Supply Chain Management

Introduction

This chapter aims to give the supply chain management side of the theoretical background for the supply chain modeling efforts which are described in chapters gif and gif. Supply chain management is a vast area. This chapter will emphasize the aspects of customer service and inventory management, and how these are interrelated with flexibility. Though the notion of agent-based computer systems have not yet been presented, the nature of the Integrated Supply Chain Management Project has been a decisive factor on the arrangement of the chapter.

The chapter is structured as follows: Section gif gives a first introduction to the term *supply chain*, Section gif treats some important issues of supply chain management, and Section gif deals with approaches to meet current challenges and improve supply chain performance.

Definition

There seems to be a universal agreement on what a supply chain is. Jayashankar et al. [25] defines a supply chain to be

> a network of autonomous or semi-autonomous business entities collectively responsible for procurement, manufacturing, and distribution activities associated with one or more families of related products.

Lee and Billington [17] has a similar definition:

> A supply chain is a network of facilities that procure raw materials, transform them into intermediate goods and then final products, and deliver the products to customers through a distribution system.

And Ganeshan and Harrison [12] has yet another analogous definition:

> A supply chain is a network of facilities and distribution options that performs the functions of procurement of materials, transformation of these materials into intermediate and finished products, and the distribution of these finished products to customers.

In this paper we use the term *supply chain* as it is defined by the last of the quotes above.

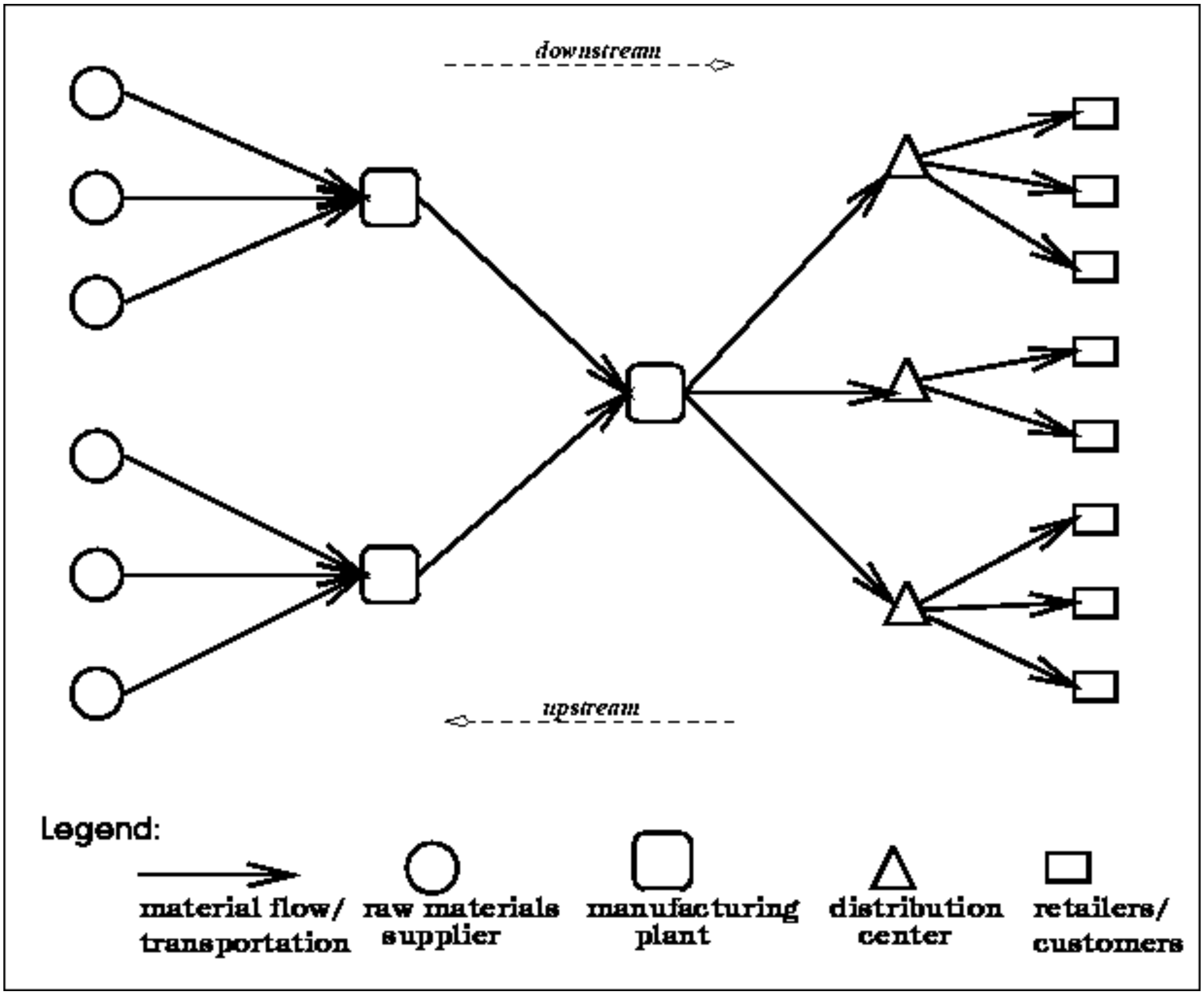

Figure: An Example of a Supply Chain.

Figure gif shows an example of a supply chain. Materials flow downstream, from raw material sources through a manufacturing level transforming the raw materials to intermediate products (also referred to as components or parts). These are assembled on the next level to form products. The products are shipped to distribution centers and from there on to retailers and customers.

Appendix gif presents some of the supply chain related terminology used in the thesis. Many of the terms used in the following will therefore not be explained further.

Issues in Supply Chain Management

The classic objective of logistics is to be able to have *the right products in the right quantities (at the right place) at the right moment at minimal cost*. Figure gif (from NEVEM-workgroup [19]) translates this overall objective into four main areas of concern within supply chain management.

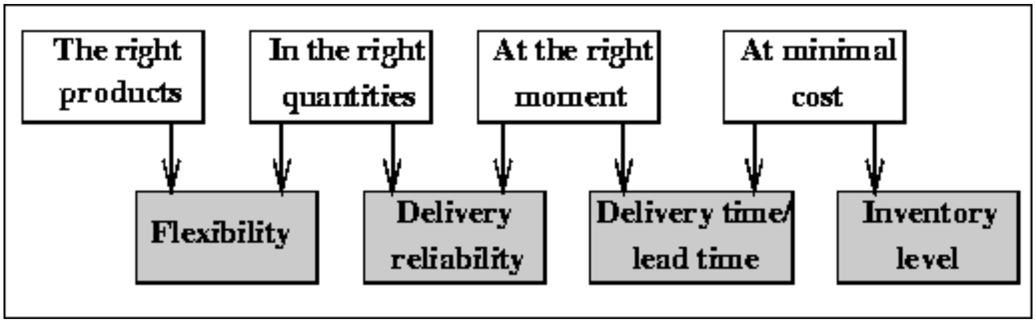

Figure: Hierarchy of Objectives.

The two middle boxes in the lower row of Fig. gif, delivery reliability, and delivery times, are both aspects of *customer service*, which is highly dependent on the first box, *flexibility*, and on the last box, *inventory*. These terms and their interrelations are discussed on Section gif.

Some important *pitfalls* of inventory management are described in Section gif. Some effects of the *globalization* of supply chains are described in Section gif. But first, in Section gif supply chain management is divided into three levels of decision making. And in Section gif the use of *metrics* to evaluate supply chain performance is described.

Decisions on Three Levels

Supply chain management decisions are often said to belong to one of three levels; the *strategic*, the *tactical*, or the *operational* level. Since there is no well defined and unified use of these terms, this Section describes the how they are used in this thesis. Figure gif shows the three level of decisions as a pyramid shaped hierarchy. The decisions on a higher level in the pyramid will set the conditions under which lower level decisions are made.

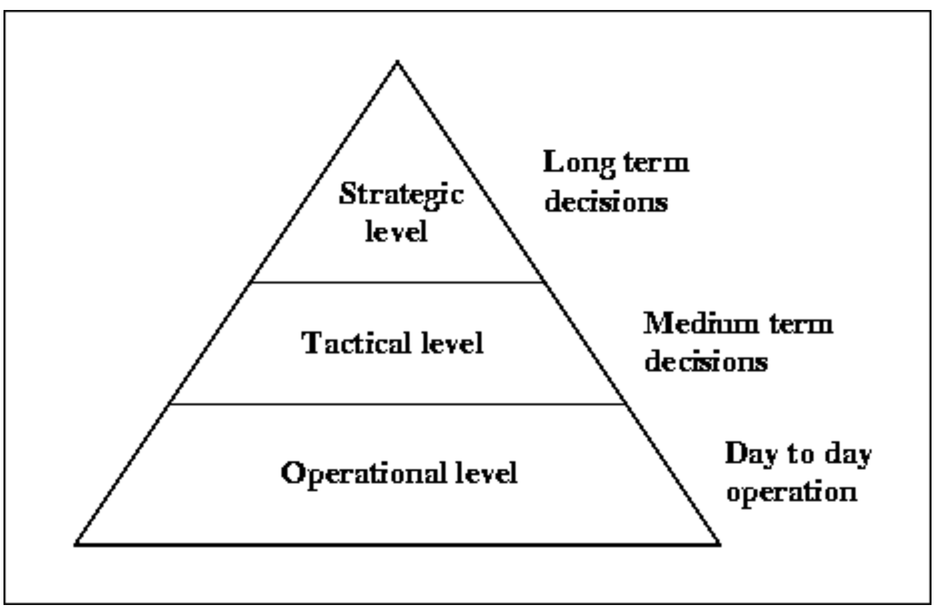

Figure: Hierarchy of Supply Chain Decisions.

On the *strategic* level long term decisions are made. According to Ganeshan and Harrison [12], these are related to location, production, inventory, and transportation. Location decisions are concerned with the size, number, and geographic location of the supply chain entities, such as plants, inventories, or distribution centers. The production decisions are meant to determine which products to produce, where to produce them, which suppliers to use, from which plants to supply distribution centers, and so on. Inventory decisions are concerned with the way of managing inventories throughout the supply chain. Transport decisions are made on the modes of transport to use.

Decisions made on the strategic level are of course interrelated. For example decisions on mode of transport are influenced by decisions on geographical placement of plants and warehouses, and inventory policies are influenced by choice of suppliers and production locations. Modeling and simulation is frequently used for analyzing these interrelations, and the impact of making strategic level changes in the supply chain.

On the tactical level medium term decisions are made, such as weekly demand forecasts, distribution and transportation planning, production planning, and materials requirement planning. The operational level of supply chain management is concerned with the very short term decisions made from day to day. The border between the tactical and operational levels is vague. Often no distinction is made, as will be the case in this thesis.

Metrics and Data Collection

Management can be defined as the *planning, execution, and control of goal oriented activities*. Today's supply chains are too complicated to be controlled based on intuition. It is necessary to have access to statistical data on the performance of the supply chain.

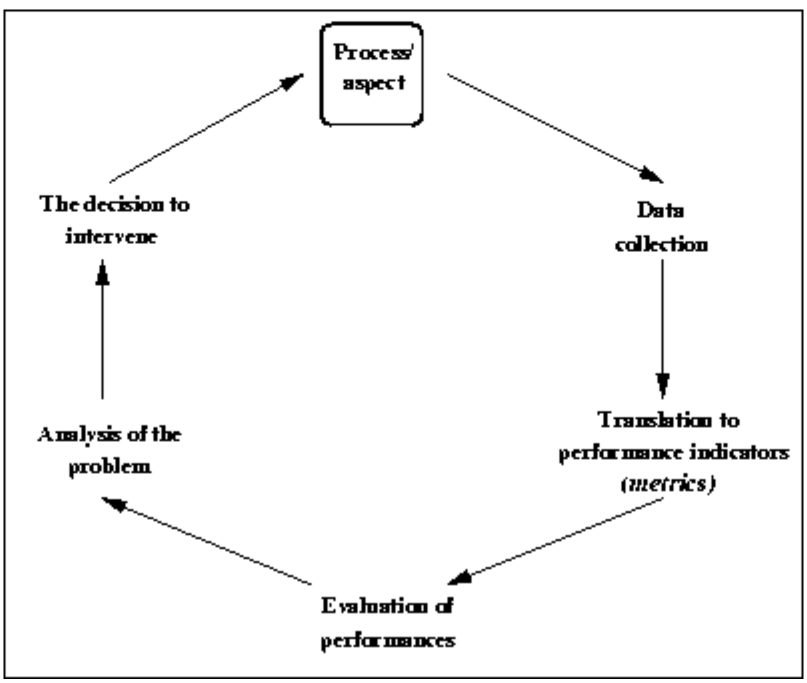

Figure: A Control Cycle.

A *metric* is a standard of measurement of performance. Figure gif (from NEVEM-workgroup [19]) shows the role of metrics in a control cycle. As we see the metrics give the basis on which to evaluate the performance of processes in the supply chain. They give managers the opportunity to follow the development of the supply chain. We see from the figure that the choice of which data to collect is of utmost importance. Only by collecting relevant data, can relevant metrics be calculated and performance be evaluated. A supply chain in which the appropriate data is not regularly collected cannot be properly managed. Pitfalls 1, 2 and 4 in Section gif below deal with this issue.

Flexibility, Inventories, and Customer Service

Satisfied customers is the desired end result of any supply chain management strategy, as illustrated by a quote from Lee and Billington[17]:

> HP management has recognized that its performance filling orders will cause it to win or lose the competitive battle.

Let us look at three key terms within supply chain management:

Customer satisfaction

gif says something about the level of satisfaction among a company's customers. It is in this sense a very vague term. Therefore customer service is often discussed in terms of the metrics which are used to measure it. Typical measures of customer service are a company's ability to fill orders within due date (fill rate), or its ability to deliver products to customers within the time quoted (on-time deliveries). Other metrics should be used to for example evaluate the delivery performance of orders that are *not* delivered on-time. A way to indicate this is to measure the average time from order to delivery.

Inventories:

Manufacturing entities have inventories for raw products (RPI), products in the production process (WIP), and finished products (FGI). In addition there are often warehouses or distribution centers between the different levels of the supply chain. Inventories are costly. Binding capital in inventories prevents the company from investing this capital in projects of higher return. The holing cost inventories are therefore often set as high as 30 - 40% of the inventory value! In addition it is desirable to avoid so-called *dead inventory*, i.e. inventory that is left when a product is no longer on the market (often referred to as end of life (EOL) write-off).

As we see it is in every company's interest to keep inventory levels at a minimum. Much effort has been put into this, for example an entire manufacturing paradigm has come out of it. A main objective of the Just in Time (JIT) paradigm is to virtually abolish inventories. The efforts made have been more or less successfulgif.

Flexibility

can be defined as the ability to respond to changes in the environment. In the case of a manufacturer, flexibility is the ability to change the output in response to changes in the demand. In a supply chain the flexibility of one entity is highly dependent on the flexibility of upstream entities (see Fig. gif). The overall flexibility of a supply chain will therefore depend on the flexibility of all the entities in a supply chain, and their interrelations.

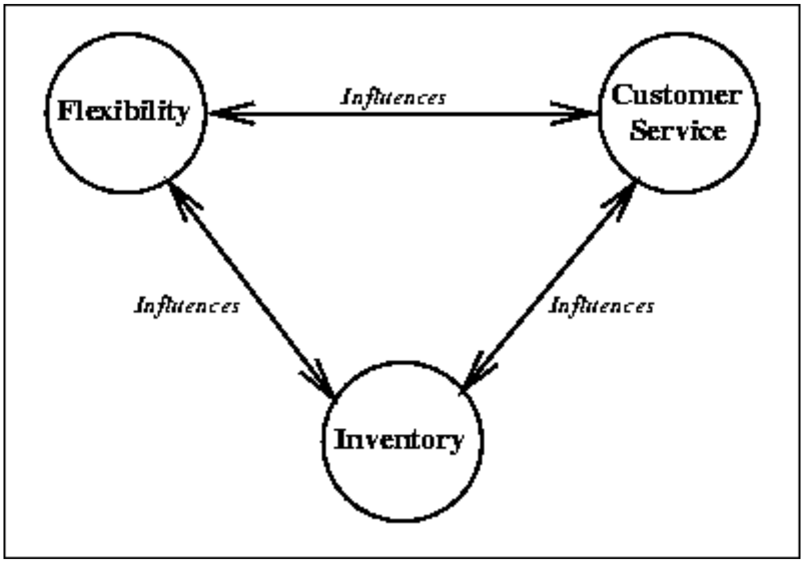

Figure: Illustrating how flexibility, inventories, and customer service are interrelated.

Figure gif shows (very simply) how the three issues described above are interdependent. To put it bluntly; all depend on all. In the following this will be discussed.

Inventory is a ``Flexibility Buffer''

A manufacturers flexibility is its ability to respond to changes in demand. Imagine a company that can receive customer orders, order and receive components, assemble these, fill the orders, and ship them to customers in one single day. This company would have a total flexibility. It would be able to respond to any unforeseen events on a daily basis, and could easily attain a hundred percent customer satisfaction without any inventory. But this is of course rarely the case. A supply chain may consist of many levels of production, transportation, and warehousing, each level adding to the lead time. The time from the first materials are ordered at the beginning of the supply chain till the finished products reach the customer may be long. In the US apparel industry this time is typically 58.5 weeks ! (from 1990, Flaherty[10])

It is evident that customers will not wait this long from order to delivery. The manufacturer needs to plan ahead, and therefore also to estimate future demand by making demand forecasts. If planning of production and inventories was perfect we would be able to implement a pure Just in Time strategy, with components arriving as they are needed, and finished goods being shipped as they leave the assembly line. But in a supply chain there are many events that can not be foreseen and uncertainties that need to be accounted for. These may be: late shipments from suppliers, defect incoming material, imperfect production yield, production process breakdown, or highly uncertain product demands.

The longer the planning horizon, the less accurate the plans will be. A typical US apparel manufacturer must see more than a year into the future ! For it to maintain a high level of customer service, all uncertainty of the year must be accounted for (see Pitfall 5 below). The long lead times make the manufacturer inflexible, and vulnerable to unforeseen changes and inaccurate demand forecasts.

A manufacturer will account for the uncertainties and unforeseen events by keeping *safety stocks*. The safety stocks assure the necessary flexibility, or rather they act as buffers for the *lack* of flexibility in the supply chain.

As we decrease lead times in the supply chain, we decrease the planning horizon, and thereby increase the flexibility. The need for a buffer in the form of inventory will also diminish. In other words; higher flexibility allows less inventory to maintain the same level of customer service.

Inventory vs. Customer Service: A Trade-Off

If we assume lead times to be constant, the ability to fill orders is directly dependent on the inventory levels in a supply chain. As long as there are products in the finished goods inventory (FGI), from which products are taken, orders can be satisfied. Other inventories, such as raw product inventories will have a more indirect effect on customer satisfaction. Stock-outs in any of these will obstruct production and may eventually lead to stock-out in the FGI. For this reason, it is common in supply chain management to keep exaggerated inventory levels. But as mentioned above inventory holding costs are often calculated as high as 30-40% of inventory values.

While oversized inventories is a costly inventory management strategy, low fill rates are also costly. Business may be lost through cancelled orders, and the company's reputation may be severely damaged. It is therefore in a company's interest to balance inventory holding cost and the cost of imperfect customer satisfaction. The trade-off inventory vs. customer satisfaction is one of the classic issues of logistics and supply chain management.

Pitfalls in Inventory Management

Based on knowledge and experience from supply chain management in electronics, computer, and automobile companies, Lee and Billington [16] identify 14 pitfalls in inventory management. Eight of which are found relevant to this project:

Pitfall 1. No Supply Chain Metrics:
: In a supply chain with multiple sites, each site will often have its fairly autonomous management team. The objectives of the various teams may differ, and even be conflicting. Inventory may for example be reduced at a Site A of a supply chain, and thereby, seen from a local perspective, the performance is enhanced. But the inventory decrease may also decrease Site A's flexibility. Because Site A now responds more slowly to changes, Site B, which is Site A's customer will have to increase its inventory (of Site A parts) in order to maintain its flexibility and level of customer service. The lack of supply chain metrics has prevented managers at Site A to see that their local improvements has not lead to improved overall performance of the supply chain. The objective of supply chain metrics is to give the basis for evaluations of the performance of the whole supply chain as one system.

Pitfall 2. Inadequate Definition of Customer Service:
: Too few and in-concise metrics for customer service. The evaluation of performance becomes difficult, and certain aspects of customer service may be overlooked.

Pitfall 3. Inaccurate Delivery Status Data:
: Customers are not correctly informed of delivery dates of orders and of late deliveries. Companies can often not readily retrieve the information needed to do so.

Pitfall 4. Inefficient Information Systems:
: Databases at different operation sites that describe system environment, inventories, backlog, future production plans, and so on are often not linked. Information must be retrieved manually, and this can be a long process. Planning cycles may therefore be long, using highly uncertain demand forecasts. The wrong products are made, and inventories and backlogs grow.

Pitfall 5. Ignoring the Impact of Uncertainties:
: Too often supply chains do not track uncertainties such as suppliers' delivery times, the quality of incoming materials, manufacturing process time, transit times, and so on. This leads to non-optimal stocking levels. In some cases uncertainties are properly tracked, but there is no follow-up.

Pitfall 6. Simplistic Inventory Stocking Policies:
: Stocking policies are often not linked to knowledge of the uncertainties mentioned above.

Stocking policies are often based on the quantity usage of the items stocked. This says nothing about the uncertainty associated with the usage. Analysis show that stocking levels could be greatly reduced by transferring stocking policies from being quantity based to being uncertainty based.

Pitfall 7. Organizational Barriers:

Entities in a supply chain may belong to different organizations within the same company. The organizations will independently measure the performance of the entities. While each entity is occupied with achieving local goals (much like in pitfall 1), important synergies may be lost.

Pitfall 8. Incomplete Supply Chain:

Supply chain managers are often focussed only on the internal supply chain. Going beyond the internal supply chain by including external suppliers and customers often exposes new opportunities for improving internal operations.

Section gif gives some thoughts on how many of these pitfalls can be avoided through increased integration and coordination. The section suggests that this can be done using agent-based management and information systems.

Globalization

Through the past decades we have seen an increasing rate of globalization of the economy and thereby also of supply chains. Products are no longer produced and consumed within the same geographical area. Even the different parts of a product may, and often do, come from all over the world. This creates longer and more complex supply chains, and therefore it also changes the requirements within supply chain management. This again affects the effectiveness of computer systems employed in the supply chain.

A longer supply chain will often involve longer order to delivery lead times. Flaherty [10] states, in accordance with the discussion in Section gif, that the consequences of longer lead times will often be;

- less dependable forecasts as these have to be made earlier,
- reduced production flexibility, i.e. greater difficulties to adjust to order changes,
- higher levels of inventory.

The evident answer to the problem of longer lead times is to speed up the supply chain. But a limit is often reached beyond which further effort to shorten lead times are futile, especially in international supply chains. Another approach is to restructure the supply chain. This simply means to reconsider the strategic level decisions priorly made. A third approach identified by Flaherty [10] is changing *coordination*: The order, forecasting, procurement, and information sharing procedures among the members of the supply chain. We will dwell on the issue of coordination in the next section.

Globalization also brings foreign competition into markets that traditionally were local. Local companies are thereby forced to respond by improving their manufacturing practices and supply chain management. Bhatnagar et al.[5] states that attempts have focused, among others, on reduction of inventory levels, and increased flexibility through reduced lead times. Yet again we see how industry focuses on the issues of inventory management and flexibility to maintain high levels of customer satisfaction.

Improving Supply Chain Management

The above sections describe issues and challenges of supply chain management. It is time to approach solutions. A key to improved supply chain management lies in *integration and coordination*, look to Section gif for a discussion. Section gif introduces important tools of supply chain managers, modeling and simulation.

Integration and Coordination

Definitions

The Webster's dictionary defines to integrate as: *To make into a whole by bringing all parts together; unify*. In an enterprise, integration can simply mean that each unit of the organization will have access to information relevant to its task and will understand how its actions will impact other parts of the organization thereby enabling it to choose alternatives that optimize the organization's goals (Fox [11]). The key to integration is coordination. To *coordinate* is to manage dependencies among activities so as to achieve coherent operation of the entire system in question.

General and Multi-Plant Coordination

Much research effort has been put into optimizing the performance of supply chains. The major part of the early work tends to focus on very limited segments, e.g. only material procurement, manufacturing, or distribution, and treat these as separate systems. Though this might lead to improved performance in the segment in question, the complex interaction among supply chain segments is ignored. Thereby potential gains from coordination are lost.

In later years we have seen an increasing focus on the integration of different segments of the supply chain. As for example Cohen and Lee [8] and Chandra and Fisher [6] who treat integration and coordination of production and distribution functions. These efforts are what Bhatnagar et al. [5], who have reviewed the existing works on coordination, refer to as *general coordination*. Bhatnagar et al. distinguish between two broad levels of coordination. General coordination is the integration of different functions, e.g. inventory and production planning, sales, and distribution.

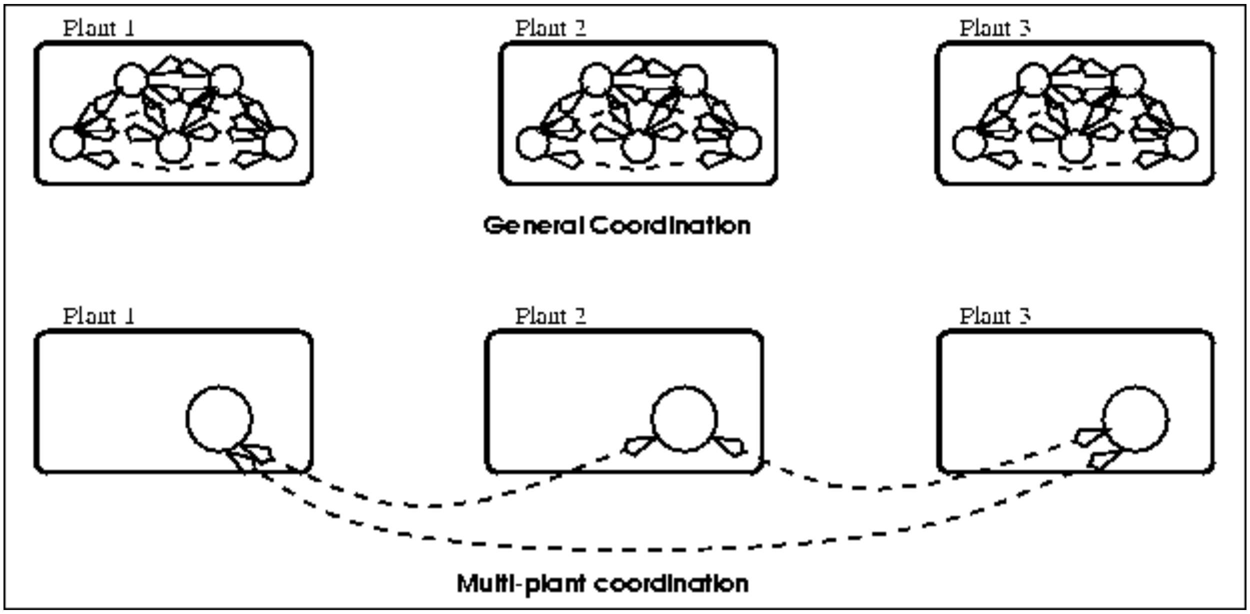

Figure: A very schematic illustration of what Bathnagar et al. calls General Coordination (top) and Multi-Plant Coordination (bottom).

The other level of coordination identified, is that on which production decisions are coordinated among the plants of an internal supply chain. This is referred to as *multi-plant coordination*. The objective of multi-plant coordination is to coordinate the production plans of several plants in a vertically integrated manufacturing company so that the overall performance of the company is improved. Still according to Bhatnagar et al., in order for such coordination to be efficient, the effects of uncertainty of final demand, uncertainties in production process at each plant, and capacity constraints at each plant must be taken into consideration.

Figure gif illustrates, in a very schematic way, the principles of these two levels of coordination. Bathnagar et al. conclude that there is much overlap and interaction between the two coordination levels, but there is today(1992) no unified body of literature on the issue. Research effort is required.

Information Technology: An Unrealized Potential?

The rapid development within the information technology and software engineering gives unprecedented opportunities for integration and coordination. The modern computer networks have the ability to rapidly distribute information to all concerned entities of an enterprise. The networks also present an infrastructure for coordination of planning and operational processes, not only within organizations, but also among them.

Chee et al. [7] states that there is an unrealized potential for using information technology in support of network coordination (1996). A survey was done of more than forty computer manufacturers. It was found that only about 15% of the partners were communicating through EDI. It was also found that much of the coordination activity occurs above the operational level.

Modeling and Simulation

A good explanation to the notions of modeling and simulation are given by Law and Kelton [15]:

> The facility or process of interest is usually called a *system*, and in order to study it scientifically we often have to make a set of assumptions about how it works. These assumptions, which usually take the form of mathematical or logical relationships, constitute a *model* that is used to try to gain some understanding of how the corresponding system behaves.
>
> ...
>
> If the relationships that compose the model are simple enough, it may be possible to use mathematical methods (such as algebra, calculus, or probability theory) to obtain exact information on questions of interest; this is called an analytic solution. However, most real-world systems are too complex to allow realistic models to be evaluated analytically, and these models must be studied by means of simulation. In a *simulation* we use a computer to evaluate a model *numerically*, and data are gathered in order to *estimate* the desired true characteristic of the model.

Modeling has been used as a tool within supply chain management for several decades. Early models of the supply chain, or segments thereof, where evaluated analytically. As is stated by the above quote, this method is not powerful enough to understand real-world systems. Swaminathan et al. [25] states that in recent years simulation as a tool for understanding issues of organizational decision-making has gained considerable attention and momentum. They mention the use modeling and simulation on the supply chain with different purposes, including studies of the effects of various supply chain strategies on demand amplification and a study of the effect of sharing supplier available-to-promise information.

Modeling and simulation is most often used to test the impact strategic level decisions have on supply chain performance. This may for example be the impact of restructuring the supply chain by reducing the number of plants, changing modes of transport, or relocating warehouses. Simulation as a method, does not give the optimal solution. It simply allows the user to test different solutions. Simulations are run with various parameters or ``set-ups'', and the results are analyzed and compared to arrive at the optimal solution *among those tested*.

In this thesis simulation is used to evaluate the impact of information sharing and coordination. All physical entities will remain unchanged, while the ways the entities share information and coordinate problem solving is varied.

Summary

In this chapter we have looked at the supply chain and supply chain management. A supply chain is defined as a network of facilities and distribution options that performs the functions of procurement of materials, transformation of these materials into intermediate and finished products, and the distribution of these finished products to customers.

The central aim of supply chain management, to have the right products in the right quantities (at the right place) at the right moment at minimal cost, is translated into the interrelated issues of customer satisfaction, inventory management, and flexibility. Customer satisfaction is to a high degree dependent on the flexibility of the supply chain, i.e. its ability to respond to changes in demand. Flexibility is often imperfect because of long lead times, uncertainties, and unforeseen event. To counterbalance this lack of flexibility companies will keep inventories at various levels of the supply chain. Balancing the costs of imperfect customer satisfaction and holding inventory is a classic issue of logistics and supply chain management.

Eight pitfalls related to inventory management are described: no supply chain metrics, inadequate definition of customer service, inaccurate delivery status data, inefficient information systems, ignoring the impact of uncertainties, simplistic inventory stocking policies, organizational barriers, and an incomplete view of the supply chain.

Increasing globalization of supply chains causes longer lead times, which worsen flexibility, and creates the need for more inventory. When lead times can no longer be shortened, an important tool for improving the supply chain performance is that of increased coordination.

We distinguish between general coordination, which is coordination within a plant, and multi-plant coordination, which is coordination among several plants. For efficient coordination within a supply chain both general and multi-plant coordination is necessary. A survey among computer manufacturers in the USA found that only 15% of the participants where communication through the use of EDI. This indicates a large unrealized potential for electronic data exchange.

Modeling is an important tool for understanding and managing the supply chain. The dynamic behavior of a real life system is usually so complex that analytic models are not powerful enough to analysis the system, simulation must therefore be used.

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Next: Intelligent Agents **Up:** No Title **Previous:** Introduction

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