

Chapter 2

Conceptual Frameworks for Supply Chain Management

No great discovery was ever made without a bold guess.
Isaac Newton

2.1 Agile, Flexible and Responsive Supply Chains

To ensure long-term competitiveness and survival, companies implement new strategies, based on collaboration with business partners and an advanced utilization of IT and Web services (Geunes *et al.* 2002). Various *competitive strategies* of agile, responsive and flexible SCs have been developed over the last decade.

In many branches, hierarchical SCs with long-term predetermined suppliers' structures and product programmes evolve into *flexible dynamic SC structuring* (Sarkis *et al.* 2007). Nowadays, agile organizations with heterogeneous structures, core competences, buyer-focused cells and extensive application of Web services are being increasingly introduced in practice (van Donk and van der Vaart 2007). Collin and Lorenzin (2006) emphasize that "an agile SC is a basic competitive requirement in the industry and building agility into operations requires a continuous planning process together with customers".

According to Vonderembse *et al.* (2006), "an agile SC profits by responding to rapidly changing, continually fragmenting global markets by being dynamic and context specific, aggressively changing, and growth oriented. They are driven by customer designed products and services".

Chandra and Grabis (2007) identified the key triggers for designing and implementing SC with regard to agility, flexibility and responsiveness. They are as follows:

- introduction of new product(s), or upgrade for existing product(s);
- introduction of new, or improvement in existing, process(es);
- allocation of new, or re-allocation of existing, resource(s);
- selection of new supplier(s), or deselection of existing ones;
- changes in demand patterns for product(s) manufactured;
- changes in lead times for product and/or process life cycles; and
- changes in commitments within or between SC members.

Within the strategy of agility, different concepts like VE, agile SCs and responsive SCs exist (Christopher and Towill 2001, Camarinha-Matos and Afsarmanesh

2004, Ross 2004, Yusuf *et al.* 2004). Lee (2004) specifies that the main objectives of SC agility are to respond to short-term changes in demand or supply quickly and to handle external disruptions smoothly. The most distinguished cases of agile SC applications are those of DELL, Benetton, AT&T, Nissan, BMW, Nokia etc. Bustelo *et al.* (2007), Collin and Lorenzin (2006) and Gunasekaran *et al.* (2008) ground the practical need and efficiency of agile SCs on the basis of empirical tests.

The advantages of agility, responsiveness and flexibility lie in customer-oriented networking and flexible configurable SCs conditioned by an enlargement of alternatives to search for suitable partners for a cooperation enabled by enterprise resource and advanced planning systems (APS) and Internet technologies. The agility, responsiveness, and flexibility ensure the following:

- flexibility and adaptation to market changes;
- building integrated business processes to unify customer relationships, forecasting, planning, replenishment, distribution, and manufacturing;
- systematic information coordination; and
- supply chain event management.

To narrow the literature analysis to the objectives of this research, we will concentrate on the problems of (1) modularization/postponement and agility, (2) virtualization and agility, and (3) coordination and agility.

2.1.1 Postponement, Modularization and Agility

Van Hoek (2001) defines *postponement* as “an organizational concept whereby some of the activities in the SC are not performed until customer orders are received”. Recent quantitative models have evaluated the cost and benefits of applying postponement to a large variety of stochastic and deterministic settings (Li *et al.* 2008).

Ernst and Kamrad (2000) introduced a conceptual framework for evaluating different SC structures in the context of modularization and postponement. In the analysis, modularization is linked to postponement. The paper introduces taxonomy and develops a corresponding framework for the characterization of four SC structures, defined according to the combined levels of modularization and postponement: rigid, postponed, modularized and flexible. The study provides examples of efficient postponement and modularization combining by HP, Suzuki, and Benetton. Additional case examples include Dell Computers, Nike, IBM and General Motors and are given by Tully (1993) and Gunasekaran *et al.* (2008).

Reichhart and Holweg (2007) synthesize the existing contributions to manufacturing and SC flexibility and responsiveness, and draw on various related bodies of literature that affect a SC's responsiveness, such as the discussion of product architecture and modularization. Picot *et al.* (2001), Warnecke and Braun (1999) and Wirth and Baumann (2001) elaborated concepts and models of value-adding

chain organization based on the integrated, customer-oriented networking of small autonomous elements (module, fractals, competence-cells and segments). Coordination between these autonomous elements usually leads to non-hierarchical organizational forms. The ideas of integrating the product and process modularity have also been extensively investigated in the mass customization approach (Chandra and Kamrani 2004).

A crucial issue in postponement and modularization is the determination of an *order penetration point* (OPP) (see Fig. 2.1). Towill and Mason-Jones (1999) have demonstrated that there are actually two decoupling points in SCs – the “material” decoupling point, or OPP, where strategic inventory is held in as generic a form as possible (this would correspond to the β -line in Fig. 2.1), and the “information” decoupling point (this would correspond to the α -line in Fig. 2.1).

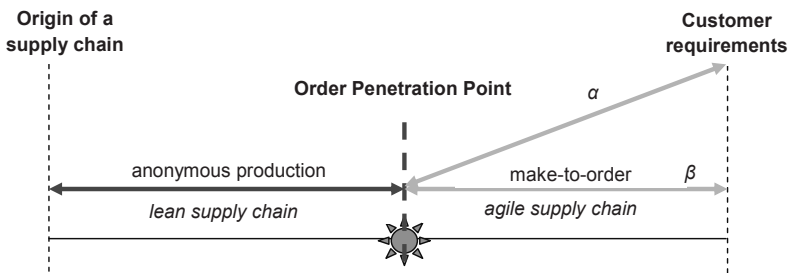


Fig. 2.1 Order penetration point

By efficient coordination in relation to these two decoupling points, a powerful opportunity for agile response can be created (Christopher and Towill 2000). The integration of lean (upstream of the OPP) and agile (downstream of the OPP) SCs was extensively discussed in Mason-Jones *et al.* (2000) and Christopher and Towill (2000). Recent study by Wang *et al.* (2009) reports on a three-dimensional concept based on the integration of product, engineering and production activities to define customer order decoupling points.

2.1.2 Virtualization and Agility

In SC agility, aspects of virtualization play a significant role. The main objective of a VE is to allow a number of organizations to develop a common working environment or *virtual breeding environment* with the goal of maximizing flexibility and adaptability to environmental changes and developing a pool of competencies and resources (Camarinha-Matos and Afsarmanesh 2004, Gunasekaran *et al.* 2008). VEs focus on speed and flexibility. A virtual enterprise is enabled by building a united information space with extensive usage of Web services.

VE structures are highly dynamic and their life cycles can be very short. The existence of a number of alternatives for SC configuration is remarkable. This is a

great advantage because of a possibility to react quickly to customers' requirements. This also builds a structural-functional reserve for SC running. Unfortunately, VEs are considered mostly from the information perspective without dealing properly with managerial and organizational aspects. Besides, our practical experiences show that there are only a few (if any) organizations that have managed to apply the main idea of the VE, collaborate for a short time and then disperse, perhaps to form new networks with other enterprises. There are two main obstacles: trust and technical project documentation.

2.1.3 Coordination and Agility

The agility and coordination of SCs have strong links to manufacturing and logistics postponement strategies. A recent AMR Research study shows the great importance of demand-oriented SC coordination: demand forecast accuracy creates high responsiveness and cuts costs right through the SC (Frischia *et al.* 2004). According to the study, the companies that are best at demand forecasting maintain on average 15% less inventory, 17% stronger perfect-order fulfilment and 35% shorter cash-to-cash life cycles.

Different concepts of *coordination* have been developed over the last two decades, such as efficient consumer response (ECR), collaborative planning, forecasting, and replenishment (CPFR) in retail as well as JIT and VMI in industries. Enablers of the coordination are IT, such as enterprise resource planning (ERP), APS, electronic data interchange (EDI), and RFID.

Collin and Lorenzin (2006) emphasize that, in practice, coordination determines the postponement strategy and the position of the OPP or decoupling point in the SC. The coordination has become a key factor in mitigating the *bullwhip effect* and in overcoming information asymmetry (Lee *et al.* 1997, Chen *et al.* 2000,). Moreover, due to Internet technologies, it has become possible to integrate customers into SC considerations, resulting in the development of the build-to-order (BTO) SCM (Gunasekaran and Ngai 2005, Sharif *et al.* 2007).

2.1.4 Flexibility, Coordination and Agility

Unlike the well-grounded manufacturing flexibility, SC *flexibility* is still an under-investigated area. Swafford *et al.* (2008) showed that achieving SC agility is a function of other abilities within the organization, specifically SC flexibility and IT integration. Using empirical data, this study grounded a domino effect among IT integration, SC flexibility, SC agility and competitive business performance. The results from this study indicate that IT integration enables a firm to tap into its SC's flexibility, which in turn results in higher SC agility and ultimately higher competitive business performance.

Tachizawa and Thomsen (2007) empirically investigated the aspects of flexibility related to the upstream SC. The results show that firms need supply flexibility for a number of important reasons (manufacturing schedule fluctuations, JIT purchasing, manufacturer slack capacity, a low level of parts commonality, demand volatility, demand seasonality and forecast accuracy), and that companies increase this type of flexibility by implementing two main strategies: “improved supplier responsiveness” and “flexible sourcing”. The results also suggest that the supply flexibility strategy selected depends on the type of uncertainty (mix, volume or delivery).

Coronado and Lyons (2007) investigated the implications of operation flexibility in industrial SCs and the effect it has on supporting initiatives designed for BTO manufacturing. The analysis has revealed the close relationship between operation flexibility and the SC flexibility dimensions of people and information systems. Wadhwa *et al.* (2008) presented a study on the role of different flexibility options (i.e., no flexibility, partial flexibility and full flexibility) in a dynamic SC model based on some key parameters and performance measures. Fotopoulos *et al.* (2008) analysed flexible supply contracts under price uncertainty. Ozbayrak *et al.* (2006) showed that flexibility is interrelated with adaptation. The study considered a number of performance metrics such as work-in-progress (WIP), tardiness, responsiveness, and mean flow time with regard to three localized control policies.

The main observation from literature analysis is that the collaborative organization with heterogeneous structures, core competences, buyer-focused cells and extensive application of Web services makes it possible to form SCs based on a project-oriented networking of core competences through a partner selection from a pool of available suppliers in a virtual environment according to customer requirements. Such SCs are expected to be more flexible and reactive, and capable of rapid evolution and surviving competition. SC agility reserves are usually considered in relation to postponement, product modularization and different inventory redundancies on the cooperation side as well as demand-driven roll-out planning and collaborative forecasting on the coordination side. Another agility reserve is a temporary customer-oriented dynamical SC structuring with operative outsourcing alternatives (Ivanov and Teich 2009).

2.2 Vision of the Adaptive Supply Chain Management (A-SCM) Conceptual Framework

2.2.1 Adaptive Supply Chains: State of the Art

The first use of the term “*adaptive supply chain management*” (A-SCM) is regarded as being in 2001–2002 and in the area of information technologies. The SAP’s (SAP 2002) initiative on adaptive SC networks can be considered as the first step in automating the SC networks using new technologies including agent-

based, RFID, and Web services. Subsequently, a number of white papers on ASCM appeared from different consulting houses.

During 2000–2009 a number of concepts were developed to meet the requirements for speed, agility, responsiveness and flexibility (Goranson 1999, Christopher and Towill 2001, Ross 2004, Yusuf *et al.* 2004, Camarinha-Matos and Afsharmanesh 2007, Gunasekaran *et al.* 2008). In these conceptual business models, SCs with heterogeneous structures and an extensive application of IT are expected to be more flexible and reactive, and capable of rapid evolution and surviving competition.

The *mathematical research* on adaptive SCs is rooted in CAS and control theory. Choi *et al.* (2001) claimed that emergent patterns in a supply network can be managed much better through positive feedback than through negative feedback from control loops. They conclude that imposing too much control detracts from innovation and flexibility; conversely, allowing too much emergence can undermine managerial predictability and work routines. Therefore, managers must appropriately balance the control and the emergence areas.

Surana *et al.* (2005) investigated how various concepts, tools and techniques used in the study of CAS can be exploited to characterize and model SC networks. These tools and techniques are based on the fields of non-linear dynamics, statistical physics, and information theory. In the study by Pathak *et al.* (2007), a theory-based framework is developed that combines aspects of CAS theory, industrial growth theory, network theory, market structure, and game theory. This framework specifies categories of rules that may evoke different behaviours in the two fundamental components of any adaptive supply networks, i.e., the environment and the firms in that environment. The framework is implemented as a multi-paradigm simulation utilizing software agents and it joins discrete-time with discrete-event simulation formalisms. Another agent-based model has been elaborated by Kaihara and Fujii (2008) to reflect SCs' abilities to adapt. The study considered the VE environment and developed a computer simulation model, clarifying the SC formulation dynamism on the negotiation process with adaptive behaviour. Many other papers have also dealt with agent-based modelling and SC adaptivity; e.g., Ahn *et al.* (2003) suggested a flexible agent system for SCs that can adapt to the changes in transactions introduced by new products or new trading partners.

Another research stream has been dealing with control policies and algorithms to adapt SCs by means of different techniques. Shervais *et al.* (2003) employed a set of neural networks to develop control policies that are better than fixed, theoretically optimal policies with regard to a combined physical inventory and distribution system in a non-stationary demand environment. The study analysed the control policies embodied by the trained neural networks and fixed policies (found by either linear programming or genetic algorithms) in a high-penalty cost environment with time-varying demand.

Scholz-Reiter *et al.* (2004) presented an adaptive control (AC) concept for production networks. This study also employed an agent-based method concerning the adaptive coordination of customer orders along the SC to handle flexibly disturbances in relation to the reallocation of alternative suppliers to ensure a timely

and accurate fulfilment of customer orders. Kim *et al.* (2005) proposed centralized and decentralized adaptive inventory-control models for a SC consisting of one supplier and multiple retailers. The objective of the two models is to satisfy a target service level predefined for each retailer using a reinforcement learning technique called the action-value method, in which the control parameters are designed to change adaptively as customer-demand patterns change.

Jang (2006) developed a new control architecture originating from modern political systems that are designed to mediate conflicts among people and to accommodate a nation's global benefits. Similarly, the proposed model should also resolve conflicts among controllers and maximize the shop floor's overall benefits. Pandey *et al.* (2007) distributed a feedback control algorithm, called the adaptive logistics controller (ALC), which simultaneously decides the order quantities for each stage of the SC subject to minimizing the total WIP (work-in-progress) in the entire SC for a given demand. Cai *et al.* (2008) presented a fuzzy adaptive model with an adaptive proportional–integral–derivative (PID) controller. A further discussion on control theory application to the SCM domain will be provided in Chap. 9.

In this book we will consider *A-SCM as a new research direction* that requires comprehensiveness with regard to interrelations and consistency of conceptual business models, engineering frameworks, mathematical models and IT. We propose to name this particular concept as an *A-SCM* (and not as, e.g., a flexible or agile SCM). Namely, the *adaptation* is the most comprehensive category defined in systems and control science that covers the system's ability to change its behaviour regarding changes in the execution environment and with regard to the system's goals. Even the ability to change is the most important driver of competitiveness in modern and feature markets.

Moreover, in particular, the adaptation is the category that corresponds to the modern stage of state of the art in management and information systems. Theoretical discussions on self-configuring and self-learning SCs cannot be properly perceived and implemented in practice with existing management systems and because of the lack of standard “mass” software solutions. However, in future, adaptive SCs should evolve into self-organizing and self-learning SCs. The difference between *adaptive* and *self-organizing* SCs is that in the adaptation approach the system's shape and goals are fixed while in self-organization both the system and its goals evolve. The system's borders become fuzzy, the system can broaden by “acquiring” a space from the environment, or the system can narrow in the reverse way.

As a new research direction, *A-SCM* requires comprehensiveness with regard to the interrelations and consistency of conceptual business models, engineering frameworks, mathematical models and IT. Recent research shows a gap regarding the engineering frameworks and mathematical models. Gaining advancements in this direction is a critical and timely issue because of the critical role of this level with regard to the practical applicability of business concepts and the development of IT that would be adequate for the business concepts.

In the further course of this chapter, we will consider the vision of the conceptual framework of *A-SCM*. In the subsequent chapters, the engineering and

mathematical frameworks will be presented. These frameworks extend the narrow understanding of adaptive SCs as mobile IT or agent systems to a comprehensive new research direction that is composed of conceptual business research as well as model-based and IT-based advanced decision-making techniques in SCM.

2.2.2 Basic Terms and Definitions

In this section, the conceptual basics of the A-SCM approach are considered. We start with the main definitions, and then we consider the A-SCM framework. Based on the frameworks of the control and systems theory, let us introduce some basic definitions.

Definitions

The SC *adaptability* is the ability of a SC to change its behaviour for the prevention, improvement or acquisition of new characteristics for the achievement of SC goals in environmental conditions that vary in time and the aprioristic information about which dynamics is incomplete.

Adaptive management is a management method of a SC with varying unknown environmental characteristics, in which for the final time defined (satisfactory, wished for, or optimum) goals of SCM are reached by means of a change of the SC parameters, processes, and structures or characteristics of control influences on the feedback loop driven basis.

Adaptive planning is a method of planning in which the plan of a SC is modified periodically by a change of parameters of the SC or characteristics of control influences on the basis of information feedback about a current condition of the SC, the past and the updated forecasts of the future.

An *adaptive SC* is a networked organization wherein a number of various enterprises:

- collaborate (cooperate and coordinate) along the entire value-adding chain and product life cycle to acquire raw materials, convert these raw materials into specified final products, deliver these final products to retailers, design new products, and ensure post-production services;
- apply all modern concepts and technologies to make SCs stable, effective, responsive, flexible, robust, sustainable, cost-efficient and competitive in order to increase SC stability, customer satisfaction and decrease costs, resulting in increasing SC profitability.

A-SCM studies the resources of enterprises and human decisions with regard to stability, adaptability and profitability of cross-enterprise collaboration processes to transform and use these resources in the most rational way along the entire value-adding chain and product life cycle, from customers up to raw material suppliers, based on cooperation, coordination, agility and sustainability throughout.

2.2.3 A-SCM Framework

As discussed in Sect. 2.1, various strategies of integrated production and logistics in industrial organizations – from SCM, VE, agile/responsive SCs up to sustainable SCs – have been developed over the last two decades. Although the strategies appear to differ in targets, presumptions, application areas, enabling technologies, and research methodologies, each complements the others, endeavouring to improve competitiveness. Considering the significance of all the strategies for organizations, the developed approach integrates the elements of these strategies to develop a framework of A-SCM (see Fig. 2.2).

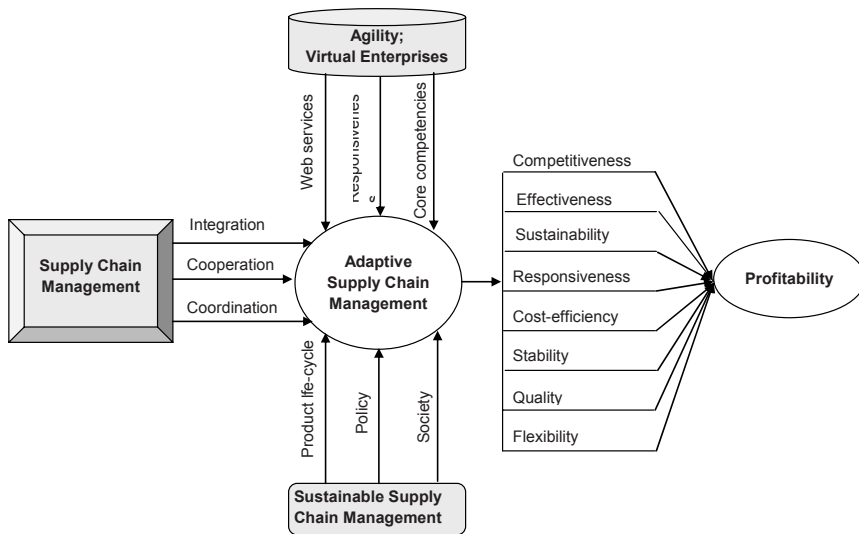


Fig. 2.2 Framework of A-SCM

In the A-SCM framework, we do not set off different value chain strategies with each other, but consider them as an integrated framework. The encapsulation of the advantages of SCM, agility, and sustainability enables A-SCM.

SCM serves as a basis for integration (organizational: suppliers and customers; functional: collaborative business processes; managerial: strategic, tactical, and operative decision-making levels), cooperation, and coordination. The strategies of *agility* enrich SCM by means of a general information space with the help of Web services and higher flexibility/responsiveness through concentration on core competencies and building virtual alliances/environments. *Sustainable SCM* integrates the consideration of the product development, utilization, product end-of-life, and recovery processes. On the other hand, sustainable SCM brings into consideration policy and society issues, which may affect the SCs and which may be affected by SCs.

2.2.4 A-SCM Drivers and Organization

Fig. 2.3 depicts the A-SCM strategy as drawn from elements of SCM, agility, and sustainability.

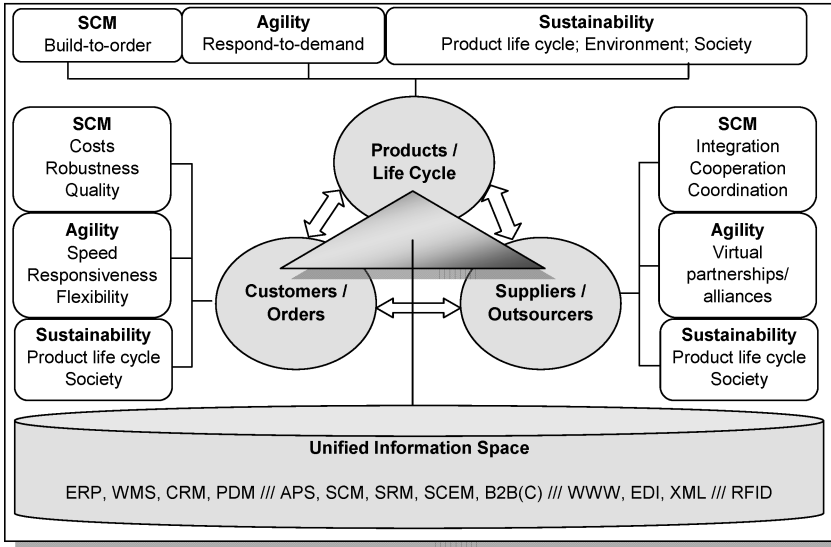


Fig. 2.3 The A-SCM drivers

In *A-SCM*, all three value chain drivers – products and their life cycles, customers and their orders, and suppliers/outsourcers – are enhanced by combining the elements from SCM, agility and sustainability. Moreover, these drivers are inter-linked within a unified information space.

A-SCM unites an SC owner (an original equipment manufacturer (OEM) or a logistics service provider), customers and suppliers. The organizational structure consists of a real SC environment and a virtual alliance/partnership environment (see Fig. 2.4).

In the real SC environment, the SC owner collaborates with its customers and suppliers in regard to the existing products and product lines in all the stages of the product life cycle. The virtual alliance/partnership environment is an adaptation structural–functional reserve of the real SC environment. In the case of market changes, new products, or an impact of operational inefficiencies due to a variety of disruptive factors (machine failures, human decision errors, information systems failure, cash-flow disruption or simply catastrophic events), these *structural–functional reserves* are activated to adapt the SC. Second, in the virtual alliance/partnership environment, new products are designed (with the integration of potential customers and suppliers).

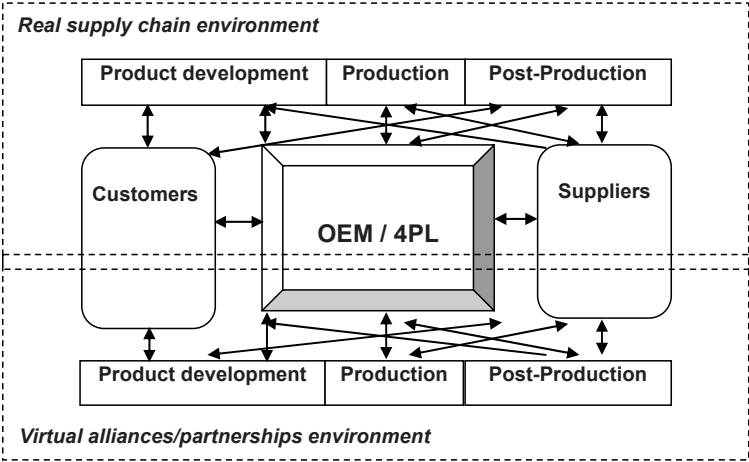


Fig. 2.4 The A-SCM organization

In traditional SCs, decisions about a customer’s order acceptance or rejection are made on a stable long-term predetermined supplier structure. In A-SCM, it is possible to build *new order-oriented structures*, taking into account technological product individualization, demand volume fluctuations, or operative disruptions in SCs (see Fig. 2.5).

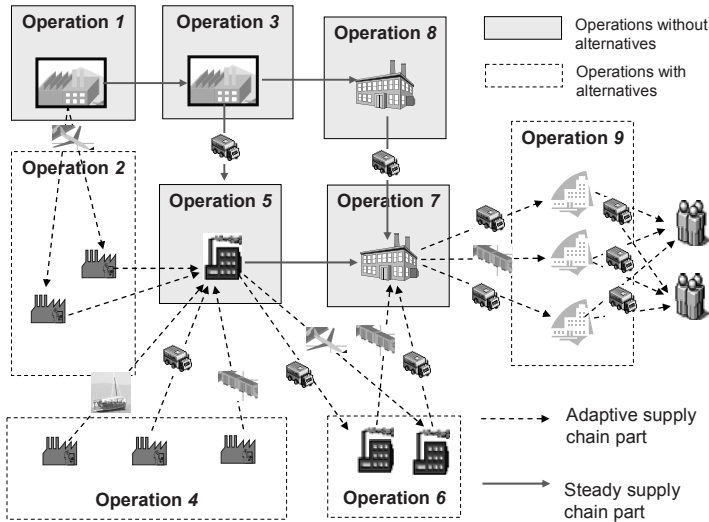


Fig. 2.5 Case description of adaptive SC organization

Figure 2.6 depicts a case example from special machinery building. Similar cases can be found in textile and or electronics industries. SCs are formed dynamically based on the offer parameters of the enterprises, customers’ require-

ments and so-called soft factors (e.g., reputation, trust, etc.). Remarkable is the existence of alternative suppliers for various project operations, which differ from each other by operations parameters. The problem consists of an evaluation of alternative SCs to select the best one for the following scenario:

- new products (customer individualized products or new product lines);
- technological disruptions (machines, IT);
- collaboration problems (errors or IT failure); and
- demand fluctuations.

The special feature of this concept lies in a customer-oriented networking of core competences and flexible configurable SCs conditioned by an enlargement of alternatives to search for suitable partners for a cooperation enabled by ERP and APS systems and Internet technologies (EDI and business-to-business).

Finally, let us consider the goal tree of A-SCM (see Fig. 2.6).

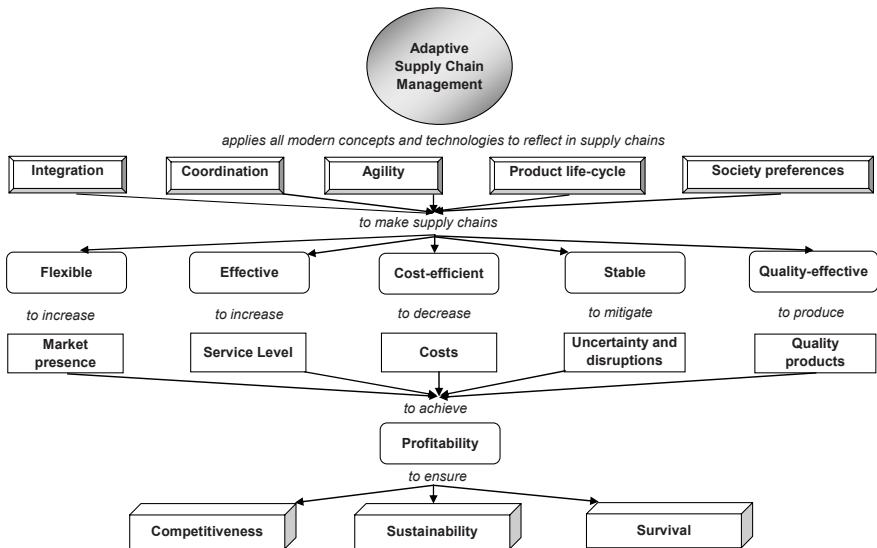


Fig. 2.6 Goal tree of the A-SCM

Figure 2.6 depicts the goal tree of A-SCM. The goal tree shows the drivers of A-SCM: integration, coordination, agility and sustainability. By reflecting these drivers, SCs can be made flexible, responsive, cost-effective, stable and quality-effective to achieve maximum profitability, which ensures long-term competitiveness, sustainability and survival.

2.2.5 Application Issues

The main aspects on which a particular emphasis should be set by practical implementation of the proposed framework are the following:

- identifying core competencies, making them describable and analysable;
- establishing trust and long-term collaboration in partnerships;
- elaborating product and process documentation throughout, especially for products and their life cycle (i.e., on the basis of CALS – continuous acquisition and life cycle support – standards);
- unifying product data within an electronic catalogue connected to an ERP system;
- integrating into the ERP/APS landscape SC event management systems;
- keeping the information architecture as simple as possible in relation to linking different information systems as well as operating by users; and
- thinking about the duality of IT's impact: on one hand, IT is an infrastructure to enable efficient coordination in SCs; on the other, IT enables new organizational methods.

Finally, let us discuss the limitations of the proposed framework. Generally, the proposed approach can be implemented in all branches. However, some particular aspects of the approach show limitations regarding the branch independence, i.e., with regard to the flexible suppliers' structuring, the approach can be applied especially to the cases where there is the possibility to attach alternative suppliers quickly to a number of operations in the value-adding process. The proposed concept can be applied in two main cases: (1) for unique products or (2) for products without strict technical quality policy).

Another very important point is the *trust and collaboration* in the network. Before automation, a huge amount of organizational work should be carried out to convince the OEMs and suppliers to collaborate within a common informational space, share the data, actualize the data and ensure financial trust. While automating, it is important to elaborate and to maintain throughout product and process technological documentation and classification. Last, but not least, the firms themselves should perceive the necessity for such collaboration.

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