to be delivered within 4 days in 66-66-44 trays to Hamburg, Germany. Operational ERP data shows that these are in stock and that distribution will take two days. Thus, only distribution activities are on customer order and these activities are selected for this order (see Figure 29: D2.5 and further).

Consider another simplified example: an order for Begonia cuttings. The configured order shows that this is an order for 5000 rooted 'Begonia Eliator Baladin' to be delivered in 7 weeks in 72-72-44 trays to Latina, Italy. Operational ERP data shows that the required cuttings are available at parent plants in Brazil and that the required air freight and greenhouse capacity is also available. The lead-time of rooting cuttings from these parent plants is 5 weeks. The total lead-time from harvesting until delivery at the customer site is 6 weeks and 3 days. This is less than 7 weeks, so all activities from harvesting onwards can be on customer order. Consequently, all activities for production of cuttings and for distribution are selected in the generic routing (see bottom-right of Figure 29).

5.5.4 Configurator development strategies

The previous analysis shows that product configurators also can be used to support process configuration. Below, it is evaluated more precisely to what extent the identified basic requirements can be met by existing configurators. This by discussing how coordination of the defined interdependencies is supported (see Figure 25):

(1) *Product Assembling*: is well supported, since this is the traditional focus of configurators. For example: Sofon provides rich functionality for defining generic product models in wizard-like questionnaires and accompanying rules, and generic Bill-of-Materials.

(2) *Process Rules Precedence*: requires solid integrations with back-office systems and mechanisms to prevent redundant process logic or to ensure consistency. For example: Sofon provides functionality to copy master data from ERP packages, but alignment has to be done manually by product experts; consistency checks are not supported.

(3) *Order Precedence*: configurators and ERP systems must be technically integrated and order-related data must be defined in a format that is executable by back-office systems. Especially in agile supply chains, functionality is required for reconfiguration of order-related data if changes in the back-office occur. For example, Sofon contains rich functionality for defining standard orders and accompanying Bill-of-Materials and it provides standard application connectors for ERP packages. However, reconfiguration of adjusted requirements after contract conclusion is not supported.

(4) *Process Assembling*: this could be supported by applying available product configuration functionality to processes. However, adequate process configuration requires rich functionality to specify reference process models and to configure Business Process Models based on configured orders and operational back-office data. In existing questionnaire-based product configurators, this functionality might be rather basic. For example, in Sofon, generic routings for customer-

within one configurator and this tool is integrated with external planning & scheduling systems, either directly or via service-oriented middleware. The external integration focuses on exchange of process flows (Process Precedence), product & capacity data (Product & Capacity Precedence), and capacity layouts (Capacity Rules Precedence).

Last option is to include both product and process configuration into the ERP system and thus integrate all features (product configuration, process configuration and planning and scheduling) within one system. In this case, the ERP system is also the front office for customer interaction. All identified dependencies are supported by integrations within the system.

5.6 Summary and Outlook

The objective of this chapter was to asses how configuration software can be used for combined product and process configuration to support mastering high uncertainty of both supply and demand. In order to answer this question, first the role of configurators in Supply Chain Management has been discussed. The traditional domain of configurators is in responsive supply chains, *i.e.* high demand uncertainty with reliable and stable supply. The additional presence of supply uncertainty in agile supply chains results in a high mutual dependence between product and processes, not only in the definition phase, but also during configuration and execution. First, in the definition phase, designers predefine integrated reference product and process models. A product reference model is constrained by the available business processes as defined in process reference models. Vice versa, a process reference model must contain the business processes that produce the variety of products as defined in product reference models. Second, in the configuration phase customised products are configured in interaction with the customer and taking into account whether the enabling business processes can be configured. Therefore, the required input products and capacity must be available to promise. The result is an accepted order, which triggers configuration of the business processes that fulfil the order. Last, the execution phase comprises planning, scheduling and completion of the configured business processes. The progress is monitored continuously and if necessary the product and process configurations are updated. The interdependence of products and processes during definition, configuration and execution has been defined more precisely in a typology of interdependencies.

In order to support coordination of the defined interdependencies, configurators must provide additional functionality for process configuration that links product configurators and planning and scheduling systems. Based on a case study in the Dutch flower industry, a conceptual information architecture has been proposed for this and tested in a Proof of Feasibility implementation. It has been found that currently flexible process configuration and back-office/front-office/customer communication are not sufficiently supported. Based on the developed information architecture, three basic development strategies have been identified, each including a different division of product configuration, process configuration and management of the order fulfilment among dedicated configurator software, ERP systems and service-oriented middleware. On the other hand, the case study has shown that the investigated firm heavily relied on improvisation by experienced staff having in-depth product and process knowledge. This type of tacit knowledge is to be captured in the system for successful application of combined product and process configuration.

The main contribution of this chapter to existing literature is that it provides an integrated typology of product and process interdependences and it develops a corresponding information architecture for its coordination. Contrary to related work, the addressed dependences go beyond the definition phase and do also include the effects of unforeseen backend events during configuration and execution. As a result, the developed architecture supports the mastering of both demand and supply uncertainty, which exceeds the traditional application domain of configurators.

The research encompasses an explorative analysis that is based on a single case study. Advantage of this approach is that it puts the different related topic areas of the studied complex phenomena into context. This is in line with Jiao *et al.* (2007) who stresses the need for a holistic view and system-wide solutions. However, an important weakness of single case study research in general is the little basis for scientific generalisation. In the chapter we used the typology of dependencies based on literature as core vehicle to abstract general development strategies from the case study. Nevertheless, future research is needed to further develop, test and implement the designed architecture. Important remaining issues include: i) development of configurable reference process models that bridge between product configuration and back-office systems, ii) broad feasibility survey of existing configurators, iii) implementation of the designed architecture in combination with ERP and SOA platforms, and iv) case studies that test the applicability in other sectors.

Chapter 6. General discussion

6.1 Introduction

In the introduction of this thesis, we have argued that the increasing volatility and diversity of demand urge agri-food supply chains to become more demand driven, *i.e.* sensitive and responsive to demand information of the ultimate consumer. Companies that participate in demand-driven supply chains must manage a high variety and variability of supply chain configurations to meet the specific requirements of their customers. Business process models can be valuable means to achieve this by supporting the design of customised supply chain configurations and subsequently the engineering of enabling information systems.

The central objective of this thesis is to develop a reference framework for business process modelling in demand-driven agri-food supply chains. This chapter evaluates to what extent this has succeeded. Before doing so, we first wrap up results of the previous chapters. Than, in the third section, we provide an overview of the designed framework. Subsequently, the fourth section revisits the research questions and formulates main conclusions. In the fifth section, we discuss practical benefits and theoretical contributions of the research. Finally, the chapter closes with a discussion of opportunities for further research.

6.2 Wrap up of the previous chapters

Before evaluating to what extent the research objectives are met, this section first briefly summarises the results as presented in the previous chapters.

Chapter 2, entitled “Towards dynamic reference information models: Readiness for ICT mass customisation”, has assessed existing reference models for production and supply chain management. It has argued that, in demand-driven supply chains, reference models should support an ICT mass customisation approach. Based on literature study, requirements on reference models for enhancement of ICT mass customisation are defined and it has been assessed how far existing reference models meet these requirements.

In the subsequent chapters, different elements of the designed reference model framework have been developed, based on literature review and supported by case study research.

Chapter 3, entitled “A framework for modelling business processes in demand-driven supply chains”, has proposed the first version of the reference framework. It has defined the object system of the research and has developed an accompanying modelling toolbox. Building on the terminology and process definitions provided by the Supply Chain Operations Reference (SCOR) model, it has modelled supply chain configurations as specific sets of business processes, control systems and coordination mechanisms. For that, it has identified modelling building blocks (reference components), a method to instantiate the model to specific cases (configuration tree) and preconfigured diagrams of typical supply chain configurations (reference templates). The designed modelling framework is applied in a multiple case study in the Dutch flower industry.

Chapter 4, entitled “Process modelling in demand-driven supply chains: A reference model for the fruit industry”, has presented an application of the reference modelling framework to fruit supply chains. Based on a multiple case study in four European countries, it has extended the modelling toolbox with model building blocks for fruit supply chains and a set of fruit-specific process model templates. Furthermore, it has incorporated a specific type of process models that visualises the product flow in a supply chain configuration, including different units of aggregation. The underlying product unit typology is added to the object system definition.

Chapter 5, entitled “Mastering demand and supply uncertainty with combined product and process configuration”, has focused on the enabling information architecture. This by exploring how configurators can be used for combined product and process configuration in order to support mastering high uncertainty of both supply and demand. Therefore, it first has defined the dependence between product and process configuration in a typology of interdependencies. Next, a conceptual architecture has been proposed for coordination of these interdependencies based on a single case study in the Dutch flower industry.

As indicated in the introduction, the research has been a highly iterative process in which the main design artefact, *i.e.* the reference modelling framework, has been updated several times based on the case study findings. Consequently, the chapters as discussed above each have contributed to the framework. The next session presents an integrated overview of the final version of the framework.

6.3 Overview of the designed framework

The main result of this thesis is the design of a reference framework for business process modelling in demand-driven agri-food supply chains. The framework provides concepts and a toolkit for modelling a wide variety of supply chain configurations from standard model components. As such, it enhances shared understanding and reuse of process knowledge in supply chain design and information systems engineering. The figure below depicts an overview of the elements of the designed framework.

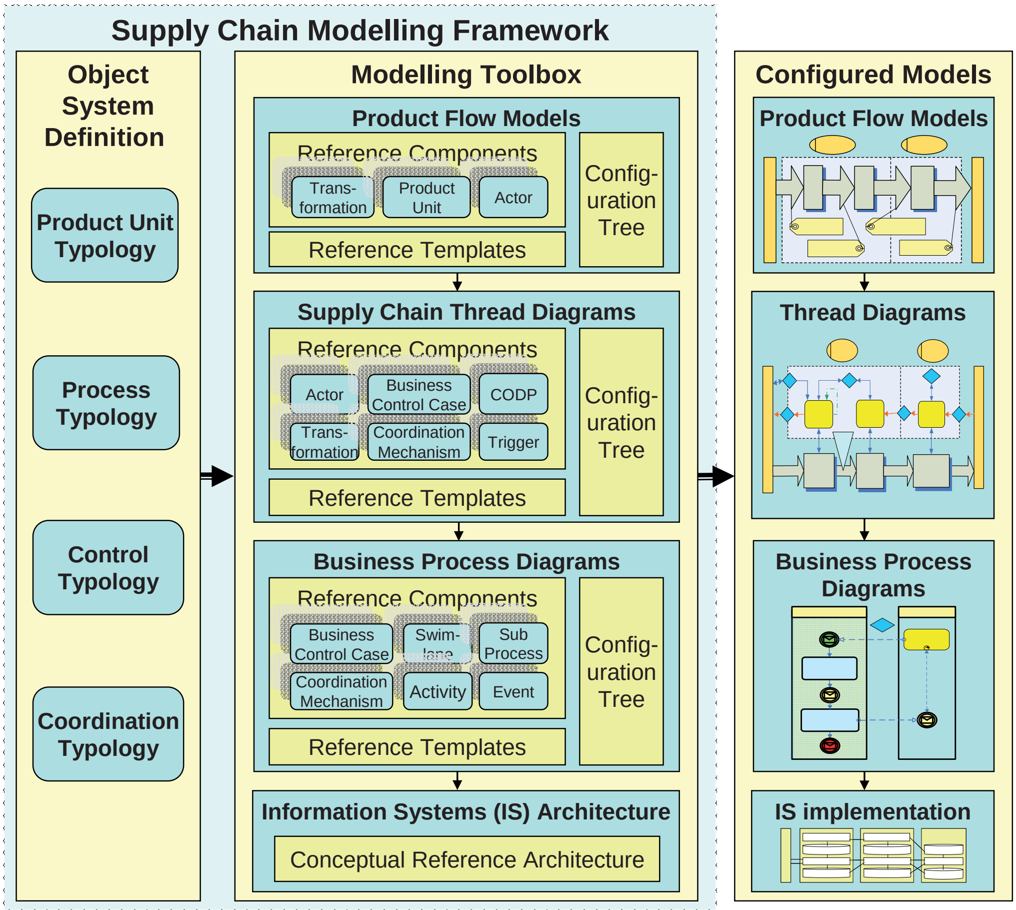

Figure 30 Overview of the designed framework

The figure shows that the modelling framework consists of two parts: i) an object system definition and ii) a toolbox for modelling the defined object system. The toolbox can be used to configure three types of supply chain process models, *i.e.* Product Flow Models, Thread Diagrams and Business Process Diagrams, and to implement enabling information systems. Next sections introduce these two parts of the framework.

6.3.1 Object system definition

The object system definition is a conceptual view of the modelling object: business processes in demand-driven supply chains. It provides typologies of the main elements of supply chain configurations, *i.e.* business processes, product units, control systems and coordination mechanisms. Next, it describes how these concepts are related in supply chain configurations, which are considered as specific networks of autonomous components (building blocks). The object system definition is primarily developed in chapter 3 and further refined in chapter 4 and 5.

Chapter 3 has defined supply chains from a systems perspective and subsequently has developed i) process, ii) control and iii) coordination typologies. First, processes are subdivided into primary, supporting and management processes. Primary processes are further classified into transformation and transaction processes, because supply chains consist of a sequence of transformation processes that add value to the product, and transaction processes that connect transformations of the involved partners.

Second, control is classified based on the position of the Customer Order Decoupling Point (CODP). The defined basic control strategies vary from strategies in which all processes are driven by customer order to fully anticipatory strategies in which all processes are based on demand forecasts, specifically engineer-to-order (ETO), make-to-order (MTO), assemble-to-order (ATO) and make-to-stock (MTS). Furthermore, detailed functions are defined that are necessarry to keep a system in control, *i.e.* maintain a steady state. These control functions are based on cybernetic control theory and include a feedback loop, input and output filters, etc.

Third, chapter 3 has developed a typology of coordination mechanisms. Based on an application of organisational theory to supply chain systems, it has classified coordination mechanisms according to the dependencies that they aim to manage. The addressed mechanisms are primarily concerned with coordination of flow dependencies: the business process output of one actor is the input of another actor’s processes (also called precedence dependencies). The identified flows among supply chain business processes are products, orders, and demand and supply information. Besides these flow dependencies, some key dependencies among multiple flows in a supply chain are identified. These are related to the common usage of resources, *i.e.* material and capacity.

Chapter 4 has added a product unit typology for the modelling of Product Flow Models. The typology defines different levels of aggregation of product flows among transformations. Based on the Global Traceability Standard of GS1, four different product units are distinguished: shipping, logistics, trade and consumer units.

Chapter 5 has introduced a configuration perspective of products and processes to the coordination typology. As a consequence, it has added dependencies and associated coordination mechanisms for integrated configuration and definition of products and processes. Furthermore, it has included process precedence to the operational supply chain dependencies of chapter 3.[16] Figure 31 (next page) integrates the coordination typologies as developed in chapter 3 and 5.

[16] On the other hand, chapter 5 has not included demand and supply information precedence because the scope of this chapter was limited to order-driven processes.

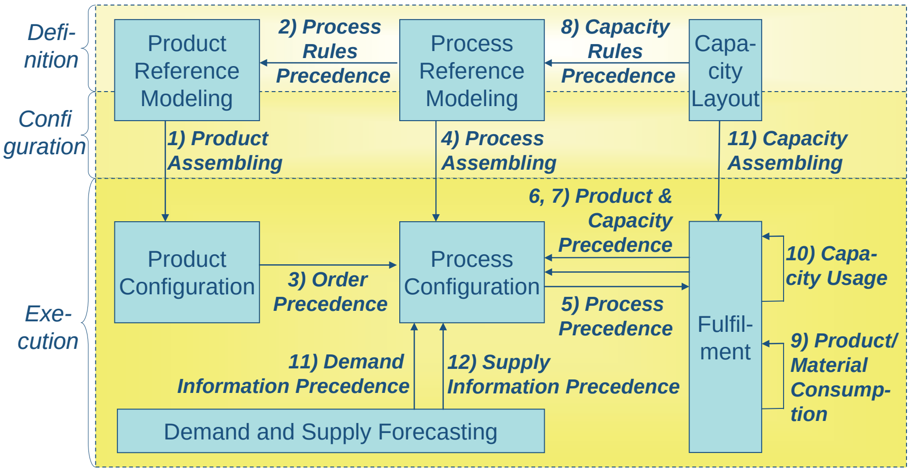

Figure 31 Overview of the defined supply chain dependencies and associated coordination mechanisms

Figure 31 distinguishes between coordination mechanisms at three different decision levels, *i.e.* definition, configuration and execution. First, in the *definition* phase designers predefine reference product and process models. A product reference model is constrained by the available business processes as defined in process reference models. Vice versa, a process reference model must contain the business processes that produce the variety of products as defined in product reference models. Furthermore, a process reference model is constrained by available capacity.

Second, the *configuration* phase starts with the configuration of customised products in interaction with the customer, and taking into account whether the enabling business process can be configured. The result is an accepted order, which triggers configuration of the business processes that fulfil the order. Besides this order-driven configuration of responsive processes, the anticipatory processes are configured based on regular planning.

Last, the *execution* phase comprises the operational scheduling and completion of configured business processes. To do this effectively and efficiently, several operational supply chain dependencies must be coordinated. These are related to the flow of orders, products, capacity, processes, demand information and supply information in supply chains (precedence dependencies) and the common usage of material and capacity.

The execution-related coordination mechanisms have been developed in chapter 3, except the coordination of process precedence, which has been added in chapter 5. Coordination mechanisms of dependencies related to configuration and definition of products and processes have been defined in chapter 5.

6.3.2 Supply chain modelling toolbox

The second part of the framework is a toolbox for modelling the defined object system. This toolbox identifies three types of supply chain process models:

1. *Product Flow Models*: visualise the allocation of basic transformations to supply chain actors and the related product flows from input material into end products (including different product units);
2. *Thread Diagrams*: visualise how order-driven and forecast-driven processes are decoupled in specific supply chain configurations (positions Customer Order Decoupling Points), and how interdependences between processes are coordinated;
3. *Business Process Diagrams*: depict the sequence and interaction of control and coordination activities (as identified in Thread Diagrams) in BPMN notation.

For each process model type, the toolbox contains i) standard model building blocks (reference components), ii) a method to configure specific diagrams (configuration tree), and iii) pre-configured models (reference templates) that capture reusable knowledge abstracted from the case studies. The toolbox also includes a conceptual model of an information architecture for implementation of configurable process models.

As stated before, the modelling toolbox is developed iteratively, which implies that it has been updated several times during the research. Below we describe how the different chapters of this research have contributed to the toolbox.

Chapter 3 has developed the first version of the toolbox. Building on the terminology and process definitions provided by the Supply Chain Operations Reference (SCOR) model, it has introduced Thread Diagrams and Process Diagrams and it has defined associated reference components, configuration trees and reference templates.

The main reference components of Thread Diagrams are business control cases and coordination mechanisms. A business control case represents a sequenced group of business processes that follow the same control strategy. They control the basic transformations source, make or deliver and can be either responsive (triggered by customer orders) or anticipatory (triggered by demand forecasts). CODPs decouple series of responsive and series of forecast-driven control cases. A coordination mechanism manages the interdependencies among business control cases. The configuration tree of Thread Diagrams includes four steps: i) specification of the customer requirements, ii) determining the sequence of basis transformations of involved actors, and iii) defining how far these transformations are order-driven, and iv) identifying the source of demand and supply information for anticipatory processes. Based on a multiple case study in the Dutch flower industry, chapter 3 has modelled three template Thread Diagrams. Two of these configurations are at both ends of the continuum from fully anticipatory (push) to fully order-driven (pull), while the third is a mixed form that balances pull and push elements.

A business process diagram can be composed by zooming in on a specific business control case or coordination mechanism. A process diagram visualises the sequence of their detailed activities and the interactions (events: start, end, intermediate) with adjacent control cases and coordination mechanisms (in separate swimlanes). The main reference components are activities, which are adopted from SCOR (except some refinements). The configuration tree of process diagrams includes three steps: i) determine relevant process category (SCOR level 2), ii) define the applicable activities (SCOR level 3), and iii) specify the sequence of the selected activities. Chapter 3 has modelled template Process Diagrams of every business control case, 18 in total *i.e.* one template per applicable SCOR process category (see Table 4 in chapter 3).

Chapter 4 has applied the designed framework to fruit supply chains and has enriched the modelling toolbox with design knowledge abstracted from a multiple case study in four European countries. More specifically, it has introduced Product Flow Models and it has extended the toolbox with a set of fruit-specific template Thread and Process Diagrams.

The reference components of Product Flow Models are actors, transformations and products defined at different levels of aggregation. The configuration tree of Product Flow Models includes four steps: i) identify the product-market combination of the supply chain configuration to be modelled, ii) define the sequence of basic transformations, including input and output products, iii) determine which actors perform the identified transformations, and iv) define the levels of aggregation of the identified products (product units). Based on the case study analysis, chapter 4 has modelled three template Product Flow Models of typical fruit supply chains, *i.e.* i) fresh hard fruits for fruit specialist shops, supplied via direct delivery, ii) fresh soft fruits for supermarkets, supplied via traditional DC delivery, and iii) processed fruits for food service providers, supplied via cross-docking transhipment.

Last, chapter 5 has extended the modelling toolkit with a conceptual model of an information architecture for implementation of configurable process models. Therefore, it has proposed a conceptual model for the coordination of the interdependence between products and processes during definition, configuration and execution.

6.4 Revisiting the research questions

The main research question of this thesis have been formulated in the introduction as "How can reference process models be designed that enable the modelling of demand-driven agri-food supply chains and the implementation of supporting information systems?" This main question has been split up into five sub-questions (see section 1.3). The present section will discuss the main findings of our research by answering these questions.

a. What are the characteristics of demand-driven supply chains?

Chapter 3 has summarised the results of a literature review to define the concept of demand-driven supply chains. A supply chain is defined as a connected series of business processes performed by a network of autonomous companies working together to provide products or services for end customers (adapted from Stevens, 1989, Lambert and Cooper, 2000, Christopher, 2005). The literature review has shown that demand-driven supply chains are often advocated as an alternative to supply chains that efficiently push products to the marketplace. They aim at a rapid and customised response to uncertain demand, rather than anticipatory supply of standard products in high volumes (Fisher, 1997, Christopher, 2000, van der Vorst and Beulens, 2002). Therefore, a demand-driven chain has been defined as a supply chain in which all actors involved are sensitive and responsive to demand information of the end customer (based on Kohli and Jaworski, 1990, Vollmann *et al.*, 2000, Cecere *et al.*, 2004). Demand-driven supply chains continuously have to match products and business processes, including the network of producers and distributors, to changing demand requirements (Day, 1994, Prahalad and Ramaswamy, 2000, De Treville *et al.*, 2004). Consequently, they are characterised by a high variety and variability of supply chain configurations. A supply chain configuration has been defined as: *"a specific set of business processes, control systems and coordination mechanisms, performed by a specific network of contributors who together produce and deliver a product or service with distinct value for the ultimate customer".* Subsequently, chapter 3 has defined and classified business processes, control and coordination in order to identify the possible variety of configurations that a company must manage in order to fulfil the different demand requirements of their customers.

b. What are the requirements on reference process models to enable the modelling of demand-driven supply chains and the implementation of supporting information systems?

From the answer of the first research question, it follows that in demand-driven supply chains, companies must manage a high variety and variability of supply chain configurations in order to fulfil the demand requirements of their customers. Business process models should therefore support rapid design of customised supply chain configurations and subsequently flexible engineering of the enabling information systems.

Chapter 2 has argued that this can be achieved if reference process models support ICT mass customisation. In such an approach, reference process models support the configuration of customised models from a repository of standard building blocks *i.e.* predefined generic model components. The chapter has positioned such models in the middle of a continuum of five basic modelling approaches, varying from pure standardisation to pure customisation. Next, five requirements on reference models for enhancement of ICT mass customisation have been defined.

- *Generic model setup*: they must be set up as generic models, which specify the generic components for configuration of specific information architectures, and that define permitted choices and combinations in explicit configuration rules.
- *Supporting software modularity*: they must support software modularity by precise definitions of the supported application services, including data specifications, interface standards and possible sequences of services.
- *Executable:* it must be possible to use the configured models in the run-time system for service orchestration.
- *Configuration support:* they have to include user-friendly means that guide users through the process of configuring specific information models.
- *Content availability*: they must provide domain-specific knowledge required in specific areas of application.

Chapter 3 has further specified the required content availability in demand-driven supply chains by developing a conceptual definition of the object system to be modelled. It has defined supply chain configurations as specific sets of business processes, control systems and coordination mechanisms, and has elaborated these concepts into process, control and coordination typologies (see previous research question). The chapter has argued that business process models in demand-driven supply chains should reflect the defined object system. Therefore, they must explicitly visualise how order-driven and forecast-driven processes are decoupled and how interdependences between processes are coordinated. It must be possible to represent a wide variety of supply chain configurations as specific networks with different allocations of business processes to supply chain participants and different modes of control and coordination, as defined in the typologies. At this, process models should link supply chain design with implementation of enabling information systems. This requires a modelling approach that supports a seamless translation of high-level supply chain designs into information engineering models that detail the information flows among activities in an executable notation. Last, chapter 3 has argued that demand-driven supply chains are characterised by a high variety and variety of supply chain configurations. Consequently, process models must be setup to enable rapid instantiation of various specific supply chain configurations (rather than dictating a single blueprint), which can be achieved using a mass customisation approach (see chapter 2).

Chapter 4 particularly has added the requirement that reference process models also must be sector-specific, *i.e.* they must include sector-inherent features and address the diversity of supply chain configuration as appears in the sector concerned.

Finally, chapter 5 has identified design requirements for information systems enabling the coordination of interdependence between products and processes during definition, configuration and execution.

In sum, these findings confirm the basic design requirements as identified in the introduction (see section 1.2) and add the requirement that supply chain models must explicity reflect the control and coordination of bussiness processes. Consequently, the following basic requirements to reference process models in demand-driven agri-food supply chains are defined (see Table 9).

Table 9 Basic requirements to reference process models in demand-driven agri-food supply chains

No.	Requirement	*Relation to requirements of Mass Customisation (chapter 2)*
R1	They must be setup to enable rapid instantiation of various specific supply chain configurations from a repository of standard building blocks instead of dictating a single blueprint	• *Generic model setup* • *Supporting software modularity* • *Executable* • *Configuration support*
R2	They must depict supply chain configurations as series of order-driven and anticipatory processes connected by coordination mechanisms	• *Content availability*
R3	They must support a seamless translation of high-level supply chain designs to detailed information engineering models	• *Content availability*
R4	They must be sector-specific *i.e.* contain domain-specific knowledge	• *Content availability*

c. To what extent do existing reference process models meet the requirements of demand-driven supply chains?

An assessment of existing reference process models has been conducted to answer this research question. Chapter 2 has presented the main results of this study. In the domain of Production and Supply Chain Management**,** it has identified 10 widely acknowledged and applied reference models. The MIT Process Handbook and the Supply Chain Management reference models, *i.e.* SCOR, VRM, and the GSCF framework, provide business knowledge for high-level process design that also can be used to define information system requirements. ISA95, Y-CIM, STEP and the CPFR model of VICS are focused on information system design. The ERP models of SAP (Curran and Ladd, 1999) and Baan (TriArch, 1998, Verbeek, 1998) focus on implementation of their specific ERP software and, therefore, incorporate very detailed system-specific models. The chapter has analysed the extent to which the investigated reference information models meet the defined requirements for ICT mass customisation. It has been found that none of the investigated models sufficiently meet all of the defined requirements. In particular they lack a generic model setup and adequate configuration support. Most of the investigated models are based on a combination of (segmented or pure) standardisation and tailored customisation. Consequently, it can be concluded that existing reference process models do not meet the first requirement (R1), *i.e.* they are not sufficiently setup to enable rapid instantiation of various specific supply chain configurations from a repository of standard building blocks.

Furthermore, chapter 2 has shown that all investigated supply chain models are high-level process models that can be used for definition of information system requirements, but do not support detailed information systems engineering. Available process models that can be used for information systems design and implementation focus on single enterprises. Consequently, it can be concluded that existing reference process models do not meet the third requirement (R3), *i.e.* they do not support a seamless translation of high-level supply chain designs to detailed information engineering models.

Chapter 3 has identified SCOR as the most comprehensive of the supply chain models assessed in chapter 2. The chapter has analysed to what extent this model provides the representation power for modelling demand-driven supply chains. It has been found that the process decompositions and definitions of SCOR provide an appropriate repository of reference components for the purpose of this thesis. However, SCOR lacks configuration support, it does not model the precise interactions among processes and its process models are not executable by run-time information systems. Furthermore, SCOR does not reflect the object system definition of this thesis (see first research question). Although it addresses different process variants for source, make, deliver and plan, the SCOR model does not make clear how these categories interrelate and what are essential differences in the underlying control systems and coordination mechanisms. This analysis has confirmed the findings of chapter 2 and in addition it has shown that existing reference process models do not meet the second requirement (R2): currently available supply chain models do not depict supply chain configurations as series of order-driven and anticipatory processes connected by coordination mechanisms.

The analysis of chapter 2 has focussed on reference models that are widely acknowledged and applied in business community. Chapter 4 has reported that no such a process model was found in the fruit industry. This finding is based on the assessment of reference models conducted in this research, which started with a broad search for existing reference models. The survey has shown that the few existing reference process models in the agri-food sector can be characterised as isolated models, which have not been used to guide the workflow in run-time information systems. Furthermore, the survey has not found reference models for supply chain processes in the agri-food industry. Consequently, it can be concluded that existing reference process models do not provide specific knowledge for the agri-food supply chains, which implies that for this domain the fourth requirement is not met (R4).

d. How can reference process models be designed that meet the requirements of demand-driven supply chains?

The modelling framework (see section 6.3), which has been developed in chapter 3, 4 and 5, answers this research question as follows.

First, the framework is setup to enable rapid instantiation of various specific supply chain configurations from a repository of standard building blocks instead of dictating a single blueprint (R1). It has defined the variety of supply chain systems in a conceptual object system definition, which includes classifications of product units, processes, control and coordination. For different types of process models, it has defined reference components, a configuration tree that guide model instantiation and multiple reference templates, *i.e.* pre-configured models of typical configurations. Last, it has included an information systems architecture for implementation of configurable process models in combination with product configuration.

Second, the framework supports depicting supply chain configurations as series of order-driven and anticipatory processes connected by coordination mechanisms (R2). It has proposed a new type of Supply Chain Thread diagrams that explicitly visualise how order-driven and forecast-driven processes are decoupled in specific supply chain configurations (positions Customer Order Decoupling Points), and how interdependences between processes are coordinated. Next, it has elaborated the sequence of their detailed activities and the interactions with adjacent control cases and coordination mechanisms in Business Process Diagrams.

Third, the framework supports a seamless translation of high-level supply chain designs to detailed information engineering models (R3). It starts with depicting the allocation of basic transformations to supply chain actors and the related product flows in Product Flow Models. Next, the coordination and control of these transformations in specific supply chain configurations is visualised in Thread Diagrams. Last, one can zoom in to Business Process Diagrams that depict the sequence and information flows among control and coordination activities. Business Process Diagrams are modelled in the BPMN notation, which can be executed in Service-Oriented Architectures (SOA) for orchestration of data amongst multiple software components that are packaged as interoperable web services.

The process models of the framework have been designed in a SOA-based Business Process Management platform, which automatically translates the Business

Process Diagrams to executable XML-code (Cordys). This tool also includes functionality to check whether the process models are correctly modelled in accordance with the BPMN-standard and specific web services can easily be linked and executed. As a result, the Business Process Diagrams of the framework are appropriate to be used in the run-time system for service orchestration.

Fourth and finally, the framework is setup to include sector-specific knowledge, which is important for effective instantiation in specific domains (R4). It combines industry-specific knowledge with reuse of generic knowledge of cross-industry standards. The definition of different types of process models and their configuration methods, and the reference components of Thread and main Business Process Diagrams are generic. Sector-specific characteristics are covered by the building blocks of Product Flow Models and Sub Process Diagrams, and by the templates of typical supply chain configurations. Next research question further discusses the application to agri-food supply chains.

e. How can reference process models of demand-driven supply chains be applied to the agri-food industry?

The present thesis has focussed on the flower and the fruit industry. The framework has been applied in three case studies, which resulted in updates of the framework with sector-specific knowledge.

Chapter 3 has applied the first version of the framework, which included Thread and Business Process Diagrams, to flower supply chains. Based on an explorative multiple case study in the Dutch pot plants industry, it has defined specific characteristics of this sector and the main diversity of its supply chain configurations. Pot plant production is a form of discrete manufacturing, in which products are assembled from plants, flowerpots, decorations, labels and packaging. It also has some features of continuous production, because of the process of continuous growth, but pot plants remain discrete units, traceable at single product level. We have identified a high variety of supply chain configurations, which have been positioned in a continuum from fully anticipatory (push) to fully order-driven (pull). The chapter has identified three typical configurations of pot plants supply chains. Two of these configurations are at both ends of the continuum, *i.e.* push and pull oriented, while the third is a mixed form that balances pull and push elements. The templates Thread Diagram of these three pot plant configurations and underlying template Business Process Diagrams (16 in total) were incorporated in the framework.

Chapter 4 has applied the second version of the framework to fruit supply chains. Based on an in-depth multiple case study in the European fruit industry, it has defined specific characteristics of this sector and the main diversity of its supply chain configurations. Specific features of business processes in the fruit-industry in particular result from the fact that fruits are living products. This makes fruit supply chains vulnerable to decay, weather conditions, pests and other factors that are difficult to control. The diversity of supply chain configurations is determined by different allocations of basic transformations to the supply chain actors and different extents to which fruit chains are order-driven. Based on this analysis, the framework has been extended with a new process model type, *i.e.* Product Flow Models. It has identified basic transformations in fruit supply chain as its fruit-specific reference components and template Product Flow Models of three typical fruit supply chains were pre-configured. Next, the chapter has modelled reference Thread Diagrams of six typical fruit supply chains. Regarding the Business Process Diagrams, it has distinguished between Main Process Diagrams, which are based on generic reference components (adopted from SCOR), and detailed Sub Process Diagrams, which are based on fruit-specific components developed in the chapter. The chapter has modelled in total 16 fruit-specific template Main Process Diagrams and 2 template Sub Process Models *i.e.* for production of fresh fruits (at the farms) and for fruit processing.

Chapter 5 has applied the designed information architecture for combined product and process configuration in the flower industry. It has defined configuration-related dependencies of a firm that produces young plants and developed a Proof of Feasibility based on the implementation of a configurator at this firm.

6.5 Practical and theoretical relevance

In this section we consider the practical and theoretical relevance of the research by discussing practical benefits and contributions to existing theory.

6.5.1 Practical benefits

This thesis has introduced the design of a framework for reference process modelling in demand-driven supply chains. The main practical value of the framework is that it helps to map, in a timely, punctual and coherent way, the business processes of the supply chain configurations that a company must manage in order to fulfil the different demand requirements of their customers.

The framework is designed for demand-driven supply chains that aim to provide a rapid and customised response to volatile demand. We have argued that this imposes stringent demands on information systems and requires the ability to design and implement customised supply chain configurations. The designed framework supports this by supplying business and ICT professionals with concepts and a toolkit for modelling a wide range of supply chain configurations. As such, although designed for demand-driven supply chains, the framework is a general tool for supply chain modelling.

The framework does not prescribe a strict blueprint of the ‘best’ supply chain design (no one size fits all), but it enables a rapid instantiation of various supply chain configurations from a repository of standard building blocks. The process models of the framework are on the one hand understandable for business managers and on the other hand they serve as a basis for information system implementation. As a result, the framework intermediates between supply chain design and information systems engineering. Furthermore, it combines agri-food-specific knowledge with reuse of knowledge provided by generic standards, in particular SCOR. As such, it enhances shared understanding and reuse of both cross-industry and sector-specific process knowledge in supply chain design and information systems engineering. This improves the speed, efficiency and quality of modelling.

However, companies will only derive sustainable benefits from the designed framework if business-driven development is ensured while keeping the model manageable and robust. To achieve this, it is necessary that the present framework functions as a basic design, which is further developed iteratively by pilots, *cf.* Wolfert *et al.* (2010). By using the basic design as a starting point, consistency and robustness of single pilots, as well as the reuse of existing knowledge, is ensured. Thus, the framework will function as a 'living' knowledge base that grows incrementally and knowledge is built up and reused by its application.

6.5.2 Theoretical contributions

The main addition of this thesis to existing theory is the design of an innovative artefact that addresses heretofore unsolved problems, as is shown by the discussion of the practical benefits above. The artefact is a new framework that captures the concepts needed to design adequate reference process models in demand-driven agri-food supply chains. Therefore, the thesis has defined, developed and evaluated the representation power needed to model a wide variety of supply chain configurations as specific networks with different allocations of business processes to supply chain participants and different modes of control and coordination. More specifically, this research has bridged the following three gaps in existing literature, which were addressed in the introduction.

First, our research has applied the concept of mass customisation to reference process models, which implies that customised models are configured from a repository of standard building blocks *i.e.* predefined model components. As such, it contributes to the emerging field of process model configuration, which is a relatively new research area. This thesis has identified two theoretical streams in this field, which study process configuration from different perspectives.

One stream originated from the research on business process management, in particular workflow management and Enterprise Resource Planning (ERP) systems (Dreiling *et al.*, 2006, van der Aalst *et al.*, 2006, Rosemann and van der Aalst, 2007, Gottschalk *et al.*, 2008, amongst others). It follows a segmented standardisation approach, in which configuration is considered to be the selection of the most appropriate variant by skipping or blocking irrelevant options from a reference model that includes numerous process variants. Contrary, our research has introduced a mass customisation approach to reference process models, which implies that customised models are assembled from a repository of standard building blocks *i.e.* predefined model components.

The other research stream originated from the field of product configuration, which is a key concept enabling a mass customisation approach. Researchers in this field have applied the principles of product configuration to the configuration of business processes (Rupprecht *et al.*, 2001, Schierholt, 2001, amongst others). However, the interdependence among product and process configuration is relatively under-researched. The scarcely available literature on this subject focuses on the definition domain, *i.e.* translation of customer requirements to an integrated design of products and manufacturing processes. Our research has introduced an integrated consideration of the interdependences during definition, configuration and execution, and a corresponding information systems architecture for the coordination of this interdependence using configurators.

Second, our research has developed a framework that combines process models at different levels of abstraction for two main purpose of usage: supply chain design and information systems engineering. As such, it contributes to the development of a common conceptualisation and consistent terminology of two of the main stakeholders of process models: business analysts and IT engineers (Abramowicz and Fensel, 2010). The gap between these two stakeholders is apparent both in practice (the so-called business-IT divide) and in research. The literature on supply chain design is traditionally dominated by quantitative modelling techniques (Min and Zhou, 2002). The available conceptual process models in Supply Chain Management literature are at a high-level of abstraction (Lambert *et al.*, 2005). They cannot visualise the sequence and interaction among their activities and do not reflect the specific differences of its management in various supply chain configurations. On the other hand, although information systems engineering research has increasingly studied business process modelling especially in the SOA field, available process models for information systems engineering so far focused on single enterprises or were designed from a pure technological point of view (Demirkan *et al.*, 2008). The architectural knowledge required to specify services and to configure business processes as a sequence of services is still missing (Papazoglou *et al.*, 2007). This thesis has combined high-level supply chain models, which visualise the actors, processes and management of specific supply chain configurations, with detailed process models that depict information flows among activities and that are interpretable by information systems guiding the workflow.

Third and finally, our research has applied the framework to specific agri-food sectors, *i.e.* pot plants and fruit supply chains. As such, it has developed sector-specific reference process models for pot plants and fruit supply chains. To the best of our knowledge, a reference process model for agri-food supply chains does not yet exist. Furthermore, our research developed a modelling method that combines specific knowledge for the fruit and pot plants industry with reuse of knowledge provided by generic cross-industry standards. The sector-specific and generic knowledge is clearly separated in different reference model elements, which are then consistently integrated (*cf.* table 7, chapter 4). As a result, the reference model can easily be extended to other sectors.

6.6 Suggestions for further research

The designed framework is based on in-depth literature review and extensive case study research. Furthermore, all chapters, presenting the research results (chapter 2-5), have successfully passed the double-blind peer review of an internationally influential scientific journal (ISI Thompson ranked). Nevertheless, we foresee some important opportunities for further research. They are related to further development, evaluation and implementation of the framework.

6.6.1 Opportunities for further development of the framework

The research has focused on the development of a framework for modelling the business processes for execution and operational management of demand fulfilment in supply chains. Main opportunities for further development are to enrich the framework with new design knowledge and to extend the framework's scope. More specifically, four challenges can be addressed.

First, the developed framework is limited to the operational level of supply chain systems. However, the configuration of operational control and coordination is constrained by higher-management echelons that follow slower paces of change. Future research is needed to include multiple levels of planning in the modelling framework. This could be a promising direction to develop flexible planning systems, which is an emergent challenge for industries facing high demand and supply uncertainty such as the agri-food industry (see for example (Van Wezel *et al.*, 2006, Ahumada and Villalobos, 2009, Verloop *et al.*, 2009).

Second, the supply chain Viable System Model (VSM), as developed in chapter 3, shows that the framework focuses on the control and coordination of business processes in a supply chain. Coordination mechanisms and control systems are based on governance structures, *i.e.* formal and informal arrangements that govern supply chain cooperation. It should be further researched how various governance structures constrain the configuration of process models of the framework. Important issues at this are the impact of i) different allocations of property and decision rights, ii) different risk and rewarding mechanisms, iii) different types of buyer-supplier relations and iv) different levels of trust. Incorporation of this governance dimension could be a valuable next step in linking the fields of Supply Chain Management and Network Theory, which still are two different worlds that hardly cooperate in researching the same object system.

Third, the framework focuses on the primary processes that match supply chain capabilities to demand requirements from the point of origin to the point of consumption, in particular distribution, production and management of sales and purchase. It could be researched how the designed reference model can be extended to other processes, such as returns management, product development and (collaborative) innovation, Customer Relation Management (CRM), marketing and supporting processes. The different models of the Supply Chain Council may provide valuable knowledge for this, specifically SCOR for returns, DCOR for development & innovation and CCOR for marketing & CRM.

Fourth, as indicated in the previous section, process model configuration is a relatively new research area with many challenges for future research. The current framework addresses product configuration as a starting point for process configuration, but it has not yet included configurable product models. Future research is needed to further develop configurable models for combined configuration of products and processes as suggested in chapter 5. This includes the development of an integrated formalisation of configuration product and process models. This could be a mathematical formalisation, contributing to the research on configurable process models in the workflow management field (*e.g.* Dreiling *et al.*, 2006, Rosemann and van der Aalst, 2007), or a formalised ontology, contributing to the research on process ontology's of the information technology community (*e.g.* Uschold *et al.*, 1998, Scholten, 2009).

Fifth and finally, the designed artefact is a framework for process modelling and consequently it excludes data models. However, data are an important basis for process models. The Business Process Diagrams of the framework visualise how data are exchanged among activities. Hereby, multiple process models use the same data objects. When developing the Business Process Diagrams of the framework, we therefore have identified a list of generic data objects that are used in the process models and we have checked the consistency with the inputs and outputs as defined in SCOR. Future research is needed to model the relations between these data objects in data diagrams. Furthermore, an important step for further development is to link the generic data objects with existing standards for electronic messages. This could be done with tools that support both process modelling and meta data modelling. For example, in Cordys, one of the tools used in this research, it is possible to define generic data objects in data templates and map these generic templates to various specific data objects.

6.6.2 Opportunities for further evaluation and implementation

The framework is evaluated in three case studies in two agri-food sectors: the pot plants and fruit industry. For evaluation of the applicability in the agri-food in general, it should also be tested in other agri-food sectors, such as cut flowers, bulbs, tree nursery, arable farming, dairy, meat, and feed. The use of a generic framework suggests that the design can easily be extended to other sectors, but further research is needed to provide evidence for this. Interesting additional questions are how agri-food specific knowledge can be reused in multiple agri-food branches and how the model should deal with connections between branches, for example the supply chain of a mixed fruit and milk drink.

Furthermore, the evaluation methods that have been applied in the case studies are requirements verification, conceptual validation and face validation (see section 1.4.3). Two important other methods of evaluation are not used, *i.e.* empirical and operational validation.

Empirical validation tests the value of the model in solving real problems by comparing model and real systems output (Harrison, 1991, Qureshi *et al.*, 1999, Wolfert, 2002). It requires that the effects of implementing the design can be measured in a large number of cases for statistical evidence. This method is not applicable for our design, because implementation of the design in real-life systems has not been feasible in this research and it would hardly be possible to isolate the impact of the implemented model on supply chain performance. However, the development of simulation models for a quantitative evaluation of the designed process models would be a valuable issue for future research.

Operational validation determines whether the implemented design can be used for its intended purpose, usually by potential users (Wolfert, 2002, Sargent, 2005). For the present thesis, this would require implementation of the design in a working information system, which has not been feasible in this research. Therefore, future research is needed to implement and evaluate the instantiation of the designed framework in operational information systems. At this, three specific challenges can be mentioned.

First, the designed framework includes a description of steps to configure specific process models. We have argued in this thesis that configurable process models must be accompanied by tools that guide users interactively through these steps in a wizard-like approach. These tools must be able to take into account dependencies between multiple configuration choices and operational constraints arising from resource availability. Based on the resulting configuration choices, process models should be generated automatically. The Proof of Feasibility of chapter 5 has not yet resulted in a satisfactory technical solution for this. Further research is needed to develop a system that meets all the defined requirements for combined product and process configuration.

Second, chapter 2 has shown that the implementation of reference models in a mass customisation approach requires a technical infrastructure that enables modularisation and integration of existing software systems. It should be researched how to deal with many of the currently running ERP systems, which are monolithic and non-modular by nature (Akkermans *et al.*, 2003, Rettig, 2007, Zhao and Fan, 2007). Furthermore, solutions have to be found to solve problems arising from redundancy of the knowledge as defined in process models and the hard-coded process logic in legacy systems. Also, the incorporation of process model configuration into run-time systems will impact systems performance, in particular if reference models are used by multiple organisations. In the latter case, also security will be an issue.

Third and finally, besides the technical implementation challenges discussed above, organisational implementation is a major remaining issue. Implementation of the framework requires a human change process. The tacit process knowledge in the heads of experienced staff is to be captured in the framework and stakeholders have to get used to a business modelling approach. Furthermore, the ownership of the framework and the responsibilities for model maintenance and further development must be allocated. Further research is needed about how this could be organised.

List of Appendices

Appendix A. Questionnaire for interviewing reference model experts

The following questionnaire is used for in the interviewing the experts in the reference model investigation of chapter 2 (in Dutch).

Doel interview

- Expert input aanvullend op inventarisatie referentiemodellen.
- Inzicht in inhoud, ontwikkelproces, gebruik (implementatie, exploitatie en onderhoud) van het referentiemodel, inclusief de succesfactoren en knelpunten die daarbij te onderkennen zijn.

Interviewmethode

- Semi-gestructureerde interviews
  - Open vragen, doorvragen.
  - Checks met vooraf gedefinieerde gesloten vragen (vanwege lengte niet opgenomen in deze bijlage, zijn op verzoek verkrijgbaar bij auteur)
- Vragenlijst wordt vooraf zo veel mogelijk ingevuld a.d.h.v. literatuur
- Focus interview op ontbrekende informatie en validatie van gevonden informatie.
- Totale verslag gesprek wordt gecontroleerd en goedgekeurd door geïnterviewde.
- Geen voorbereiding door geïnterviewden
- Vragen richten zich op inhoud/techniek, ontwikkelproces en gebruik. Per categorie eerst algemene vragen naar beschrijving/knelpunten/succesfactoren, dan specifiekere vragen.
- In de vragen wordt onderscheid aangebracht afhankelijk van de rol van de geïnterviewde ten opzichte van het referentiemodel:
  - Ontwikkelaar (O)
  - Implementator (I)
  - Gebruiker (G)
  - Manager ontwikkeling/exploitatie (M)
  - Financier / Opdrachtgever (FO)
  - Allen (X)
- Duur van het interview ongeveer 2 uur.

Introductie

Interview objective	Korte introductie promotieonderzoek + doel en interviewmethode toelichten.	X
Role interviewee	Wat is uw huidige functie?	X
	Op welke manier bent u bij het referentiemodel betrokken?	X

Inhoud & techniek

Naam	Wat is de naam van het referentiemodel?	X
Contact	Welke organisatie en / of persoon is het aanspreekpunt voor het referentiemodel?	X
Beschrijving	Kunt u kort omschrijven wat het referentiemodel inhoudt?	X
Context	Waarom is het referentiemodel gemaakt, wat was de aanleiding?	X-G
Zwakten	Wat zijn de zwakke punten van het referentiemodel?	X
Sterkten	Wat zijn de sterke punten van het referentiemodel?	X
Categorie	In welke categorie valt het referentiemodel?	X
Referenties	Zijn er publicaties van het model beschikbaar? Zo ja, welke?	X
Functionele domeinen	Welke functionele domeinen dekt het referentiemodel?	X
Niveau	Wat is het niveau van het object systeem?	X
Branche	In hoeverre is het referentiemodel domeinspecifiek?	X
Rules	In hoeverre zijn de instantiatie regels expliciet?	X-G

Type componenten	Welke type modellen bevat het referentiemodel?	X
Complexiteit	Hoe groot is het model?	X
Modelleerethode	Welke modelleermethode wordt gebruikt?	X
Tool support	Met welke tool is het referentiemodel gemodelleerd?	X
Beschrijving techniek	In hoeverre is het referentie informatiemodel geïntegreerd met de applicatie?	X
Standaardisatie	In hoeverre wordt aangesloten op breed geaccepteerde standaarden?	X

Ontwikkelproces

Ontwikkelproces	Hoe heeft de ontwikkeling van het model plaatsgevonden?	O, FO, M
Knelpunten	Welke knelpunten deden zich voor bij de ontwikkeling van het referentiemodel?	O, FO, M
Succesfactoren	Wat waren de belangrijkste succesfactoren bij de ontwikkeling van het referentiemodel?	O, FO, M
Opdrachtgever	Voor wie is het referentiemodel gemaakt, door wie is het betaald?	O, FO, M
Kosten	Hoeveel heeft de ontwikkeling van het referentiemodel gekost?	O, FO, M
Status	Wat is de status van het model, in hoeverre is het referentiemodel nu af?	X
Kwaliteit	In welke mate is het referentiemodel getest en hebben (onafhankelijke) validaties plaatsgevonden?	O, FO, M

Gebruik (implementatie, exploitatie en onderhoud)

Implementatie	Beschrijving hoe implementaties plaatsgevonden?	I, G
Knelpunten	Welke knelpunten doen zich voor bij het gebruik van het referentiemodel?	X
Succes-factoren	Wat zijn de belangrijkste succesfactoren bij het gebruik van het referentiemodel?	X
Instantiatie	Hoe vond de instantiatie van het generieke referentiemodel naar het implementatiespecifieke model plaats?	I, G
	Tegen welke beperkingen liep u aan bij de instantiatie? Hoe bent u daar mee omgegaan?	I, G
	Waarin wijkt het geïnstantieerde model af van het referentiemodel?	I, G
Dynamiek	Hoe vaak worden nu nog wijzigingen aangebracht in het model?	I, G
Verspreiding	Wie gebruikt het referentiemodel, hoeveel implementaties?	X
Gebruikerseisen	Welke kennis en vaardigheden zijn nodig om het referentiemodel te kunnen implementeren?	M, I, O
Openheid	In hoeverre is het gebruik van het referentiemodel open?	X
Verantwoordelijk-heden	Wordt het model onderhouden en zo ja, door wie (beheerder)?	X
Uitbating	Wordt het referentiemodel commercieel uitgebaat en zo ja hoe?	X
IP	Hoe is het intellectueel eigendom geregeld?	M, FO
ROI	In hoeverre is exploitatie winstgevend?	M, FO
Verbetering	In hoeverre worden implementatie-ervaringen in het model verwerkt?	X
Onderhoud	Op welke manier is het beheer georganiseerd?	X

Overig

Overig	Nog dingen vergeten?	X
Sneeuwbal	Heeft u nog tips wie ik voor deze inventarisatie nog meer zou kunnen interviewen?	X
Afsluiting	Vervolgprocedure toelichten en bedanken voor medewerking	X

Appendix B. Reference models for production and supply chain management

Name	Stage	Introduction of the investigated reference models
SAP	Imple-mentation	ERP market leader SAP developed detailed reference models to support SAP implementation processes (Curran and Ladd, 1999). Major elements of the model are process diagrams in the process modelling language Event-Driven Process Chains (EPCs) and data models. The EPC language has been conducted by SAP AG and the IDS Scheer AG in a collaborative research project in the years 1990-1992 (Rosemann and van der Aalst, 2007). The EPC models are integrated with the SAP ERP system and with NetWeaver, an SOA-based integration platform. The SAP reference model is set up for many industries. It contains different scenarios per major process. For example: the scenarios of production logistics are production by lot size, repetitive manufacturing, process manufacturing (including continuous production, discontinuous production and regulated production), 'Make-to-Order' production, and project – related 'Engineer to Order' (Curran and Ladd, 1999).
Baan	Imple-mentation	In the mid-1990s, the Baan Company developed reference models of 14 industries to accelerate and improve implementations. Major elements of these models are high-level Business Control Models (BCM), decompositions of business functions (including predefined parameter settings) and detailed process models (including roles, work instructions and links to specific Baan functionality). The reference models are developed with the tool DEM, which is a module of the Baan system (Verbeek, 1998). User-specific menus can be generated from the implemented DEM reference models and the models can be used in the workflow module of the system. On the basis of the industry models, at the end of the 1990s, a multiple-domain reference model was developed, named the Hybrid Logistics Model (TriArch, 1998). This model is further developed in the Enterprise Business Model (EBM), which is currently maintained by Infor, the company that acquired Baan.
Y-CIM	Design	The Y-CIM reference model was developed by Prof. Scheer in the early 1980s. Y-CIM encompasses integrated processes for logistics, including production, product engineering and the accompanying information and coordination processes (Scheer, 1994). The underlying modelling methodology was ARIS, which is further developed and commercialised in the ARIS Toolset of IDS Scheer AG, nowadays a leading supplier of business process modelling software. The Y-CIM reference model is broadly acknowledged in the industrial sector and has been developed into a comprehensive reference model that is also applied in other sectors.
STEP	Design	STEP (STandard for the Exchange of Product model data) is an ISO standard (ISO 10303) of which the first parts were published in 1994 (Pratt, 2001). It includes a reference data model for the electronic exchange of product data between computer-based product lifecycle systems, focussing on design and manufacturing applications. It covers a wide variety of different product types and lifecycle stages, such as design, analysis, planning, and manufacture. The information architecture of STEP is modelled in the Express language that can be represented in XML (STEP-XML, part of the standard).
ISA95	Design	ISA95 (formerly S95) is a standard of ISA for the integration of enterprise and manufacturing control systems, that is ERP and MES (ISA, 2008). It involves functions for business planning & logistics, manufacturing operations & control, and control (batch, continuous, and discrete). ISA95

		contains hierarchy models that describe the levels of functions and domains of control, a data flow model and an object model that focuses on the interfaces between MES en ERP systems, including XML specifications. The model builds upon The Purdue Reference Model, the MESA International Functional Model and the ISA S88 standard for batch control.
MIT Process Hand-book	Require-ments	The MIT Process Handbook was developed in the 1990s as a tool for (re)designing business processes and organising business process knowledge (Malone *et al.*, 1999). Important underlying concepts are the specialisation of processes based on inheritance notions and managing dependencies based on coordination theory. The handbook includes models of business activities, different business model archetypes, specific case examples, and frameworks for classifying activities. The activity models also include reference process models developed elsewhere, amongst others SCOR.
CPFR-model of VICS	Design	In the short time since first publication in 1998, the Collaborative Planning, Forecasting, and Replenishment (CPFR) model of VICS has been acknowledged as best practice in business-to-business (B2B) commerce(VICS, 2004). It provides a general framework for collaborative aspects of planning, forecasting and replenishment processes, focussing on the activities Strategy & Planning, Demand & Supply Management, Execution and Analysis. The framework contains process and data models. It addresses four different process variants: conventional order management, supplier-managed inventory, co-managed inventory and retail VMI. CPFR includes XML specifications that are integrated with the broader set of UN-CEFACT.
SCOR	Require-ments	The Supply Chain Operations Reference model (SCOR) has been developed and endorsed by the Supply Chain Council (SCC) as the cross-industry standard for supply-chain management (SCC, 2008c). The SCC was organised in 1996 by PRTM and AMR Research, and initially included 69 voluntary member companies (mainly in the U.S.). At the moment about 1000 companies are members of the SCC and the model is internationally acknowledged. The SCOR model focuses on the plan, source, make, deliver and return processes. It provides process models on three aggregation levels, standard process descriptions, performance metrics (in the categories Delivery Reliability, Responsiveness, Flexibility, Costs and Asset Management Efficiency), and best-practice descriptions.
VRM	Require-ments	In April 2005 the Value-Chain Group was launched by former representatives of the Supply Chain Council. It has developed the Value Reference Model (VRM), which contains process models and metrics focussing on planning, governing and execution activities for product development, logistics and commercial processes (VCG, 2007). The model is integrated with SOA standards including FERA.
GSCF Frame-work	Require-ments	The Global Supply Chain Forum (GSCF) introduced another Supply Chain Model (Lambert *et al.*, 1998). This model is built on eight key business processes that are both cross-firm and cross-functional, including functions such as production, R&D, logistics, marketing, purchasing and finance. The business processes that are addressed are Customer Relationship Management, Supplier Relationship Management, Customer Service Management, Order Fulfilment, Demand Management, Manufacturing Flow Management, Product Development and Commercialisation and Returns Management.

Appendix C. Questionnaire case studies in the Dutch flower industry

Structure of the questionnaire and main questions of the multiple case study (chapter 3) and the single case study (chapter 5) in the Dutch flower industry:

A. Introduction
- Please, could you introduce your organisation and your current function?
- What are the main products of your organisation?

B. Supply Chain Structure
- Which are the main organisations in your Supply Chain?
- To what extent do your customers demand your company specific requirements?
- How far do you collaborative with your customers? (including type of arrangements).
- How do you evaluate the current cooperation, *i.e.* what are the most important success factors and points for improvement?

C. Business Processes
- Please, could you describe the business processes in which you are involved?
- How far are your business processes integrated in the supply chain?
- What are the most important bottlenecks in current business processes?

D. Control
- To what extent are your processes order-driven?
- How do you make your future (production) planning?
- What are your most important control challenges?

E. Information Management
- What are your main information systems?
- How far are you satisfied with your information systems?
- What is your vision about the possibilities of ICT for better performance?

F. To conclude
- How does your organisation look like 5 years hence?

See below for the detailed questionnaire (in Dutch).

Algemene gegevens

Naam geïnterviewde	Vooraf invullen
Functie	Vooraf invullen
Bedrijfsnaam	Vooraf invullen
Datum interview	Vooraf invullen

Algemene bedrijfsgang

Bedrijf	**Kunt u kort omschrijven waar uw bedrijf zich mee bezighoudt?**
	• Product? • Kernactiviteiten? • Hoeveel productie per jaar? • Omzet per jaar? • Hoeveel hectare? • Aantal medewerkers (per functiegroep) • …
	Historie?
	Hoe ontstaan? Hoe oud?

Rol geïnter-viewde	**Wat is uw rol?**
	Functie, verantwoordelijkheden, etc.
Product	**Wat zijn de belangrijkste producten van uw organisatie?**
	Variatie? Goederen, diensten, informatie?

Ketenstructuur

Afnemers	**Wie zijn uw klanten?**
	• Onderscheid type klanten • Doorvragen naar de klant van de klant tot aan consument • Grootte van de klanten (in hoeverre afhankelijkheid van 1 of enkele afnemers) • Wat is de vraag, orde van grootte? • Minimale bestelgrootte? • Frequentie van uitlevering? • Hoe verloopt de informatievoorziening? Wat voor informatie, van wie?
	In hoeverre stellen klanten specifieke eisen?
	• Productkwaliteit • Verpakking? • Service? • Informatie? • Nalevering? • …
	In hoeverre werkt u samen met uw klanten (relatie)?
	Bij doorvragen indelen naar de volgende typen (Webster 1992): • Niet (transacties) • Herhaalde transacties • Lange termijn relaties • Partnerships • Strategic Alliances (inclusief Joint Ventures) • Network organisations • Verticale integratie
	In hoeverre heeft u contracten met uw afnemer?
	• Welk type? • Afspraken over: o Hoeveelheden? o Kwaliteit? o Levertijd and plaats? o Verpakking? o Toegevoegde diensten? o Informatie?
Leve-ranciers	**Wie zijn uw leveranciers?**
	• Onderscheid type leveranciers: grondstoffenleveranciers, service providers, … • Grootte van de klanten (in hoeverre afhankelijkheid van 1 of enkele afnemers) • Minimale leveringen? • Frequentie (betrekken op het bedrijf, waar vind opslag plaats, etc.) • ….
	In hoeverre stelt u uw leveranciers specifieke eisen?
	• Productkwaliteit? • Verpakking? • Service? • Informatie? • …

Leve-ranciers (vervolg)	**In hoeverre werkt u samen met uw leveranciers (relatie)?**
	Bij doorvragen indelen naar de volgende typen (Webster 1992): • Niet (transacties) • Herhaalde transacties • Lange termijn relaties • Partnerships • Strategic Alliances (inclusief Joint Ventures) • Network organisations • Vertical integration
	In hoeverre heeft u contracten met uw leveranciers?

	• Welk type?
	• Afspraken over:
	    o Hoeveelheden?
	    o Kwaliteit?
	    o Levertijd and plaats?
	    o Verpakking?
	    o Toegevoegde diensten?
	    o Informatie?
	• Eventueel: voorbeeld contracten inzien.

Verticale & horizontale integratie	**Hebben zich in het verleden bij uw bedrijf fusies of overnames voorgedaan?**
	Sluit aan op voorgaande vragen over relaties met afnemers / leveranciers Zo ja, welke en waarom?
Waardering keten-samen-werking	**In hoeverre bent u tevreden over de samenwerking met uw klanten (en leveranciers)?**
	• 3 belangrijkste succesfactoren? • 3 belangrijkste verbeterpunten?
	Wat is uw visie over de samenwerking met uw klanten (en leveranciers) in de toekomst?
	• Marktontwikkelingen • Impact op samenwerking • Ideaalbeeld • ….

Bedrijfs- en ketenprocessen

Inven-tarisatie	**Wat zijn uw belangrijkste bedrijfsprocessen?**
	• Productie/teelt • Distributie • Productontwikkeling • Verkoop/inkoop • Voorraadbeheer • Customer Service • …. Vooraf inschatting maken, checken met antwoord, doorvragen.
	Kunt u kort per proces schetsen hoe de werkwijze is?
	• …
	Wat is de beslisstructuur binnen uw bedrijf? (schema?/organogram?)

	▪ Verantwoordelijke?
	▪ Businessstructuur
	    o Functioneel?
	    o Matrix?
	    o Team?

Inven-tarisatie (vervolg)	**In hoeverre zijn uw bedrijfsprocessen geïntegreerd in de keten (afstemming met klanten en leveranciers)?**
	Deelname van klanten/leveranciers in uw bedrijfsprocessen: • Verkoop/inkoop: bijvoorbeeld gezamenlijk promotiecampagnes opzetten. • Distributie • Productie/teelt • Productontwikkeling • Voorraadbeheer • ….
Waardering	**Wat zijn per proces de belangrijkste knelpunten/uitdagingen?**
	• …

Ketenmanagement

Inven-tarisatie	**In hoeverre zijn uw processen klantordergedreven?**
	• Doorvragen naar verschillende dimensies totdat posities CODP helder zijn en daarmee grondvorm(en) illustreren met een voorbeeld. o Deliver from (local) stock o Make to Stock o Assemble to Order o Make to Order o Engineer to Order
	Op welke manier voert u uw planning uit?
	Open beginnen, doorvragen naar de specifieke planning and control per process: • Productieplanning op verschillende niveaus: master production schedule, material & resource requirementsplanning, scheduling en shopfloor control • Sales planning: gebeurt het en hoe demand forecasting? • Overige planningen: inkoopplan/ inclusief replenishment rules, distributieplan, etc.
	In hoeverre is uw planning en control geïntegreerd in de keten?
	• Doorvragen naar: o In hoeverre forecast op basis van klantinformatie/Point of Sales o Uitwisseling van planningsinformatie met klanten / leveranciers, zoals purchase schedule customer (based on MRP) geïntegreerd met Sales/Demand Planning o …
Waardering	**Wat zijn uw grootste control uitdagingen, wat heeft de hoogste prioriteit?**
	• Top 3, nog meer? • Doorvragen naar sectorspecifieke punten • ….

Keteninformatievoorziening

Inven-tarisatie	**Van welke informatiesystemen maakt u gebruik?**
	ERP, MES, BI, CRM, etc.
	Welke processen ondersteunen deze en op welke manier?
	Leg de link met voorgaande vragen over bedrijfs- en ketenprocessen
	Welke informatie wisselt u uit met uw afnemers?
	Welke informatie wisselt u uit met uw leveranciers?
	Welke informatie wisselt u uit met andere externe partijen?
Waardering	**In hoeverre bent u tevreden met uw informatiesystemen?**
	• Top 3 sterke punten, nog meer? • Top 3 verbeterpunten, nog meer? • Doorvragen naar sectorspecifieke punten • ….

Waardering (vervolg)	**Wat is uw visie op de mogelijkheden van informatievoorziening voor betere ketenperformance?**
	….

Slot

Visie	**Hoe ziet uw bedrijf er over 5 jaar uit?**
	• Belangrijke vraag, goed doorvragen! • Doorvragen naar omgevingsontwikkelingen (Kansen?, Bedreigingen?) • Wat is de strategie om hier op in te spelen, visie hoe? • …
Overig	**Nog dingen vergeten?**
	Wat verder ter tafel komt.
Sneeuwbal	**Heeft u nog tips wie ik nog meer zou interviewen?**
	Zo ja, vraag naar rol en contactgegevens.
Afsluiting	**Vervolgprocedure toelichten en bedanken voor medewerking**
	Verslag, controle, acceptatie, interesse in verdere betrokkenheid bij het onderzoek?

Appendix D. Steady-state control functions

Control Function	Transformation Processes	Transaction Processes
Input Coding	Receives input material and translates it into the proper format. This includes completing product-related information required for further processing such as article code, Bill of Material or ingredients, history information, country of origin and certificates. Furthermore, it includes repacking and assuring that the proper handling unit is used (*e.g.* putting products from pallets on specific carriers for internal transportation).	Receives order and translates it into the proper format. This particularly involves specification of customer requirements within possibilities and registration in the order processing system that is complete and appropriate for further processing, including article codes, related Bill of Material (BOM), required delivery time and place, routing or process model of order-driven activities and customer's credit information.
Input Filter	Verifies whether input material meets the requirements as agreed with the supplier.	Assesses whether the registered order can be accepted. This particularly concerns the Available to Promise (ATP) check.
Feed Forward	Preventive control loop, which measures the quantity and availability of input products and capacity, corrects any disturbances in the input flow (*e.g.* by ordering extra material), feeds production in time with the required material and ensures that appropriate capacity is in place when needed.	Ensures that all preconditions for order fulfilment are met and subsequently triggers execution. This particularly concerns reservation of the required products (including material and semi-finished products) and capacity, including distribution planning. If the order cannot be (completely) fulfilled in the own organisation, this function concludes outsourcing arrangements with partners.
Input Buffer & Safety Function	Stores input material until production needs it (including monitoring of quality decay), replenishes inventory and, if necessary, dumps input material if buffer is over its maximum capacity or if buffered material no longer meet quality requirements *e.g.* due to deterioration or changing requirements;	Backlog of orders that are waiting for fulfilment, including monitoring whether the requirements can still be met. If this is not the case, *e.g.* because of disruptions in fulfilment of other orders or because of changing customer requirements, the feed forward function is triggered to solve the problem (*e.g.* by outsourcing, negotiating new requirements or order cancellation).
Trans-formation	Production process that physically converts raw or semi-finished material to a state of completion and greater value. Main forms are discrete production, continuous production and mixed forms (batch and semi-process production). Transformation includes packaging, as far as it is part of the product.	All processes that convert orders into accepted fulfilment. This includes transformation processes depending on how far these processes are order-driven and the type of relation (*e.g.* single transactions versus long-term contracting).
Internal Control Functions	Measure disturbances and intervene in production processes during transformation. Include management of internal transportation, changeovers and buffers of semi-finished products in between different production phases.	Monitor order fulfilment and intervene if agreed customer requirements are in danger.

Supporting Processes	Ensure service levels (including availability) of the required resources, both human resources and (technical) capacities particularly machines and other facilities.	Ensure service level of required resources for order fulfilment. This partly overlaps the supporting processes for transformation processes, but also includes means for sales, order management, installation and service.
Output Filter	Tests quality of the produced products, determines whether rejected products can be repaired and manages waste disposal.	Customer assessment of the delivered product. In the case of rejection, determines how far contractual requirements have been met and agrees interventions with customers.
Repair Function	Moves rejected products back to input zone in order to transform it into output that finally meets quality requirements.	Actions to satisfy customers after rejection of product delivery. Besides repairing product defects, this might involve actions such as delivering additional services or giving discounts.
Feedback	Corrective control loop, which measures characteristics of the output product, determines deviations from the requirements and intervenes to correct disturbances.	Corrective loop that measures acceptation of order fulfilment and implement corrective measure in order to prevent future disturbances.
Output Buffer & Safety Function	Stores output until needed by next process (including monitoring of quality decay) and, if necessary, dumps it into environment if buffer is over its maximum capacity or if buffered products no longer meet quality requirements.	Queue of orders that are delivered but not yet accepted by the customer, including communication with customer if acceptance takes too long or if agreed deadlines for acceptance have passed.
Decoding	Translates produced products into appropriate format for next process. This includes adding product-related information that is needed for further processing such as barcodes, certificates, best before date and shipping documentation. It also ensures that the packaging and handling unit required for shipping is used, *e.g.* putting products on pallets.	Registration of customer's acceptance (including satisfaction), invoicing and order closure after receipt of payment.
Initiation & Evaluation	Product-related requirements can be derived from defined control functions and include required product format and handling unit, required production volume, quality criteria, lead-times, required material and capacity. The initiation and adjustment of these requirements are triggered by product and capacity related coordination processes.	Order-related requirements can be derived from defined control functions and include required order format, order acceptation criteria, required output (particularly product amount and quality, delivery time and place), etc. The initiation and adjustment of these requirements are triggered by order-related coordination processes.

Appendix E. Questionnaire case study in the European fruit industry

The following questionnaire is used in the interviews of the multiple case study in the European fruit industry, chapter 4 (Verdouw, 2008a).

General information

Name interviewee	Fill in before the interview.
Function	Fill in before the interview.
Company name	Fill in before the interview.
Date interview	Fill in before the interview.

Introduction

<table>
<tr><td rowspan="2">Interview objective</td><td colspan="2">Brief introduction of the research, interview objective and method</td></tr>
<tr><td colspan="2">See information above.</td></tr>
<tr><td rowspan="8">Company profile</td><td colspan="2">Please, could you briefly introduce your company?</td></tr>
<tr><td colspan="2">After having answered this open question, check the following information which should be gathered as much as possible beforehand.</td></tr>
<tr><td>• Products, most important brands and or varieties?</td><td></td></tr>
<tr><td>• Core activities?</td><td></td></tr>
<tr><td>• Production amount per year?</td><td></td></tr>
<tr><td>• For growers: how many hectares (total plus percentage fruit/apple)?</td><td></td></tr>
<tr><td>• Organizational Structure</td><td>If applicable: organization chart!</td></tr>
<tr><td>• Which locations: where and type of locations (plant, nursery, sales office, …), spread or concentrated?</td><td></td></tr>
<tr><td rowspan="2">Profile inter-viewee</td><td colspan="2">What is your role in the company?</td></tr>
<tr><td colspan="2">Function, responsibilities, etc.</td></tr>
</table>

SCN Actors & Governance

Which are the main organizations in your Supply Chain?		
Actor	*Type*	*Brief Explanation /Relative Importance*
Input Supplier	Customer/ Supplier/ Other	
Breeder	Customer/ Supplier/ Other	
Research Institute	Customer/ Supplier/ Other	
Marketing Organization (for promotion, brand development, etc.)	Customer/ Supplier/ Other	
Tree Nursery	Customer/ Supplier/ Other	
Fruit Producer	Customer/ Supplier/ Other	
Producers Organization / or other forms of cooperatives	Customer/ Supplier/ Other	
Auction	Customer/ Supplier/ Other	
Processor	Customer/ Supplier/ Other	
Packaging Firm	Customer/ Supplier/ Other	
Distributors transportation companies)	Customer/ Supplier/ Other	
Wholesale	Customer/ Supplier/ Other	
Importer	Customer/ Supplier/ Other	
Exporter	Customer/ Supplier/ Other	

Retail	Customer/ Supplier/ Other	
Food Service	Customer/ Supplier/ Other	
Second Order Industry (uses fruits or residual products as ingredient to produce non-fruit products)	Customer/ Supplier/ Other	
Consumer	Customer/ Supplier/ Other	
……	Customer/Supplier/ Other	

CUSTOMERS

To what extent do your CUSTOMERS demand your company specific requirements?	
Specific requirements about:	*Brief explanation / Relative Importance* *If applicable: distinguish between different (types of) customers!*
Product?	
Quality?	
Packaging?	
Service?	
Information (*e.g.* for tracking & tracing, denomination of origin, etc.)?	
…	

What type of relations do you have with your CUSTOMERS?	
Type of cooperation	*Brief Explanation / Relative Importance (percentage of total customers) If applicable: distinguish between different (types of) customers!*
Individual transactions	
Repeated transactions	
Long term relations (informal)	
Partnerships (formalized, contracts)	
Strategic Alliances (including & Joint Ventures)	
Vertical integration (‘internal customers’)	
……	

Which type of arrangements do you have with your CUSTOMERS?	
Agreements (both formal and informal) about:	*Brief Explanation / Relative Importance* *If applicable: distinguish between different (types of) customers!*
Quality?	
Quantities?	
Delivery time and place?	
Packaging?	
Added services?	
Information?	
…	
Do you have examples of contracts? If yes, would it be possible to view/get it for our research?	

SUPPLIERS

How far do you demand your SUPPLIERS specific requirements?	
Specific requirements about:	*Brief explanation / Relative Importance* *If applicable: distinguish between different (types of) customers!*
Product?	
Quality?	
Packaging?	
Service?	
Information?	*E.g.* for tracking & tracing, denomination of origin, etc.
…	

What type of relations do you have with your SUPPLIERS?	
Type of cooperation	*Brief Explanation / Relative Importance (percentage of total customers)* *If applicable: distinguish between different (types of) customers!*
Individual transactions	
Repeated transactions	
Long term relations (informal)	
Partnerships (formalized)	
Strategic Alliances (including Joint Ventures)	
Vertical integration (‘internal customers’)	
……	

Which type of arrangements do you have with your SUPPLIERS?	
Agreements (both formal and informal) about:	*Brief Explanation / Relative Importance* *If applicable: distinguish between different (types of) customers!*
Quality?	
Quantities?	
Delivery time and place?	
Packaging?	
Added services?	
Information?	
…	
Do you have examples of contracts? If yes, would it be possible to view/get it for our research?	

SCN Business Processes & Control

What are your most important business processes?		
Main Business Process	***Please, describe !*** *(brief explanation /what are main sub activities?) If applicable: describe whether business processes are outsourced!*	*Order Driven?*
Product Development		Yes/No/Partly
Production (of trees, fruit, processed fruit, …)		Yes/No/Partly
Sorting		Yes/No/Partly
Packing		Yes/No/Partly
Cooling / Storage		Yes/No/Partly
Distribution/ Transportation		Yes/No/Partly
Sourcing/Procurement		Yes/No/Partly

Marketing/Sales		Yes/No/Partly
……….		Yes/No/Partly
Additional comments and explanation		

How far are your business processes customer order-driven?
⇒ ***In other words: which processes start after the customer order hare been received (so which processes are not executed before customers are ordering for it?***
Please, indicate in the table above how far the mentioned business processes are order-driven.

How do you make your future (production) planning? Do you use market information for it? If yes: which?	
Which type?	*Brief explanation*
Planning without taking into account market information?	
Planning based on own estimate of market information?	
Planning based on sales information from customer / end-customer?	
Planning based on consumer trends from market research organizations?	
………..	
Additional comments and explanation	

Do you have descriptions/models/diagrams of your business processes (*e.g.* as part of quality manuals)?
If yes, could we receive a copy of it (or summary, main flows)?

SCN Resources

What are critical resources for your company? Do you share resources with others? If yes, which, with whom and how?			
Resource Category	*Which resource?*	*Sharing with which type of partner?*	*Comments, specifications!*
Staff	Sales Expertise	…………	
	Product Development Expertise	…………	
	Production Expertise	…………	
	Transportation Expertise	…………	
	……….	…………	
Production facilities	Machines	…………	
	Field	…………	
	……….	…………	
Transport facilities	Trucks	…………	
	……….	…………	
Other: …………	…………	…………	
Comments, specifications!			

Do you share information with others? If yes, which, with whom and how far automated?				
Information Category	*Which resource?*	*Sharing with which type of partner?*	*How far automated?*[17]	*Comments, specifications!*
Demand-related infor-mation?	E-commerce: order/transaction related information	Retailer: …. : ….	Yes/ No/ Partly	
	Demand information (patterns of past transactions, trends, ..) for better forecasting	…. ….	Yes/ No/ Partly	
	Consumer/market information for new innovations	…. ….	Yes/ No/ Partly	
	………..	…. ….	Yes/ No/ Partly	
Supply-related infor-mation?	Product assortment information	Retailer: …. : ….	Yes/ No/ Partly	
	Production planning information (*e.g.* expected harvesting times, quantities, qualities)	…. ….	Yes/ No/ Partly	
	Product traceability information	…. ….	Yes/ No/ Partly	
	………..	…. ….	Yes/ No/ Partly	
Comments, specifications!				

SCN Strategy & Tactics

What is your mission statement? In other words: what is the main competitive advantage of your company in the market place?	
Lowest price High product quality Unique product 'One stop shopping' Excellent service …..	*Comments?*

What are the main objectives of your company? Please, indicate priority. Do you measure objectives in order to monitor achievement of your strategies? If yes, which?			
Objective (at least: top 3)	*Priority (1/2/3/etc.)*	*Measured? (Yes/No/Partly)*	*Comments*
Product Quality			
Costs			
Responsiveness			
Flexibility			
Service Level			
……..			

[17] Automated means that the information is exchanged via Information & Communication Technology e.g. EDI, the internet or shared software systems.

Do you share common objectives in the chain or align strategies with customers/suppliers?
Yes/No/Partly: Please explain.

Which are the main challenges/bottlenecks[18] you are facing in your company?	
Type	*Challenge/bottleneck*
SCN Actors & Governance	……………………
SCN Processes & Control	……………………
SCN Resources	……………………
Other ……?	

Which kind of changes did your company go through over the last 5 years?		
Change		*Brief explanation*
Product	New variety	
	……..	
Process	Implementation of Vendor Managed Inventory	
	Implementation quality management system	
	……………	
Marketing	New market channel (*e.g.* web shop, entrance in food service, …)	
	Implementation of a new type of promotion campaigns	
	……………	
Organi-zational	Merger	
	Reorganization	
	……..	

Which kinds of changes are you thinking about or are planned to work on?		
Change		*Brief explanation*
Product	New variety	
	……..	
Process	Implementation of Vendor Managed Inventory	
	Implementation quality management system	
	……………	
Marketing	New market channel (*e.g.* web shop, entrance in food service, …)	
	Implementation of a new type of promotion campaigns	
	……………	
Orga-nizational	Merger	
	Reorganization	
	……..	

To conclude

Others	**Have I forgotten relevant things?**
	What further comes up for consideration
Snow-ball	**Are you interested to become further involved in the ISAfruit research?**
	If yes, tell about the intended case studies: interested to participate?
	Do you have suggestions for other people that might be interested to participate in this project?
	If yes, ask about role and contact information.
Closure	**Tell what's next and thank for cooperation**
	Report, review, acceptation,

[18] Please, be careful how to ask this question. Interviewees sometimes do not like to talk about problems. Positive formulation (challenges/ desirable improvements) or indirect questions can help.

Appendix F. Supply chain structure of the investigated cases in the European fruit industry

In this appendix, the supply chain structure of the investigated cases is summarised. An in-depth description is provided by Van Uffelen et al. (2008).

1. Fresh Apple Chain (Poland)
Main actor in this supply chain is a cooperative of 28 apple growers with a total production area of 230 hectares. Primary customer segment is the local retail, specifically about 250 of supermarkets and fruit shops in the Warsaw agglomeration. Additional market channels are wholesalers and exporters. Distribution is outsourced to a transportation company. The cooperative has long-term relations with retailers, partly formalised in contracts that are concluded after harvesting when quantities and qualities are known. Wholesalers and exporters are mainly supplied via the spot market. The cooperative delivers a year-round supply to the retail segment. Therefore, the cooperative stores apples for the long-term in controlled atmosphere. Additionally, foreign apples are imported to supplement the assortment. The supermarkets have different requirements in particular to size, colour, firmness and packaging. Small apples are processed into juice. Apples are often packed to order, especially in case of apples on trays. The cooperative uses different types of market information for planning purposes, including observations of demand in shops and periodic point-of-sales data for different varieties of some retailers. The retailer cooperates with a marketing research agency that delivers trend information.

2. Organic Fruit Chain (Poland)
This supply chain delivers organic fruits to local and international retailers, as well as organic food shops. The majority of the assortment comprises processed fruits such as juices, jams, dried fruit and muesli. It is a closed chain that is coordinated by a central orchestrator. This firm has partnerships formalised in long-term contracts with over 300 fruit farms, several processing plants, transportation companies and retailers. The orchestrator has a warehouse from which they supply the retail. For some retailers, they are responsible for replenishment (Vendor Managed Inventory) and for organising promotion campaigns. All fruit products must be certified according to organic fruits standards, including information for tracking and tracing. The orchestrator bases its demand forecast on sales information of retailers and on consumer trends from various open sources. The information is passed on to the involved fruit farms, processors and breeders.

3. Fresh Apple Chain (Greece)
This supply chain comprises of 740 farmers, organised in a cooperative, that supply fresh apples to big local retailers, to exporters for foreign markets and to local wholesalers. Apples that do not match the quality criteria for the fresh segment are sold to processing companies for juice production. The cooperative has its own storing, freezing and controlled atmosphere facilities. Growers are contractually committed for 10 years to deliver their total produce to the cooperative. The

customers have specific requirements to especially packaging and quality. For example: one retailer demands for apples that are not kept in controlling atmosphere. All products have to match to PDO (Protected Designation of Origin) quality standards and the cooperative has adopted several other product quality protocols. Furthermore, in all cases HACCP and Integrated Pest Management systems are applied. The stable clientele forms the majority of the cooperative's customer base. They have informal agreements with big retailers and yearly contracts with some wholesalers. The cooperative uses sales information from retailers for planning purposes. Vice versa, they share supply information with retailers. The cooperative obtains production information through farmer logs.

4. Canned Fruits Chain (Greece)
This supply chain comprises a joint venture of three cooperatives which produces canned fruits (mainly peaches) for big international retailers, either directly or via importers. Farmers are obliged to deliver their entire production to the investigated cooperative for at least three years. In total, 2200 farmers are member of the involved cooperatives and their cultivations cover about 3200 hectares. Additionally, they import specific frozen fruits, *e.g.* raspberries and strawberries, which then are canned in the own factory. The joint venture has yearly contracts with retailers and also maintains informal open agreements. Each retailer has its own requirements, for example about the syrup sweetness, type of cans and certain quality certificates (often country-specific). The company uses past transactions for demand forecasting. The exchange of supply information, such as expected harvesting times, quantities, and qualities, with the member-growers is intensively. The company has implemented a traceability system for its suppliers. Furthermore, it has developed specialised software, based on GIS and satellite technology, for monitoring the actual conditions of each involved farm.

5. Seedless Watermelon Chain (Spain)
This supply chain delivers branded watermelons to supermarkets and fruit shops, mainly via wholesalers. The melons have a certified quality in terms of weight, sugar content, homogeneity and labelling, and they are seedless, which makes in particular appropriate for children. The producers grow the melons according to a protocol which is formed by the association of producers. The melons are collected, stored, packed and traded by a trading firm that is member of this association. This firm is formed from a merger of 17 local auctions. It is supplied by over 2500 growers in the region, usually via spot market transactions. In case of this branded watermelon, the trader has a contract with the growers about the production volume (hectares). The packed melons are sold via different market channels, both local and export. The investigated local greengrocer sources at a wholesale market where approximately 200 wholesalers supply their fruit and vegetables. Customers do not have specific requirements beyond the association's standardised requirements, except some large retailer that require special packages. Furthermore, the producers and traders that are member of the association exchange information about expected supply for planning purposes. There is no exchange of information with retailers.

6. Fresh Stone Fruits Chain (Spain)
The main actors of this supply chain are a producer cooperative and a retailer cooperative. The producer cooperative produces fresh fruits of in total 3000 hectares for international retailers, exporters and local retailers, wholesalers and food service providers. Main product categories are peaches, nectarines, pears and apples. Most of the fruits are sold directly without any processing and stored only very short. Fruits can be ready for distribution 24 hours after harvesting. However, they are trying new products that include processing, such as peach cubes in their own juice. The type coordination with customers differs a lot, including spot market, informal long-term relations, formalised contracts and partnerships. Especially the big retailers have specific requirement regarding variety, size, ripeness, certificates, labels and packaging. For example, the investigated retailer cooperative demands special returnable packages, with one layer of fruits and a specific number of pieces per box in order to guarantee best quality and efficient logistics.
The retailer cooperative has supermarkets all over the country, 10 logistics platforms, 10 cash and carry stores that supply the food service segment and several providers of additional services. Transportation is outsourced. In total 1700 companies are member of the group. The company prefers long-term relations with their supplier and concludes formal agreements that specify quantity and quality of supply. Both the producer and retailer group use various sources of market information for future planning, including point-of-sales information. Furthermore, the retailer associates can place order electronically and track the order progress. The producer cooperative receives tracking and tracing information of their members in weekly reports.

7. Black Currant Ingredient Chain (The Netherlands)
This supply chain focuses on the delivery of black currents as an ingredient of food products, in particular ice creams. The main actors are a cooperative of 28 growers, a pre-processing firm, a food processor and a retailer. The growers cool (and pulp if requested) the black currants and sell them via the cooperative. The cooperative has long-term contracts with food processors, but delivers also to the spot market. The pre-processing company sources high-quality fruits based on long-term contracts (5-10 years) containing specific requirements. However, an important part of the fruits are sourced at the spot market on a very irregular basis, *i.e.* only if the prices of fresh fruits are low.
The black currants are pre-processed by the use of a cold infusion technique. This causes the water in the fruit to be largely replaced by sugars. The advantage of this process is that the fruits remain soft, even when they are frozen. The currants must contain enough sugar, they must be firm, and crates may not exceed 25 kg in order to avoid damage. The company has yearly contracts with most customers, which include very stringent quality requirements. Also the food processor has yearly contracts with retailers. Demand forecasting is done mainly based on own historical sales information. The food processor uses a specialised software application to communicate its demand with suppliers and for monitoring sustainability requirements.

8. Fruit Salad Chain (The Netherlands)

This supply chain focuses on supply of fruit salads to a catering company. The salad producer has seasonal contracts with fruit producers all over the world that guarantee baseline supply. Besides that, if necessary, it sources additional fruits at the spot market. After cutting and addition of preservation syrup, the shelf life is limited to 15 days at the maximum. As a consequence, the emphasis is on short lead-times and flexibility. Recipes can be adjusted to the wishes of specific customer. The main customers are the catering and retail industry, both local and export. The investigated local caterer is part of a big multinational that is active in 80 countries. Main customers are corporate services, health care and education. The firm has a five-year contract with a big local wholesaler dedicated to the food service industry. For most products, this firm tenders twice a year. With the more innovative suppliers, including the fruit salad producer, they build long-term relations. There is intensive information exchange between the wholesaler and the caterer. The local catering sites can order electronically. The wholesaler groups these orders and passes them on to their suppliers. However, the company notes that most their fruit and vegetable suppliers are not able accept orders electronically and do not provide standard GS1 barcodes. As a result, handling costs are high. Both the caterer and the wholesaler use point-of-sales information for demand forecasting purposes. This information is not shared their suppliers, including the fruit salad producer.

Appendix G. Specific characteristics of business processes in fruit supply chains

This appendix is based on the case study investigation of chapter 4 and the following additional literature: Trienekens (1999), GS1 (2007) and Van der Vorst et al. (2007).

1. Fruit Production

Key fruit-specific feature	Impact on business processes
Fruit production is a process of continuous growth depending on natural conditions, such as climate (day length and temperature), pests and weather	• Specific production activities: planting trees, pruning, thinning, fertilizing, irrigating, pests management, and harvesting • Importance of environmental inputs (water, soil, sunshine, manure, bees for pollination, pesticides) and outputs (emissions of pesticides and nitrates to air, soil, and ground and surface water; pesticides remain on fruit products) • Unpredictable variations in quality and quantity of supply (unpredictable production yields) *Additional measures to ensure supply of qualified products, especially:* • Diversification of production locations: in different climates and weather conditions, spread the risk for pests • Diversification of markets, each having different requirement and different time horizon in the agreements (long-term agreements versus spot market) in order to sell different qualities (co-products) • Diversification of varieties, each having different sensitivity for pests, weather and other natural conditions • Communicate supply information with customers (forecasts, messages) for optimal planning • Advanced production techniques to get the growing process in control • Flexibility in post harvest activities in order to deal with high supply uncertainty • Emphasis on Quality Management Systems and Certification
Seasonal growing	• Harvesting is limited to a specific period, dependent on the climate, weather conditions and variety *Additional measures to ensure year-round availability, especially:* • Diversification of production locations: in different climates and weather conditions, so different harvesting periods • Diversification of varieties, each having different harvest periods
Long pre-harvesting lead-times (producing new or additional products takes a lot of time)	• Limited possibility for order-driven production: customer-specific procedures for growing and harvesting to influence fruit attributes only possible in long-term agreements
Risk for damaging in post harvesting treatments (like washing and sorting).	• Reducing number of post-harvest handlings, doing it as much as possible during harvesting • Advanced harvesting, washing, sorting and transportation techniques to prevent damages
Increasing environmental demands regarding to production processes, including food safety legislation and standards.	• Emphasis on Quality Management Systems and Certification, with a special emphasis on environmental issues and food safety • Tracking & Tracing systems that log data during production that can be linked to specific product units (especially lots or single products) including environmental data especially use of pesticides

2. Fruit Processing

Key fruit-specific feature	Impact on business processes
Fruit processing is a process of semi-continuous production, transforming bulk fruits into packaged consumer products or ingredients	• Semi-continuous (batch) production planning and control: exact timing and sequencing, combining bulk (continuous) and packaging (discrete) • Importance of recipe management • High volume, low variety production systems (although variety is increasing)
Unpredictable supply of produce in a short period of time	• Importance techniques for long-term storage *e.g.* in frozen form • Global sourcing: from different climates with different harvesting periods • Variable recipes: use of different fruit varieties with different harvest moments for same processed fruit product • Use supply information (supply forecasts, messages) of suppliers to optimise planning • Planning Flexibility
Quality variation between different producers, between different lots of produce and within lots	• Variable recipes: use of different fruit varieties and qualities for same processed fruit product • Importance of processing techniques for quality standardisation • Diversification of markets: need for alternative markets for by and co products • Emphasis on Quality Management Systems and Certification

Techniques for managing decay	• Production techniques for increasing shelf live
	  o In processed fruit: transforming fruit into non-perishables
	  o In prepared fruit: increasing shelf-lives while retaining freshness
	• Importance of cooling facilities for transportation and storage
	• In processed fruit, relatively long processing lead-times
	• In prepared fruit, very short processing lead-times and frequent delivery

Increasing environmental demands regarding to production processes, including food safety legislation and standards	• Emphasis on Quality Management Systems and Certification • Tracking & Tracing systems that log data, during production that can be linked to specific product units (especially lots or single products)

3. Fruit Distribution

Key fruit-specific feature	Impact on business processes
High volume distribution combined with frequent delivery and increasingly fine-mesh distribution	• Combining speed, efficiency and customisation • Importance robust and real-time planning and control systems
Very short order-to-delivery lead-time due to product freshness	• Importance of cooling facilities for transportation and storage to increase shelf life • Much pre- and re-packing • Postponement of labelling • Flexibility and rapid response: much improvisation and administrative tasks are often done afterwards, because registration may not delay delivery • Back orders occur only incidentally

	• First Expire First Out (FEFO) replenishment • Traceability info must included also Best Before Date / Production Date, Production Location and Country of Origin • Techniques to influence the ripening process, delay (ULO) or accelerate

Unpredictable quantity and quality of supply	• Importance possibility for long-term storage in controlled atmosphere storage
	• Global sourcing: from different climates with different harvesting periods
	• Changing product compositions because of variable quality and necessity for year-round supply
	  o No fixed compositions of packaged fruits, but different varieties and slightly different characteristics (weight, colour)
	  o Possibility to define products from customer perspective in product categories and from supplier perspective in detailed article codes
	• Use supply information (supply forecasts, messages) of suppliers to optimise planning
	• Diversification of markets: need for alternative destinations for different qualities and quantities
	  o Different types of agreements: year, season, week, daily
	  o Spot market remains important in order to deal with supply fluctuations
	• Importance of mutual sales in order to deliver complete assortment and year-round supply
	• Planning flexibility

Products are sold in different units including unpacked loose products are ordered	• Both countable products and volumes/weights are needed
	  o Price is sometimes dependent on volume
	  o Different checkout solutions weight products
	• Identification must be possible at multiple product units, and not all products are bar coded

Increasing demand for traceability and quality labels	• Emphasis on Quality Management Systems and Certification • Tracking & Tracing systems that log data during production that can be linked to specific product units (especially lots or single products)
Important role of import/export, including phytosanitary inspections	• Additional inspections, resulting among others in longer lead-times • Country-specific trade and phytosanitary requirements, resulting in different information needs • Need for separated quarantine rooms

Summary

The increasing volatility and diversity of demand urge agri-food supply chains to become more demand driven, *i.e.* sensitive and responsive to demand information of the ultimate consumer. Companies that participate in demand-driven supply chains must manage a high variety and variability of supply chain configurations to meet the specific requirements of their customers. Business process models can be valuable means to achieve this by supporting the design of customised supply chain configurations and subsequently the engineering of enabling information systems.

However, existing reference process models do not sufficiently support specific requirements in demand-driven agri-food supply chains. Therefore, the present research aims to design a reference framework for business process modelling that i) is setup to enable the instantiation of various specific supply chain configurations, ii) supports a seamless translation of high-level supply chain designs to detailed information engineering models, and iii) is sector-specific *i.e.* contains domain-specific knowledge for the agri-food sector.

The research addresses the following main research question: *"How can reference process models be designed that enable the modelling of demand-driven agri-food supply chains and the implementation of supporting information systems?"* This main question is split up into the following sub-questions:

a. What are the characteristics of demand-driven supply chains?
b. What are the requirements on reference process models to enable the modelling of demand-driven supply chains and the implementation of supporting information systems?
c. To what extent do existing reference process models meet the requirements of demand-driven supply chains?
d. How can reference process models be designed that meet the requirements of demand-driven supply chains?
e. How can reference process models of demand-driven supply chains be applied to the agri-food industry?

The research used a design-oriented methodology to answer the defined research questions. It started with the definition of basic design requirements based on literature review and subsequently existing reference models were assessed on these requirements. Based on this assessment and the reviewed literature, a generic framework was constructed. This generic framework was applied, evaluated and refined in three different case studies: i) an explorative multiple case study in the Dutch flower industry, ii) an in-depth multiple case study in the European fruit industry, and iii) a single case study in the Dutch flower industry on implementation of the framework in configurable process models.

The main result of this thesis is the design of a framework for reference process modelling in demand-driven agri-food supply chains. The framework provides concepts and a toolkit for modelling a wide variety of supply chain configurations from standard model components. As such, it enhances shared understanding and reuse

of process knowledge in supply chain design and information systems engineering. The framework consists of two parts: i) an object system definition and ii) a toolbox for modelling the defined object system.

The object system definition is a conceptual view of the modelling object: business processes in demand-driven supply chains. It provides typologies of the main elements of supply chain configurations, *i.e.* business processes, product units, control systems and coordination mechanisms. Next, it describes how these concepts are related in supply chain configurations, which are considered as specific networks of autonomous components (building blocks).

The toolbox provides the representation power for modelling the defined object system. It identifies three types of supply chain process models:

1. *Product Flow Models*: visualise the allocation of basic transformations to supply chain actors and the related product flows from input material into end products;
2. *Thread Diagrams*: visualise how order-driven and forecast-driven processes are decoupled in specific supply chain configurations (positions Customer Order Decoupling Points), and how interdependences between processes are coordinated;
3. *Business Process Diagrams*: depict the sequence and interaction of control and coordination activities (as identified in Thread Diagrams) in an executable notation.

For each process model type, the toolbox contains i) standard model building blocks (reference components), ii) a method to configure specific diagrams (configuration tree), and iii) pre-configured models (reference templates) that capture reusable knowledge abstracted from the case studies. The toolbox also includes a conceptual architecture for implementation of enabling information systems.

With the analysis, design and evaluation of this framework, the addressed research questions are answered as follows.

a. What are the characteristics of demand-driven supply chains?
Based on literature review, a demand-driven chain is defined as: *"a supply chain in which all actors involved are sensitive and responsive to demand information of the end customer"*. It has been found that demand-driven supply chains continuously have to match products and business processes, including the network of producers and distributors, to changing demand requirements. Consequently, they are characterised by a high variety and variability of supply chain configurations. A supply chain configuration is defined as: *"a specific set of business processes, control systems and coordination mechanisms, performed by a specific network of contributors who together produce and deliver a product or service with distinct value for the ultimate customer".* Subsequently, the thesis has defined and classified business processes, control and coordination in order to identify the possible variety of configurations that a company must manage in order to fulfil the different demand requirements of their customers.

b. What are the requirements on reference process models to enable the modelling of demand-driven supply chains and the implementation of supporting information systems?

The research has identified the following basic requirements to reference process models in demand-driven agri-food supply chains:

R 1. They must be setup to enable rapid instantiation of various specific supply chain configurations from a repository of standard building blocks instead of dictating a single blueprint;

R 2. They must depict supply chain configurations as series of order-driven and anticipatory processes connected by coordination mechanisms;

R 3. They must support a seamless translation of high-level supply chain designs to detailed information engineering models;

R 4. They must be sector-specific *i.e.* contain domain-specific knowledge.

c. To what extent do existing reference process models meet the requirements of demand-driven supply chains?

In the domain of Production and Supply Chain Management, this thesis has identified ten widely acknowledged and applied reference models. It has been found that none of the investigated models sufficiently meet all of the defined requirements:

R 1. None of the investigated models do fully support ICT mass customisation, in particular because they lack a generic model setup and adequate configuration support.

R 2. None of the investigated models depict supply chain configurations as series of order-driven and anticipatory processes connected by coordination mechanisms.

R 3. All investigated supply chain models are high-level process models that can be used for definition of information system requirements, but do not support detailed information systems engineering. Available process models that can be used for information systems design and implementation focus on single enterprises.

R 4. The few existing reference process models in the agri-food sector can be characterised as isolated models, which have not been used to guide the workflow in run-time information systems. Furthermore, our survey has not found reference models for supply chain processes in the agri-food industry.

d. How can reference process models be designed that meet the requirements of demand-driven supply chains?

The designed framework meets the addressed basic design requirements as follows.

R 1. It has defined the variety of supply chain systems in a conceptual object system definition, which includes classifications of product units, processes, control and coordination. For different types of process models, it has defined reference components, a configuration tree that guide model instantiation and multiple reference templates, *i.e.* pre-configured models of typical configurations. Last, it has included an information systems architecture for implementation of configurable process models in combination with product configuration.

R 2. The framework includes a new type of Supply Chain Thread diagrams that explicitly visualise how order-driven and forecast-driven processes are decoupled in specific supply chain configurations (positions Customer Order Decoupling Points), and how interdependences between processes are coordinated. Next, it has elaborated the sequence of their detailed activities and the interactions with adjacent control cases and coordination mechanisms in Business Process Diagrams.

R 3. The framework starts with depicting the allocation of basic transformations to supply chain actors and the related product flows in Product Flow Models. Next, the coordination and control of these transformations in specific supply chain configurations is visualised in Thread Diagrams. Last, one can zoom into Business Process Diagrams that depict the sequence and information flows among control and coordination activities. Business Process Diagrams are modelled in the BPMN notation, which can be executed in Service-Oriented Architectures (SOA) for orchestration of data amongst multiple software components that are packaged as interoperable web services.

R 4. The framework combines industry-specific knowledge with reuse of generic knowledge of cross-industry standards. The definition of different types of process models, the configuration methods and the reference components of Thread and main Business Process Diagrams are generic. Sector-specific characteristics are covered by the building blocks of Product Flow Models and Sub Process Diagrams and by templates of typical supply chain configurations.

e. How can reference process models of demand-driven supply chains be applied to the agri-food industry?

The framework has been applied in three case studies, which resulted in updates of the framework with sector-specific knowledge. The first case study has applied the first version of the framework to flower supply chains in an explorative multiple case study in the Dutch flower industry. The second case study has applied the updated version of the framework to fruit supply chains in an in-depth multiple case study in the European fruit industry. The third case study has applied the designed information architecture for implementation of configurable process models in a single case study in the Dutch flower industry.

The main addition of this thesis to existing theory is the design of an innovative artefact: a new framework that captures the concepts needed to design adequate reference process models in demand-driven agri-food supply chains. Therefore, the thesis has defined, developed and evaluated the representation power needed to model a wide variety of supply chain configurations as specific networks with different allocations of business processes to supply chain participants and different modes of control and coordination. More specifically, three additional contributions can be mentioned.

First, our research has applied the concept of mass customisation to reference process models, which implies that customised models are configured from a repository of standard building blocks *i.e.* predefined model components. As such, it contributes to the emerging field of process model configuration, which is a relatively new research area.

Second, our research has developed a framework that combines process models at different levels of abstraction for two main purpose of usage: supply chain design and information systems engineering. As such, it contributes to the development of a common conceptualisation and consistent terminology of these two research streams.

Third, our research has applied the framework to specific agri-food sectors, *i.e.* pot plants and fruit supply chains. As such, it has developed sector-specific reference process models for pot plants and fruit supply chains, which do not yet exist.

The main practical value of the framework helps to map, in a timely, punctual and coherent way, the business processes of the supply chain configurations that a company must manage in order to fulfil the different demand requirements of their customers. The framework is designed for demand-driven supply chains that aim to provide a rapid and customised response to volatile demand. We have argued that this imposes stringent demands on information systems and requires the ability to design and implement customised supply chain configurations. The designed framework supports this by supplying business and ICT professionals with concepts and a toolkit for modelling a wide range of supply chain configurations. As such, although designed for demand-driven supply chains, the framework is a general tool for supply chain modelling.

Finally, this thesis has addressed some opportunities for further research.

Main opportunities for further development are to enrich the framework with design knowledge, particularly:

- Multiple levels of planning, including higher-management echelons;
- Impact of various governance structures on the configuration of process models;
- Other business processes, such as returns management, product development and (collaborative) innovation, Customer Relation Management (CRM), marketing and supporting processes;
- Configurable product models;
- Data modelling and integration with existing standards for electronic messages.

Main opportunities for further evaluation and implementation include:

- Application in other agri-food sectors, such as cut flowers, bulbs, tree nursery, arable farming, dairy, meat, and feed;
- Development of simulation models for a quantitative evaluation;
- Development of sufficient tool support for combined product and process configuration;
- Solving technical implementation issues such as: how to deal with legacy systems, systems performance and security;
- Solving organisational implementation issues such as: how to manage change, how to capture tacit process knowledge and how to allocate ownership and maintenance.

Samenvatting

Door de groeiende volatiliteit en diversiteit van de vraag neemt voor agri-voedingsketens de noodzaak toe om vraaggestuurd te werken, d.w.z. continu alert te zijn op informatie over de vraag van de eindconsument en daar vervolgens snel op in te spelen. Bedrijven in vraaggestuurde ketens moeten om kunnen gaan met een hoge variëteit en variabiliteit van ketenconfiguraties om te voldoen aan de specifieke eisen van hun klanten. Bedrijfsprocesmodellen kunnen waardevolle hulpmiddelen zijn om dit te bereiken. Dit door het op maat ontwerpen van ketenconfiguraties en vervolgens door het ontwikkelen van de benodigde informatiesystemen te ondersteunen.

Echter, bestaande referentieprocesmodellen voldoen onvoldoende aan de specifieke eisen van vraaggestuurde agri-voedingsketens. Dit onderzoek heeft daarom tot doel een referentieraamwerk te ontwerpen voor het modelleren van bedrijfsprocessen dat:

i) Het instantiëren van diverse specifieke ketenconfiguraties mogelijk maakt;
ii) Een naadloze vertaling ondersteunt van ketenontwerp op hoog niveau naar gedetailleerde modellen voor het bouwen van informatiesystemen, en
iii) Sectorspecifiek is, oftewel: domeinspecifieke kennis bevat voor de agri-voedingssector.

Het onderzoek richt zich op de volgende centrale onderzoeksvraag: *"Hoe kunnen referentieprocesmodellen worden ontworpen voor het modelleren van vraaggestuurde agri-voedingsketens en het implementeren van ondersteunende informatiesystemen?"* Deze hoofdvraag is vervolgens opgedeeld in de volgende sub-onderzoeksvragen:

a. Wat zijn de kenmerken van vraaggestuurde ketens?
b. Wat zijn de eisen aan referentieprocesmodellen voor het modelleren van vraaggestuurde agri-voedingsketens en het implementeren van ondersteunende informatiesystemen?
c. In hoeverre voldoen bestaande referentieprocesmodellen aan de eisen van vraaggestuurde ketens?
d. Hoe kunnen referentieprocesmodellen worden ontworpen die voldoen aan de eisen van vraaggestuurde ketens?
e. Hoe kunnen referentieprocesmodellen voor vraaggestuurde ketens worden toegepast op de agri-voedingssector?

Het onderzoek heeft gebruik gemaakt van een ontwerpgerichte methodologie om de gedefinieerde onderzoeksvragen te beantwoorden. Het begon met de definitie van primaire ontwerpeisen op basis van literatuuronderzoek. Vervolgens is geanalyseerd in hoeverre bestaande referentiemodellen aan deze eisen voldoen. Op basis van deze analyse en de onderzochte literatuur is een generiek raamwerk ontwikkeld. Dit generieke raamwerk is toegepast, geëvalueerd en verfijnd in drie verschillende

casestudies: i) een verkennende meervoudige casestudie in de Nederlandse sierteelt, ii) een diepgaande meervoudige casestudie in de Europese fruitsector, en iii) een enkelvoudige casestudie in de Nederlandse sierteelt naar de implementatie van het raamwerk in configureerbare procesmodellen.

Het belangrijkste resultaat van dit onderzoek is het ontwerp van een raamwerk voor referentieprocesmodellering in vraaggestuurde agri-voedingsketens. Het raamwerk bevat concepten en hulpmiddelen voor het modelleren van een breed scala van ketenconfiguraties vanuit standaard modelcomponenten. Als zodanig versterkt het wederzijds begrip en hergebruik van proceskennis in ketenontwerp en in de ontwikkeling van informatiesystemen. Het raamwerk bestaat uit twee delen: i) een definitie van het objectsysteem en ii) een instrumentarium voor het modelleren van het gedefinieerde objectsysteem.

De definitie van het objectsysteem is een conceptuele zienswijze op het object van modellering: bedrijfsprocessen in vraaggestuurde ketens. Het bevat typologieën van de belangrijkste elementen van ketenconfiguraties, namelijk bedrijfsprocessen, producteenheden, besturingssystemen en coördinatiemechanismen. Vervolgens is beschreven hoe deze concepten aan elkaar gerelateerd zijn in ketenconfiguraties, die worden beschouwd als specifieke netwerken van autonome componenten (bouwstenen).

Het modelleerinstrumentarium biedt de representatiekracht voor het modelleren van het gedefinieerde objectsysteem. Het onderkent drie soorten ketenprocesmodellen:

1. *Productstroommodellen*: visualiseren de allocatie van de basistransformaties aan ketendeelnemers, inclusief de bijbehorende productstroom van uitgangsmateriaal tot eindproducten;
2. *Ketenconfiguratiediagrammen* (zogenaamde thread-diagrammen): visualiseren hoe ordergedreven en voorspellingsgestuurde processen ontkoppeld zijn in specifieke ketenconfiguraties (posities KlantOrderOntkoppelPunten), en hoe onderlinge afhankelijkheden tussen processen worden gecoördineerd;
3. *Bedrijfsprocesdiagrammen*: geven de volgorde en de interactie weer tussen de activiteiten voor de besturing en coördinatie zoals gedefinieerd in ketenconfiguratiediagrammen; dit in een door informatiesystemen uitvoerbare notatie.

Voor elk type procesmodel, bevat het instrumentarium: i) standaard modelbouwstenen (referentiecomponenten), ii) een methode om specifieke diagrammen te configureren (configuratieboom), en iii) vooraf geconfigureerde modellen die herbruikbare kennis vastleggen, zoals geabstraheerd van de case studies (referentiesjablonen). Verder maakt ook een conceptuele architectuur voor de implementatie van ondersteunende informatiesystemen deel uit van het instrumentarium.

Met de analyse, het ontwerp en de evaluatie van dit raamwerk zijn de geadresseerde onderzoeksvragen als volgt beantwoord.

a. Wat zijn de kenmerken van vraaggestuurde ketens?
Op basis van het literatuuronderzoek is een vraaggestuurde keten gedefinieerd als: *"een keten waarin alle betrokken actoren alert en responsief zijn op vraaginformatie van de eindklant"*. Het is gebleken dat vraaggestuurde ketens hun producten en bedrijfsprocessen, inclusief het netwerk van producenten en distributeurs, continu moeten afstemmen op veranderende markteisen. Daardoor worden ze gekenmerkt door een grote variëteit en variabiliteit van ketenconfiguraties. Een ketenconfiguratie is als volgt gedefinieerd: *"een specifieke set van bedrijfsprocessen, besturingssystemen en coördinatiemechanismen, uitgevoerd door een specifiek netwerk van deelnemers dat gezamenlijk een product of dienst met een onderscheiden meerwaarde voor de uiteindelijke klant produceert en levert."* Vervolgens zijn de concepten bedrijfsprocessen, besturing en coördinatie nader gedefinieerd en geclassificeerd. Dit om de mogelijke verscheidenheid in kaart te brengen van de configuraties die een bedrijf moet beheersen om aan de verschillende eisen van hun klanten te voldoen.

b. Wat zijn de eisen aan referentieprocesmodellen voor het modelleren van vraaggestuurde agri-voedingsketens en het implementeren van ondersteunende informatiesystemen?
Het onderzoek heeft de volgende ontwerpeisen aan referentieprocesmodellen in vraaggestuurde agri-voedingsketens benoemd:

- R 1. Zij moeten zijn opgezet om het instantiëren van diverse specifieke ketenconfiguraties vanuit een bibliotheek van standaard bouwstenen mogelijk te maken, in plaats van één blauwdruk te dicteren;
- R 2. Zij moeten ketenconfiguraties weergeven als aaneenschakelingen van ordergedreven en anticiperend processen, met elkaar verbonden door coördinatiemechanismen;
- R 3. Zij moeten een naadloze vertaling ondersteunen van ketenontwerp op hoog niveau naar gedetailleerde modellen voor het bouwen van informatiesystemen.
- R 4. Zij moeten sectorspecifiek zijn en dus domeinspecifieke kennis bevatten.

c. In hoeverre voldoen bestaande referentieprocesmodellen aan de eisen van vraaggestuurde ketens?
In het domein van productie- en ketenmanagement heeft dit proefschrift tien breed erkende en toegepaste referentiemodellen geïdentificeerd. Er is gebleken dat geen van de onderzochte modellen aan alle gedefinieerde eisen voldoet:

- R 1. Geen van de geanalyseerde modellen ondersteunt volledig een benadering voor ICT-massamaatwerk. Vooral een generieke modelopzet en een adequate ondersteuning van het configuratieproces ontbreken.

R 2. Geen van de onderzochte modellen geven ketenconfiguraties weer als aaneenschakelingen van ordergedreven en anticiperende processen met elkaar verbonden door coördinatiemechanismen.

R 3. Alle onderzochte ketenmodellen zijn abstracte procesmodellen die gebruikt kunnen worden voor de definitie van eisen aan informatiesystemen. Zij bieden echter geen gedetailleerde ondersteuning voor het ontwikkelen van informatiesystemen. Daarentegen zijn beschikbare procesmodellen voor het ontwerp en de implementatie van informatiesystemen gericht op afzonderlijke ondernemingen.

R 4. De weinige referentieprocesmodellen in de agri-voedingssector kunnen worden gekarakteriseerd als geïsoleerde modellen die niet gebruikt worden om de procesgang in operationele informatiesystemen te sturen. Bovendien zijn in dit onderzoek geen referentiemodellen voor ketenprocessen in de agri-voedingsbranche gevonden.

d. Hoe kunnen referentieprocesmodellen worden ontworpen die voldoen aan de eisen van vraaggestuurde ketens?

Het ontworpen raamwerk voldoet als volgt aan de gedefinieerde ontwerpeisen.

R 1. In het onderzoek is de variëteit van ketensystemen gedefinieerd in een conceptuele objectsysteemdefinitie. Deze bevat classificaties van producteenheden, processen, besturing en coördinatie. Voor verschillende soorten procesmodellen zijn referentiecomponenten, een configuratiemethode voor modelinstantiatie en verschillende referentiesjablonen (vooraf geconfigureerde modellen van kenmerkende ketenconfiguraties) gedefinieerd. Verder bevat het raamwerk ook een conceptuele architectuur voor de implementatie van configureerbare procesmodellen in combinatie met productconfiguratie.

R 2. In het onderzoek is een nieuw type ketenconfiguratiediagrammen ontwikkeld, waarin expliciet zichtbaar gemaakt wordt hoe ordergedreven en voorspellingsgestuurde processen ontkoppeld zijn in specifieke ketenconfiguraties (posities KlantOrderOntkoppelPunten) en hoe onderlinge afhankelijkheden tussen processen worden gecoördineerd. Vervolgens worden van deze ketenconfiguraties de volgorde van de gedetailleerde activiteiten en de interacties met de aangrenzende besturing en coördinatie uitgewerkt in gedetailleerde bedrijfsprocesdiagrammen.

R 3. Het raamwerk begint met een weergave van de allocatie van basistransformaties aan ketenactoren en de gerelateerde productstromen in productstroommodellen. Vervolgens wordt de coördinatie en besturing van deze transformaties in specifieke configuraties gevisualiseerd in ketenconfiguratiediagrammen. Ten slotte kan men inzoomen op gedetailleerde bedrijfsprocesdiagrammen die de volgorde en informatiestromen tussen besturings- en coördinatie-activiteiten weergeven. Bedrijfsprocesdiagrammen worden gemodelleerd in de BPMN-notatie, waardoor ze in Service-Oriented Architectures (SOA) kunnen worden uitgevoerd voor de orkestratie van gegevens over meerdere softwarecomponenten, die zijn verpakt als koppelbare webdiensten.

R 4. Het raamwerk combineert sectorspecifieke kennis met het hergebruik van generieke kennis uit sectoroverstijgende standaarden. De definitie van de verschillende soorten procesmodellen, de configuratiemethoden en de referentiecomponenten van de ketenconfiguratie- en hoofd-bedrijfsprocesdiagrammen zijn generiek. Sectorspecifieke kenmerken komen naar voren in de bouwstenen van productstroommodellen en sub-procesdiagrammen, en in de sjablonen van kenmerkende ketenconfiguraties.

e. Hoe kunnen referentieprocesmodellen voor vraaggestuurde ketens worden toegepast op de agri-voedingssector?
Het raamwerk is toegepast in drie casestudies. De resultaten van deze studies zijn verwerkt in het raamwerk, dat daardoor verrijkt is met sectorspecifieke kennis. De eerste casestudie heeft de eerste versie van het raamwerk toegepast op sierteeltketens in een verkennende meervoudige casestudie in de Nederlandse potplantensector. De tweede casestudie heeft de bijgewerkte versie van het raamwerk toegepast in een diepgaande meervoudige case studie in de Europese fruitsector. De derde studie heeft de ontworpen informatie-architectuur voor de implementatie van configureerbare procesmodellen toegepast in een enkelvoudige casestudie in de Nederlandse sierteeltsector.

De belangrijkste toevoeging van dit proefschrift aan de bestaande theorie is het ontwerp van een innovatief artefact: een nieuw raamwerk dat de concepten bevat die nodig zijn om adequate referentieprocesmodellen te ontwerpen voor vraaggestuurde agri-voedingsketens. Doorvoor heeft dit proefschrift de representatiekracht gedefinieerd, ontwikkeld en geëvalueerd die nodig is om een brede variëteit van ketenconfiguraties te kunnen modelleren als specifieke netwerken met verschillende allocaties van bedrijfsprocessen aan ketenactoren en met verschillende vormen van controle en coördinatie. Meer in het bijzonder, kunnen drie aanvullende bijdragen worden genoemd.

In de eerste plaats heeft het onderzoek het concept van massamaatwerk toegepast op referentieprocesmodellen. Dit betekent dat specifieke modellen worden geconfigureerd vanuit een bibliotheek van standaard bouwstenen, namelijk vooraf gedefinieerde modelcomponenten. Als zodanig draagt het onderzoek bij aan het relatief nieuwe onderzoeksgebied van de configuratie van procesmodellen.

Ten tweede heeft ons onderzoek een raamwerk ontwikkeld dat procesmodellen op verschillende niveaus van abstractie combineert voor twee gebruiksdoelen: ketenontwerp en het bouwen van informatiesystemen. Als zodanig draagt het onderzoek bij aan de ontwikkeling van een gemeenschappelijke conceptualisering en een consistente terminologie voor deze twee onderzoeksstromingen.

Ten derde is het raamwerk toegepast in specifieke agri-voedingssectoren, namelijk potplanten en fruit. Als zodanig heeft het onderzoek sectorspecifieke referentieprocesmodellen ontwikkeld voor potplanten- en fruitketens, die momenteel nog niet bestaan.

De belangrijkste praktische waarde van het raamwerk is dat het helpt bij het op een tijdige, zorgvuldige en coherente wijze in kaart te brengen van de bedrijfsprocessen in de ketenconfiguraties die een bedrijf moet beheersen om aan de specifieke eisen van hun klanten te voldoen. Het raamwerk is ontworpen voor vraaggestuurde ketens die gericht zijn op het snel en klantspecifiek inspelen op een sterk fluctuerende vraag. We hebben betoogd dat dit hoge eisen stelt aan informatiesystemen en het vermogen vereist om ketenconfiguraties op maat te kunnen ontwerpen en implementeren. Het ontworpen raamwerk ondersteunt dit door bedrijfs- en ICT-professionals te voorzien van de concepten en een instrumentarium voor het modelleren van een breed scala van ketenconfiguraties. Hoewel het raamwerk ontworpen is voor vraaggestuurde ketens, is het daarmee een algemeen hulpmiddel voor ketenmodellering.

Tot slot heeft zijn in dit proefschrift een aantal suggesties voor verder onderzoek benoemd. In de eerste plaats wordt geadviseerd het raamwerk verder te ontwikkelen door het te verrijken met ontwerpkennis over:
• Meerdere niveaus van planning, inclusief hogere managementniveaus;
• Impact van verschillende governance-structuren op de configuratie van procesmodellen;
• Overige bedrijfsprocessen, zoals het beheer van retourzendingen, productontwikkeling en (gezamenlijke) innovatie, beheer van klantrelaties (CRM), marketing en ondersteunende processen;
• Configureerbare productmodellen;
• Datamodellering en integratie met bestaande standaarden voor de elektronische berichten.

Vervolgens zijn een aantal suggesties gegeven voor verdere evaluatie en implementatie van het raamwerk:
• Toepassing in de andere agri-food sectoren, zoals snijbloemen, bloembollen, boomkwekerij, akkerbouw, zuivel, vlees, en diervoeders;
• Ontwikkeling van simulatiemodellen voor kwantitatieve evaluatie;
• Ontwikkeling van goede software voor ondersteuning van gecombineerde product- en procesconfiguratie;
• Het oplossen van technische implementatiepunten, zoals: hoe om te gaan met bestaande systemen, impact op de snelheid van software en het garanderen van de veiligheid;
• Het oplossen van organisatorische implementatiepunten zoals: hoe veranderingen te beheersen, hoe impliciete proceskennis vast te leggen, en hoe het eigendom en de verantwoordelijkheden voor beheer en verder ontwikkeling te beleggen.

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About the author

Cors Nicolaas (Cor) Verdouw was born on July 8th 1975 in Barneveld, The Netherlands. He holds a M.Sc. degree in Business Economics from the Erasmus University Rotterdam, The Netherlands. His specialisation was in Management & Organisation and his M.Sc. thesis focussed on the management of organisational change processes. After his graduation in 1998, he worked as a business consultant at Profuse, a Dutch ERP service provider, on projects in the field of IT service management, business process modelling and ERP-implementation in various industries. Since 2002 he is working at LEI Wageningen UR. First he was project leader at the information systems department of this institute. Since 2004 he is scientific researcher on Supply Chain Management and ICT. In this position, he started in 2005 with the Ph.D. research presented in this thesis.

Over de auteur

Cors Nicolaas (Cor) Verdouw is op 8 juli 1975 geboren in Barneveld. Hij studeerde bedrijfseconomie aan de Erasmus Universiteit Rotterdam. Hij koos voor de afstudeerrichting Management & Organisatie en schreef een scriptie over het management van organisatorische veranderprocessen. Na zijn afstuderen in 1998 werkte hij als bedrijfskundig adviseur bij Profuse, een Nederlandse ERP-dienstverlener, aan projecten op het gebied van IT-beheer, procesmodellering en ERP-implementatie in verschillende sectoren. Sinds 2002 werkt hij bij LEI Wageningen UR. Hij was eerst projectleider bij de IT-afdeling van dit onderzoeksinstituut. Sinds 2004 is hij wetenschappelijk onderzoeker op het gebied van ketenmanagement en ICT. In deze functie begon hij in 2005 met het promotieonderzoek, dat in deze dissertatie wordt gepresenteerd.

Annex to statement
Name C.N. Verdouw
PhD student, Mansholt Graduate School of Social Sciences (MG3S)
Completed Training and Supervision Plan

Description	Institute / Department	Year	ECTS*
Courses:			**21**
Mansholt Introduction course	Mansholt Graduate School of Social Sciences	2005	1
Workshop SCM and ICT	SOM Research School	2005	1
Using Cordys Business Collaboration Platform	Cordys Academy	2005	3
Mansholt Seminar *"Modelling demand-driven agri-food chain networks"*	Mansholt Graduate School of Social Sciences	2007	1
Methodology of Research & Design	Institute for Governance Studies	2007	8
Advanced Modelling and Simulation (INF-30806)	Wageningen University	2007	6
Writing a Scientific Article	Taalcentrum VU Amsterdam	2008	1
Presentations at conferences and workshops:			**8**
2nd European Forum on Market-Driven Supply Chains, Milan. *"Leagile ICT in demand driven chains: A reference model approach"*		2005	2
First annual Congress Promoting the Stable to Table Approach, Genua. *"FoOD-Dynamo: Designing demand-driven food chains"*		2006	2
eChallenges e-2008 Conference, Stockholm. *"Mastering Demand and Supply Uncertainty with Configurator Software"*		2008	2
4th International European Forum on System Dynamics and Innovation in Food Networks, Igls/Innbruck, Austria. *"Business Process Modelling in Demand-Driven Agri-Food Supply Chains"*		2010	2
Accredited prior training:			**7**
Prince2 for Project Managers	Profuse Academy	2000	2
Dynamic Enterprise Modelling (DEM)	Profuse Academy	2000	1
Time Management	Yntema Result	2001	1
Acquisition of research projects	LEI/Meander Training	2003	3
Total (minimum 30 ECTS)			**36**

*One ECTS on average is equivalent to 28 hours of course work

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