Chapter 2
Scope of Supply Chain Configuration Problem

2.1 Introduction

As firms position themselves to stay competitive, they face the challenge of transforming their operations from a static to a dynamic business environment. An obvious choice for transformation is supply chain operations because of their potential impact on almost every aspect of the business encompassing the extended enterprise. This is a complex undertaking because supply chain management entails managing the following under the umbrella of a common framework:

- Entity relationships, such as product, process, resource, organization, supplier, retailer, and customer
- Flow of goods, services, cash, and information
- Objectives, strategies, and policies

Further, the framework is developed to account for risk and uncertainty caused by factors internal and external to the enterprise. Obviously, this requires reconfiguring the supply chain in order to keep pace with the changing environment.

In this chapter, we focus on studying the nature of the supply chain and its configuration in a dynamic business environment. We develop an understanding of the basis for a supply chain configuration problem, its classifications, and its various dimensions. This chapter also introduces a running example of bicycle suppl0y chain used throughout the book to illustrate various concepts and methods.

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2.2 Supply Chain and Supply Chain Management

Companies deliver products and services in response to the customer demand. In order to produce and deliver products, companies procure services and materials from their partners. As a result, a partnership network of the companies is established. The main characteristics of the network are (1) the flow of products starting with materials used in production to the ready to use end-products, (2) the flow of information about customer demand and coordination of production and delivery activities, and (3) dependence of all companies involved in the network on satisfaction of the end-customers. The definition below captures all three aforementioned facets of supply chains:

> Supply chain is a network of supply chain units collaborating in transforming raw materials into finished products to serve common end-customers.

A supply chain unit is defined as an entity involved in the supply chain and having a distinct legal or spatial identity. Although each unit can perform multiple roles in the supply chain, they usually have a type characterizing the main purpose of the unit such as manufacturing plant, distribution center or warehouse. All supply chain units can belong to one company as in the case of vertically integrated supply chains or supply chain units belonging to different companies.

The supply chain units are linked together in multiple ways forming a network structure. Nevertheless a chain-type of superstructure is imposed by movement of materials and products from their initial state to the final state in the form of end-products. The links are mainly used to represent physical movement of products although the pervasive use of information technology makes this distinction vague because of developments like 3D printing (see Chap. 12). Multiple links are possible between any two units in the supply chain.

Figure 2.1 shows a graphical representation of SCC Bike supply chain, which is used as an example throughout the book (the SCC Bike case is described in Appendix). The supply chain is represented as a directed graph. The supply chain units and links are shown as the graph's nodes and edges, respectively. The unit type is indicated by a marker. Given that supply chains often have a large number of units, some of the units are represented in an aggregated manner using clusters. In this example, customers are divided into clusters according to their geographical location.

Systematic and predictable supply chain operations are achieved through rigorous supply chain management. Supply chain management is a coherent set of techniques for planning and execution of all supply chain management processes, enacting a chosen supply chain strategy and ensuring customer demand satisfaction. The supply chain strategy is derived on the basis of competitive strategies of companies involved in the supply chain, and there are four main supply chain

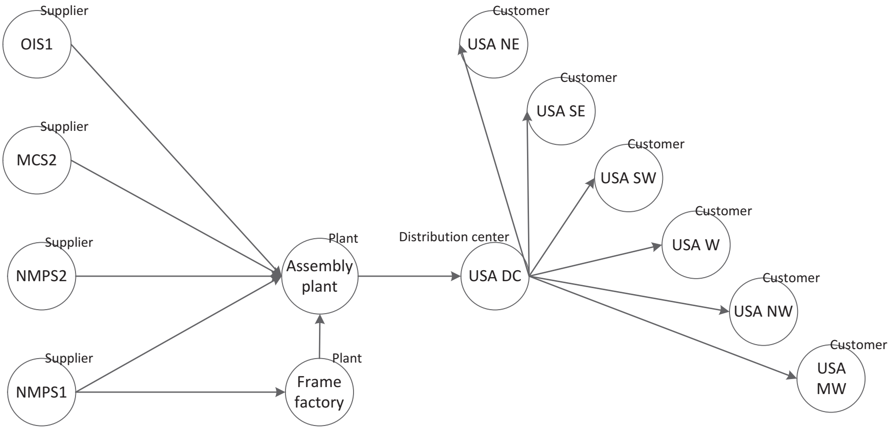

Fig. 2.1 Sample supply chain network

strategies, namely, lean, flexible, agile, and service-oriented. There is a large number of supply chain management processes described in Sect. 2.2.2. The key property of the supply chain management processes is their cross-enterprise and cross-sectional nature.

2.2.1 Supply Chain Management Strategies

The three typical supply chain management strategies are lean, flexible and agile strategies. The service-oriented strategy is added here to emphasize emerging importance of services including electronic services in supply chains. Companies often employ different combinations of strategies and hybrid strategies depending upon product and market segmentation, as well as other factors.

2.2.1.1 Lean

According to Vonderembse et al. (2006), "a lean supply chain employs continuous improvement efforts that focus on eliminating waste or non-value steps along the chain. It is supported by the reduction of setup times to allow for the economic production of small quantities; thereby achieving cost reduction, flexibility and internal responsiveness. It does not have the ability to mass customize and be adaptable easily to future market requirements." This type of supply chain is essentially based on the lean principles, which advocate the reengineering of business processes to remove all non-value added activity, generally ascribed as the source of waste in the system. Another significant feature of the lean technique applied in the lean supply chain is integration across functions of the enterprise.

The accrued benefits are a high capacity utilization rate, shorter lead times, and minimization of total supply chain costs. Jasti and Kodali (2015) have summarized these features as the pillars of lean supply chain management. The eight pillars are information technology management, supplier management, elimination of waste, JIT production, customer relationships management, logistics management, top management commitment, and continuous improvement.

From the supply chain network perspective, it is expected that the influence of lean supply chains focuses on establishing long-term links among the supply chain units and minimization of number of units and links. The lean supply chains aim towards simplifying and streamlining the supply chain network, while providing a high level of standardization and specialization.

2.2.1.2 Flexible

The flexible supply chain strategy addresses uncertainties associated with supply chain operations and primarily demand uncertainty. The flexibility is an ability in a relatively inexpensive way to respond to changes in customer demand and shift production and delivery to products with the highest demand and value. This ability usually is already built-in in the system, therefore, supply chain already should be designed to provide a certain level of flexibility. This characteristic limits a kind of changes and level of uncertainty the supply chain is able to react, and designing flexible systems usually is more expensive than designing lean systems.

From the supply chain network perspective, flexible supply chains have built-in redundancies and cushions in the form of extra units and links to deal with changes and uncertainties. The supply chain units and links are less specialized and multiple functions can be performed. It is argued that the flexible supply chain strategy attempts to deal with uncertainty without drastic overhaul of the supply chain network.

2.2.1.3 Agile

The agile supply chain strategy supplements the flexible supply chain strategy. However, it does not shy away from substantial changes in the supply chain network and attempts to introduce changes in a proactive manner. The agile supply chain configuration strategy is often described as a combination of flexibility and adaptability by reconfiguring the supply chain network. The key enablers of the agile strategy are collaboration among the supply chain units, advanced information technology and other technical capabilities and knowledge management (Gunasekaran et al. 2008). The key limitation of the agile strategy is the difficulty to balance agility and restrictions set by long-term investments in the supply chain network.

From the supply chain network perspective, agile supply chains are characterized by large variety of units involved, often performing fine-granularity functions.

2.2.1.4 Service-Oriented

The key feature of service orientation is provisioning of required capabilities and resources on-demand from service providers. The services are composed together to create a supply chain suited for current or expected business opportunities. The service-oriented approach minimizes fixed investments and ramp-up time. It relies on using advanced information technologies and cloud computing as discussed in Part III of this book.

From the supply chain network perspective, service-oriented supply chains have much less strong associations with particular spatial location of supply chain units and customers. More importantly, the primary focus switches from the physical movement of products to the electronic movement of information and delivery of services. The distinction between the physical and electronic worlds blurs in service-oriented supply chains.

2.2.2 Supply Chain Management Processes

The supply chain network describes the static structure of the supply chain while processes provide a dynamic representation of supply chain management activities. Supply chain management processes are cross-enterprise, cross-sectional, and self-similar.

The cross-enterprise processes involve multiple companies in the execution of supply chain processes. The important feature of these collaborative processes is that the companies involved are mainly concerned with their inter-communications rather than with internal operations of each supply chain unit. That simplifies development and execution of complex supply chain processes. The cross-sectional processes involve multiple supply chain problem areas such as sales, purchasing, and logistics. This characteristic implies that supply chain decision-making and process execution cannot be done in isolation and mutual interactions and dependencies among different problem areas should be taken into account.

The Supply Chain Operations Reference (SCOR) model (Supply Chain Council 2011) categorizes supply chain management processes in five groups: (1) plan, (2) source, (3) make, (4) deliver, and (5) return. The plan processes represent planning of supply chain operations. The source processes describe receiving of the products from preceding supply chain units. The make processes describe transformation of products at the supply chain unit. The deliver processes represent delivery of the products to consecutive supply chain units. The return processes represent reverse logistics activities. It suggests that these characteristic processes define the base dynamics of supply chain operations and they can be observed for different levels of aggregation of supply chain units. Therefore, the processes are referred to as self-similar. The processes can be further detailed at different levels of abstraction, making it possible to analyze cross-sectional supply chain characteristics.

2.3 Supply Chain as a System

A supply chain can be perceived as a social-technical system. The system is defined as a tuple:

`System = <Components, Interrelationships, Boundary, Purpose, Environment, Input, Output, Interface, Constraints>`

Refining the system's properties specifically to the supply chain case yields:

`Supply Chain = <Supply Chain Units, Links, Boundary, Purpose, Environment, Input, Output, Interface, Constraints>`

`Components` become `Supply Chain Units` as supply chains consist of supply chain units, and similarly `Interrelationships` are replaced by `Links`. The system boundary can be formally described as all links attached to the supply chain units without specifying their source or target. Logically that means connections with other supply chains and units outside of the scope of the given supply chain. The overall supply chain purpose is to serve its customers. The more detailed breakdown of supply chain objectives is given in Chap. 7. The supply chain environment is defined by its competitive environment. The supply chain inputs are materials and services provided by supply chain units outside the scope of the given supply chain, and outputs are products and services delivered to customers. Customers are often shown as final nodes in the supply chain networks and thus within the supply chain system. However, this representation of customers concerns only their physical location while their logical behavior is external to the supply chain system. The main supply chain `Interface` is customer demand. Supply chain constrains are classified as network wide constraints and unit wide constraints. The network wide constraints mainly define global operating requirements such as regional differences, legal requirements and others. The unit wide constraints define local operational requirements, such as allocation of resources, capacities, labor, and capital.

As for any other system, the key properties of the supply chain system are decomposition, modularity, coupling and cohesion. The supply chain can be decomposed starting with the top level network. As stated above, the top level network consists of units having distinct legal or spatial characteristics. The units are further decomposed to represent their internal structure. For instance, a warehouse consists of multiple docking places and subdivisions. The decomposition is related to different levels of supply chain decision making. There are decisions: (1) associated with the entire supply chain; (2) made at the unit level; and (3) made at the unit subdivision level. Similarly, supply chain decisions are categorized as strategic, tactical, and operational. The strategic decisions are made in the planning horizon measured in years; the tactical decisions are made in the planning horizon measured in months; and the planning horizon of the operational decisions is measured in weeks or shorter time units. Different planning horizons can be used at every decision-making level, e.g., there could be operational decisions made at the network level.

2.4 Supply Chain Management Problem Domain

Supply chain management involves dealing with multiple managerial and technical problems (Cooper et al. 1997; Mentzer et al. 2001; Soni and Kodali 2013). These problems highlight several common issues that must be addressed for a supply chain to function effectively and efficiently. We discuss below some of these issues and how they have been addressed in the published literature.

2.4.1 Key Challenges

Customer engagement. This issue takes a holistic view of sales and customer relationships. Customer relationships management and business analytics techniques are used to provide customized customer services on a global scale. From the supply chain perspective, it changes cost optimization focus to customer service focus implying not only high fill rates and responsiveness but also social responsibility, supply chain transparency, and environmental consciousness (Carter and Rogers 2008; Danese and Romano 2013).

Distribution Network Configuration. This issue deals with the selection of warehouse locations and capacities, determining the production level for each product at each plant, and finalizing transportation flows between plants and warehouses so as to maximize production, transportation, and inventory costs. This issue relates to information sharing: (a) inter-firm between marketing, production planning, inventory planning, and receiving and warehousing functions, and (b) intra-firm between manufacturer, suppliers, distributors/retailers, and transporters. It is a complex optimization problem dealing with network flows and capacity utilizations (Ballou 2001; Mangiaracina et al. 2015).

Inventory Management and responsiveness. This issue deals with stocking levels at various echelons in the supply chain. Demands from echelon-to-echelon are considered in making this decision. This is a decision problem solution which involves using algorithms for forecasting, and inventory management, in conjunction with simulation and optimization capabilities. Retailers, suppliers, and manufacturers deal with this issue in a supply chain by sharing information on customer demand, inventory levels, and replenishment schedules (Childerhouse et al. 2002; Sheffi 1985).

Supply Contracts. This issue deals with setting up relationships between suppliers and buyers in the supply chain through establishment of supply contracts that specify mutually agreed-to prices, discounts, rebates, delivery lead times, quality standards, and return policies. This approach differs from traditional approaches because its central focus is on minimizing the impact of decisions made at not just one echelon in the supply chain, but on all its players. A retailer sets up these contracts with a distributor or directly with a manufacturer. To manage this issue, it is incumbent upon various supply chain players to share information related to product price, cost, profit margins, warranty, and so on. This is a decision problem solution that could range from a simple linear programming problem to a complex game theory algorithm (Cachon 2002; Fisher et al. 1997; De Matta and Miller 2015).

Distribution Strategies. This issue deals with decisions pertaining to the movement of goods in the supply chain. Among the strategies available are direct shipments, cross-docking involving trans-shipments, and load consolidation. The objective is to minimize warehousing (storage) and transportation costs. A manufacturer makes decisions about either warehousing or direct shipment to the point of usage of various products, utilizing information shared among manufacturers, suppliers, distributors, and retailers in the supply chain. Solutions to this problem involve network algorithm utilizing linear, and nonlinear programming techniques in deterministic and stochastic environments (Frohlich and Westbrook 2001; Cagliano et al. 2008).

Supply Chain Integration and Strategic Partnering. One of the key issues in managing supply chains is integration (Bramham and McCarthy 2004). Information sharing and joint (or collaborative) operational planning are basic ingredients for solving this issue. Implementation of Collaborative Planning, Forecasting and Replenishment (CPFR) (Aviv 2001; Ng and Vechapikul 2002; Caridi et al. 2005; Fliedner 2003), as carried out by Wal-Mart retail stores in their supply chain aided by information sharing through common software platforms such as Enterprise Resource Planning (ERP) are viable strategies (Akkermans et al. 2003). In a manufacturing supply chain, it would mean CPFR among the retailer, supplier, and the manufacturer of products. The main idea of this technique is to avoid carrying excess inventory through accurate forecasting, and utilizing commonly agreed to demand data, information about which is shared among various supply chain partners (Anonymous 2000).

Outsourcing and Procurement Strategies. An important issue to consider is what to manufacture internally and what to buy from external sources. One of the problems to be dealt with when making these decisions is identifying risks associated with these decisions and minimizing them. Another issue to consider is the impact of the Internet on procurement strategies and what channels to utilize (public or private portals) when dealing with trading partners. In arriving at the decision of whether to outsource or buy, various optimization models may be utilized to balance risk and payoffs. Once this decision has been made, use of appropriate information technology components, such as Internet portals and procurement software, plays a key role in these decisions. An example of this issue in a manufacturing supply chain may be the decision to outsource a component assembly rather than making it in-house. Information sharing for outsourcing and other procurement issues is accomplished in the supply chain and its extended enterprise, for intra-firm and inter-firm, via Intranet, Extranet, and Internet portals (Chen et al. 2004).

Information Technology and Decision Support Systems. One of the major issues in supply chain management is the lack of information for decision-making. Information technology plays a vital role in enabling decision-making via information sharing throughout the supply chain. Some of the key ingredients of information technology in the supply chain are use of Internet and Web-based service portals, integrated information/knowledge within ERP software, and decision support systems that utilize proven algorithms for various strategic, tactical, and planning problems in specific industry domains (Fiala 2005). Significant progress has been achieved in enabling physical supply chain integration. Lau and Lee (2000) use the distributed objects approach to elaborate on an infrastructure of integrated component-based supply chain information systems. Kobayashi et al. (2003) conceptually discuss workflow-based integration of planning and transaction processing applications, which allows for effective integrated deployment of heterogeneous systems. Verwijmeren (2004) develops the architecture of component-based supply chain information systems. The author identifies key components and their role throughout the supply network. Themistocleous et al. (2004) describe the application of enterprise application integration technologies to achieve physical integration of supply chain information systems. However, approaches and technologies for logical integration at the decision-modeling level, where common understanding of managerial problems is required, are developed insufficiently (Delen and Benjamin 2003).

Challenges for Information Sharing in the Supply Chain. In light of various decision-making levels and issues facing effective management of the supply chain, it becomes imperative to find globally optimal integrated solutions. However, it is difficult to achieve depending on whether the problem-solving models designed for the purpose achieve local (or sequential) or global optimization of the supply chain network. Depending on which approach is adopted, the requirement for information sharing will be starkly different. For example, in the case of sequential supply chain optimization, the objective of its individual partners is optimized without regard to the overall supply chain network objective. Accordingly, the need for information sharing is limited and/or closed, sometimes nonexistent and usually offline. For global supply chain optimization, however, the objective for the overall supply chain takes precedence over each partner's objective. For this scenario, information sharing is extensive, open, and online (Beamon 1998; Fiala 2005; Simchi-Levi et al. 2007).

2.4.2 General Problems

The main general supply chain management problems are:

Competitiveness. The house of supply chain management (Stadtler 2008) considers solving this problem as the ultimate goal of supply chain management. To maintain competitiveness, a supply chain must outperform competing supply chains in at least some aspects such as prices, quality, or delivery responsiveness.

Customer service. It characterizes the ability of supply chains to meet customer requirements. Approaches to addressing this problem are as diverse as the customer requirements representing such aspects as cost, quality, and responsiveness.

Coordination. Coordination of decisions by each supply chain member are made with regard to the impact these decisions will have on the performance of other supply chain members.

Collaboration. Joint activities performed by supply chain members to achieve common goals (Kliger et al. 2015) include product design and planning. In the case of collaborative product design; manufacturers, suppliers, and potential customers work together to design product that best suits market requirements and the capabilities of parties involved.

Environmental protection. Supply chains as a system operate and interact with its environment including they impact on nature and consumption of natural resources. Increasingly supply chain management decisions are made with regard to these concerns.

Flexibility and agility. Customer requirements and operating environments are dynamically changing. Addressing flexibility and agility issues implies the ability of reactive and proactive response to change.

Globalization. This presents both opportunities and challenges. Cost reduction and expansion in new markets have become possible. On the other hand, increasing competition, local regulations, and cultural adjustments cause additional difficulties.

Integration. Addressing the integration problem enables customer service improvements, coordination, and collaboration. Information sharing is an important integration sub-problem.

Mass customization and postponement. Customers demand individualized products with similar cost and delivery time characteristics as those of standardized products. Postponement is one of the strategies for delivering market-specific and customized products. It implies location (in time and space) of the product finishing close to the point of demand.

Outsourcing. Firms focus on their core competencies to achieve a high level of competitiveness in specific areas while allocating supporting functions to partners.

Risk/benefit sharing. Implemented supply chain decisions have different impacts on supply chain members. Some of the units may assume larger risks and incur additional costs in the name of overall supply chain benefit. Risk and benefit sharing is essential for building trust and enforcing commitment among supply chain members.

Robustness. Supply chains operate in uncertain environments. Operations need to be planned and executed with respect to this uncertainty.

Sustainability and social responsibility. Supply chains are designed and operated with regard to social, cultural, and environmental issues.

2.4.3 Specific Problems

The main specific supply chain management problems are:

Demand planning and forecasting. Demand data are required for other supply chain management activities. Demand planning attempts to influence demand to make supply chain operations more efficient.

Finance. In the supply chain management framework, this concerns planning of supply chain costs and controlling supply chain performance.

Inventory management and logistics. Problems deal with delivering products and services to customers, including planning of distribution structure, inventory management, warehousing, and transportation activities. Reverse logistics is employed to process customer returns and residue of other supply chain operations

Production planning and manufacturing. These problems address creation of products and services in response to customer demand. It includes such supply chain management concerns as master production planning, capacity allocation, scheduling, maintenance of manufacturing facilities, and manufacturing quality.

Marketing and sales. The primary concerns of these managerial problems are attracting customers and processing their orders.

Network design. A network of supply chain units meeting product and process design requirements is established. Problems to be addressed concern location and role of supply chain units, allocation of products, strategic-level capacity planning, and establishing transportation and information exchange links.

Process design. This is a significant supply chain management problem because of the very large number of processes that can be potentially enumerated as the supply chain is functionally decomposed top-down from a tier → unit → function → process level, and then need to be properly managed. One of the key problems that arise is how to develop a composite process design of the supply chain that clusters these processes based on similarities in features and characteristics, and arranges clusters according to an optimal implementation schedule.

Product design and bill of materials. This is not an explicit supply chain management problem, although there are significant interactions between design and logistics activities and at this stage, it is a major input for further supply chain management activities. From the supply chain management perspective, this problem concerns collaborative product design, balancing product design requirements and supply chain capabilities, and providing the bill of materials for further planning purposes.

Personnel management. Workforce requirements are considered while dealing with the personnel management problem. This includes workforce planning, hiring, layoffs, promotion, training, and incentives.

Supplier selection and purchasing. This deals with procurement of materials and services that are needed from suppliers to satisfy customer demand. The problem includes such issues as identification of materials and services needed, supplier relationships (i.e., supplier selection, contract negotiation, supplier evaluation) and execution of procurement operations.

2.5 Supply Chain Configuration

The supply chain design problem is one of the key supply chain management problems. It defines the underlying network structure of the supply chain and is interrelated with a number of other supply chain management problems such as logistics, purchasing, and others. The concurrent decision-making concerning supply chain network structure and key attributes of the supply chain at the network level is referred to as supply chain configuration. For the purposes of this book, the following definition is adopted:

> Supply chain configuration is a set of supply chain units and links among these units defining the underlying supply chain structure and the key attributes of the supply chain network.

The supply chain configuration problem is to select appropriate supply chain units and to establish links among these units, as well as to make key decision concerning supply chain attributes at the network level. From the configuration point of view, every supply chain unit has specific geographical location and functions, and the links are mainly used for physical movement of goods from one unit to another. The configuration decisions are made according to the overall supply chain strategy. The appropriate supply chain units are selected from a number of alternatives depending upon the unit type.

A configurable supply chain is a system that efficiently adapts to its environment, offered in the form of supply and demand issues for the product(s) to be manufactured. A configurable supply chain is needed to manage logistics in a configurable system. This is because the adopted policies for product, process, and resource components of a configurable system have to be integrated with both inbound and outbound logistics decisions to realize benefits of flexible strategies. Some of the key triggers for designing and implementing a configurable supply chain 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 reallocation 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
- Changes in commitments within or between supply chain members

A configurable supply chain can help in assessing the impacts of one or more of the following factors/activities in a configurable system:

- Flows due to materials, inventory, information, and cash
- Throughput due to movement of products
- Capacity utilization
- Costs at various stages of the product development life cycle
- Lead time in product development
- Batch and lot sizing
- Process redesign
- Product development strategies
- Procurement and/or allocation of resources
- Strategic, tactical, and operational policies for the supply chain

Analysis of these factors/activities involves dealing with a wide range of managerial problems and spans across all tiers of the supply chain. Problem-solving approaches need to consider both interactions among factors and activities, and supply chain members.

2.6 Supply Chain Configuration Dimensions

The supply chain configuration problem solving allows to define scope of the given supply chain system. The scope is defined along multiple dimensions, namely, horizontal extent, vertical extent, objectives and criteria, decisions made, and parameters.

2.6.1 Horizontal Extent

The supply chain is usually divided into tiers (or stages, or echelons). Each tier consists of units with the same general functionality. The concept of tier should be treated with care, however, as differentiation between tiers is often fuzzy and units can belong to multiple tiers. That has become even more profound as supply chains assume networked structures. Still, tiers help structure the supply chain configuration problem and facilitate identification of common features of supply chain units.

The typical supply chain tiers, which can be further decomposed, are

- Customer tier—the most downstream tier
- Distribution tier
- Manufacturing tier
- Supply tier—the most upstream tier

Demand for supply chain products or services originate at the customer tier and it is transmitted upstream along the supply chain (Fig. 2.2). In many cases, customer nodes in this tier are an aggregation of individual customers clustering in a particular geographical location.

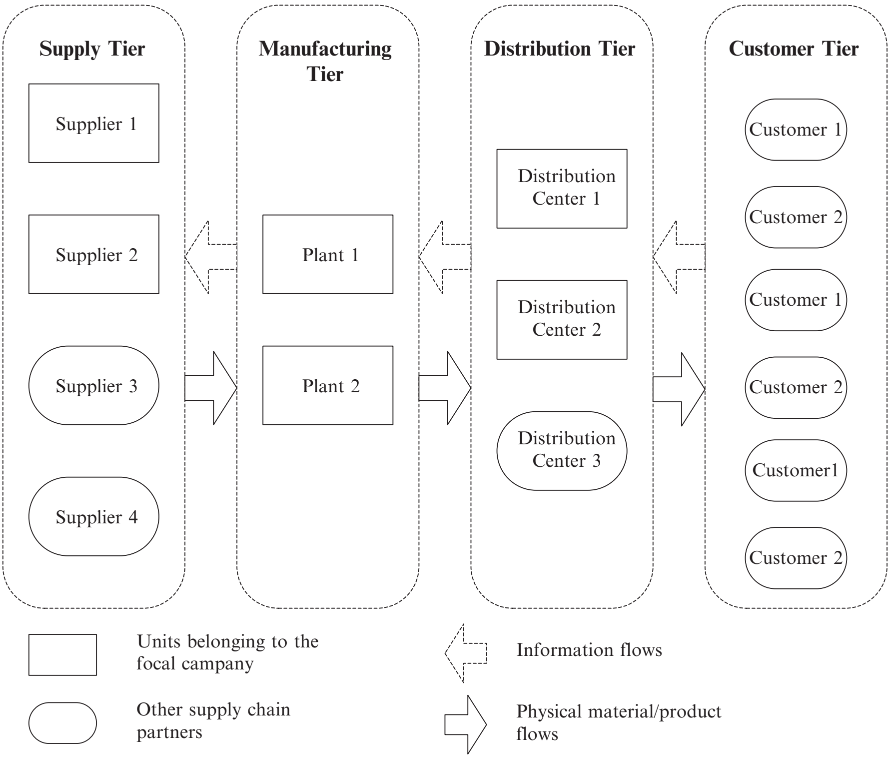

Fig. 2.2 Horizontal extent of supply chain

The distribution tier receives customer requirements and is responsible for delivering required products or services. It involves such general units as warehouses, distribution centers, and cross-docking points. These units are grouped into distribution sub-tiers. Alternatively, supply chain units in the distribution tier can be classified as wholesalers, retailers, and brokers. Third-party logistics providers present a special case for belonging to the distribution tier. In some situations, these can be represented by a single supply chain node.

There are two distinct scenarios to organize the supply chain's operations. The first, where manufacturing tier directly creates products or services demanded by the supply chain's customers. It receives demand information from the distribution tier. In return, it provides products to the distribution tier and orders materials from the supply tier. In the second scenario, the manufacturing tier can also be divided into several sub-tiers, such as preprocessing, assembly, final assembly, and finishing. Manufacturing outsourcing can be represented either in the manufacturing tier or in the supply tier. The first scenario is more relevant to representing the manufacturing tier for an engineering company such as Ericsson, which has outsourced almost all manufacturing operations and retained only product and process design as their primary competency, or in the case of capacity sharing agreements. The second scenario is more relevant for representation of manufacturing of components (for instance, the Ford and Visteon case).

The supply tier provides materials to manufacturing according to orders received. This tier can be divided into sub-tiers, linking raw materials suppliers, secondary suppliers, and direct suppliers. Representation of the supply tier depends upon the importance of supplied materials. Suppliers providing widely available and substitutable materials do not need to be represented by individual nodes.

A return tier could be treated as a separate tier in supply chains. It is responsible for handling customer returns and disposal of the returned products and waste. However, recycling of returns could occur at any of the identified core tiers and can be perceived as one of the integral processes performed along with the supply, manufacturing, and distribution activities.

One additional supply chain tier not sufficiently exposed in the literature is the utility tier. This tier includes providers of basic infrastructural services such as electricity, water, and recycling. That is of particular concern for global supply chains, because availability, cost, and quality of such services vary substantially.

Definition of this supply chain configuration dimension includes specifying the number of tiers in the supply chain, defining general types of units in each tier, and identifying specific constraints for the tier as a whole (for instance, the number of suppliers required).

2.6.2 Vertical Extent

As noted earlier, a supply chain consists of several members spread across many tiers. Each of the tiers consists of one or many business units (entities). Each of these business units is, by itself, an enterprise comprising functional areas such as design, marketing and sales, production planning and control, inbound and outbound logistics (procurement, receiving, warehousing, shipping), and so on. Each unit may also pursue its own independent strategies to manage its functions and strive to achieve specific goals and objectives.

A *within* unit (local) vertical integration would entail synchronizing and coordinating strategies and policies, for example, between its sales and marketing and manufacturing functions to achieve a common objective for the unit.

A *between* (global or supply chain level) vertical integration within a tier (comprising all units) would be to implement common strategies and policies to achieve a common (global) objective across units in their tier.

Vertical integration could be achieved at strategic, tactical, and operational levels of decision making within a tier of the supply chain. This is primarily achieved by means of implementing strategies and policies appropriate at these levels that are aimed at achieving long-term, mid-term, and short-term goals and objectives.

Definition of this supply chain configuration dimension includes specifying the number of units in each tier in the supply chain and identifying specific constraints and objectives: (a) within a unit at high level and by functional areas at low level, and (b) between units at high level and across functional areas at low level.

2.6.3 Objectives

Decision-making objectives are chosen according to general strategic objectives. Certain quantitative criteria or metrics are associated with each identified objective. General managerial concerns related to the supply chain configuration problem are

- What is the current supply chain performance?
- "What if" analysis?
- How to improve customer service?
- How to improve supply chain robustness and delivery reliability?
- Could supply chain be made more profitable?
- Is supply chain sufficiently flexible?
- How to improve cooperation?
- How to comply with local requirements?
- Whether to pursue outsourcing?
- Which partners to choose?
- Where to locate supply chain facilities?

Answering these questions leads to formulation of general supply chain configuration decision-making objectives. These objectives can be formulated on the basis of performance attributes identified in the SCOR model (Stewart 1997) as described in Table 2.1.

Table 2.1 Decision-making objectives

ID	Objective	Description
O1	To improve supply chain delivery reliability	The performance of the supply chain delivering the correct product, to the correct place, at the correct time, in the correct condition and packaging, in the correct quantity, with the correct documentation, to the correct customer
O2	To increase supply chain responsiveness	The velocity at which a supply chain provides products to the customer
O3	To increase supply chain flexibility	The agility of a supply chain in responding to marketplace changes to gain or maintain competitive advantage
O4	To optimize supply chain costs	The costs associated with operating the supply chain
O5	To improve supply chain asset management efficiency	The effectiveness of an organization in managing assets to support demand satisfaction. This includes the management of all assets—fixed and working capital

The aforementioned objectives usually can be expressed in quantitative terms and are used for decision-making on the basis of analytical models

2.6.4 Decisions

Initially, general supply chain configuration decisions are identified following the supply chain configuration decision-making objectives. These are subsequently specified using particular decision variables. Five groups of decisions are defined, characterizing structure, links, quantity, time, and policies used.

Structural decisions are

- Location of supply chain facilities at different tiers
- Facility opening
- Supplier selection
- Product allocation
- Definition of facility's capabilities

Decisions characterizing links among supply chain units are:

- Establishing a fixed link among a pair of units–if a link between units cannot be established on the spot, decisions must involve which units' link should be established
- Restricting cooperation to specified links–implies that a particular unit can cooperate only with a limited group of other units (i.e., a customer zone is served by only one particular distribution center)
- Choice of products or services delivery mode
- Choice of information exchange mechanisms

Alternative production location according to ownership, international/global, and product state are described by Meixell and Gargeya (2005).

Decisions characterizing quantity are:

- Quantity of purchased materials
- Quantity of products produced
- Quantity of products processed
- Quantity of products delivered
- Quantity of products stored in inventory
- Shipment quantities along supply chain links
- Capacity-related decisions

Decisions characterizing quantity often differ by their interpretation and level of detail. For instance, manufacturing capacity is specified for each product separately at a plant or for the entire plant. The main decision characterizing time is delivery time.

Decisions characterizing policies are

- Choices of manufacturing strategies. The most general values of these decisions are make-to-plan (make-to-stock), make-to-order, and assemble-to-order. The choice of the manufacturing strategy influences propagation of demand information along the supply chain and functions performed by different units
- Adoptions of information sharing policies. Information sharing policies affect manufacturing, inventory, and transportation, as well as several other decisions and characteristics. They also influence requirements towards information exchange infrastructure and adoption of common information exchange standards. Other IT-related decisions, such as implementation of ERP and manufacturing execution systems can also be considered
- Choice of distribution channels. Values these decisions assume include Internet-based distribution, third-party logistics, direct sales, quick response, continuous replenishment, and vendor-managed inventory. Some of the policies may be represented in relation to the horizontal extent dimension. For instance, the direct shipment policy implies the absence of intermediate distribution tiers. Multiple distribution strategies can be used in a single supply chain
- Choices of procurement policies. Some alternatives include volume consolidation, alliances and partnerships with suppliers, just-in-time (JIT), and manufacturing resource planning (MRP). From a technical perspective, various types of e-procurement can be chosen (for instance, EDI, Internet-based business-to-business (B2B) approaches, and trading networks)
- Adoption of outsourcing. Decisions apply to separate supply chain functions and indicate whether these are outsourced or not. That influences the way supply chain costs are accounted for. For instance, outsourcing may reduce fixed costs associated with a facility opening

Each of these policies can be parameterized by a set of particular structural, linkage, quantitative, and time parameters. For instance, if the decision is between using EDI or the Internet for information exchange purposes, a parameter characterizing a fixed cost for establishing links among manufacturing facilities and suppliers is larger for the first. Policies influence which supply chain management problems need to be addressed during decision-making. For instance, evaluation of the built-to-stock manufacturing strategy requires consideration of the inventory management problem.

The decisions listed above do not provide an exhaustive list of all supply chain configuration decisions. That, especially, applies to policy decisions. Decisions relevant to a particular decision-making problem, and decision variables characterizing these decisions, are defined during the supply chain configuration problem-solving process.

2.6.5 Parameters

Parameters usually are more specific to a particular decision-making problem compared to other supply chain dimensions discussed earlier. Some common features, however, can be identified.

Parameters are traditionally classified as internal and external. External variables for the supply chain configuration problem are customer demand and requirements in general, taxes, governmental regulations, and others.

The first group of internal variables represents structural characteristics, which includes representation of the existing supply chain structure, bill of materials, available capacity, and capacity requirements. This group also includes parameters describing attributes of alternative transportation channels (e.g., distance, speed).

Supply chain operations are described by cost- and time-related parameters. These are classified as fixed and variable parameters. Fixed cost parameters describe costs due to opening (closing) and operating supply chain facilities, capacity buildup costs, and costs associated with establishing and maintaining links among supply chain units. Inventory replenishment, manufacturing setup, and fixed transportation costs can also be considered. Variable costs are incurred per each processed product. Processing can assume various forms including transportation, assembly, inventory handling, and others. Parameters for representing processing time can also be used. Specific parameters may be needed to describe various attributes of the supply chain management policies considered.

2.7 Aligning Objectives

One of the major tasks of any supply chain configuration effort is to align the objectives according to several alignment perspectives (Table 2.2). The system perspective discussed in Sect. 2.3 concerns trade-offs among supply chain unit at various levels of aggregation, e.g., whole supply chain, partnership of individual units, or individual units. This issue is addressed using joint decision-making facilities and by considering profit and risk sharing among supply chain members.

Table 2.2 Methods for achieving alignment of supply chain configuration objectives

Alignment perspective	Alignment methods
System perspective	Joint decision-making Profit and risk sharing
Planning horizon	Multiple modeling views
Problem domain	Model integration Concurrent engineering

For instance, a metal processing company pays suppliers inventory carrying costs to prevent an inventory glut at the manufacturing site.[1] The planning horizon perspective concerns exploration of supply chain configuration decisions at strategic, tactical, and operational levels. Different factors are taken into account at each of the decision-making levels. Multiple modeling views at different levels of granularity are used to ensure that strategic decisions can be implemented at the operational level and that operational process are designed to support strategic decisions.

The problem domain perspective implies that supply chain configuration is shaped by the interplay of various general and specific supply chain management problems what is addressed by an increasing tendency to perform supply chain configuration concurrently with other managerial decisions. This increases modeling complexity although model integration helps to alleviate these issues. Multi-objective modeling is an approach for addressing all three alignment challenges.

2.8 Summary

In this chapter, we explore supply chain as a systems concept, and its configuration in the face of a dynamic business environment. We discuss various aspects of supply chain configuration problems, its classifications, and its various dimensions. We posit supply chain configuration as a supply chain management problem and argue that it can be successfully achieved if properly modeled around the decision-making levels and aligned with objectives formulated along different alignment perspectives.

The scope definition also includes identification of synergies and contradictions among configuration objectives along different alignment perspectives. It is suggested that key methods for achieving alignment are joint decision-making using integrated multi-view models, profit and risk sharing, multi-objective decision-making, and concurrent engineering.

[1] https://www.pnc.com/content/dam/pnc-com/pdf/smallbusiness/IndustrySolutions/Whitepapers/Driving_SupplyChain_Svgs_1110.pdf

Appendix. SCCB Case Description

SCC Bike is a sample bicycle manufacturing company and it is used throughout the book to illustrate various concepts and methods. The sample company reminisces real-life bicycle companies and the example is particularly influenced by the GBI and Shimano cases (Magal and Word 2012; Chang 2006). Factual information is derived from industry reports provided by Bicycle Retailer[2] and other professional publications.

The company is headquartered in Midwest USA, where it has a frame plant and an assembly plant. It manufactures medium to high end bicycles and offers around 20 different end-products manufactured out of around 250 parts. The manufacturing volume is around 250,000 bicycles a year. The bicycle production life-cycle is 150 days. Bicycle parts are categorized as non-moving, mechanical, and other industry parts. Examples of non-moving parts are saddle, rims, and handlebar. Examples of mechanical part are drivetrain, brakes, and gears. The other industries suppliers supply, for example, tires. A detailed bill-of-materials used in bicycle manufacturing is described by (Galvin and Morkel 2001). Parts are sourced from suppliers around the world and distributed through a set of specialist wholesalers and retailers. It is assumed that suppliers specialize in providing one specific category of parts and they provide a set of parts (as opposed to providing individual items). Suppliers are not necessarily manufacturers of the parts they provide. Specialist wholesalers and retailers collectively referred to as customers represent a specific sales area, the unit is responsible for.

The company's mission is to provide high quality bicycles at lower than premium pricing for cycling enthusiasts. It also focuses on providing professional customer care and direct collaboration with a limited number of specialist sellers. The demand for bicycles is growing continuously and supply chain configuration activities are driven by the need to provide an adequate customer service in new locations, which are currently only served by limited amount of bicycles sold over the Internet. Therefore, the main configuration objective is location of new distribution facilities and allocation of supplies to these distribution facilities. At the same time the manufacturing facilities are relatively stable. The company also continuously works with its suppliers to improve products and services. Some of the components can be sourced from several alternative suppliers.

Figure 2.3 shows the supply chain network of SCC Bike. The supply chain units in the figure are shown using their short names and Table 2.3 defines abbreviations used. The focal point of the supply chain is frame factory located in US MW and it supplies both assembly plants with hand-made carbon and aluminum frames. The suppliers deliver parts to the assembly plants, and each assembly plant is served by its regional set of suppliers. The customers are served from the regional distribution centers. The US DC is responsible for handling web sales. The SCC Bike has a bundling deal with cycling mobile app developers.

[2] http://www.bicycleretailer.com/

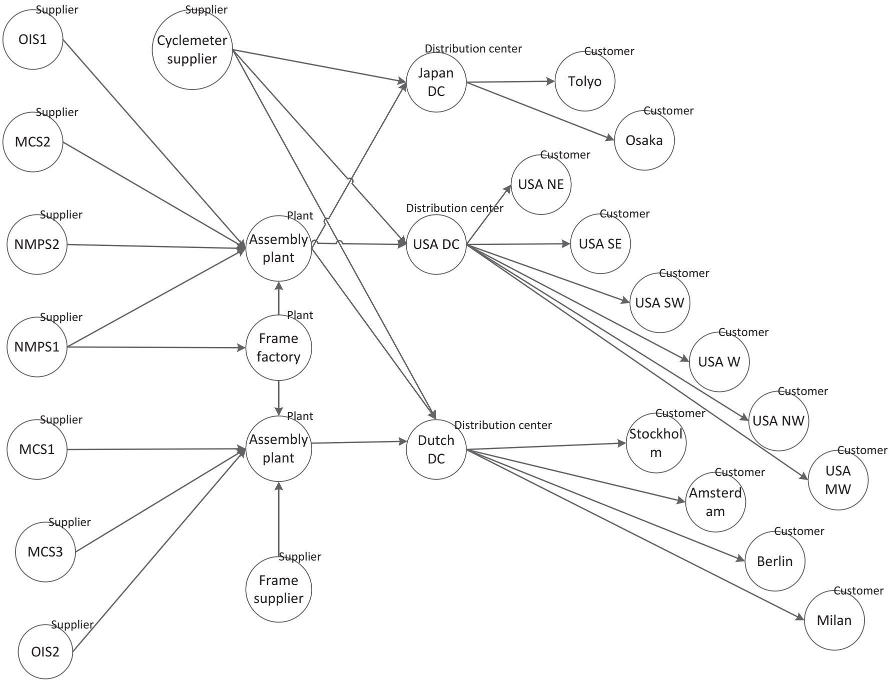

Fig. 2.3 The SCC Bike supply chain network

Table 2.3 Description of supply chain units for the SCC bike case

#	Short name	Name	Type	Location (state, country)
1	FF	Frame factory	Plant	WI
2	AP1	Assembly plant (US)	Plant	WI
3	CS	Cyclemeter supplier	Supplier	CA
4	MCS1	Mechanical components supplier	Supplier	ITA
5	OIS1	Other industries supplier	Supplier	NY
6	NMPS1	Non-moving parts supplier	Supplier	IL
7	MCS2	Mechanical components supplier	Supplier	CHI
8	MCS3	Mechanical components supplier	Supplier	TWA
9	NMPS2	Non-moving parts supplier	Supplier	CHI
10	US DC	US DC	Distribution center	WI
11	EU DC	Dutch DC	Distribution center	NL
12	JP DC	Japan DC	Distribution center	JPN
13	US NE	US NE	Customer	NY
14	US SE	US SE	Customer	FL
15	US SW	US SW	Customer	TX
16	US W	US W	Customer	CA
17	US NW	US NW	Customer	WA

(continued)

Table 2.3 (continued)

#	Short name	Name	Type	Location (state, country)
18	Tokyo	Tokyo	Customer	JPN
19	Osaka	Osaka	Customer	JPN
20	AMS	Amsterdam	Customer	NL
21	Berlin	Berlin	Customer	GER
22	Milan	Milan	Customer	ITA
23	STH	Stockholm	Customer	SWE
24	AP2	Assembly plant (EU)	Plant	NL
25	OIS2	Other industries supplier	Supplier	NL
26	NMPS3	Non-moving parts supplier	Supplier	NL
27	US MW	US MW	Customer	IL
28	GL WEB	Global web customers	Customer	

All supply chain units and links are also characterized by their attributes. These are introduced in the following chapters

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