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SUPPLY CHAIN MANAGEMENT: A SURVEY

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Abstract

Supply Chain Management is a buzz word that encompasses many ideas, theory and perspectives on the management, possibly optimal, of the activities needed to provide a product and/or a service to final customers starting from raw materials. Many authors, usually, restrict themselves to logistic and inventory related activities. Here, we will take a holistic approach by considering all the activities (financial, legal, marketing, etc.) needed to provide the product and/or service. We will analyze the historical evolution of supply chain management models.

Key words: Supply Chain Management.

1. Introduction

The *Supply Chain Management* term is one of those buzz word able to convey many concept, theories, perspective which are not easily or possibly described in a comprehensive and detailed way. If there is a consensus about what a supply chain is, [32], [29], [53], [36], a system made up of *suppliers*, *manufacturers*, *distributors*, *carriers*, *retailers* and *customers* in which there is a material flow from suppliers to final customers and an information flow in both direction- it is not easy, instead, to reach a consensus on what, exactly, *Supply Chain Management* is. In this survey we will define *Supply Chain Management* as the (possibly optimal) management of all the activities that take place within a single firm and among its commercial partners in order to produce and sell a good and/or a service. In this general framework we need to consider not only the traditional topics of logistics and industrial production but also those typical of other areas such as marketing, economics, budgeting and financial planning, legal, and so on. In this perspective, defining a SCM model means primarily defining a business model. Obviously, the business model needs to conform and be adapted to the firm and its entire supply chain business environment. From this simple observation it follows that does not exist a supply chain management model "optimal" by itself but there can only exist an optimal supply chain management model for a very specific supply chain, in a quite defined social and economic environment. Once one has defined the appropriate "business model" for the given supply chain, it is still necessary to define a "methodology" to make the model viable and a "mathematical model" to analyze problems in detail and above all solve them. Regardless the chosen business model we can still define the macro-processes which characterize supply chain design and management and, at a lower resolution, the single firm. In the next section we will define these macro-processes while in the second we will analyze the evolution of supply chain management models from a historical perspective.

2. Macro-Processes

We can define the following macro-activities that, somehow, describe the production and sale process along a time dimension.

- **Defining the Product or Service**

  This is probably the most important phase of a company's life in which the product or service gets "defined" in technical and business terms. The choices taken at this stage are those that will decide the success or the failure of the company. We stress, here, the fact that these choices bind the supply chain management models that the company can possibly adopt and, hence, have a deep impact on its competitiveness, service level, cost structure, and so on. As an example, let us think of choosing the "market position". This choice will impact, e.g., price dynamics (and hence cost)and customer service level and these, in turn, will bind and limit possible commercial partners and suppliers. Other choices, such as those related to the product technical aspects, are even more binding. At the end of this phase, the following elements (among others) will be characterized:

  Demand: which markets (along space, time and quantity dimensions), segmentation (whenever possible), customer profiling.

  Phases: production phases: what to outsource and what is the "core business"

Partners and Suppliers : first, rough, selection of partners and suppliers. This is, potentially, a large group that will be shrunken by future choices.

Resources: which technology, capacity, production sites, etc.

Sale Channels and Customer Care: owned retailers, franchising, large distributors, sales rep., internet, etc.

At the end of this complex process it will be possible to define mathematical models which will help the company to select the "optimal" (in some sense) supply chain structure. An efficient model will give suggestion about optimal sites and capacities but will leave as large as possible the supplier base, removing only those that do not satisfy constraints.

At this point we remind here the reader the common, accepted meaning of the typical supply chain elements, i.e., suppliers, retailers, producer, and so on.

Retailer It has the double function of sale channel and of inventory depot for the retailer[1] demand. Usually it is also a customer care and a return point for defective items. Internet has made possible to separate these functions into different channels.

Distributor/Warehouse They are primarily depots for physical inventory and their main function is that of reducing the transportation lead-time between demand (final or retailers') and the production sites (or other inventory depots). "Risk pooling" is another of their functions since, by serving many sites, they aggregate demand and decrease its volatility, decreasing at the same time the safety stock level. A commonly[2] accepted difference among the two terms is that the first is a depot and an indirect sale channel, carrying many products possible from competing companies, while the second is a depot for a single product or it is owned by the same company.

Production Site They refer to those places where "products" are made. Within one production site many production phases can be carried out and there can be different production sites with the same function. In the past, usually, production sites belonged to the same company, while now, phases outsourcing has replaced many production sites of a company supply chain with corresponding suppliers.

Supplier Suppliers can be classified in many ways. A usual classification divides them into *direct* and *undirect* with the first supplying "directly" the production process and the second otherwise. Depending on their strategic importance and on the type of partnership they can be further classified into first-tier suppliers, second-tier suppliers, and so on.

Logistic providers/Carriers They support the physical carriage of materials and finished products among the different elements of the supply chain. Usually, Logistic Providers means that they are "suppliers" of a given company that could, in fact, manage its own transportation fleet.

- **Demand Management**

  In this phase demand is further analyzed according to various dimensions: product type, life-cycle, segmentation,etc. Accordingly, the relationships *service level /price* and *quantity/price* will be defined. Each supply chain element will have its own demand forecast

[1] in some model the retailer inventory can also be allocated to other retailers

[2] many authors, though, do not follow this

time horizon and final demand will be rolled over the entire chain. In order to achieve this, appropriate coordination and information sharing mechanisms need to be in place.

- **Supply Management**

  This is probably the most complex phase in which the company has to decide the collaboration type and level with its commercial partners and suppliers and set up the right contracts and interaction mechanisms. Also, it has to define and optimize all its internal activities in order to reach its business goals. Contracts type among the company and its partners and supplier depend on their relative "strength". SCM recent literature focuses on designing contracts to coordinate each part actions and reach a Nash equilibrium. Other decisions to be taken at this stage are: optimal replenishment and inventories policies, pricing policies (discounts and promotions), optimal resources planning (Factory and transportation planning), etc.

- **Execution Management** In the past, Supply Chain Management activities were usually divided into two classes: planning activities and execution activities. Distinction was based on the time horizon: planning activities were referring to a longer time horizon (weeks, months, years) than execution activities (days, hours) and, consequently, to a higher uncertainty. Technology advancements, shorter and shorter product life-cycles, stronger competition, shorter time-to-market, have forced companies to change their planning and execution procedures in order to adapt to an ever changing business environment. Hence, many "decisions", once belonging to the "planning" phase, e.g., production loads, optimal inventory level, direct material requests, have to be taken and above all modified practically in real time. Hence the distinction between a planning phase and an execution phase is blurring. These days, a more significant distinction is between SCM activities based on certain information (or, better, given) and those based on uncertain information. At this point, we can simplify and include in *demand management* also "order management" and in *supply management* all the typical activities of the (supply side) execution phase.

3. The Evolution of Supply Chain Management Models

As pointed out in the introduction, Supply Chain Management is a business model which must hence evolve and adapt to the new market needs. A first, qualitative, analysis must hence start from today business environment. If we look at business trends, we can easily say that they are characterized by a strong, global competition, product proliferation, savvy customers, deverticalization and outsourcing phenomena and constant technological advancements which open up new frontiers for companies but, at the same time, create new problems. This business environment means companies face a very high pressure on profits and that their relationship with customers must follow the mantra: give them the "right" product (possibly customized), at the "right" time, in the "right" place, in the "right" way and at the "right" price. To be in line with this mantra means companies had and have to deeply modify their way of doing business and manage processes. Optimal Supply chain management has become hence a clear competitive advantage and a priority on top managers agenda. The modern company must adopt the following:

- Flexibility. Company's structure and processes must continuously adapt to changes in the economic and business environment to take advantages of all the opportunities and to limit losses in case of unfavorable events.

- Speed. Processes time length need to be reduced as much as possible and decision need to be taken in real time.
- Efficiency. All activities need to be aligned, with the appropriate incentive schemes, to the company business goals.
- Coopetition. The right balance between "competition" and "collaboration" with company partners and suppliers in order to achieve system wide savings and efficiency which improve customer service and profits.

Changes in the Demand profile have also deeply modified the optimal production process: from mass production of (possibly) few product lines to custom production. Product features are based on the direct input (communicated through a low cost medium such as internet) of the single customer but production processes are (or should be) organized in such a way to reach economic scale savings. The production input comes directly from demand so that the production system is more similar to a "pull" system than to the traditional "push" system. Outsourcing is another key aspect of the modern company. This trend was predicted by the nobel prize Ronald Coase in its fundamental work *The nature of the firm*. He proved there that outsourcing will happen as soon as transaction costs between different firms are low enough. Internet and competition are lowering these costs so that an atomic-like structure of many companies focused on core competencies is expected.[3] In this business environment a tight collaboration with commercial partners is required but as long as one of the party is selling and the other is buying, negotiation mechanisms will prevail. From a historical perspective, we can see the totally integrated, vertical model of the '40-'70, the horizontal model of the '80-'90 and the current, core-business centered model.

It should be apparent that managing a "vertical" enterprise's supply chain is relatively easier than managing a supply chain made of many, independent firms. In this last case, in fact, one needs to align divergent objectives and coordinate independent decision makers that interact through typical negotiation mechanisms. This fact by itself should be enough to support the thesis that supply chain models used in the past can not be viable anymore. We will add more on this, though, by showing that different business environments entail different supply chain management models.

In the period '40-'80 there are still oligopolies and monopolies in many industrial sectors: as a consequence, there were few (or none) substitute products and customer had little bargaining power. There were "local" markets with very little information exchange and this prolonged products life cycle (already very long when compared to today's ones). In this business environment it was easy for companies "imposing" a given product and demand cycles were much more predictable. Long product life cycles meant obsolescence low cost, i.e., the possibility of carrying over the inventory and push it into the market in the next sale cycle basically at the same price. Wrong demand forecast had a relatively low cost, practically physical inventory holding cost and capital locking up. The supply chain management model adopted by most company was based on the following three phases:

1. Strategic decisions
2. Demand management: "Choosing" market quota target and rough demand forecast

[3]This trend, though, is adversely affected by other types of economic and social trends.

3. Supply management: resources planning along the entire supply chain (company owned)

The demand management phase was quite simple as compared to today and demand forecast was mainly based on the quotas given to sales men and on marketing consideration. Once "defined" (more than forecasted) the demand target one could plan and optimize all the necessary activities to satisfy that demand. Planning of the entire supply chain could be done at the central level since company owned the entire supply chain and changes in the "plan" could easily happen without negotiation and contract based penalties. The mathematical model used to optimize resources was "linear programming". This model was conceived by its inventor[4] George B. Dantzig in 1947 in order to develop an automatic supply planning system while working for US government. The term "programming" comes, in fact, from the practice of calling "programs" the logistic plans. Since Dantzing model (and its variants, i.e., integer, mixed, etc.) is so flexible it has become "the" reference mathematical model to solve most problems in industry, from shop-floor scheduling to optimal routing, from optimal production schemes to line balancing. It is important, at this point, to remind the reader that the model applicability to a real life setting depends on two main requirements: a unique objective function and deterministic data, basically constant over the considered time horizon. This model was, hence, quite suitable to manage the supply chain of "vertical" enterprises, in a business environment in which the fundamental parameters had a low variability and were demand was a company target. Now, though, in a quite different business environment a different mathematical model is in need. Beside this obvious statement, operators in supply chain management have implicitly and explicitly used this model as the reference model. Leader software company in the supply chain management sector (e.g., i2, SAP, PeopleSoft, etc.) still use this approach. Till few years ago, there was the believe (based on increasing power computation) that huge mathematical programs, centrally managed by consortia (private market places), would possibly coordinate and optimize entire supply chains. All such attempts have failed or lowered expectations. There are many reasons behind this failure. Among the others, we remind here the difficulty of defining, implementing and solving a mathematical programs with thousand and thousand of variables and above all the impossibility of the model of managing continuous variations in the input data. Actually, the idea of using a market place to optimally allocate resources among commercial partners and match demand and supply was a good idea as proved by recent research trends as "coordination contracts" and the use of different optimality criteria (Pareto and/or Nash). Unfortunately, this intuition has not become yet a viable, comprehensive model for managing supply chains, mainly because they were using market models developed for other objectives (i.e., finance, commodity market). The market place logic needs to be integrated to close the lead time gap between a complex, constrained demand and an even more complex and more constrained supply, owned by different firms with different objectives. Moreover, it is necessary to find different optimization schemes that can cope with the complexity and above all variability of modern supply chains. As of today no such model exists.

Abandoned the idea of a unique mathematical program to manage the entire supply chain companies are still using a mathematical programming approach to manage company resources. They are trying to get around the model inadequacy by:

1. Accurate forecasting along the entire supply chain, using collaboration mechanisms to reach a consensus over the final customer demand and on that of each supply chain entity.

[4]Actually, the first to invent the model was the Russian mathematician and economist Kantorovich that in 1939 had modelled and solved a linear program to optimize resources planning, but his work remained unknown until 1959

2. Real time information sharing along the entire supply chain to update plans when new events occur.

3. Complex contracts with commercial partners to mitigate some parameters variability and define "a priori" interaction protocols.

The need for a collaborative process for demand forecast depends mainly by the so called bullwhip effect: demand variability increases moving along the supply chain, from retailer to supplier. It is an empirically observed phenomena and most research effort has focused on proving existence, identify its causes and find ways of reducing it [9], [20], [33], [40], [43]. The bullwhip effect main impact is on inventory, whose size increases with the demand variability increase for a given service level. An increase in Demand variability impacts also capacity and production management with an increase in its costs because of expedited shipments. Researcher have identified the following causes to explain the bullwhip effect:

1. Lack of information coordination
2. Lead times
3. Rationing and shortage gaming
4. Order batching
5. Price fluctuations

Next, we will briefly go trough the causes and point out the methods used in practice to mitigate its effects.

Lack of information coordination and different lead times Supply chain entities other than retailers have little or no visibility on final, customer demand. Their forecasts are, hence based, upon historical series of their own customers "orders" or on their own customer order forecasts (next entities in the chain). Order size, though, does not depend only on actual demand but also by the firm replenishment policy and by discount policies. By varying these two factors the orders probability distribution will change even if final demand itself remains the same. Hence, the idea of giving to all supply chain entities information about final customer demand will certainly reduce the bullwhip effect but will not eliminate it. In the practice, many firms have included in their contracts with customers (retailers) the obligation of sharing sale data (POS data). Another way of reducing the bullwhip effect is to reduce the supply chain length by, for example, selling directly to final customer through internet. The problem of multiple and independent forecasts can be alleviated through collaboration and information sharing so that a unique, agreed forecast can be made. Usually, though, collaboration and information sharing are not enough to to line up demand forecasts mainly because of different forecasting horizon due to different process lead time. In this case it is necessary to give appropriate incentives to line up forecasting horizons [45]. In practice, there are various methods (and acronyms) to alleviate these problems and improve performance of the entire supply chain: ECR (Efficient Consumer response), CPFR (Collaborative Planning Forecasting and Replenishment) VMI (Vendor managed Inventory), etc. As an example, the CPFR model follows the following phases:

1. Setting up collaboration contracts

2. Setting up joint business lan
3. Development of joint sale forecast upon which supply plans will be arranged
4. Identification of exceptions and development of joint reaction plans
5. Development of orders forecasts (taking into account optimal replenishment policies)
6. Identification of exceptions and development of joint reaction plans
7. Orders generation

The VMI model is a centralized system of replenishment in which a distributor is managing the inventories of a group of independent retailers, optimizing each of them replenishment policy and optimizing transportation. In order to work, the distributor needs a complete visibility of each retailer inventory, actual and forecasted sales. For an interesting analysis of these practices benefits see [6], [7], [26], [28], [30].

Order Batching The optimal order size depends (among others) by the fixed cost of placing an order, by discount policies, by promotions on bundles and by transportation economics (Full Truck Load). Order batching increases demand variability and as countermeasure one can think of implementing the following: automatization (e.g. e-procurement) to decrease the fixed cost, discount policies based on total volume over a period (e.g., 1 year) rather than on the single order size, using third party logistic provider to optimize capacity transportation.

Rationing and Shortage Gaming Sometime firms, having not a clear idea of supply and fearing possible supply shortages and consequent increase of prices, tend to inflate their forecasts or even order more than they think to sell (if their contract with supplier include a buy-back clause). Suppliers, on the other hand, fearing this behavior, may tend to under-produce. In order to avoid this gaming, information sharing is encouraged. Hence we need information sharing not only on demand side but also on the supply side. Firms allocate capacity resources to their clients based also on past orders and not only on forecasts. Order cancellation and modification or capacity reservation are allowed only within given time windows.

Price Fluctuation Sometimes, firms modify their buying patterns because of discount and promotion campaign of suppliers. These normal commercial practice add on demand variability. Some firms, in order to avoid this side effect on their demand profile have adopted an Every Day Low Price policy.

The actual trend in supply chain management is based hence on the idea that coordination and collaboration among partners can improve performance and profits of all parties (win-win situation) by increasing the pie size more than competing for a bigger slice of a smaller pie. On this idea builds also a new research trend in SCM: defining contracts (among commercial partners) with transfer payment that line up single firm objective with those of the entire supply chain. The idea is to find schemes that compensate single firms in order to arrive to an optimal supply chain status (as defined by an ideal centralized management). Usually, in fact, simple information sharing is not enough to line up behavior and actions of all parties involved on the single objective of system (supply chain) optimality: incentives are needed. The most important type of contracts used are: **wholesale price contract**, in which unit price is fixed and independent of ordered quantity; **quantity discount contract**, in which the unit price varies depending on ordered quantity; **buy back contract** in which supplier sell at the unit price w but buys back at the unit price b/w all unsold items; **revenue sharing contracts** in which supplier sell at a unit price and receive also a percentage of sales; **sales rebate contracts** in which supplier sell at the unit price w but compensate the buying firm with a value d for each product unit sold above a given threshold; **quantity flexibility contract** in which supplier sell at the unit price but compensate the buyer for unsold items. The difference with the buy-back is that in this case the buyer gets full protection on a given percentage (contract defined) of the order; in the buy back the buyer gets partial protection on the entire order size. Each of these contracts has advantages and disadvantages depending on the supply chain. For example, single supplier-single buyer, single supplier-many buyers, single order-many orders, etc. The criteria for choosing a contract type are the following:

1. The contract coordinates the supply chain This happens if the optimal actions implied by the contract are a Nash equilibrium, i.e., none of the parties has incentive to deviate by the action optimal for the system (supply chain)

2. The contract allows (by modifying parameters) an arbitrary reallocation of the supply chain profits among the parties.

If a contract satisfies these 2 conditions then it always exists a contract which Pareto dominates all the contracts that do not satisfy the first condition, i.e., all parties profit are not worse and for at least one party better off than using another contract. For more detail on this subject, see [14], [24], [58], [60].

Even though improved demand management and above practices are very important to improve supply chain efficiency and performances they are still not enough to make efficient using a mathematical program at the single firm level in order to optimize resources at the system (supply chain) level. The main problem is still the same: the system is too variable to be modelled by a mathematical program, best fitted for static systems. In order to deal with "variability", new paradigms, such as Stochastic Programming, have been introduced. For example, in the case in which the Mathematical Program parameters are known only within certain limits, the preferred approach is Robust Optimization: finding a feasible solution for all possible instances which is somehow "optimal". When parameters and data probability distributions are known then we more properly talk of Stochastic Programming. In this case, solving the stochastic program means to find a solution feasible for most instances and which maximize (or minimize) the expected value of a given function. A popular approach to stochastic programming are two-stages linear programs. The decision maker using the model takes some action at the first stage based on the output of the stochastic program. After that events, described by the probabilistic models, are realized, influencing decisions taken at the first stage, the decision maker takes other decisions at the second stage to counter balance, possibly, events. The two stage stochastic program solution is hence made by a set of actions (policies) to be taken at the first stage and a set of decision rules that will tell what to do for each possible event. Extension to more stages follows, more or less, the same principle. It is easy to understand that when we have many variables and many contingencies the program becomes intractable. In fact, finding the optimal policy means to solve a large scale program (known as the deterministic equivalent) whose dimension increases by increasing the number of stochastic variables and by increasing the sample set size of each variable. Another interesting approach to stochastic programming is the so called "Chance Constraints" methodology. According to this method, a stochastic programming solution satisfies constraints with a certain probability. For more detail on stochastic programming and its application see [2], [11], [13], [42], [50], [52].

In conclusion, we can say that the reference, theoretical model for optimal supply chain management is still mathematical programming. Recently, a more “economic” approach has been proposed, based on Pareto and Nash equilibrium principle. At the best of our knowledge, though, a complete and coherent model for supply chain management is still lacking.

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