

**A PRICE-SENSITIVE QUANTITY-FLEXIBLE  
SUPPLY CHAIN CONTRACT MODEL  
AS A SUPPLY CHAIN PERFORMANCE DRIVER**

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**FİYATA DUYARLI VE MİKTAR ESNEKLİĞİ OLAN BİR  
TEDARİK ZİNCİRİ SÖZLEŞME MODELİNİN  
TEDARİK ZİNCİRİ PERFORMANS GELİŞTİRİCİSİ OLARAK KULLANIMI**

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## ABBREVIATIONS

<b>APS</b>	: Advanced Planning and Scheduling
<b>ATP</b>	: Available To Promise
<b>CPFR</b>	: Collaborative Planning, Forecasting, and Replenishment
<b>CRM</b>	: Customer Relationship Management
<b>CTP</b>	: Capable To Promise
<b>EDI</b>	: Electronic Data Interchange
<b>ERP</b>	: Enterprise Resource Planning
<b>GSCM</b>	: Global Supply Chain Management
<b>ISCM</b>	: Integrated Supply Chain Management
<b>IT</b>	: Information Technology
<b>JIT</b>	: Just-In-Time
<b>MRP</b>	: Material Requirements Planning
<b>MRP II</b>	: Manufacturing Resource Planning
<b>SCIS</b>	: Supply Chain Information Systems
<b>SCM</b>	: Supply Chain Management
<b>SKU</b>	: Stock Keeping Unit
<b>TMS</b>	: Transportation Management System
<b>VAS</b>	: Value Added Services
<b>VBA</b>	: Visual Basic for Applications
<b>VMI</b>	: Vendor Managed Inventories
<b>WMS</b>	: Warehouse Management System
<b>XML</b>	: Extensible Markup Language

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## LIST OF SYMBOLS

$a, b$	: Linear elasticity demand function coefficients
$\alpha, \beta$	: Quantity flexibility contract coefficients
$b$	: Buyback price
$c$	: Wholesale price
$d$	: Market size scale value
$D$	: Demand
$\delta$	: Discount percentage
$\epsilon$	: Constant elasticity demand function coefficient
$h$	: Holding cost
$I$	: Inventory
$m$	: Markup percentage
$\mu(p)$	: Expected demand
$p$	: Selling price
$\pi(p)$	: Expected profit
$Q, Q^+, Q^-$	: Committed supply
$R$	: Throughput
$s$	: Retailer salvage value
$T$	: Flow time
$v$	: Manufacturer unit cost
$w$	: Manufacturer salvage value

## **A PRICE-SENSITIVE QUANTITY-FLEXIBLE SUPPLY CHAIN CONTRACT MODEL AS A SUPPLY CHAIN PERFORMANCE DRIVER**

### **SUMMARY**

A supply chain consists of all stages involved, directly or indirectly, in fulfilling a customer request. The objective of every supply chain is to maximize the overall value generated. The value a supply chain generates is the difference between what the final product is worth to the customer and the effort the supply chain expends in filling the customer's request. For most commercial supply chains, this value will be strongly correlated with supply chain profitability, the difference between the revenue generated from the customer and the overall cost across the supply chain. The objective of maximizing this supply chain surplus can be achieved by improving the supply chain performance in terms of efficiency and responsiveness using the four supply chain drivers: inventory, transportation, facilities, and information.

In this dissertation, we discussed these four drivers and introduced supply chain contracts as another driver to maximize supply chain profitability. Of particular interest here are contracts that specify the parameters within which a buyer places orders and a supplier fulfills them in order to maximize the total supply chain surplus.

We discussed two supply chain contract models. First, where a retailer facing price sensitive demand may obtain a discount by committing a fixed quantity over a finite horizon, and second where a manufacturer offering buyback or quantity flexibility contracts may increase the total supply chain profit.

We concluded that the first model incorporates demand as a function of the selling price but does not address the crucial issue of total supply chain surplus maximization. On the other hand, the second model, although it increases the total supply chain surplus, does not incorporate the demand elasticity.

We then developed a model to address the individual weaknesses of the models discussed by incorporating the price sensitive demand into quantity flexibility contracts by determining the optimal level of product availability, as a function of the

selling price, which maximizes the total supply chain profit. We also proposed two solutions to the issue of profit sharing related to the distribution of the additional supply chain profit generated by using the contracts. We then showed, through numerical experiments, that our model maximizes total supply chain surplus by incorporating demand elasticity and profit sharing into quantity flexibility contracts.

It is our belief that the supply chain contract model developed in this dissertation can be an integral part of any Advanced Planning and Scheduling (APS) system.

# **FİYATA DUYARLI VE MİKTAR ESNEKLİĞİ OLAN BİR TEDARİK ZİNCİRİ SÖZLEŞMESİ MODELİNİN TEDARİK ZİNCİRİ PERFORMANS GELİŞTİRİCİSİ OLARAK KULLANIMI**

## **ÖZET**

Tedarik zinciri, bir ürünün tasarım aşamasından son müşterinin eline ulaşıncaya kadar geçireceği ve gerekli olan tüm aşamaları kapsar. Her tedarik zincirinin amacı kattığı değeri en üst düzeye çıkartmaktır. Bu değer tüketiciye ulaşan en son ürünün getirisiyle tedarik zincirinin bu ürünü müşteriye ulaştırıncaya kadar harcadığı tüm emeklerin arasındaki farktır. Genelde bütün ticari tedarik zincirlerinde bu katma değer, tedarik zincirinin tüketiciden elde ettiği getiri ile ürünün toplam maliyeti arasındaki farka eşittir. Bu katma değeri en üst düzeye çıkartma amacı tedarik zincirinin etkinliğini arttırmakla, diğer bir deyişle, en az masraf ile tüketici beklentilerini en üst düzeyde karşılamakla sağlanır. Bunun için de tedarik zincirinin bilinen dört performans geliştiricisi: stok, nakliyat, tesisler, ve bilgi sistemleri kullanılır.

Çalışmamızda, yukarıdaki dört performans geliştiricisi bu yönden incelenmiş ve tedarik zinciri sözleşmelerinin bir diğer performans geliştiricisi olarak nasıl tedarik zinciri katma değerini en üst düzeye çıkartmada kullanılabileceği araştırılmıştır. Özellikle, tedarik zinciri içindeki bir üretici ve satıcı arasında tedarik zinciri katma değerini en üst düzeye çıkaran fiyat ve miktarları belirleyen sözleşmeler incelenmiştir.

İki tedarik zinciri sözleşmesi modeli incelenmiştir. İlk sözleşme tipi olarak, ürüne olan talebin satış fiyatı ile bağlantılı olduğu bir ortamda, üreticinin satıcıya belli bir miktarda ürün alma garantisi karşılığı önerdiği indirimler incelenmiştir. İkinci sözleşme tipi olarak ise, üreticinin toplam tedarik zinciri katma değerini arttırmak için satıcıya önerdiği satılmayan ürünü geri alma veya satın almada miktar esnekliği sağlama sözleşmeleri ele alınmıştır.

Birinci modelde, görüleceği üzere, her ne kadar talep satış fiyatı ile bağlantılı ise de, sonuç yalnız satıcı açısından değerlendirildiğinden, modelin tedarik zinciri toplam

katma deęeri üzerindeki etkisi belirsizdir. Dięer yandan, ikinci model tedarik zincirinin toplam katma deęerini arttırdığı halde, talebin fiyat duyarlılığı göz önüne alınmamıştır.

Çalışmamızda, bu modellerin zayıf noktalarına cevap veren ve talebin fiyata duyarlı olduğu bir ortamda üretici-satıcı arasında miktar esneklięi sağlayarak tedarik zinciri katma deęerini en üst düzeye çıkaran bir model geliştirdik ve sözleşmeden kaynaklanan bu ek katma deęer artışının her iki tarafın da kazanması için nasıl paylaştırılabileceğini gösteren iki yöntem belirledik. Ayrıca, geliştirdiğimiz fiyata duyarlı olan ve ek katma deęer artışının paylaşımını sağlayan miktar esneklięi modelinin tedarik zinciri katma deęerini en üst düzeye çıkarıldığını sayısal örneklerle gösterdik.

İnancımız, bu çalışmada geliştirilen tedarik zinciri sözleşme modellerinin bütün APS (Advanced Planning and Scheduling / İleri Planlama ve Çizelgeleme) sistemlerinde kullanılabileceğidir.

## **CHAPTER 1. INTRODUCTION**

APICS, The Educational Society for Resource Management, dictionary defines the term supply chain as the processes from the initial raw materials to the ultimate consumption of the finished product linking across supplier-user companies [1, p: 3]. A supply chain consists of all stages involved, directly or indirectly, in fulfilling a customer request. Over the last three decades, information technology resources, such as Electronic Data Interchange (EDI), the Internet, Enterprise Resource Planning (ERP), and Supply Chain Management (SCM) software have reshaped how firms manage the production and distribution of goods and services by sharing and analyzing the information in the supply chain. Competitive pressures have forced the companies to streamline supply chain operations to increase their efficiency while improving their responsiveness.

The supply chain performance in terms of efficiency and responsiveness can be improved using the four supply chain drivers: inventory, transportation, facilities, and information [2, p: 50]. The supply chain not only includes the manufacturer and suppliers, but also transporters, warehouses, retailers, and customers themselves. The forecast of future customer demand and its unavoidable variability form the basis for all strategic and planning decisions in a supply chain in terms of production and distribution.

In this dissertation, we present a series of models to redistribute the absorption of variability using contracts and show that effective use of contracts as a supply chain driver can substantially increase the overall supply chain profitability and its competitive advantage by forcing companies to evaluate every action in the context of the entire supply chain. A company's partners in the supply chain may well determine the company's success, as the company is intimately tied to its supply chain partners. This broad intercompany scope increases the size of the surplus to be shared among all stages of the supply chain.

## **1.1 Supply Chain Contracts and Committed Delivery Strategies**

A contract specifies the parameters within which a buyer places orders and a supplier fulfills them. It may contain specifications regarding quantity, price, time, and quality. At one extreme, a contract may require the buyer to specify the precise quantity required, with a very long lead time. In this case, the buyer bears the risk of overstocking and understocking, and the supplier has exact order information well advance of delivery. At the other extreme, buyers may not be required to commit to the precise purchase quantity until they are certain of their demand, with the supply arriving with a short lead time. In this case, the supplier has little advance information, and the buyer can wait until demand is known before ordering. As a result, the supplier must build inventory in advance and bear most of the risk of overstocking and understocking. As contracts change, the risk different stages of the supply chain bear changes, which affects the retailer's and supplier's decisions and the supply chain profitability.

In this dissertation, we will analyze three specific types of contracts:

- Committed deliveries where by committing to periodic deliveries of a specific quantity, a retailer facing price-sensitive demand absorbs some of the supply chain variability in exchange of a discount on committed deliveries.
- Buyback contracts where the manufacturer specifies a wholesale price along with a buyback price at which the retailer can return any unsold units.
- Quantity flexibility contracts where the manufacturer allows the retailer to change the quantity ordered after observing demand.

## **1.2 Overview**

This dissertation examines several supply chain contracts. In Chapter 2, we review relevant literature. In Chapter 3, we look at various supply chain stages, decision phases, cycles, and supply chain implementation with the objective of maximizing the overall value generated by the supply chain. In Chapter 4, we review the supply chain performance in terms of a strategic fit to match supply chain's responsiveness with demand uncertainty along with major demand patterns, and the need of an Intercompany Interfunctional scope to maximize total supply chain surplus. We also look at various supply chain drivers to achieve the balance between efficiency and



responsiveness, and obstacles to achieve this strategic fit as well as the implications of supply chain management in agile manufacturing.

In Chapter 5, we look at the impact of information technology structure upon the development and rapid expansion of supply chain collaboration as we review various enterprise execution systems. Particularly, In Section 5.3 we look at how Advanced Planning and Scheduling (APS) systems seek to integrate information and coordinate overall supply chain decisions while recognizing the dynamics between functions and processes. In a sense, supply chain contracts we developed also seek the same objective while recognizing the dynamics between supply chain partners. Using Collaborative Planning, Forecasting, and Replenishment (CPFR) processes, the necessary coordination can be achieved.

In Chapter 6, we present various contract models and then develop our own model. Sections 6.1 and Section 6.2 describe Retailer Profit without and with Commitment Opportunity, respectively, with Demand as a Function of the Selling Price. The strength of the model is the inclusion of demand as a function of the selling price. However, the model is restricted with the intracompany scope maximizing only the retailer's profit without taking into account the total supply chain profit. The same is true for Retailer Profit without Commitment Opportunity with Normally Distributed Demand described in Section 6.3.

Section 6.4 addresses the weakness of intracompany approach by introducing the total supply chain surplus with the intercompany view, which requires that both the manufacturer and the retailer evaluate their actions in the context of the entire supply chain. Section 6.5 and Section 6.6 describe how to maximize the total supply chain surplus using Buyback Contracts and Quantity Flexibility Contracts, respectively, with Normally Distributed Demand. Both buyback and quantity flexibility contracts help maximize the total supply chain profit. However, there are two issues that need to be addressed. The first one is related to profit sharing, i.e., how to share the additional supply chain surplus thus generated. The second issue, the main weakness of the contracts discussed, is the fact that demand has not been correlated to the selling price.

In Chapter 7, we introduce our proposed model. First, in Section 7.1, we analyze and then evaluate two solutions to address the issue of profit sharing for quantity flexibility contracts. Then in Section 7.2, we develop a model to address the individual weaknesses of the models discussed by incorporating the price-sensitive demand into quantity flexibility contracts to maximize the total supply chain profit:

Committed Deliveries using Quantity Flexibility Contracts to Maximize Supply Chain Surplus with Demand as a Function of the Selling Price. In Section 7.3, we develop a computer program to help simulate the system to find optimum contract parameters. Finally, in Section 7.4, we compare the models and emphasize the benefits of using supply chain contracts with a price-sensitive demand function and profit sharing.

In Chapter 8, we summarize our findings and discuss areas for future research.

## CHAPTER 2. LITERATURE REVIEW

There has been much research addressing coordination among stages in the supply chain [3]. The literature covering supply chain management is vast and well developed. However, In spite of their prevalence in industry over the last thirty years, little has appeared in Operations Research or Management Science literature discussing supply chain contracts. Historically, the business literature has extolled the virtues of using multiple suppliers as a means of improving negotiating position.

Heide [4] provides a review of existing theories of relationship management from a marketing channel perspective. Ellinger [5] and Hagy [6] emphasize the importance of integration and point to the need of a strong and significant relationship within the supply chain.

Noordewier, John, and Nevin [7] set forth a theory that stronger interorganizational ties result in greater adaptive capabilities, thus firms with closer ties are better able to react to variability. Buvik and John [8] expand this theory to include the implications of asset specificity. Cashon and Fisher [9] support the notion of all players working as a unit focused on the requirements of product development and the value of shared information.

Chandra and Kumar [10] analyze various issues important to supply chain management and provide broader awareness of supply chain principles and concepts. Balloe, Gilbert, and Mukherjee [11] discuss the new managerial challenges from supply chain opportunities. Motwani, Larsin, and Ahuja [12] present a survey of the global supply chain management (GSCM) literature with specific emphasis on the application of the process, services and products used by organizations to achieve competitive advantage and market position.

Fox, Chionglo, and Barbuceanu [13] describe the goals and architecture of the Integrated Supply Chain Management System (ISCM). They consider the supply chain as a system which can be managed by a set of intelligent software agents, each responsible for one or more activities in the supply chain, and each interacting with other agents in the planning and execution of their responsibilities.

Sengupta and Turnbull [14] review the general ideas of supply chain, the key point being to keep all units synchronized and to solve the entire business problem by manoeuvring through upstream and downstream information. Success of the supply chain depends on several primary factors, including early visibility to changes in demand all along the supply chain and a single set of plans that drives the supply chain and integrates information.

Humphreys, Shiu, and Chan [15] present the initial findings from the responses of large companies in Hong Kong and show the trend in supply chain relationships moving towards a more collaborative approach. Tracey and Tan [16] discuss a confirmatory factor analysis and path analysis to examine empirically the relationships among supply chain partners, and Masella and Rangone [17] propose different vendor selection systems based on the cooperative relationships. Liu, Ding, and Lall [18] demonstrate an application of data envelopment analysis in evaluating the relationships on the overall performance of suppliers in a manufacturing firm. Weber, Current, and Desai [19] present a similar approach using data envelopment analysis and multi objective programming.

Lambert, Cooper, and Pagh [20] provide several approaches to define supply chain and its complexity. Trent and Monczka [21] discuss the complexity of external organizational systems and difficulties in fostering close partnerships and integration across the supply chain. Milgate [22] presents a conceptual model to identify basic dimensions of the complexity involved. Spina and Zotteri [23] explore strategic and structural contingencies surrounding partnerships in a global survey and analyze collaborative practices along the operations integration and co-design dimensions.

Anupindi and Akella [24] develop optimal ordering policies for a single buyer with multiple vendors. They present an optimal ordering policy that orders nothing when the inventory level is above an upper bound, orders from one vendor when the inventory level is between bounds, and orders from both vendors when the inventory level is below the lower bound.

Kohli and Park [25] investigate joint ordering policies as a method to reduce costs between a single vendor and a group of buyers. They present expressions for optimal joint order quantities assuming all products are ordered in each joint order. Their model calculates the savings in fixed order costs, but does not explicitly model transportation costs. Furthermore, the requirement that every product is included in each order is limiting.

He *et. al.* [26] examine the effect of order crossing in a system with stochastic lead times. They show that the common single cycle analysis approach overestimates both cost and optimal order quantity.

Weng [27-29] addresses a two-echelon, infinite horizon model with quantity discounts and price-sensitive demand. His work focuses on using quantity discount schedules as a mechanism for channel coordination. Rau, Wu, and Wee [30] present an integrated inventory model under a multi-echelon supply chain environment.

Building on a work of Ernst and Pyke [31] and Yano and Gerchak [32], Henig *et. al.* [33] study a two-echelon system where a discount is offered for transportation capacity commitment. For an infinite horizon, stationary demand system, they show that for a given level of contracted transportation capacity, the optimal ordering policy is characterized by two critical numbers such that when on-hand inventory falls within a certain range, exactly the contracted capacity is used.

Bassok and Anupindi [34] develop optimal inventory policies for a firm that has made a quantity commitment over some finite horizon. In their model, the committing firm is free to order any quantity in any period, as long as the total contracted quantity is purchased by the end of the horizon.

Anupindi and Bassok [35] develop approximations for an inventory system with multiple items and a discount for a total volume commitment. The supplier extends the discount to a certain fraction above the commitment level. In numerical studies, they observe that increased demand variability leads to increased commitment, and increased flexibility offered by the supplier leads to decreased commitment.

Bassok *et. al.* [36] study a finite horizon, stochastic demand inventory system with a supply contract frequently used in the electronic component industry. The contract requires the buyer to commit to order quantities in each of  $T$  periods. In the current period, the buyer must order a quantity within a fixed percentage  $\alpha$  of the committed quantity. The buyer may also update future period commitments within a fixed percentage  $\beta$ .

Eppen and Iyer [37, 38] examine a two-stage stochastic inventory model. Their model is motivated by backup agreements common to the fashion industry. Under such an agreement, a buyer chooses an order quantity, and the vendor holds back a fraction of the commitment. After observing initial demand, the buyer can acquire up

to the remainder of their commitment at the original price, paying a penalty cost for committed units not purchased.

Tsay [39] models a manufacturer-retailer chain where the retailer gives a point estimate of demand. The two parties then agree on a minimum purchase commitment, a maximum quantity guaranteed to be available, and a transfer price. He shows that without such contract structure, inefficiencies may result.

Vargas and Metters [40] present a dual-buffer approach designed to improve the cost and fill rate performance of a production system. They apply basic lot-sizing techniques to demand forecasts and use stochastic inventory theory to set safety stock levels. Their approach attempts to avoid scheduling a replenishment order merely to replenish safety stock.

Smith and Zhang [41] study infinite horizon production planning with convex production and inventory costs and time varying, deterministic demand. They show that the optimal production levels for the infinite horizon problem can be obtained by solving a series of finite horizon problems. They also derive expressions for the minimum horizon length.

DeCroix and Arreola-Risa [42] examine an inventory system where the likelihood that demand is lost rather than backlogged can be influenced by an economic incentive. They assume a backorder response function to describe the probability that customers will agree to backorder as a function of a monetary incentive offered. Optimal control parameters and backorder incentives can be found efficiently when the decision to offer the incentive can be made when a shortage occurs.

Glasserman and Tayur [43] present a computational method for estimating inventory cost sensitivity with respect to centralized system parameters for a capacitated serial inventory system. Lee and Whang [44] reconsidered the same serial inventory system where operational decisions are made locally. The incentive scheme proposed requires all stages to share both demand distribution and cost parameters information. Ganeshan, Boone, and Stenger [45] study the impact of inventory and flow planning parameters on supply chain performance.

Kapuscinski and Tayur [46] study a capacitated production-inventory model with seasonal demand. They establish that the optimal policy takes the form of a modified order-up-to system where the producer builds up to the order-up-to level, or as close to this level as possible if bounded by capacity. Excess demand is

backlogged. Results from numerical experimentation indicate that increased mean demand, increased demand variability, and decreased capacity all lead to increased order-up-to levels. Zipkin [47] addresses the uncapacitated version of this problem.

Moon, Kim, and Hur [48] study an integrated process planning and scheduling to minimize total tardiness in a multi-plants supply chain and Tipme and Kallrath [49] present an optimal planning in large multi-site production networks. Vergara, Khouja, and Michalewicz [50] discuss an algorithm optimizing material flow order release and Chan *et. al.* [51] develop a simulation model to assess order release mechanisms. Syarif, Yun, and Gen [52] also study a multi-stage logistics chain network and present a spanning tree-based generic algorithm.

Doran [53] discusses a case study examining the characteristics of synchronous manufacturing within an automotive context and concludes that the nature of buyer-supplier relationships moves toward a modular supply model. Min and Guo [54] develop a cooperative competition strategy in line with the modular supply model and Han *et. al.* [55] present a similar model for supply chain integration in developing countries.

Masters [56] examines multi-echelon distribution inventories and develops a model determining near optimal stock levels. Sox and Muckstadt [57] study a multi-item, multi-period production planning problem with stochastic demand. They develop a Lagrangian relaxation algorithm that performs quite well in numerical experiments.

Moinzadeh and Nahmias [58] develop a continuous review, stochastic demand inventory with two supply modes. Lead times are deterministic. One of the modes has a shorter lead time and is more expensive either in fixed order cost, variable cost, or both. This faster mode is used as an emergency mode. The form of the policy they analyze is a generalization of the well known  $(Q, R)$  policy, where an order  $Q_1$  units is placed via the slower mode when on-hand inventory drops to  $R_1$ . If on-hand inventory drops to  $R_2$ , and an order placed via the fast method will arrive before the outstanding order for  $Q_1$  arrives, an order for  $Q_2$  is placed. Numerical experiments indicate that substantial savings can be obtained by using two modes.

Gurnani [59] studies a stochastic demand, finite horizon, periodic review inventory system where the probability that the supplier offers a discounted price in any time period is some constant  $\beta$ . In each period, the distributor chooses an order quantity at the regular price before learning if there will be a discount offered. The optimal

policy is defined by three regions. If inventory is above a high threshold value, order nothing, even if a discount is offered. If inventory is below the high threshold but above a lower one, it is optimal to order if a discount is offered. If inventory is below the low threshold value, it is optimal to order even at full price.

Zheng [60] analyzes a continuous review model with stochastic demand and discount opportunities arriving according to a Poisson process. The author establishes that a two-tiered reorder point model  $(s, c, S)$  is optimal. That is, when on-hand inventory drops to  $s$ , order up to  $S$ . When a discount opportunity arrives, if inventory is below  $c$ , order up to  $S$ .

Moinzadeh [61] studies a continuous review, deterministic demand model with discount opportunities that arrive according to a Poisson process. The optimal policy takes on a two-tiered form, similar to that in Zheng [60].

Ritchken and Tapiero [62] consider a risk management approach using negotiated option contracts for hedging against quality and price uncertainty in the procurement of inventory. They design an optimal mesh of contingent claims with purchasing commitments that will best meet the risk-reward preferences of the decision maker.

Kohli and Park [63] take a game theoretical approach to the problem of deterministic inventory acquisition. They consider quantity discounts, which are offered by a monopolistic supplier in the context of a bargaining problem where the buyer and supplier negotiate over the average unit price and the order quantity. They consider both incremental and block discounts in the model and show that the outcome of the negotiations maximizes the joint efficiency gain between the buyer and the supplier.

Gallego and Moon [64] analyze the newsvendor problem with normally distributed price-sensitive demand. Numerous extensions to the newsvendor problem have been proposed in the academic literature.

Lau and Lau [65] introduce a price-sensitive demand model under two objectives: maximize expected profit, and maximize the probability of achieving a target level of profit.

Khouja [66] examines a newsvendor model where a fixed proportion of excess demand can be satisfied from an emergency supply option. Two objective functions are examined: maximize expected profit and maximize probability of achieving a target profit.



Thomas [67] develops a model for a distributor facing price-sensitive demand and given the opportunity to receive a discount on fixed quantity committed deliveries. He also analyzes the pricing and profit implications of committed delivery strategies and extends his model to committed deliveries with flexible quantities. Using computational experiments, he shows that the value of flexibility in commitments is significant, especially when the commitment discount is relatively large compared to the holding cost. Using a constant elasticity expected demand function, simple expressions capturing price and profit sensitivity are developed.

Barnes-Schuster [68] discusses how the long term contracts influence the activities of a buyer-supplier relationship. The author shows that system safety stocks should not be split between a buyer and supplier and derives conditions indicating when the supplier or the buyer(s) should keep the system safety stock based on system cost parameters, production lead times, and demand distributions.

### **CHAPTER 3. SUPPLY CHAIN MANAGEMENT**

A supply chain consists of all stages involved, directly or indirectly, in fulfilling a customer request. The supply chain not only includes the manufacturer and suppliers, but also transporters, warehouses, retailers, and customers themselves. Within each organization, such as a manufacturer, the supply chain includes all functions involved in filling a customer request. These functions include, but not limited to, new product development, marketing, operations, distribution, finance, and customer service [2, p: 3-15].

A supply chain is dynamic and involves the constant flow of information, product, and funds between different stages. Each stage of the supply chain performs different processes and interacts with other stages of the supply chain. The primary purpose for the existence of any supply chain is to satisfy customer needs, in the process generating profits for itself. Supply chain activities begin with a customer order and end when a satisfied customer has paid for the purchase. It is important to visualize information, product, and funds flows along both directions of this chain and it may be more accurate to use the terms supply network or supply web to describe the structure of a supply chain [69-73].

Although each stage need not be present, a typical supply chain includes:

- Suppliers
- Manufacturers
- Distributors
- Retailers
- Customers

The objective of every supply chain is to maximize the overall value generated. The value a supply chain generates is the difference between what the final product is worth to the customer and the effort the supply chain expends in filling the customer's request. For most commercial supply chains, value will be strongly correlated with supply chain profitability, the difference between the revenue generated from the customer and the overall cost across the supply chain.

All flows of information, product, and funds generate costs within the supply chain. Supply Chain Management (SCM) involves the management of flows between and among stages in a supply chain to maximize total profitability.

### **3.1 Decision Phases in a Supply Chain**

Successful supply chain management requires several decisions relating to the flow of information, product, and funds. These decisions fall into three categories or phases, depending on the frequency of each decision and the time frame over which a decision phase has an impact: strategy, planning, and operation phases.

#### **3.1.1 Supply Chain Strategy**

During this phase, a company decides how to structure the supply chain. It decides what the chain's configuration will be and what processes each stage will perform. Strategic decisions made by companies include the location and capacities of production and warehousing facilities, products to be manufactured or stored at various locations, modes of transportation to be made available along different shipping legs, and type of information system to be utilized. A company must ensure that the supply chain configuration supports its strategic objectives during this phase. Strategic supply chain decisions are typically made for the long term and are very expensive to alter on short notice. Consequently, when companies make these decisions, they must take into account uncertainty in anticipated market conditions over the next few years.

#### **3.1.2 Supply Chain Planning**

During this phase, companies define a set of operating policies that govern short term operations based on the supply chain's configuration determined in the strategic phase that establishes constraints within which planning must be done. Typically, companies start the planning phase with a forecast for the coming year of demand in different markets. Planning includes decisions regarding which markets will be supplied from which locations, the planned build-up of inventories, the subcontracting of manufacturing, the replenishment and inventory policies to be followed, the policies that will be enacted regarding backup locations in case of a stockout, and the timing and size of marketing promotions. Planning establishes parameters within which a supply chain will function over a specified period of time.

In the planning phase, companies must include uncertainty in demand, exchange rates where applicable, and competition over the time horizon in their decisions.

### **3.1.3 Supply Chain Operation**

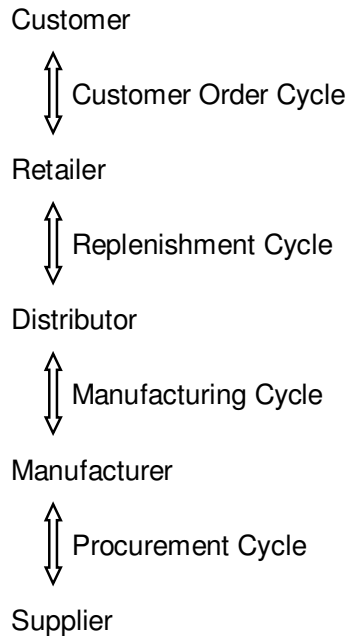
During this phase where the time horizon is weekly or daily, companies make decisions regarding individual customer orders. At the operational level, supply chain configuration is considered fixed and planning policies defined. The goal of supply chain operations is to implement the operating policies in the best possible manner. The companies allocate individual orders to inventory or production, set a date that an order is to be filled, generate pick lists at a warehouse, allocate an order to a particular shipping mode and shipment, set delivery schedules, and place replenishment orders. Because operational decisions are being made in the short term, there is less uncertainty about demand information. The goal during this phase is to exploit the reduction of uncertainty and optimize performance within the constraints established by the configuration and planning policies.

## **3.2 Process View of a Supply Chain**

A supply chain is a sequence of processes and flows that take place within and between different supply chain stages and combine to fill a customer need for a product. There are two different ways to view the processes performed in a supply chain: Cycle view and Push/Pull view.

### **3.2.1 Cycle View**

The processes in a supply chain are divided into a series of cycles, each performed at the interface between two successive stages of a supply chain. Given the five stages of a supply chain, all supply chain processes can be broken down into four process cycles as shown in Figure 3.1 [2, p: 8].



**Figure 3.1:** Supply Chain Process Cycles

### 3.2.1.1 Customer Order Cycle

The customer order cycle occurs at the customer/retailer interface and includes all processes directly involved in receiving and filling the customer's order. The processes involved include:

- Customer arrival
- Customer order entry
- Customer order fulfillment
- Customer order receiving

The starting point for any supply chain is the customer arrival and a key goal is to facilitate the contact between the customer and the appropriate product so that the customer's arrival turns into a customer order. The objective of the customer arrival process is to maximize the conversion of customer arrivals to customer orders.

The term customer order entry refers to customers telling the retailer what products they want to purchase and the retailer allocating products to customers. The objective of the customer order entry process is to ensure that the order entry is quick and accurate and is communicated to all other supply chain processes that are affected by it.

During the customer order fulfillment process, the customer's order is filled and sent to the customer. All inventories will need to be updated, which may result in the initiation of the replenishment cycle. In general, customer order fulfillment takes place from retailer inventory. In a build-to-order scenario, in contrast, order fulfillment takes place directly from the manufacturer's production line. The objective of the customer order fulfillment process is to get the correct and complete orders to customers by the promised due dates and at the lowest possible cost.

During the customer order receiving process, the customer receives the order and takes the ownership. Records of this receipt may be updated and payment initiated.

### **3.2.1.2 Replenishment Cycle**

The replenishment cycle occurs at the retailer/distributor interface and includes all processes involved in replenishing retailer inventory. It is initiated when a retailer places an order to replenish inventories to meet future demand. The replenishment cycle is similar to the customer order cycle except that the retailer is now the customer. The objective of the replenishment cycle is to replenish inventories at the retailer at minimum cost while providing the necessary product availability to the customer. The processes involved include:

- Retail order trigger
- Retail order entry
- Retail order fulfillment
- Retail order receiving

As the retailer fills customer demand, inventory is depleted and must be replenished to meet future demand. A key activity the retailer performs during replenishment cycle is to devise replenishment or ordering policy that triggers an order. The objective when setting replenishment order triggers is to maximize profitability by balancing product availability and cost. The outcome of the retail order trigger process is that a replenishment order is generated.

The retail order entry process is similar to customer order entry at the retailer. The only difference is that the retailer is now the customer placing the order with the distributor or manufacturer. The objective of the retail order entry process is that an order be entered accurately and conveyed quickly to all supply chain processes affected by the order.

The retail order fulfillment process is very similar to customer order fulfillment except that it takes place either at the distributor or the manufacturer. A key difference is the size of each order. Customer orders tend to be much smaller than replenishment orders. The objective of the retail order fulfillment is to get the replenishment order to the retailer on time while minimizing costs.

Once the replenishment order arrives at a retailer, the retailer must receive it physically, update all inventory records, and settle all payable accounts. The process involves product flow from the distributor or the manufacturer to the retailer as well as information and financial flows. The objective of the retail order process is to update inventories and displays quickly and accurately at the lowest possible cost.

### **3.2.1.3 Manufacturing Cycle**

The manufacturing cycle typically occurs at the distributor/manufacturer (or retailer/manufacturer) interface and includes all processes involved in replenishing distributor (or retailer) inventory. The manufacturing cycle is triggered by customer orders, replenishment orders from a retailer or distributor, or by the forecast of customer demand and current product availability in the manufacturer's finished product warehouse. In general, a manufacturer produces several products and fills demand from several sources. The manufacturing cycle can be reacting to customer demand (referred to as a pull process) or anticipating customer demand (referred to as a push process). The processes involved in the manufacturing cycle include:

- Order arrival from the distributor, retailer, or customer
- Production scheduling
- Manufacturing and shipping
- Receiving at the distributor, retailer, or customer

During the order arrival process, a distributor sets a replenishment order trigger based on the forecast of future demand and current product inventories. The resulting order is then conveyed to the manufacturer. In some cases, the customer or the retailer may be ordering directly from the manufacturer. In other cases, a manufacturer may be producing to stock a finished product warehouse. In the latter situation, the order is triggered based on product availability and a forecast of future demand. This process is similar to the retail order trigger process in the replenishment cycle.

The production scheduling process is similar to the order entry process in the replenishment cycle where inventory is allocated to an order. During the production scheduling process, orders are allocated to a production plan or schedule. Given the desired production quantities, the manufacturer must decide on the precise production sequence. The manufacturer must also decide which products to allocate each line if there are multiple production lines. The objective of the production scheduling process is to maximize the proportion of orders filled on time while keeping costs down.

The manufacturing and shipping process is equivalent to the order fulfillment process in the replenishment cycle. During the manufacturing phase of the process, the manufacturer produces to the production schedule while meeting quality requirements. During the shipping phase of this process, the product is shipped to the customer, retailer, distributor, or finished product warehouse. The objective of the manufacturing and shipping process is to ship the product by the promised due date while meeting quality requirements and keeping costs down.

In the receiving process, the product is received at the distributor, finished goods warehouse, retailer, or customer, and inventory records are updated. Other processes related to storage and fund transfers also take place.

#### **3.2.1.4 Procurement Cycle**

The procurement cycle occurs at the manufacturer/supplier interface and includes all processes necessary to ensure that materials are available for manufacturing to occur according to schedule. During the procurement cycle, the manufacturer orders components from suppliers that replenish the component inventories. The relationship is quite similar to that between a distributor and manufacturer, with one significant difference: whereas retailer/distributor orders are triggered by uncertain customer demand, component orders can be determined precisely once the manufacturer has decided what the production schedule will be. Component orders are dependent on the production schedule. Thus, it is important that suppliers be linked to the manufacturer's production schedule. However, if a supplier's lead times are long, the supplier has to produce to forecast because the manufacturer's production schedule may not be fixed that far in advance.

In practice, there may be several tiers of suppliers, each producing a component for the next tier. A similar cycle would then flow back one stage to the next.



As a summary, the cycle view of the supply chain clearly defines the processes involved and the owners of each process. This view is very useful when considering operational decisions because it specifies the roles and responsibilities of each member of the supply chain and the desired outcome for each process.

### **3.2.2 Push/Pull View**

All processes in a supply chain fall into one of two categories, depending on the timing of their execution relative to customer demand. In pull processes, execution is initiated in response to a customer order. Push processes are those that are executed in anticipation of customer orders. At the time of execution of a pull process, demand is known with certainty. At the time of execution of a push process, demand is not known and must be forecast. Pull processes may also be referred to as reactive processes because they react to customer demand. Push processes may also be referred to as speculative processes because they respond to forecast rather than actual demand. The push/pull boundary in a supply chain separates push processes from pull processes.

A push/pull view of the supply chain is very useful when considering strategic decisions relating to supply chain design. This view forces a more global consideration of supply chain processes as they relate to a customer order. Such a view may result in responsibility for certain processes being passed on to a different stage of the supply chain if making this transfer allows a push process to become a pull process. Supply chain contracts help achieve these transfers.

### **3.3 How to Implement Supply Chain Management**

The power of supply chain management is its potential to include the customer as a partner in supplying the goods or services provided by a supply chain. Integration improves the flow of information throughout the supply chain. Customer information is more than data. It is data that has been analyzed in some manner so that there is insight into the needs of the customer. In the typical supply chain the further the members of a chain are from the end customer, the less understanding these members have of the needs of the customer. This increases the supply chain member's uncertainty and complicates the planning. Firms respond to uncertainty differently. Some firms may increase inventory while others may increase lead times. Either action reduces their ability to respond to their customers. As

uncertainty is reduced because they have more information, firms are able to develop plans with shorter lead times. By improving the information flow in the supply chain, firms throughout the chain have less uncertainty to resolve during the planning process. This, in turn, allows the chain to increase its responsiveness to their customers [1, p: 5-10].

Another advantage of integrating the customer into the supply chain is that it integrates the product development function with the other functions in the firm. This integration allows the product development staff to communicate more with the customer both internally and externally to the firm, which increases the firm's responsiveness to the customer's needs.

Some firms use the concept of internal customer to remind their employees that each employee performs just one step in a supply chain whose purpose is to provide a good or service to the end customer. The purpose of the internal customer logic is to keep each employee focused on the needs of the end customer. This helps employees to recognize that not only is their firm just one link of a larger supply chain, but that the firm itself can be viewed as a chain of processes each of which is a customer of the preceding process.

Supply chain management requires an unprecedented level of cooperation between the members of the supply chain. It requires an open sharing of information so that all members know they are receiving their full share of the profits. Since many of the firms in a supply chain may not have a history of cooperation, achieving the trust necessary for supply chain management is a crucial task.

A firm in the supply chain must initiate the attempt to form partnerships and actively manage the supply chain. Often a firm that has a large amount of market power in the chain will become the leader of the supply chain.

This leader firm needs to justify the effort to manage the supply chain by explaining the benefits that will accrue to each member in the supply chain and to itself. To do this, the supply chain leader must show the partners where the improvements in the supply chain will arise, and then how these improvements will lead to a gain for everyone involved. To establish trust among the members of the supply chain, the lead firm must also suggest how communication can be opened up and how every member will be ensured that it is receiving its fair share of profits.

Managing a supply chain is more complex and difficult than managing an individual firm. But, the principles of management used to integrate a firm's own internal functions also apply to managing the entire supply chain. For example, a well understood phenomenon in the management of a firm is that there is always a bottleneck that constrains sales. This bottleneck may be internal to the firm (a process that cannot produce enough to meet demands) or it may be external to the firm (market demand that is less than the capacity of the firm). This principle applies to the entire supply chain. While the supply chain is driven by customer demand, it is constrained by its own internal resources. One difference is that these resources may not be owned by the same firm. It is possible for the output of an entire supply chain to be limited because one firm does not have the capacity to meet the surging demand. It is also possible for every firm in the supply chain to be operating at a low utilization because there is not enough demand in the market for the products from the supply chain. There are bottlenecks inside the supply chain just as there are bottlenecks inside firms. To properly manage the supply chain, its members must be aware of the location of their bottlenecks internally and also of the bottlenecks in the entire supply chain.

## **CHAPTER 4. SUPPLY CHAIN PERFORMANCE**

Creating a strategic fit between a company's competitive strategy and its supply chain strategy affects performance. The intercompany scope of strategic fit requires firms to evaluate every action in the context of the entire supply chain. This broad scope increases the size of the surplus to be shared among all stages of the supply chain. Achieving strategic fit is critical to a company's overall success [2, p: 25-46].

### **4.1 Competitive and Supply Chain Strategies**

A company's competitive strategy defines the set of customer needs that it seeks to satisfy through its products and services. To execute a company's competitive strategy, all the functions in its value chain play a role, and each must develop its own strategy. In an organization, the value chain consists of new product development, marketing and sales, operations, distribution, and service. It emphasizes the close relationship between all the functional strategies within a company. Each function is crucial if a company is to be profitably satisfying customer needs. Therefore, the various functional strategies cannot be formulated in isolation. They are closely intertwined and must fit and support each other if a company is to succeed. A company's competitive strategy and its supply chain strategy must fit together.

### **4.2 Strategic Fit**

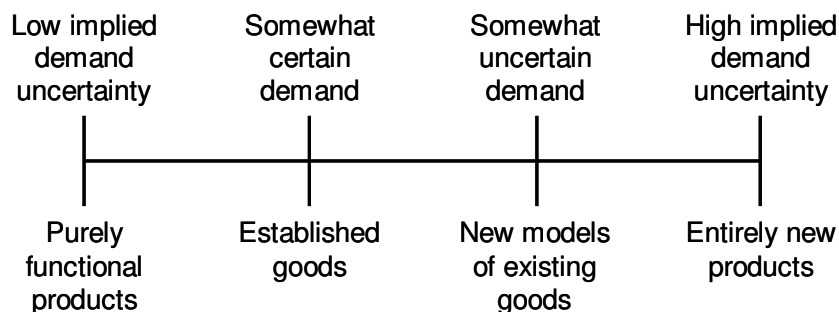
Strategic fit means that both the competitive and supply chain strategies have the same goal. It refers to consistency between the customer priorities that the competitive strategy is designed to satisfy and the supply chain capabilities that the supply chain strategy aims to build. There are three basic steps to achieving this strategic fit: understanding the customer, understanding the supply chain, and achieving strategic fit [2, 74-78].

### 4.2.1 Understanding the Customer

To understand the customer, a company must identify the needs of the customer segment being served. In general, customer demand from different segments may vary along several attributes:

- The quantity of the product needed in each lot
- The response time that customers are willing to tolerate
- The variety of products needed
- The service level required
- The price of the product
- The desired rate of innovation in the product

Each customer in a particular segment will tend to have similar needs, whereas customers in different segments can have very different needs. In a very fundamental sense, each customer need can be translated into the metric of implied demand uncertainty, the uncertainty that exists due to the portion of demand that the supply chain is required to meet. This is different than the demand uncertainty, which reflects the uncertainty of customer demand for a product. For example, a firm supplying only emergency orders for a product will face a higher implied demand uncertainty than a firm that supplies the same product with a long lead time. Another illustration of the need for this distinction is the impact of service level. As a supply chain raises its service level, it must be able to meet a higher and higher percentage of actual demand, forcing it to prepare for rare surges in demand. Thus, raising the service level increases the implied demand uncertainty even though the product's underlying demand uncertainty does not change. As each individual customer need contributes significantly to the implied demand uncertainty, implied demand uncertainty can be used as a common metric with which to distinguish different types of demand. Figure 4.1 [2, p: 31] illustrates the implied uncertainty spectrum.



**Figure 4.1:** The Implied Uncertainty Spectrum

The first step in achieving strategic fit is to understand customers by mapping where their demand is located on the implied uncertainty spectrum.

Implied demand uncertainty is also often correlated with other characteristics of the demand, as shown in Table 4.1 [2, p: 31].

**Table 4.1:** Correlation Between Implied Demand Uncertainty and Other Attributes

Attribute	Low Implied Uncertainty	High Implied Uncertainty
1. Product margin	Low	High
2. Average forecast error	10%	40% to 100%
3. Average stockout rate	1% to 2%	10% to 40%
4. Average forced season-end markdown	0%	10% to 25%

1. Products with uncertain demand are often less mature and have less direct competition. As a result, margins tend to be high.
2. Forecasting is more accurate when demand is more certain.
3. Increased implied demand uncertainty leads to increased difficulty matching supply with demand. For a given product, this dynamic can lead to either a stockout or an oversupply situation. Increased implied demand uncertainty thus leads to both higher oversupply and a higher stockout rate.
4. Markdowns are high for products with high implied demand uncertainty because oversupply often results.

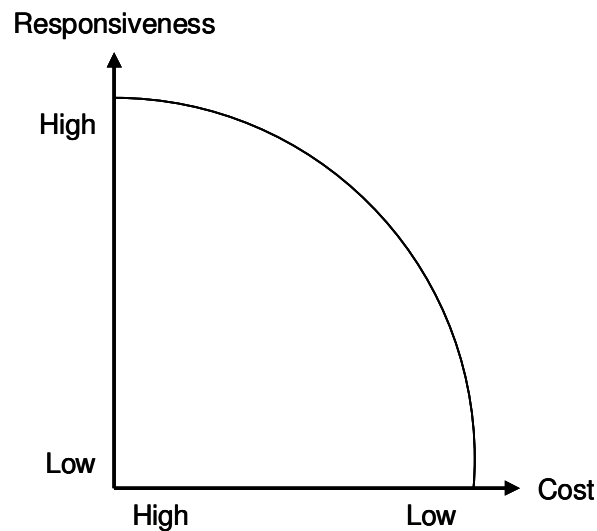
#### 4.2.2 Understanding the Supply Chain

Creating strategic fit is all about creating a supply chain strategy that best meets the particular type of demand that a company has targeted. Like customer needs, supply chains have many different characteristics. Supply chain responsiveness includes a supply chain's ability to:

- Respond to wide ranges of quantities demanded
- Meet short lead times
- Handle a large variety of products

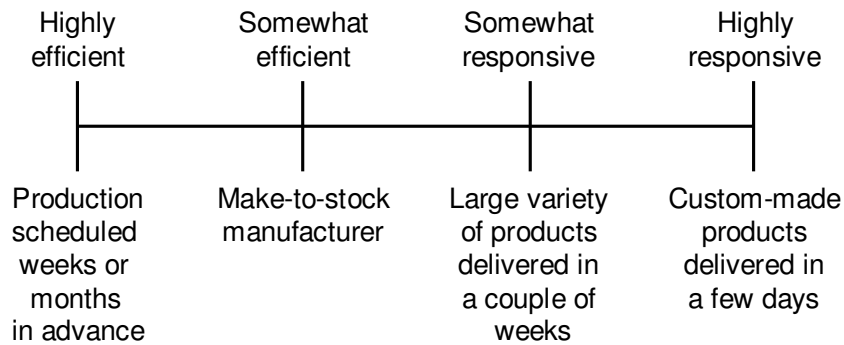
- Build highly innovative products
- Meet a very high service level

Responsiveness, however, comes at a cost. Supply chain efficiency is the cost of making and delivering a product to the customer. Increases in cost lower efficiency. For every strategic choice to increase responsiveness, there are additional costs that lower efficiency. The trade-off between responsiveness and efficiency can be represented by the cost-responsiveness efficient frontier curve as shown in Figure 4.2 [2, p: 33].



**Figure 4.2:** Cost-Responsiveness Efficient Frontier

The efficient frontier represents the cost-responsiveness performance of the best supply chains. Not every firm is able to perform on the efficient frontier. A firm that is not on the efficient frontier can improve both its responsiveness and its cost performance by moving toward the efficient frontier. In contrast, a firm on the efficient frontier can improve its responsiveness only by increasing cost and becoming less efficient. Of course, firms on the efficient frontier can also improve their processes and change technology to shift the efficient frontier itself. Given the trade-off between cost and responsiveness, a key strategic choice for any supply chain is the level of responsiveness it seeks to provide. Figure 4.3 [2, p: 33] shows the responsiveness spectrum and where some different supply chains fall on this spectrum.



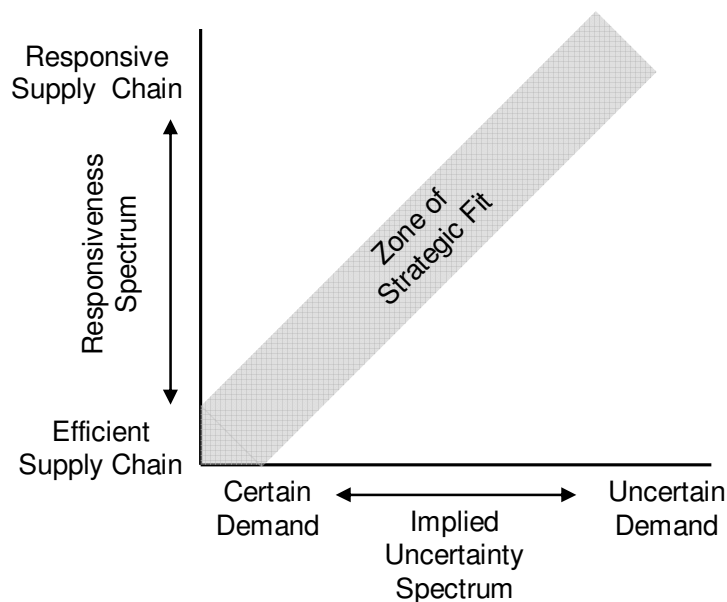
**Figure 4.3:** The Responsiveness Spectrum

The second step in achieving strategic fit is to understand the supply chain and map it on the responsiveness spectrum.

#### 4.2.3 Achieving Strategic Fit

The third and final step in achieving strategic fit is to match supply chain responsiveness with the implied demand uncertainty in the zone of strategic fit. All functional strategies within the value chain must also support the supply chain's level of responsiveness. In other words, the degree of supply chain responsiveness should be consistent with the implied demand uncertainty.

The graph shown in Figure 4.4 [2, p: 35] is referred to as uncertainty/responsiveness map. A point in this graph represents a combination of implied demand uncertainty and supply chain responsiveness.



**Figure 4.4:** Uncertainty/Responsiveness Map



The implied demand uncertainty represents customer needs or the firm's strategic position. The supply chain's responsiveness represents the supply chain strategy.

In order to achieve strategic fit, the greater the implied demand uncertainty, and the more responsive the supply chain should be. Increasing implied demand uncertainty from customers is best served with increasing responsiveness from the supply chain. This relationship is represented by the zone of strategic fit. For a high level of performance, companies should gear their competitive strategy toward the zone of strategic fit.

To achieve complete strategic fit, a firm must consider all functional strategies within the value chain. It must ensure that all functions in the value chain have consistent strategies that support the competitive strategy. Table 4.2 [2, p: 36] lists some of the major differences in functional strategy between supply chains that are efficient and those that are responsive.

**Table 4.2:** Comparison of Efficient and Responsive Supply Chains

	Efficient Supply Chains	Responsive Supply Chains
Primary Goal	Supply demand at the lowest cost	Respond quickly to demand
Product Design Strategy	Maximize performance at a minimum product cost	Create modularity to allow postponement of product differentiation
Pricing Strategy	Lower margins because price is a prime customer driver	Higher margins as price is not a prime customer driver
Manufacturing Strategy	Lower costs through high utilization	Maintain capacity flexibility to meet unexpected demand
Inventory Strategy	Minimize inventory to lower cost	Maintain buffer inventory to meet unexpected demand
Lead time strategy	Reduce but not at the expense of costs	Aggressively reduce even if the costs are significant
Supplier Strategy	Select based on cost and quality	Select based on speed, flexibility, and quality
Transportation Strategy	Greater reliance on low cost modes	Greater reliance on responsive modes

#### **4.2.3.1 Multiple Products and Customer Segments**

Most companies produce and sell multiple products and serve multiple customer segments, each with different characteristics. A department store may sell seasonal products with high implied demand uncertainty along with products with low implied demand uncertainty. The demand in each case maps to different parts of the uncertainty spectrum. When devising supply chain strategy, the key issue for a company is then to create a supply chain that balances efficiency and responsiveness given its portfolio of products and customer segments.

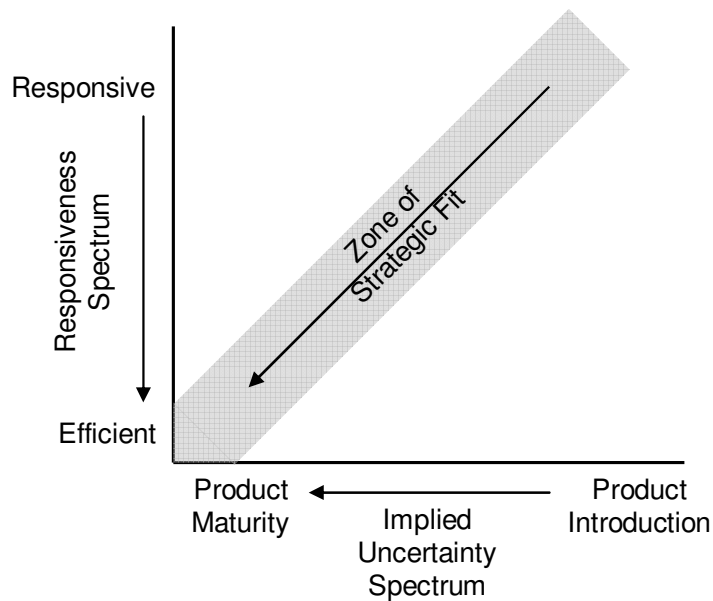
There are several possible routes a company can take. One is to set up independent supply chains for each different product or customer segment. This strategy is feasible if each segment is large enough to support a dedicated supply chain. A preferable strategy is to tailor the supply chain to best meet the needs of each product's demand, taking advantage of any economies of scope that often exist between a company's different products.

Tailoring the supply chain requires sharing some links in the supply chain with other products while having separate operations for other links. The links are shared to achieve maximum possible efficiency while providing the appropriate level of responsiveness to each segment. Appropriate tailoring of the supply chain helps a firm achieve varying levels of responsiveness for a low overall cost.

#### **4.2.3.2 Product Life Cycle**

As products go through their life cycles, the demand characteristics and the needs of the customer segments being served change. High-tech products are particularly prone to these life cycle swings over a very compressed time span. A product goes through life cycle phases from the introductory phase, when only the leading edge of customers is interested in it, all the way to the point at which the product becomes a commodity and the market is completely saturated. To maintain strategic fit, a company's supply chain strategy must evolve as its products enter different phases.

As the product becomes a commodity product later in its life cycle demand becomes more certain, margins are lower due to an increase in competitors, and price becomes a significant factor in customer choice. As products mature, the corresponding supply chain strategy should, in general, move from being responsive to being efficient, as illustrated in Figure 4.5 [2, p: 39].



**Figure 4.5:** Changes in Supply Chain Strategy over a Product's Life Cycle

The key point here is that demand characteristics change over a product's life cycle. Because demand characteristics change, the supply chain strategy must change over the product's life cycle as well if a company is to continue achieving strategic fit. The change in supply chain strategy and the change in demand characteristics must mesh.

#### 4.2.3.3 Competitive Changes over Time

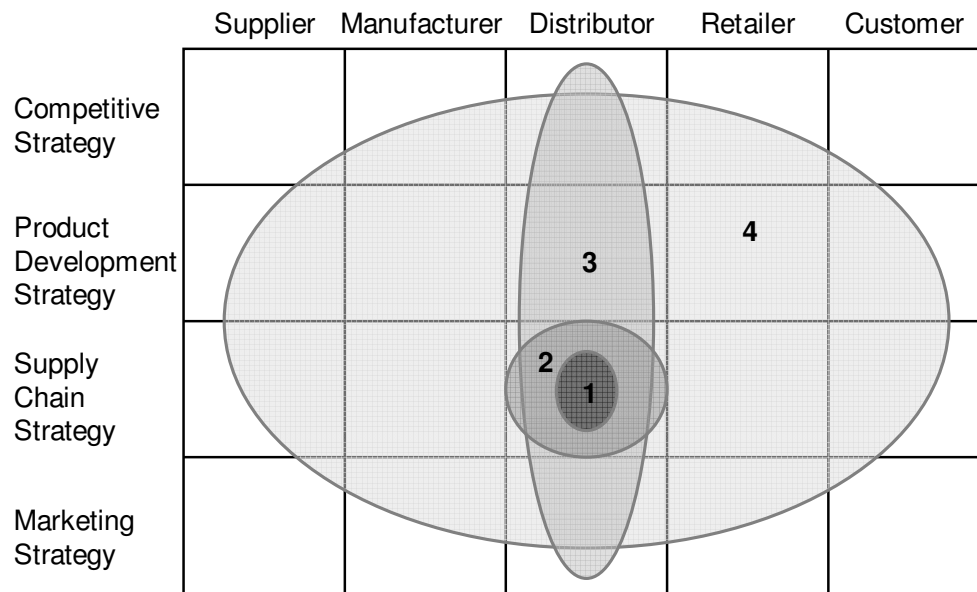
Like product life cycles, competitors can change the landscape, thereby requiring changes in a firm's competitive strategy. As competitors flood the marketplace with product variety, customers are becoming accustomed to having their individual needs satisfied. Thus, the competitive focus is on producing sufficient variety at a reasonable price. As the competitive landscape changes, a firm is forced to alter its competitive strategy. With the change in competitive strategy, a firm must also change its supply chain strategy to maintain strategic fit.

### 4.3 Expanding Strategic Scope

A key issue related to strategic fit is the scope, in terms of supply chain stages, across which the strategic fit applies. Scope of strategic fit refers to the functions and stages within a supply chain that devise an integrated strategy with a shared objective. At one extreme, every operation within each functional area devises its

own independent strategy with the objective of optimizing its own performance. In this case, the scope of strategic fit is restricted to an operation in a functional area within a stage of the supply chain. At the opposite extreme, all functional areas within all stages of the supply chain devise strategy jointly with a common objective of maximizing supply chain profit. In this case, the scope of strategic fit extends across the entire supply chain.

Figure 4.6 [2, p: 41-44] represents the scope of strategic fits across different supply chain stages versus different functional strategies.



- 1: The Intracompany Intraoperation Scope of Supply Chain Management
- 2: The Intracompany Intrafunctional Scope of Supply Chain Management
- 3: The Intracompany Interfunctional Scope Strategic Fit
- 4: The Intercompany Interfunctional Scope Strategic Fit

**Figure 4.6:** Scopes of Supply Chain Strategy and Strategic Fits

#### 4.3.1 Intracompany Intraoperation Scope: The Minimize Local Cost View

The most limited scope over which strategic fit has been considered is one operation within a functional area in a company where each operation within each stage of the supply chain devises strategy independently. The intracompany intraoperation scope often results in different operations and functions having conflicting objectives.

#### **4.3.2 Intracompany Intrafunctional Scope: The Minimize Functional Cost View**

With the intracompany intrafunctional scope, the strategic fit is expanded to include all operations within a function. The key weakness of the intracompany intrafunctional view is that different functions may have conflicting objectives and may hurt the firm's overall performance.

#### **4.3.3 Intracompany Interfunctional Scope: The Maximize Company Profit View**

With intracompany interfunctional scope, the goal is to maximize company profit. To achieve this goal, all functional strategies are developed to support each other and the competitive strategy. However, intracompany interfunctional scope of strategic fit has still two major weaknesses.

The first derives from the fact that the only positive cash flow for the supply chain occurs when the customer pays for the product. All other cash flows are simply a resettling of accounts within the supply chain and add to supply chain cost. The difference between what the customer pays and the total cost generated across the supply chain represents the supply chain surplus. The supply chain surplus represents the total profit to be shared across all companies in the supply chain. Increasing supply chain surplus increases the amount to be shared among all members of the supply chain. The intracompany interfunctional scope leads to each stage of the supply chain trying to maximize its own profits, which does not necessarily result in the maximization of the supply chain surplus. Supply chain surplus is maximized only when all supply chain stages coordinate strategy together.

The second major weakness of the intracompany scope becomes apparent when speed becomes a key driver of supply chain success. The companies can succeed not only because they have the lowest priced or highest quality products, but also because they are able to respond quickly to market needs and get the right product to the right customer at the right time. However, the most significant delays are created at the interface between the boundaries of different stages of a supply chain.

#### **4.3.4 Intercompany Interfunctional Scope: The Maximize Supply Chain Surplus View**

The intercompany scope forces every stage of the supply chain to look across the entire supply chain and evaluate the impact of its actions on other stages as well on the interfaces. A company's partners in the supply chain may well determine the company's success, as the company is intimately tied to its supply chain. This broad scope increases the size of the surplus to be shared among all stages of the supply chain. Intercompany view requires that each company evaluate its actions in the context of the entire supply chain. Supply chain contracts help achieve this scope.

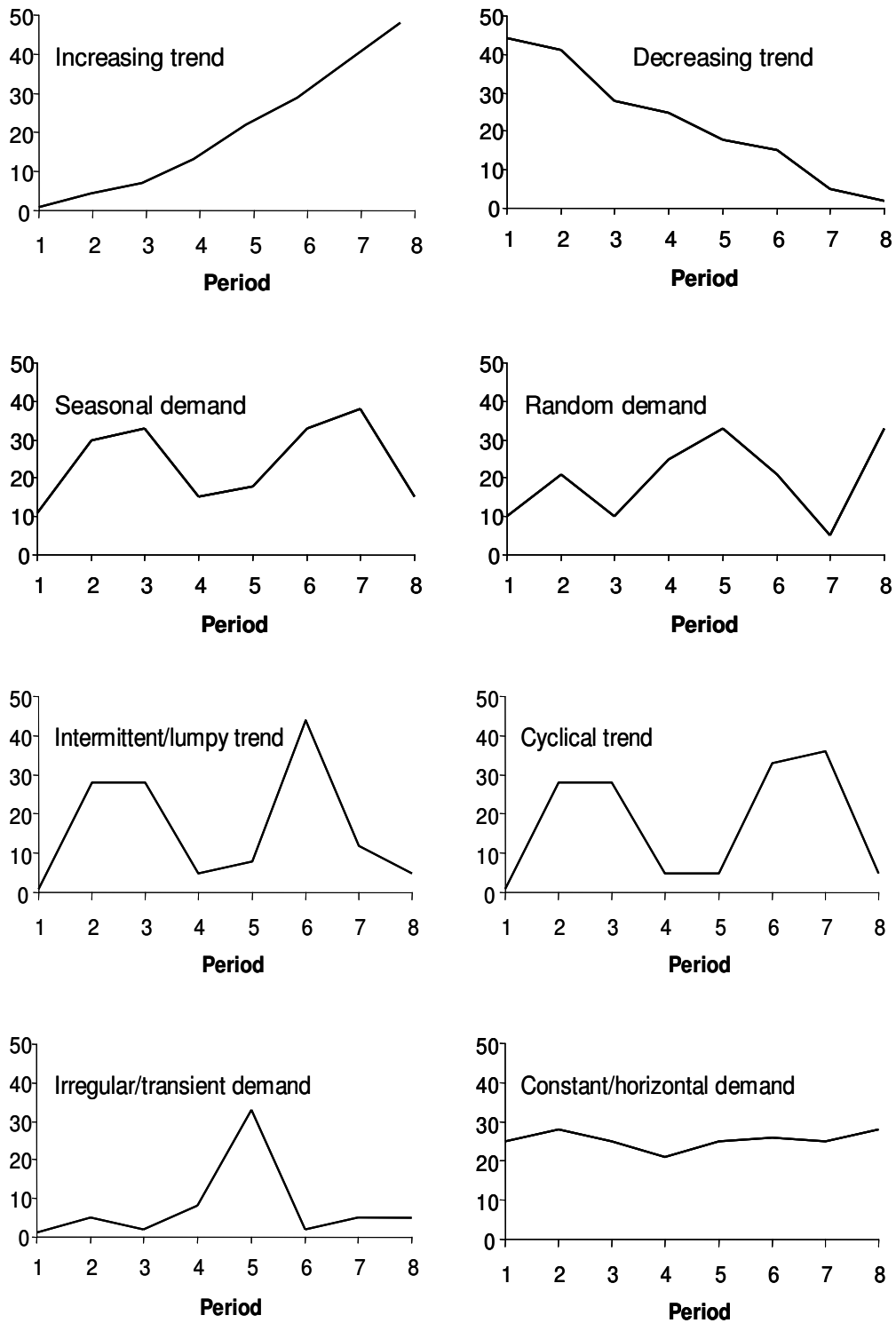
#### **4.3.5 Flexible Intercompany Interfunctional Scope**

Flexibility refers to a firm's ability to achieve strategic fit when partnering with stages that change over time in the supply chain. Firms must think in terms of supply chains consisting of many partners at each stage. The flexible intercompany scope allows strategic fit to apply to a moving target. Flexibility becomes more important as the competitive environment becomes more dynamic.

### **4.4 Demand Driven Supply Chain**

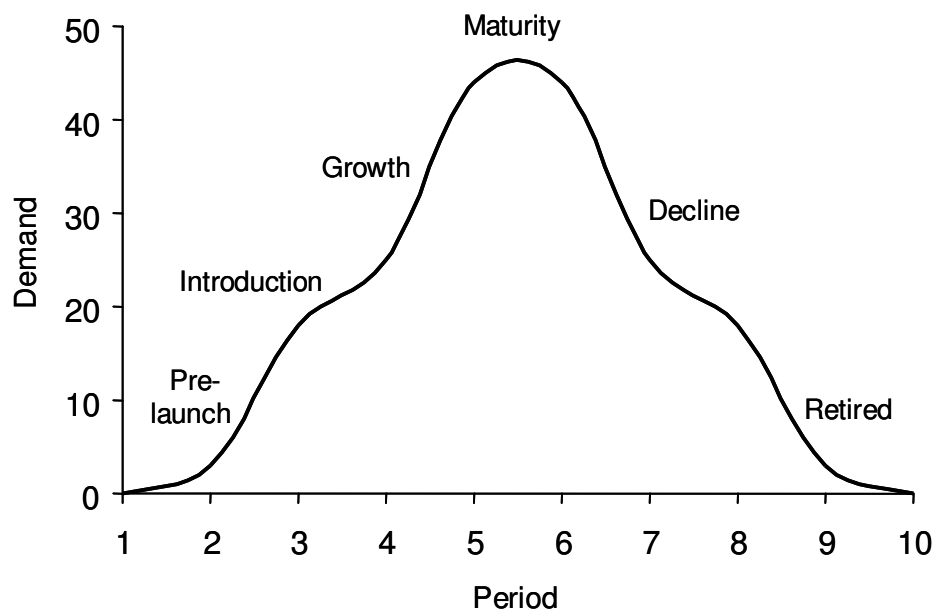
Supply chain surplus is maximized only when all supply chain stages coordinate strategy together. However, a supply chain's surplus is also significantly impacted by demand. Revenues are typically higher when overall demand increases in general. On the other hand, consumer demand for most products and services are a function of the price the customer is willing to pay. If an increase in a product's price has a direct negative relationship with the total demand, this elasticity will create a reduction or shift in the total demand. Therefore, price elasticity is a key factor influencing the supply chain surplus and must be incorporated into supply chain contracts and strategies aimed to achieve maximum surplus. In section 5, constant and linear elasticity functions will be discussed and used as an integral part of any supply chain contracts aimed to maximize the supply chain surplus.

Another key factor is to understand the demand patterns. The major demand patterns are shown in Figure 4.7 [74, p: 30]. A constant/horizontal pattern with normally distributed demand where the mean demand is a function of the selling price is used in this dissertation.



**Figure 4.7: Major Demand Patterns**

Coupled with these demand patterns, the product life cycle is another primary driver for demand economics impacting the overall supply chain surplus. Consumer demand for most products and services varies over time and forms natural demand patterns. There are six primary phases of the product life cycle. These phases include pre-launch, introduction, growth, maturity, decline, and retired as shown in Figure 4.8 [74, p: 28]. A product that currently resides in a specific stage of the cycle will have a different demand pattern from a product in another stage. The actual shape of this bell curve is based on the specific nature of the product and the industry, the competitive intensity, and the level of marketing investment.



**Figure 4.8:** Product Life Cycle Curve

The pre-launch phase of the life cycle has practically no demand. Estimates of market share, prices, and potential demand are all outcomes of this phase in the process.

During the introduction phase of the life cycle, demand can exhibit multiple patterns. At this point, demand is very uncertain and management of demand is based on either associating similar patterns experienced for other new products introduced historically, or by market research estimates.



As products reach the growth phase, demand becomes more stable and predictable. Demand management can use trends and statistics to define the pattern accurately.

During the maturity phase, demand is quite stable. As products mature, the corresponding supply chain strategy should, in general, move from being responsive to being efficient, as previously illustrated in Figure 4.5. The demand functions used in this dissertation assume that the products are in their maturity phases.

Predicting demand during the decline phases is often the most difficult. The intensity and timing of the decline make it very difficult to understand the demand pattern. The best way to analyze the product's decline is to explore historical similar product declines and associate a similar intensity and timing evidenced in other products and categories. Prices tend to be at historical lows during the decline phase.

At the retired phase, the product has been phased out. All demand that existed has either been transferred to a complementary or replacement item, or has been moved to a competitor's product.

In summary, each of the phases of the life cycle result in changes to the demand pattern, and likewise require a different type of technique to analyze and manage demand. The use of collaboration within the chain is essential during all phases of the product life cycle in order to achieve improved and accurate forecasts.

#### **4.5 Supply Chain Performance Drivers**

The strategic fit requires that a company achieve the balance between responsiveness and efficiency in its supply chain that best meets the needs of the company's competitive strategy [75-80]. The drivers of supply chain performance not only determine its performance in terms of responsiveness and efficiency, they also determine whether strategic fit is achieved across the supply chain [2, p: 49-60]. The five drivers of supply chain performance are:

- Inventory
- Transportation
- Facilities
- Information
- Contracts

Inventory is all raw materials, work in process, and finished goods within a supply chain. Inventory is an important supply chain driver because changing inventory policies can dramatically alter the supply chain's efficiency and responsiveness.

Transportation entails moving inventory from point to point in the supply chain. Transportation can take the form of many combinations of modes and routes, each with its own performance characteristics and transportation choices have a large impact on supply chain responsiveness and efficiency.

Facilities are the places in the supply chain network where inventory is stored, assembled, or fabricated. The two major types of facilities are production sites and storage sites. Whatever the function of the facility, decisions regarding location, capacity, and flexibility of facilities have a significant impact on the supply chain's performance.

Information consists of data and analysis regarding inventory, transportation, and customers throughout the supply chain. Information is potentially the biggest driver of performance in the supply chain as it directly affects the other drivers.

Contracts are most effective for governance and specify the parameters within which a buyer places orders and a supplier fulfills them. Contracts can potentially increase the total supply chain surplus and they are the core subject of this dissertation. Contracts will be discussed in details in Chapter 6.

#### **4.5.1 Inventory**

Increasing the inventory will generally make the supply chain more responsive to the customer. However, this choice comes at a cost as the added inventory decreases efficiency [81-86].

##### **4.5.1.1 Role in the Supply Chain**

Inventory exists in the supply chain because of a mismatch between supply and demand. This mismatch is intentional at the retailer in anticipation of future demand. An important role that inventory plays in the supply chain is to increase the amount of demand that can be satisfied by having the product ready and available when the customer wants it. Supply Chain contracts play a significant role to achieve this purpose. Another significant role inventory plays is to reduce cost by exploiting any economies of scale that may exist during both production and distribution.

Inventory is spread throughout the supply chain from raw materials to work in process to finished goods that suppliers, manufacturers, distributors, and retailers hold. Inventory is a major source of cost in a supply chain, and it has a huge impact on responsiveness.

Inventory has also a significant impact on the material flow time in a supply chain defined as the time that elapses between the point at which material enters the supply chain to the point at which it exits. Another important area where inventory has a significant impact is throughput, the rate at which sales to the end customer occur. If inventory is represented by I, flow time by T, and throughput by R, the three can be related as [2, p: 52]:

$$I = RT \quad (4.1)$$

Reduced flow time can be a significant advantage in a supply chain by reducing the inventory needed without reducing responsiveness.

#### **4.5.1.2 Role in the Competitive Strategy**

Inventory plays a significant role in a supply chain's ability to support a firm's competitive strategy. If a firm's competitive strategy requires a very high level of responsiveness, a company can use inventory to achieve this responsiveness by allocating large amounts of inventory close to the customer. Conversely, a company can also use inventory to make itself more efficient by reducing inventory through centralized stocking. The latter strategy would support a competitive strategy of being a low cost producer. The trade-off implicit in the inventory driver is between the responsiveness that results from more inventory and the efficiency that results from less inventory.

#### **4.5.1.3 Components of Inventory Decisions**

Major inventory related decisions to create more responsive and more efficient supply chains involve cycle inventory, safety inventory, and seasonal inventory.

Cycle inventory is the average amount of inventory used to satisfy demand between receipts of supplier shipments. The size of the cycle inventory is a result of the production or purchase of materials in large lots to exploit economies of scale in the production, transportation, or purchasing process. The basic trade-off is the cost of holding larger lots of inventory versus the cost of ordering the product frequently.

Safety inventory is held just in case demand exceeds expectations to counter uncertainty. Choosing safety inventory involves making a trade-off between the costs of having too much inventory and the costs of lost sales due to not having enough inventory.

Seasonal inventory is built up to counter predictable variability in demand. Companies using seasonal inventory will build up inventory in periods of low demand and store it for periods of high demand when they will not have the capacity to produce all that is demanded. If a company can rapidly change the rate of its production system at low cost, then it may not need seasonal inventory. The basic trade-off is the cost of carrying the additional seasonal inventory versus the cost of having a more flexible production rate.

#### **4.5.2 Transportation**

The fundamental trade-off for transportation is between efficiency, the cost of transporting a given product, and responsiveness, the speed with which the product is transported [87-93].

##### **4.5.2.1 Role in the Supply Chain**

Transportation moves the product between different stages in a supply chain. Like the other supply chain drivers, transportation has a large impact on both responsiveness and efficiency. Faster transportation, whether in the form of different modes of transportation or different amounts being transported, allows a supply chain to be more responsive but reduces its efficiency. The type of transportation a company uses also affects the inventory and facility locations in the supply chain.

##### **4.5.2.2 Role in the Competitive Strategy**

The role of transportation in a company's competitive strategy figures prominently when the company is considering the target customer's need. If its competitive strategy targets a customer that demands a very high level of responsiveness and that customer is willing to pay for this responsiveness, then a company can use transportation as one driver for making the supply chain more responsive. On the other hand, if it targets customers whose main criterion is price, then the company can use transportation to lower the cost of the product at the expense of responsiveness.

As a company may use both inventory and transportation to increase responsiveness or efficiency, the optimal decision for the company often means finding the right balance between the two.

#### **4.5.2.3 Components of Transportation Decisions**

Major transportation related decisions to create more responsive and more efficient supply chains involve mode of transportation, route and network selection, and in house or outsource decisions.

The mode of transportation is the manner in which a product is moved from one location in the supply chain network to another. Companies have four basic modes from which to choose. In decreasing responsiveness, companies may choose air, truck, rail, or ship transportation modes. Depending on the product, pipeline and electronic transportation can also be used. Each mode has different characteristics with respect to the speed, size of shipments, cost of shipping, and flexibility that lead companies to choose one particular mode over the others.

Another major transportation decision is the route and network along which products are shipped. A route is the path along which a product is shipped, and a network is the collection of locations and routes along which a product can be shipped. A company may need to decide whether to ship products directly to customers or to use a series of distribution layers. Companies make some routing decisions at the supply chain's design stage, and they make others on a short term basis.

Traditionally, much of the transportation function has been performed in house. Today, however, much of transportation, even entire logistics systems, is outsourced. Having to choose between bringing parts of transportation in house or outsourcing leads to another dimension of complexity when companies are designing their transportation systems. In this dissertation, transportation related costs are not considered separately, but rather assumed to be included in the unit price.

#### **4.5.3 Facilities**

The fundamental trade-off for facilities is between efficiency, the cost of the number, location, and type of facilities, and the level of responsiveness that these facilities provide the company's customers [88, 94-98].

#### **4.5.3.1 Role in the Supply Chain**

If inventory is what is being passed along the supply chain and transportation as how it is passed along, then facilities are the where of the supply chain. They are the locations to or from which the inventory is transported. Within a facility, inventory is either transformed into another state, manufacturing, or stored before being shipped to the next stage, warehousing.

#### **4.5.3.2 Role in the Competitive Strategy**

Facilities and their corresponding capacities to perform their functions is a key driver of supply chain performance in terms of responsiveness and efficiency. Companies may gain economies of scale when a product is manufactured or stored in only one location. This centralization increases efficiency. However, the cost reduction comes at the expense of responsiveness, as many of company's customers may be located far from the production facility. On the other hand, locating facilities close to customers increases the number of facilities needed and consequently reduces efficiency. However, if the customer demands and is willing to pay for the responsiveness that having numerous facilities adds, then this facilities decision helps meet the company's competitive strategy goals.

#### **4.5.3.3 Components of Facilities Decisions**

The components of facilities decisions are the location, capacity, manufacturing methodology, and various warehousing methodologies.

Deciding where a company will locate its facilities constitutes a large part of the design of a supply chain. A basic trade-off is whether to centralize to gain economies of scale or decentralize to become more responsive by being closer to the customer. Companies must also consider related issues to the characteristics of the local area in which the facility may be situated. These include macroeconomic factors, strategic factors, quality and cost of workers, cost of facility, availability of infrastructure, proximity to customers and the rest of the network, and tax effects.

Companies must also decide what a facility's capacity to perform its intended function or functions will be. A large amount of excess capacity allows the facility to be very flexible and to respond to wide swings in the demands placed on it. Excess capacity, however, costs money and therefore can decrease efficiency. A facility with little excess capacity will likely be more efficient per unit of product it produces

than one with a lot of unused capacity. On the other hand, the high utilization facility will have difficulty responding to demand fluctuations. Therefore a company must make a trade-off between flexibility and efficiency to determine the right amount of capacity to have at each of its facilities.

Companies must also make a major decision regarding the manufacturing methodology that a facility will use. They must decide whether to design a facility with a product focus or a functional focus. A product focused factory performs many different functions, such as fabrication and assembly, in producing a single type of product. A functional focused factory performs few functions, such as only fabrication or only assembly, on many types of products. A product focus tends to result in more expertise about a particular type of product at the expense of the functional expertise that comes from a functional manufacturing methodology. Companies must decide which type of expertise will best enable them to meet customer needs. They must also make a decision regarding the relative level of flexible versus dedicated capacity in their portfolios. Flexible capacity can be used for many types of products but is often less efficient whereas the more efficient dedicated capacity can be used for only a limited number of products. The trade-off is again between efficiency and responsiveness.

As with manufacturing, there are a variety of methodologies from which companies can choose when designing a warehouse facility, including Stock-keeping Unit (SKU) storage, Job Lot Storage, and Crossdocking.

#### **4.5.4 Information**

Many information systems increase both responsiveness and efficiency. The trade-off is between the cost of information which comes with a reduction in efficiency and the responsiveness that information creates in the supply chain.

##### **4.5.4.1 Role in the Supply Chain**

Information could be overlooked as a major supply chain driver because it does not have a physical presence. Information, however, affects every part of the supply chain in many ways [99-108]. It serves as the connection between the supply chain's various stages, allowing them to coordinate their actions and bring about many of the benefits of maximizing total supply chain profitability. Information is also crucial to the daily operations of each stage in a supply chain.

#### **4.5.4.2 Role in the Competitive Strategy**

Information is a driver whose importance has grown as companies have used it to become both more efficient and responsive. The tremendous growth of the importance of information technology is a testimony to the impact information can have on improving a company. However, like the other drivers, even with information, companies reach a point where they must make the trade-off between efficiency and responsiveness.

Another key decision involves what information is most valuable in reducing cost and improving responsiveness within a supply chain. This decision will vary depending on the supply chain structure and the market segments served.

#### **4.5.4.3 Components of Information Decisions**

Key components of information within a supply chain to increase efficiency and improve responsiveness are push versus pull, coordination and information sharing, forecasting and aggregate planning, and enabling technologies.

When designing processes in the supply chain, managers must determine whether these processes are part of the push or pull phase in the chain. Push systems generally require information in the form of elaborate material requirements planning (MRP) systems to take the master production schedule and roll it back, creating schedules for suppliers with part types, quantities, and delivery dates. Pull systems require information on actual demand to be transmitted extremely quickly throughout the entire chain so that production and distribution of parts and products can accurately reflect the real demand. Just-in-time (JIT) production is often referred as a pull system.

Supply chain coordination occurs when all the different stages of a supply chain work toward the objective of maximizing total supply chain profitability, rather than each stage devoting itself to its own profitability. Again, supply chain contracts can play a significant role to achieve this objective. Lack of coordination may result in a significant loss of total supply chain profit. Coordination between different stages in a supply chain requires each stage to share appropriate information with other stages.



Forecasting is the art and science of making projections about what future needs and conditions will be. Obtaining forecasting information frequently means using sophisticated techniques to estimate future demand or market conditions. Companies often use forecasts both on a tactical level to schedule production and on a strategic level to determine whether to build new plants or even whether to enter a new market. Aggregate planning transforms forecasts into plans of activity to satisfy the projected demand. A company's aggregate plan significantly affects the demand on both its suppliers and its supply to its customers.

Today, many technologies exist that share and analyze information in the supply chain [109-112]. The technologies include Electronic Data Interchange (EDI), the Internet, Enterprise Resource Planning (ERP), Supply Chain Management (SCM) software, and Advanced Planning and Scheduling (APS). As we will see in Chapter 5, these technologies are vital for successful supply chain contract implementations.

## **4.6 Obstacles to Achieving Strategic Fit**

A company's ability to find a balance between responsiveness and efficiency along the responsiveness spectrum that best matches the type of demand it is targeting is the key to achieving strategic fit. In deciding where this balance should be located on the responsiveness spectrum, companies must overcome the following obstacles. Many of these obstacles have made it increasingly difficult for supply chains to achieve strategic fit [2, p: 60-62]. Overcoming these obstacles offers a tremendous opportunity for firms to use supply chain performance drivers, including supply chain contracts, to gain competitive advantage.

### **4.6.1 Increasing Variety of Products**

With customers demanding ever more customized products, manufacturers have responded with mass customization. The increase in product variety complicated the supply chain by making forecasting and meeting demand much more difficult. The rise of e-commerce, which makes it easy to offer variety to the customer, reinforces the customization trend. Increase variety tends to raise uncertainty, and uncertainty frequently results in increased cost and decreased responsiveness within the supply chain. Again, supply chain contracts can help overcome this obstacle.

#### **4.6.2 Decreasing Product Life Cycles**

In addition to the increasing variety of product types, the life cycle of products has been shrinking. This decrease in product life cycles makes the job of achieving strategic fit more difficult, as the supply chain must constantly adapt to manufacture and deliver new products in addition to coping with these product's demand uncertainty. Shorter life cycles increase uncertainty while reducing the window of opportunity within which the supply chain can achieve strategic fit. Increased uncertainty combined with a smaller window of opportunity has put additional pressure on supply chains to coordinate and create a good match between supply and demand. Once again, supply chain contracts can be used to create this match.

#### **4.6.3 Increasingly Demanding Customers**

Companies can clearly see how customer demands have increased when considering delivery lead times, cost, and product performance. Today's customers are demanding faster fulfillment, better quality, and better performing products for the same price they paid years ago meaning that the supply chain must provide more just to maintain its business.

#### **4.6.4 Fragmentation of Supply Chain Ownership**

Over the past several decades, most firms have become less vertically integrated. As companies have shed noncore functions, they have been able to take advantage of supplier and customer competencies that they themselves did not have. However, this new ownership structure has also made managing the supply chain more difficult. With the chain broken into many owners, each with its own policies and interests, the chain is more difficult to coordinate. Potentially, this problem could cause each stage of a supply chain to work only toward its own objectives rather than the whole chain's, resulting in the reduction of overall supply chain profitability. As we will see in Chapter 6, supply chain contracts can be used very effectively to overcome this obstacle.

#### **4.6.5 Globalization**

The increase in globalization over the past few decades has had two main impacts on the supply chain. The first impact is that supply chains are now more likely than ever to be global. Having a global supply chain creates many benefits, such as the

ability to source from a global base of suppliers who may offer better and cheaper goods than were available in a company's home nation. However, globalization also adds stress to the chain because facilities within the chain are farther apart, making coordination more difficult.

The second impact of globalization is an increase in competition. This competitive situation makes supply chain performance a key to maintaining and growing sales while also putting more strain on supply chains and thus forcing them to make their trade-offs even more precisely.

#### **4.6.6 Difficulty in Executing New Strategies**

Creating a successful supply chain strategy is not easy. However, once a good strategy is formulated, actually executing the strategy can even be more difficult. Many high talented employees at all levels of the organization are necessary to make a supply chain strategy successful. The increasing impact of all these obstacles has led to supply chain management becoming a major factor in the success or failure of firms.

#### **4.7 Managing Predictable Variability**

As discussed in Section 4.5, aggregate planning transforms forecasts into plans of activity to satisfy the projected demand. A company's aggregate plan significantly affects the demand on both its suppliers and its supply to its customers. For products whose demand is stable with little change in volume over time, devising an aggregate plan is simple. In such cases, a company arranges for sufficient capacity to match the expected demand and then produces an amount to match that demand. Products are made close to the time when they will be sold. The supply chain carries little inventory [2, p: 121-127].

However, demand for many products changes from period to period, often due to a predictable influence such as seasonal factors and promotions [113-116]. Predictable demand is the change in demand that can be forecasted. Products that undergo this type of change in demand cause numerous problems in the supply chain, ranging from high levels of stockouts during peak demand periods to high levels of excess inventory during periods of low demand. These problems increase the cost of products and decrease the responsiveness of the supply chain. Supply

and demand management will have the greatest impact when it is applied to predictably variable products.

A company must choose between two broad options to handle predictable variability: managing supply and managing demand.

#### **4.7.1 Managing Supply**

Supply of products can be controlled by a combination of production capacity and inventory. When managing capacity to meet predictable demand, companies use a combination of the following approaches:

- Time flexibility from workforce
- Use of seasonal workforce
- Use of subcontracting
- Use of both dedicated and flexible facilities
- Designing product flexibility into the production processes

When managing inventory to meet predictable variability, companies use a combination of the following approaches:

- Using common components across multiple products
- Build inventory of high demand or predictable demand products

#### **4.7.2 Managing Demand**

In many instances, supply chains can influence demand in different periods using pricing and other forms of promotion. When a promotion is offered during a period, that period's demand will tend to go up. This increase in demand results from a combination of the following factors:

- Market growth
- Stealing share
- Forward buying

The first two factors increase the overall demand whereas the third simply shifts future demand to the present.

In Chapter 6, we will discuss how product availability and supply chain profits are affected by contracts between stages of the supply chain. Effective use of contracts

as a supply chain driver can substantially increase the overall supply chain profitability and its competitive advantage.

#### **4.8 Implications of Supply Chain Management in Agile Manufacturing**

Supply chain management evolution has provided a number of practices that directly relate to improving agility within and between organizations [117-128]. Changing customer and technological requirements force manufacturers to develop agile supply chain capabilities in order to be competitive. The requirements for organizations to become more responsive to the needs of customers, the changing conditions of competition, and increasing levels of environmental turbulence is driving the concept of agility. The concept has also been extended beyond the traditional boundaries of the individual organization to encompass the operations of the supply chain within which the organization operates. It is imperative for companies to cooperate and leverage complementary competencies such as using market knowledge and a virtual corporation to exploit profitable opportunities in a volatile marketplace. There has also been much research combining the lean philosophy and agile manufacturing [129-135].

Agility performance factors such as time, cost, flexibility, dependability are all affected by the management of the supply chain. The following have been defined as exemplary practices for strategic supplier relationships [136, p: 361]:

- Development of long term, performance oriented supplier partnerships,
- Continuous quality improvement and joint learning by both the customer and its supplier base,
- Focus on total cost of ownership, not just on price,
- Companies are taking a boundaryless view of their participation in the supply chain,
- Long term contracts,
- Multi level relationship across the organization including inter company project teams,
- Critical buying decision based on value,
- Early involvement in marketing, design, and product development cycle,
- Exchange of information including not only information on work in progress, but also information on basic costs and insight into long term strategy,
- Integrated quality control,
- Mutual support and joint problem solving,
- Joint teams sharing information and expertise,

- A genuine insight into the buy decision and market forces up and down the supply chain, and
- Two or three suppliers at most, with single sourcing agreements, thus enabling the purchasing, engineering, production, and quality personnel to work more closely.

Strategic supplier relationships exist in a number of industries and are on the rise. Supply chain contracts are part of these partnerships and alliances.

## **CHAPTER 5. INFORMATION TECHNOLOGY STRUCTURE AND SUPPLY CHAIN CONTRACTS**

The impact of technology upon the development and rapid expansion of supply chain collaboration has been profound. In this chapter, we will discuss how technology drives and facilitates supply chain integration, a vital necessity for successful supply chain contract implementations.

### **5.1 Information Networks**

Supply chain information systems initiate activities and track information regarding processes and facilitates information sharing both within the firm and between supply chain partners resulting to successful supply chain contracts. All component systems must be integrated to provide comprehensive functionality for analyzing, initiating, and monitoring supply chain operations [137, p: 191-196], thus facilitating the supply chain contracts with timely and accurate information.

#### **5.1.1 Information System Functionality**

There are four reasons why timely and accurate information is vital. First, customers perceive information about order status, product availability, delivery schedule, shipment tracking, and invoices as necessary elements of total customer service. Customers demand access to real time information. Second, with the goal of reducing total supply chain assets, thus supply chain profitability, information can be used to reduce inventory and human resource requirements, especially by minimizing demand uncertainty. Third, information increases flexibility in supply chain contracts with regard to how, when, and where resources may be utilized to gain strategic advantage. Fourth, enhanced information transfer and exchange capability utilizing the Internet is changing relationships between buyers and sellers and redefining channel relationships. Supply chain information systems (SCIS) provide integration on four levels of functionality: transaction systems, management control, decision analysis, and strategic planning.

A transaction system is characterized by formalized rules, procedures, and standardized communications [138-141]. The combination of structured processes and large transaction volume initiated by supply chain contracts places a major emphasis on information system efficiency on transaction activities including, but not limited to, order entry, inventory assignment, order selection, shipment, pricing, invoicing, and customer inquiry. The customer order performance cycle is completed through a series of information system transactions.

The second level, management control, focuses on performance measurement and reporting. Performance measurement is necessary to provide feedback for supply chain contracts regarding performance and resource utilization. While some control measures, such as cost, are well defined, other measures, such as customer service and quality, are less specific. While internal measures are relatively easy to track, external measures are more difficult to obtain since they require monitoring performance regarding specific customers.

The third level, decision analysis, focuses on software tools to assist supply chain partners in identifying, evaluating, and comparing strategic and tactical alternatives for improved contract effectiveness. Decision analysis should also include a centralized database and reporting over a wide range of potential logistics situations. Decision analysis applications are also being used to manage customer relationships by determining the trade-offs associated with having satisfied customers. Because decision analysis is used to guide future contracts, thus operations, users require more expertise and training to benefit from its capability.

Finally, as we will develop in Chapter 6, strategic planning can be used to organize and synthesize transaction data into a wide range of business planning and decision making models that assist in evaluating the probabilities and payoffs of various strategies with the main focus on enhanced supply chain system integration.

### **5.1.2 Communication Systems**

Information technology is also critical for information sharing to facilitate logistics and supply chain planning and operations. Historically, coordination of logistics has been difficult since logistics activities are often performed at locations distant from information technology hardware. As a result, information was not available at the location of essential work in terms of both time and content. The past decade has witnessed remarkable advances in logistical communication systems capability. EDI,



the Internet, Extensible Markup Language (XML), and satellite technology exist to facilitate communication between firms and facilities. Radio frequency allows short-range communication within facilities such as warehouses. Image, bar coding, and scanner technologies allow communication between supply chain information systems and their physical environment.

While further communication system improvement will continue to reduce uncertainty, it is likely that major opportunities for future performance enhancers will be through supply chain analysis and strategic planning systems, including supply chain contracts.

## **5.2 Enterprise Resource Planning (ERP) and Execution Systems**

Enterprise Resource Planning (ERP) and execution systems are the major software components of logistical information systems [142-144]. ERP provides the central database and the transaction capability to initiate, track, monitor, and report on customer and replenishment orders to further refine supply chain contracts. ERP systems provide firms with information consistency, economies of scale, and integration.

ERP system design includes the central database and application modules to facilitate supply chain, financial, and human resource management. Supply chain system design includes components for planning and coordination of operations and inventory deployment.

Enterprise execution systems provide the interface between the ERP and the day-to-day operations with the customer, transportation, and the warehouse. On the other hand, Customer Relationship Management (CRM) systems offer 'insight regarding the firm's activity level and performance with key customers. Benefits of within the context of supply chain contracts can be summarized as:

- Quickened information response time,
- Increased interaction across the supply chain,
- Improved order management and order cycle,
- Decreased financial close cycle,
- Improved interaction with customers,
- Improved on-time delivery,
- Improved interaction with suppliers,

- Reduced direct operating costs, and
- Lowered inventory levels.

Gaining strategic advantage, the outcome of a successful supply chain contract, is listed as one of the top motivations to implement ERP systems [145, p: 5-7]

### **5.2.1 Rationale for ERP Implementation**

Regardless the size of the firms in the supply chain, ERP investments are typically rationalized through three factors: consistency, economies of scale, and integration [130, p: 223].

The first major ERP objective is to create a system that utilizes consistent data and processes. In a typical application, the data is resident in a common data warehouse that can be accessed globally. In addition, the data can be modified with appropriate security and controls using transactions available in the supply chain. Transactions are initiated by specific supply chain activities and implemented using common assumptions and timing. Such a unified perspective offers supply chain partners a consistent integrated view.

As firms merged and expanded, management made increasing demands to take advantage of global scale economies through resource utilization. ERP offers firms potential economies of scale in several ways. First, a single centralized processor or a network of decentralized processors with common configurations offers the potential for substantial procurement and maintenance scale economies. Second, the centralized ERP approach offers significant software scale economies since only a limited number of software licenses are necessary within the supply chain. Third, potential scale economies for ERP expertise exists since relatively few individuals have developed extensive skills. Finally, the centralized ERP approach increases the potential for shared resources and services. All those economies of scale can and should be factored into supply chain contracts.

Integration results from a common integrated database and implementation of common processes. Typical common processes in ERP include order entry, order processing, warehouse management, invoicing, and accounting. Such integration also results in standard financial practices within the supply chain. A new generation of ERP systems, identified as ERP II, integrate traditional ERP along with a Customer Relationship Management (CRM) system to better integrate the

requirements and expectations of key customers. ERP II is the external connectivity critical for supply chain collaboration.

## **5.2.2 Enterprise Execution Systems**

ERP systems are substantially enhancing process and information consistency and integration of supply chain operations. Yet the focus on integrated processes has generally reduced the system functionality and features, particularly for operational elements such as warehouse and transportation management. The result is that ERP modules may not be capable of performing some of the major activities, particularly those focused on enhancing value required to support supply chain operations. Enterprise execution systems, including CRM, TMS, and WMS are evolving to meet these specific requirements as they are very important factors in successful supply chain contract implementations.

### **5.2.2.1 Customer Relationship Management (CRM)**

CRM is designed to extend the functionality of the ERP sales and delivery applications. Firms are using CRM to transition from treating customers as income sources to be exploited to treating as assets to be nurtured [137, p: 241]. While the traditional sales and delivery application was designed to accept customer orders in a wide range of formats and allow those orders to be managed throughout the fulfillment process, a broader range of capabilities is necessary to manage the customer relationship. Beyond this basic functionality, CRM requires sales tracking, sales history analysis, pricing management, promotion management, product mix management, and category management, all providing vital information for supply chain profitability and, implicitly, for supply chain contracts. For example, it is becoming more common for grocers to expect their suppliers to manage both the product mix and the shelf quantities for major product categories. This practice which can be factored in supply chain contracts requires substantial information support from the manufacturer but also facilitates information sharing.

### **5.2.2.2 Transportation Management System (TMS)**

In general, the advanced TMS should proactively identify and evaluate alternative transportation strategies and tactics to determine the best methods to move product within the existing constraints. The principal deliverables of TMS are cost savings

and increased functionalities. Coupled with a supply chain contract, TMS can provide:

- Order consolidation,
- Route optimization,
- Carrier rate management,
- EDI links with carriers,
- Internet-based shipment tracking, and
- Integrated claims management.

### **5.2.2.3 Warehouse Management System (WMS)**

Historical warehouse system functionality focused on receiving replenishment shipments, stock putaway, and order picking. Warehouses today must offer a broader range of services as they are frequently performing some light manufacturing. They also require managing more inventory on a just-in-time basis. Advanced WMS functionalities include:

- Yard management, which refers to the process of managing the vehicles and the inventory within vehicles while in the warehouse yard,
- Labor management to maximize the use of warehouse labor,
- Warehouse optimization to select the best location within the warehouse for the storage and retrieval of products to minimize time and movement,
- Value Added Services (VAS) to coordinate various warehouse activities to customize products, such as labelling, kitting, and setting up displays,
- Planned cross-docking and merging, which refers to the integration of two parts of a customer order that have been supplied from a different source without maintaining inventory, and
- Reverse logistics activities such as returns, repair, and recycling.

### **5.3 Advanced Planning and Scheduling (APS)**

Advanced Planning and Scheduling (APS) systems work with ERP systems by providing business analysis and decision support capabilities. The majority of ERP systems are still transaction oriented and have limited decision support features. An APS system leverages the data residing in an ERP system to provide decision support for production planning, demand planning, and transportation planning [145, p: 96].

Historically, logistics and supply chain planning processes were completed sequentially and independently. Each supply chain process developed both short and long term plans based on independent assumptions and constraints. The result, as we will see in Chapter 6 in the context of supply chain contracts, was inconsistent sourcing, production, inventory, warehousing, transportation, and pricing. The planning differences resulted in excess inventories, redundant capacity, and poor resource utilization. Capacity and inventory buffers were necessary to allow for the requirement inconsistencies resulting from independent plans. While this ineffective use of resources was once viewed as a part of business, such resources waste is not acceptable today. Enhanced performance requires increased planning integration across the supply chain processes.

APS systems seek to integrate information and coordinate overall supply chain decisions while recognizing the dynamics between functions and processes. In a sense, supply chain contracts seek also the same objective while recognizing the dynamics between supply chain partners.

### **5.3.1 Rationale for Advanced Planning and Scheduling**

The four factors driving APS development and implementation are planning horizon recognition, supply chain visibility, simultaneous resource consideration, and resource utilization [137, p: 249].

#### **5.3.1.1 Planning Horizon Recognition**

The first consideration is the movement to a shorter and shorter planning horizon for operations decisions. In the past, supply chain activities were planned months in advance with limited flexibility for change within the current timeframe. This lock-in time was often termed the freeze period for production and supply chain planning decisions. The reduced flexibility caused by external freeze periods resulted in poor customer service because production and shipping could not respond quickly or failure to respond to required changes would result in excess inventory. Supply chain contracts, especially supply chain quantity flexible contracts we will develop in Chapter 6, help accommodate these complex dynamics. This ability to accommodate change will then result to shorter planning cycles which, in turn, requires more comprehensive and effective planning tools.

### **5.3.1.2 Supply Chain Visibility**

The second consideration in APS development is the need for visibility regarding location and status of supply chain inventory and resources, a major component of the supply chain contracts. Visibility implies not only being able to track supply chain inventory and resources but also that information regarding available resources can be effectively evaluated and managed. However, simply being able to identify shipments and inventory is not sufficient; supply chain visibility requires exceptional coordination to highlight the need for resource or activity plans to minimize or prevent potential problems. Limited visibility regarding inventory in-transit and expected arrival times result to significant uncertainty regarding product availability. The model we develop in Chapter 7 incorporates the price sensitive demand into quantity flexible contracts and determines the optimal level of product availability. An effective APS system certainly integrates with information provided by other supply chain partners and provide the necessary visibility.

### **5.3.1.3 Simultaneous Resource Consideration**

Once the planning system determines resource status and availability through visibility, the third APS consideration is the need to develop a plan that incorporates combined supply chain demand, capacity, material requirements, and constraints. The keyword here is the combined demand, the ultimate objective for supply chain contracts to maximize supply chain surplus. Quantity flexible supply chain contract requirements we develop in Chapter 7 reflect the price sensitive customer demand for product quantity, delivery timing, and location. While some of these customer requirements may be negotiable, logistics should execute to the agreed-to-requirements and standards.

The constraints to meeting customer requirements are materials, production, storage, and transportation capacity. These requirements represent the physical limitations of processes and facilities. Prior planning methods have typically considered these capacity constraints in a sequential manner. For example, an initial plan is made that operates within production constraints. The initial plan is then adjusted to reflect material and resource constraints. The second plan is then revised again to consider storage and transportation constraints. Achieving integrated supply chain performance requires simultaneous consideration of relevant supply chain capacity constraints to identify trade-offs where increased functional costs, such as in manufacturing or storage, might lead to lower overall

system costs. The APS system needs to quantitatively evaluate the trade-offs and suggest plans that can optimize overall supply chain performance. Supply chain contracts developed in Chapter 7 are targeted to evaluate these trade-offs quantitatively and simultaneously.

#### **5.3.1.4 Resource Utilization**

Logistics and supply chain management decisions have major influences on many enterprise resources, including production, distribution facilities and equipment, transportation equipment, and inventories. These resources consume a substantial proportion of a typical firm's fixed and working assets. The typical result was long production runs and minimum setups and changeovers. However, longer production runs invariably result in more finished inventory, as substantial quantities are manufactured in anticipation of projected demand. More inventory increases working capital requirements while the additional space requirements increase. This trend toward more inventory is further aggravated by the increased uncertainty resulting from the need to forecast longer into the future.

With functional resource trade-offs in mind, the final consideration driving APS system development and implementation is the need to implement an integrated planning approach that minimizes combined supply chain resources. This is a critical capability when supply chain performance place a strong emphasis on overall asset utilization to maximize supply chain surplus targeted with the supply chain contracts.

### **5.3.2 Supply Chain APS Applications**

There are a growing number of APS applications. New applications are evolving by the need to consider a broader range of activities and resources within the scope of supply chain planning. There are, however, some applications that are typical for many supply chain planning environments [137, p: 249]. Within the supply chain contract context, these include demand planning, production planning, inventory and requirements planning, and transportation planning.

#### **5.3.2.1 Demand Planning**

The increasing complexity of product offerings and marketing tactics in conjunction with shorter product life cycles requires more accuracy, flexibility, and consistency in

determining inventory requirements. Demand planning APS systems attempt to provide such capabilities and should be utilized in supply chain contracts.

Demand planning develops the forecast that drives anticipatory supply chain processes. The forecasts are the projections of monthly, weekly, or even daily demand that determine production and inventory requirements. Each projected quantity might include, based on supply chain price sensitive quantity flexible contracts developed in Chapter 7, some portion of future orders placed in anticipation of customer demand along with some portion of forecasted demand based on history. Essentially, the demand planning process integrates historically based forecasts with other information regarding events that could influence future sales activities (e.g., promotional plans, pricing changes, and new product introductions) to obtain the best possible integrated statement or requirements. Thus, price sensitive quantity flexible contracts, once again, can be the major drivers.

Another aspect of the demand planning process focuses on creating forecast consistency across multiple products and distribution facilities. Effective integrated management requires accurate forecasts for each item and distribution facility. The aggregate and combined requirements should reflect a plan which is consistent with overall sales and financial projections anticipated in supply chain contracts.

### **5.3.2.2 Production Planning**

Production planning uses the statement of requirements obtained from demand planning in conjunction with manufacturing resources and constraints to develop a workable manufacturing plan. The statement of requirements defines the items that need to be produced and the time they will be needed. The limitations occur in the form of facility equipment and labor availability.

Production planning APS matches the requirements plan with the production and supply chain contracts constraints, the objective being to satisfy the necessary requirements at the minimum total production cost while not violating any constraints. Effective production planning results in a time sequenced plan to manufacture the correct items in a timely manner while operating within facility, equipment, labor, and contracts constraints.



### **5.3.2.3 Requirements Planning**

Requirements planning APS extends the planning process beyond the plant walls. While it is important to achieve economical plant performance, effective supply chain management requires consideration of the impact production decisions have on downstream performance. For example, production plan may suggest a long run of a single item. This will build up finished inventory requiring storage and transport capacity. While such long manufacturing runs might minimize manufacturing cost, overall system performance might be better served, within the supply chain contracts, with shorter runs resulting in less storage and transport requirements. The requirements planning APS uses evaluative techniques to trade-offs the costs of production, storage, and transportation for different supply chain contracts. The analysis attempts to satisfy customer demand, minimize overall cost, thus maximize overall supply chain surplus.

### **5.3.2.4 Transportation Planning**

Another APS application focuses on transportation planning. Historically, purchasing and finished goods transportation both attempted to minimize their freight cost individually. Procurement minimized the expense of raw material movement by working with suppliers and inbound carriers. Logistics focused on minimizing outbound freight expense by working with customers and their transportation carriers. The individual perspectives of transportation often resulted in limited economies of scale, limited information sharing, and excessive transportation expenses.

Transportation APS integrates transportation requirements, transportation resources, and relevant costs into a common tactical decision support system that seeks to minimize overall freight expense. The analysis suggests ways that freight, again within the supply chain contracts constraints, can be shifted among carriers or consolidated to achieve scale economies. It also facilitates information sharing within the supply chain to enable better asset utilization.

## **5.3.3 APS System Components**

While there are many conceptual approaches to designing APS, the major components are fundamentally the same: demand management, resource management, resource optimization, and resource allocation [137, p: 255].

### **5.3.3.1 Demand Management**

An APS demand management module develops the supply chain contract requirement projections for the planning horizon. In effect, it generates the sales forecasts based on sales history, currently scheduled orders, scheduled marketing activities, and customer information. It thus ideally works collaboratively and interactively both internally across the functional components of the organization and externally with supply chain partners to develop a common and consistent forecast for each time period, location, and item. The forecast should also incorporate feedback from customers to integrate the influence of combined demand generation activities such as advertising, promotion, and new product introduction.

### **5.3.3.2 Resource Management**

APS resource management module coordinates and records supply chain system resources and constraints. Because APS systems use the resource and constraint information to evaluate the trade-offs associated with supply chain decisions, information accuracy and integrity are critical to provide optimal decisions required by the supply chain contracts and enhance planning system credibility.

In addition to the requirements definition developed by the demand management module, APS requires product and customer definitions, resource definitions and costs, system constraints, and planning objective function.

The product and customer definitions provide the constants regarding the products and customers to support the planning process. The product definitions provide the product descriptions and physical characteristics, such as weight and volume, standard costs, and bill of material. The customer definitions provide the ship to location and distribution assignments, along with special service requirements. The combination of both defines what is being manufactured, distributed, where it is being delivered, and the performance cycles involved in distribution.

The resource definitions specify the physical resources used to accomplish supply chain activities such as manufacturing, storage, and movement. The resources include manufacturing equipment and process rates, storages facilities, and transportation equipment and availability. In addition to defining the existence of specific resources, the database must include the cost and performance characteristics and costs associated with resource usage.

System limitations define the major constraints limiting supply chain activities, including the capacity limitations associated with production, storage, and movement. Production capacity defines how much product can be manufactured within a specific time period and what are the trade-offs associated with making various quantity flexible products. Storage capacity defines the amount of product that can be stored in a specific facility. Movement capacity defines the volume of product that can be transported between facilities or to customers within a time period.

The planning objective function defines criteria for developing a planning solution. Typical objective functions include minimizing total cost subject to meeting all requirements or minimizing the number of instances when capacity is exceeded.

This combination of information provides the basis for the APS analysis. The module includes the database to store the definitions, resources, constraints, and objectives as well as the processes to effectively validate and maintain integrated, accurate and consistent data.

#### **5.3.3.3 Resource Optimization**

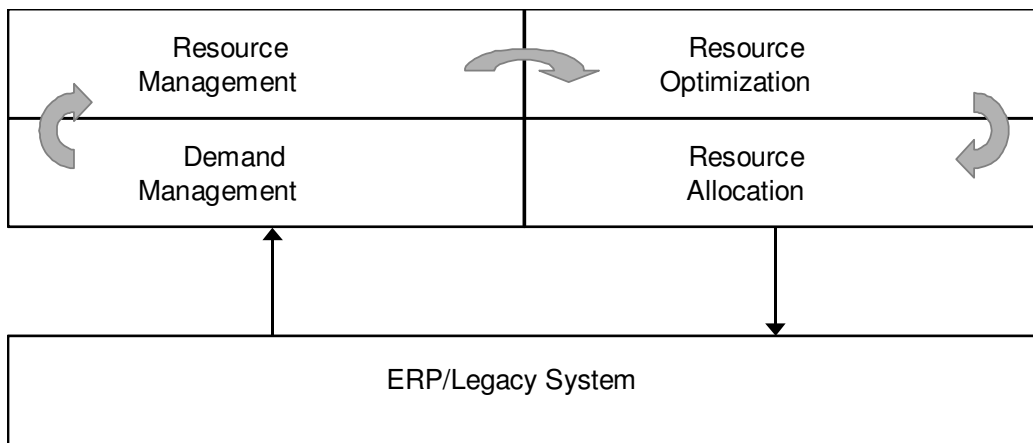
The resource optimization module is the computational engine of any APS system. Using the requirements from the demand management module and the definitions, resources, limitations, and objectives from the resource management module, resource optimization uses a combination of mathematical programming and heuristics to determine how to best meet customer requirements while utilizing resources most effectively. The resource optimization module also determines when requirements cannot be met and which resources are the most limiting on supply chain performance. The resource optimization module output is a supply chain plan projected into future time periods that minimizes overall costs while attempting to operate within major constraints. The plan specifies which products should be produced when and where and determines movement and storage requirements across the supply chain.

The resource optimization module can also be used to conduct sensitivity or what-if analysis, as we will demonstrate in Chapter 7, to determine the impact of changes in market requirements or assumptions as well as in supply chain contracts. These analyses allow the supply chain planner to isolate the impact of demand and performance uncertainty on supply chain capabilities and operations imposed by

price sensitive quantity flexible contracts. Using the insight regarding the trade-offs and the impact of uncertainty, the APS resource optimization module guides the planners in establishing the most effective supply chain contracts.

#### 5.3.3.4 Resource Allocation

APS resource allocation module refines the resource assignments and communicates with the ERP module to initiate appropriate transactions. The results include requirements for procurement, production, storage, and transport. Figure 5.1 [137, p: 255] illustrates how APS modules relate to each other and to the ERP or legacy system.



**Figure 5.1:** ASP System Modules

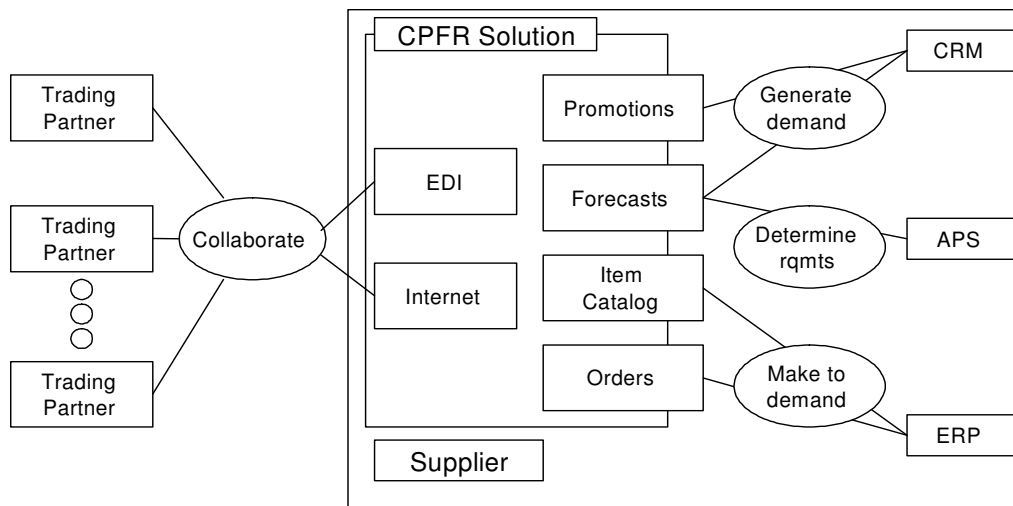
The resource allocation module also provides information regarding when products are available to promise (ATP) or capable to promise (CTP). ATP is used to designate that even though actual inventory is not currently available, it will be available for shipment at a specific date in the future. In effect, the ATP designation allows firms to commit scheduled production to customers. CTP is used to designate when requested product can be promised for future delivery. CTP requires a much broader analysis as it determines whether there is future specific capacity or capability, given current and projected supply chain demands, and therefore should be used in any supply chain quantity flexible contracts.

#### 5.3.4 Collaborative Planning, Forecasting, and Replenishment (CPFR)

Collaborative Planning, Forecasting, and Replenishment (CPFR) is a process initiated by the customer products industry to achieve coordination through the supply chain and is an integral part of any supply chain contract. In essence, CPFR

coordinates the requirements plan for the demand creation and demand fulfillment activities. The CPFR solution shares information involving promotions, forecasts, item data, and orders with trading partners. The collaboratively developed information is then used jointly and iteratively by planners to generate demand, determine replenishment requirements, match production to demands, and refine supply chain contracts.

The first step in the CPFR process is joint business planning wherein a retailer and supplier share, discuss, coordinate, and rationalize their own individual strategies to create a partnership strategy, thus a supply chain contract. A common sales forecast is created and shared between retailer and supplier based on shared knowledge. CPFR includes an iterative process until a consensus is reached. In Chapter 7, we also developed profit sharing solutions related to the sharing of the additional supply chain profit thus generated. Using this consensus forecast, production, replenishment, and shipment plans are developed. The forecast becomes a commitment by the trading partners in terms of supply chain contracts. Besides, these alliances and partnerships create long term relationships between supply chain partners. Figure 5.2 [137, p: 271] illustrates base CPFR relationships within the supply chain.



**Figure 5.2: CPFR**  
Collaborative Planning, Forecasting, and Replenishment

### **5.3.5 APS Benefits and Considerations within the Supply Chain Contracts Context**

From a supply chain contracts point of view, especially for the price sensitive quantity flexible model we developed in Chapter 7, there are three broad benefits that accrue from APS utilization. These include responsiveness to changes, comprehensive perspective, and resource utilization.

Historically, logistics and supply chain managers have used extended lead times and schedule freezes to plan for future supply chain activity. The long lead times and freeze periods were necessary since the planning process was complex and required substantial analyses. The plans had to be defined early and then frozen to allow the firm time to execute them. While this approach reduced uncertainty, it also substantially reduced flexibility and responsiveness, thus reducing the supply chain surplus.

Today's customers requires more responsiveness to market needs, and demand for lower inventory levels rules out long cycle times. Marketplace and firm changes can be quickly made in the demand management and resource management modules, allowing for the planning process to use the most current and accurate information. The requirements optimization module, where the model we developed in Chapter 7 can be part of, then solves the allocation, allowing short term planning cycles rather than long term. APS thus results in a planning process that can be much more responsive to marketplace or firm changes.

Second, effective supply chain management requires planning and coordination across the supply chain. The process must consider the trade-offs associated with shifting activities, resources, and inventories across organizations. Such a comprehensive perspective increases planning process complexity substantially. The complexity follows from the number of organizations, facilities, products, and assets that must be considered when coordinating activities and resources across an entire supply chain. APS offers the capability to consider a comprehensive perspective and make the appropriate trade-offs to achieve optimal supply chain performance.

Third, APS typically results in substantial supply chain performance improvements in line with the main objective of maximizing the supply chain performance of supply chain contracts. While more comprehensive planning and reduced uncertainty usually result in improved customer service, the major APS benefit is enhanced

resource utilization and common objectives. More effective and responsive planning allows a more even assignment of requirements to existing sourcing, production, storage, and transportation capacity. The result is that existing capacity is used more effectively within the supply chain contracts constraints. APS can also significantly reduce asset requirements by smoothing resource demands. The decreases include reductions in plant, equipment, facilities, and inventory.

While comprehensive APS is a relatively new capability, the future outlook is bright as the technology and capacity to effectively evaluate and manage integrated supply chains are developed. APS can take a comprehensive and dynamic perspective of the entire supply chain and focus on maximizing the supply chain surplus. Thus, it is our belief that the models we developed in Chapter 7 can and should be an integral part of any APS system.

## **CHAPTER 6. SUPPLY CHAIN CONTRACTS AND COMMITTED DELIVERY STRATEGIES**

The strategic fit requires that a company achieve the balance between responsiveness and efficiency in its supply chain that best meets the needs of the company's competitive strategy. The drivers of supply chain performance not only determine its performance in terms of responsiveness and efficiency, they also determine whether strategic fit is achieved across the supply chain. In Chapter 4, we analyzed the impact of inventory, transportation, facilities, and information as the drivers of supply chain performance. In this chapter, we will analyze supply chain contracts and their role in maximizing the total supply chain surplus.

Contracts specify the parameters within which a buyer places orders and a supplier fulfills them. By entering into such a contract, the buyer often stands to gain guaranteed delivery of the product, which is very useful in times of scarcity, shorter delivery times, lower purchasing price, or a lower safety stock level. The supplier will also benefit with a better production plan, reduced variance of demand, economies of scale, or less paperwork. Harder to measure, but also important, is the increased level of trust and cooperation which can develop between a buyer and a supplier who decide to engage in such a contract.

Of particular interest here are contracts that will maximize the total supply chain surplus.

For simplicity, our supply chain consists of a single manufacturer, a single retailer, and customers. Transportation costs are included in the wholesale price of the product, which is assumed at maturity phase of its product life cycle with a normally distributed constant/horizontal demand pattern. The models can be extended to more complex supply chains, and/or different demand patterns at different phases of the product's life cycle.

This chapter is organized as follows:

In Sections 6.1 and 6.2, we consider a commitment model for a retailer facing price-sensitive demand and given the opportunity to receive a discount on committed



deliveries by using a standard economic model addressed by Lau and Lau [65] and Thomas [67] that can be viewed as a newsvendor style model. The strength of the model is the inclusion of demand as a function of the selling price. However, the model is restricted with the intracompany scope maximizing only the retailer's profit without taking into account the total supply chain profit.

In Sections 6.3 to 6.6, we address this weakness of intracompany approach by introducing the total supply chain surplus with intercompany view, which requires that both the manufacturer and the retailer evaluate their actions in the context of the entire supply chain using buyback and quantity flexibility contracts modeled by Chopra and Meindl [2]. The strength of this model is that both buyback and quantity flexibility contracts help increase the total supply chain profit. However, there are two issues that need to be addressed. The first one is related to profit sharing, i.e., how to share the additional supply chain surplus thus generated. The second issue, the main weakness of the contracts discussed, is the fact that demand has not been correlated to the selling price.

We have used Excel Statistical Functions to evaluate normal distribution functions used in our numerical experiments. These functions, described in Appendix A, are then used in a computer program we compiled to find optimum contract parameters for the model we develop in Chapter 7.

### **6.1 Retailer Profit without Commitment Opportunity with Demand as a Function of the Selling Price**

Without the opportunity to obtain a discount for commitment, a retailer will seek to maximize its expected profit  $\pi(p)$  where  $p$  is the selling price set by the retailer,  $c$  is the total unit cost (including transportation) and  $\mu(p)$  is the expected demand as a function of the selling price. It is assumed that a lower price generates greater demand so that  $\mu'(p) < 0$  and there is no fixed ordering cost. Furthermore, it is also assumed that the retailer can order any quantity any time during the horizon and there is no lead time for delivery. The retailer seeks to maximize its expected profit:

$$\max_p \pi(p) = (p - c) \mu(p) \tag{6.1}$$

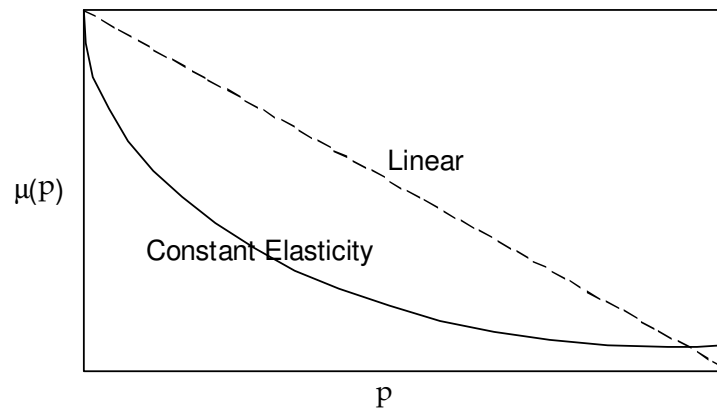
Demand functions considered are linear (6.2) and constant elasticity (6.3) demand functions shown in Figure 6.1 [67].

$$\mu(p) = d(a - p) / b \quad : a - b \leq p \leq a \quad (6.2)$$

$$\mu(p) = dp^{-\varepsilon} \quad : p \geq 0, \varepsilon > 1 \quad (6.3)$$

For the linear form,  $d$  is a scale value representing the size of the market. For  $p$  in the specified range,  $(a - p) / b$  will be between zero and one and represents the retailer's market share. The elasticity of demand measures the percentage increase in demand for a 1% increase in price and is formally defined as:

$$\varepsilon_{\mu}(p) = p\mu'(p) / \mu(p) \quad (6.4)$$



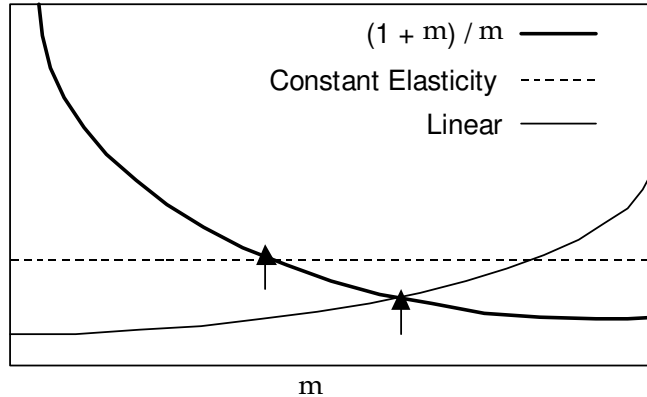
**Figure 6.1:** Linear and Constant Elasticity Demand Functions

Let  $m$  to be the percentage markup,  $p = c(1 + m)$ . Then, the necessary and sufficient conditions for a unique optimal price can be characterized in terms of the markup  $m$  and the elasticity  $\varepsilon_{\mu}[c(1 + m)]$ . The first order optimality condition implies that  $\mu(p^*) + (p^* - c) \mu'(p^*) = 0$ , which after algebraic manipulations becomes [67]:

$$(1 + m^*) / m^* = - \varepsilon_{\mu}[c(1 + m^*)] \quad (6.5)$$

For a constant elasticity mean demand function, the right hand side of Equation (6.5) is a constant greater than 1. For any constant elasticity mean demand function there is a unique optimal price. For general demand functions, the necessary and sufficient condition for a unique optimal price is that the elasticity, as a function of the markup, is bounded and crosses the function  $f(m) = (1 + m) / m$  only once.

This necessary and sufficient condition is graphically represented in Figure 6.2 [67] for both a constant elasticity mean demand function and a linear mean demand function that satisfies the condition for a unique optimal price.



**Figure 6.2:** Conditions for Unique Optimal Price

The optimal prices, markups, and corresponding profits for the mean demand functions are shown in Table 6.1 [67]. For the two demand functions considered here, it is clear that a reduction in the unit cost results in a reduction in the optimal price. In other words, a reduction in cost cannot result in an increase in the optimal price for any non-increasing expected demand function.

**Table 6.1:** Optimal Prices and Profits

$\mu(p)$	$p^*$	$m^*$	$\pi^*$
$dp^{-\epsilon}$	$c\epsilon / (\epsilon - 1)$	$1 / (\epsilon - 1)$	$(d/\epsilon) [c\epsilon / (\epsilon - 1)]^{1-\epsilon}$
$d(a - p) / b$	$(a + c) / 2$	$[(a + c) / 2c] - 1$	$d(a - c)^2 / 4b$

As it can also be observed from Table 6.2, when there is no reduction in unit cost, the optimal price and profit remains the same for a linear elasticity function. The same is also true for a constant elasticity function. Therefore, there may not be any incentive for the retailer to increase the demand by decreasing the selling price. This is the main weakness of the model since it is restricted with the Intracompany Interfunctional Scope: The Maximize Company Profit View.

**Table 6.2: Optimal Prices and Profits**  
 $d = 1500, a = 300, b = 150, c = 100$

P (\$)	c (\$)	$\mu(p)$	$p^*$ (\$)	$m^*$	$\pi^*$ (\$)
180	100	1,200	200	1.00	100,000
190	100	1,100	200	1.00	100,000
200	100	1,000	200	1.00	100,000
210	100	900	200	1.00	100,000
220	100	800	200	1.00	100,000

In order to maximize the supply chain surplus, Intercompany Interfunctional Scope: The Maximize Supply Chain Surplus View needs to be implemented. Table 6.3 shows the effect of reduction in unit cost on retailer's optimal prices and profits for the same demand level. Although not shown explicitly in the table, it is clear that the manufacturer can increase/decrease its own profit by decreasing/increasing the unit price it charges to the retailer. The question is how to balance retailer's and manufacturer's profits in order to achieve maximum supply chain surplus. Committed deliveries can help achieve this objective.

**Table 6.3: Optimal Prices and Profits**  
 $d = 1500, a = 300, b = 150, p = 200$

P (\$)	c (\$)	$\mu(p)$	$p^*$ (\$)	$m^*$	$\pi^*$ (\$)
200	80	1,000	190	1.38	121,000
200	90	1,000	195	1.17	110,250
200	100	1,000	200	1.00	100,000
200	110	1,000	205	0.86	90,250
200	120	1,000	210	0.75	81,000

## 6.2 Retailer Profit with Commitment Opportunity with Demand as a Function of the Selling Price

As discussed in Section 6.1, without the opportunity to obtain a discount for commitment, a retailer will seek to maximize its expected profit  $\pi(p)$  where  $p$  is the selling price set by the retailer,  $c$  is the total unit cost (including transportation) and  $\mu(p)$  is the expected demand as a function of the selling price. We now return back to analyze the impact of committing periodic deliveries over some finite horizon.

By accepting periodic deliveries, the retailer permits the manufacturer and transportation provider to efficiently utilize their resources. In exchange for absorbing this variability, the manufacturer offers a percentage discount  $\delta$  for these committed deliveries. The manufacturer and the retailer jointly choose a total commitment quantity  $Q$  at unit cost  $c(1 - \delta)$ . The retailer may still place supplemental orders at any time during the horizon at unit cost  $c$ . We assume that both committed supply and demand occur at a constant rate during the horizon.

Let  $(x)^+ = \max(x, 0)$ . Under the constant rate assumption, the number of supplemental orders is equal to the demand minus committed supply  $(D - Q)^+$ , and the average inventory is equal to committed supply minus demand divided by two,  $(Q - D)^+ / 2$ . Furthermore, let  $h'$  be the fractional holding cost rate and  $s$  the fractional salvage value. It follows that the understock cost is the supplemental ordering cost  $\delta$  and the overstock cost is  $h = (h'/2) + (c - s)$ .

Using  $f_S(\cdot)$  as the standard normal density function and  $F_S(\cdot)$  as the standard normal cumulative distribution function for demand, the retailer seeks to maximize its expected profit:

$$\max_p \pi(p) = [p - c(1 - \delta)] \mu(p) - c(\delta + h) f_S[F_S^{-1}[\delta / (\delta + h)]] \sigma(p)$$

Let  $k(p) = \sigma(p) / \mu(p)$  denote the coefficient of variation of demand. Furthermore, let  $\delta'(p) = \delta - (\delta + h) F_S^{-1}[\delta / (\delta + h)] k(p)$ . This term can be viewed as effective discount which incorporates the fact that while some units are purchased at the reduced price  $c(1 - \delta)$ , some will still be purchased at the regular price  $c$ .

Therefore, Equation (6.1) where, without the opportunity to obtain a discount for commitment, a retailer seeks to maximize its expected profit  $\pi(p)$ :

$$\max_p \pi(p) = (p - c) \mu(p)$$

can be written with commitment opportunity as [67]:

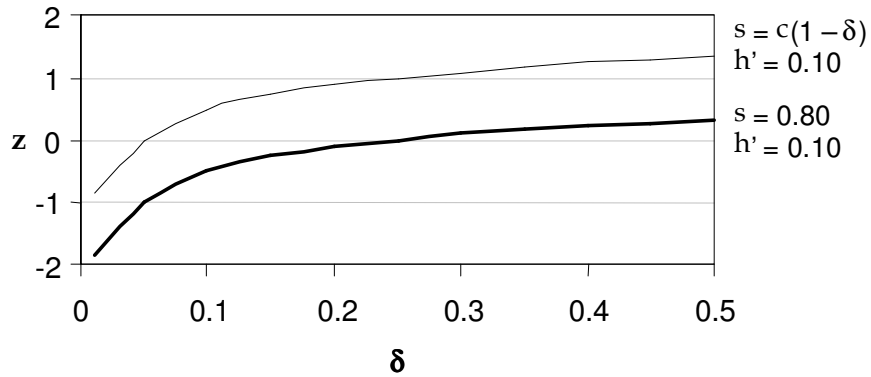
$$\max_p \pi(p) = [p - c[1 - \delta'(p)]] \mu(p) \quad (6.6)$$

As it can be observed, commitment will increase expected overstock costs since flexibility in ordering is reduced, in other words,  $\delta'(p) < \delta$ . Also, the effective per unit cost falls out even though the discount  $\delta$  is only given on committed purchases. Either  $\delta' > 0$  or the retailer is better off not committing.

Commitment strategies can offer market opportunities by contributing to the profit improvement in two ways: reduction in effective unit cost and improved pricing. However, it is still restricted with the Intracompany Interfunctional Scope: The Maximize Company Profit View.

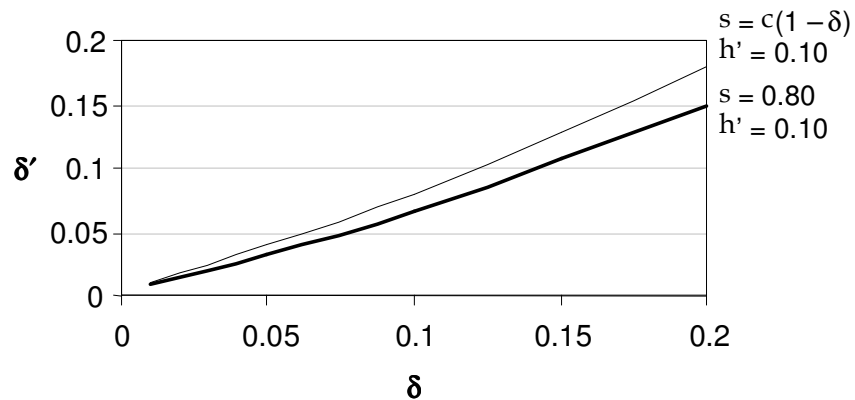
### 6.2.1 Pricing and Profit Implications of Committed Delivery Strategies

In this section, commitment and pricing decisions associated with different committed delivery strategies are compared [67]. Constant elasticity expected demand function  $\mu(p) = dp^{-\epsilon}$  with coefficient of variation = 0.3 is used in calculations performed using Excel. Two cases are considered. In the first case, it is assumed that the units are fully salvageable at the discounted unit cost  $s = c(1 - \delta)$  and that the fractional holding cost rate is  $h' = 0.10$ . Second case is for  $s = 0.80$ , and  $h' = 0.10$ . Figure 6.3 shows the standard commitment level  $z$  as a function of  $\delta$  where  $z$  denotes the optimal fractile of demand,  $z = F_S^{-1}[\delta / (\delta + h)]$ .



**Figure 6.3:** Standardized Commitment Levels

Figure 6.4 shows the effective discounts at the  $z$ -value for the same two cases.



**Figure 6.4:** Effective Discount

### 6.3 Retailer Profit without Commitment Opportunity with Normally Distributed Demand

Again, without the opportunity to obtain a discount for commitment and given that there is a lead time for delivery, the retailer will seek to evaluate its level of product availability in terms of optimal order size that maximizes profit. Here we first assume that the demand is a continuous non-negative random variable with density function  $f(x)$  and cumulative distribution function  $F(x)$ . We will then analyze the specific case where  $x$  is normally distributed with a mean  $\mu$  and standard deviation  $\sigma$ . Furthermore, let  $p$  the selling price,  $c$  the total unit cost, and  $s$  the salvage value for unsold units.

Assume that  $Q$  units are purchased and a demand of  $x$  units arises. If  $Q < x$ , all  $Q$  units are sold and a profit of  $Q(p - c)$  results. However, if  $Q > x$ , only  $x$  units are sold and a profit of  $x(p - c) - (Q - x)(c - s)$  results. The expected profit  $\pi(Q)$  is given as:

$$\pi(Q) = \int_0^Q [x(p - c) - (Q - x)(c - s)] f(x) dx + \int_Q^{\infty} [Q(p - c)] f(x) dx \quad (6.7)$$

To determine the value of  $Q$  that maximizes  $\pi(Q)$ :

$$d\pi(Q) / dQ = -(c - s) \int_0^Q f(x) dx + (p - c) \int_Q^{\infty} f(x) dx = (p - c) [1 - F(Q)] - (c - s) F(Q) = 0$$

This implies an optimal order size  $Q^*$  where [2, p: 252]:

$$F(Q^*) = (p - c) / [(p - c) + (c - s)] \quad (6.8)$$

Up to this point, we assumed that the demand is a continuous non-negative random variable with density function  $f(x)$  and cumulative distribution function  $F(x)$ . We will now derive expected profit from an order as well as expected overstock and expected understock assuming that demand is normally distributed with a mean  $\mu$  and standard deviation  $\sigma$ .

### 6.3.1 Expected Profit from an Order

Equation (6.7) can be written as [2, p: 253]:

$$\pi(Q) = \int_{x=-\infty}^Q [(p - s)x - Q(c - s)] f(x) dx + \int_{x=Q}^{\infty} [Q(p - c)] f(x) dx$$

Substituting for normal distribution with where  $f_S(\cdot)$  is the standard normal density function and  $F_S(\cdot)$  is the standard normal cumulative distribution function, the expected profit  $\pi(Q)$  becomes:

$$\pi(Q) = (p - s) \mu F_S[(Q - \mu) / \sigma] - (p - s) \sigma f_S[(Q - \mu) / \sigma] - Q(c - s) F(Q, \mu, \sigma) + Q(p - c) [1 - F(Q, \mu, \sigma)] \quad (6.9)$$



### 6.3.2 Expected Overstock from an Order

If  $Q$  units are ordered, an overstock results only if demand  $x < Q$ . We thus, for a normally distributed demand, have [2, p: 254]:

$$\text{Expected overstock} = QF_S[(Q - \mu) / \sigma] - \mu F_S[(Q - \mu) / \sigma] + \sigma f_S [(Q - \mu) / \sigma]$$

which, after algebraic manipulations becomes:

$$\text{Expected overstock} = (Q - \mu) F_S[(Q - \mu) / \sigma] + \sigma f_S[(Q - \mu) / \sigma] \quad (6.10)$$

### 6.3.3 Expected Understock from an Order

If  $Q$  units are ordered, an understock results only if demand  $x > Q$ . We thus, for a normally distributed demand, have [2, p: 255]:

$$\text{Expected understock} = (\mu - Q) + QF_S[(Q - \mu) / \sigma] - \mu F_S[(Q - \mu) / \sigma] + \sigma f_S[(Q - \mu) / \sigma]$$

which, after algebraic manipulations becomes:

$$\text{Expected understock} = (\mu - Q) [ 1 - F_S[(Q - \mu) / \sigma] ] + \sigma f_S[(Q - \mu) / \sigma] \quad (6.11)$$

## 6.4 Supply Chain Surplus

In sections 6.1, 6.2 and 6.3 we have seen how to maximize the retailer profit in isolation from the rest of the supply chain, i.e., within the Intracompany Interfunctional Scope: The Maximize Company Profit View. The Intracompany Interfunctional scope leads to each stage of the supply chain trying to maximize its own profits, which does not necessarily result in the maximization of supply chain surplus. Supply chain surplus is maximized only when all supply chain stages coordinate strategy together [146-152].

Consider a supply chain consisting of one manufacturer and one retailer. To simplify the discussion, assume that the product is seasonal and exclusively sold through the retailer. Each product costs  $v = \$10$  to produce, including transportation, and the manufacturer plans to charge a wholesale price  $c = \$100$  per unit. The retailer plans to sell the product for a price  $p = \$200$ . At this price, the retailer estimates the demand to be normally distributed with a mean of  $\mu = 1,000$  and a standard

deviation of  $\sigma = 300$ . Also assume that the retailer is unable to salvage anything for unsold products, resulting in a salvage value of  $s = \$0$ .

Using Equation (6.8), the retailer finds it optimal to order 1,000 units. Equation (6.9) evaluates expected profit to be \$76,063. In this case, the manufacturer sells 1,000 units for a total profit of \$90,000. Therefore, the total expected supply chain profit is \$166,063.

Now consider the intercompany view which requires that each company evaluate its actions in the context of the entire supply chain. The supply chain makes \$190 for each unit of product sold. From the perspective of the entire supply chain, the cost of understocking is \$190 and the cost of overstocking is \$10. It is thus optimal for the supply chain, using the same equations, to produce 1,493 units resulting in a total expected supply chain profit of \$183,812.

The gap in profit exists because of double marginalization. Each party makes decisions considering only a portion of the total supply chain [2, p: 243].

## 6.5 Buyback Contracts

We next consider how the manufacturer can offer buyback contracts to induce the retailer to order quantities that increase the total supply chain profit. A manufacturer can increase the quantity the retailer purchases by offering to buy back any leftover units at the end of the season at a fraction of the purchase price. The action has the effect of increasing the salvage value per unit for the retailer who, as a result, increases its order size. The manufacturer may benefit by taking on some of the cost of overstocking because the supply chain will, on average, end up selling more products [153, 154].

In a buyback contract, the manufacturer specifies a wholesale price  $c$  along with a buyback price  $b$  at which retailer can return any unsold units. In this scenario, the salvage value for the retailer becomes  $s = b$  and the manufacturer has also a different salvage value  $w$  for the units returned from the retailer [2, p: 243-244]. Again, the optimal order quantity and the expected retailer profit can be evaluated using Equations (6.8) and (6.9) where the salvage value for the retailer is  $s = b$  and the salvage value for the manufacturer is nil. The expected profit at the manufacturer depends on the overstock at the retailer evaluated using Equation (6.10) and can be expressed as:

Expected manufacturing profit =  $Q^* (c - v) - b(\text{expected overstock at retailer})$

Table 6.4 provides the outcome obtained using Excel for different buyback contracts that the manufacturer offers the retailer. Again, each product costs  $v = \$10$  to produce and the sale price  $p$  of a unit of product is \$200. Demand at this price is assumed to be normally distributed with a mean of  $\mu = 1,000$  and a standard deviation of  $\sigma = 300$ . At this stage, we also assume that there is no transportation or other cost associated with any returns. Table 6.4 shows that a buyback contract allows both the manufacturer and the retailer to increase their profits by increasing total supply chain profits by about 10%. In many instances, buyback contracts can be used to increase total supply chain profit. In general, it is optimal for the manufacturer to offer to buy back at a fraction of the wholesale price. An alternative way to buyback contracts is the use of holding cost subsidies [155-157] where manufacturers pay retailers a certain amount for every unit held in inventory.

**Table 6.4:** Order Sizes and Profits at the Manufacturer and the Retailer Under Different Buyback Contracts

Wholesale Price (\$)	Buyback Price (\$)	Optimal Order Size	Expected Profit (Retailer) (\$)	Expected Returns	Expected Profit (Man.) (\$)	Expected Supply Chain Profit (\$)
100	0	1,000	76,063	120	90,000	166,063
100	30	1,067	80,154	156	91,338	171,492
100	60	1,170	85,724	223	91,886	177,610
<b>100</b>	<b>95</b>	<b>1,501</b>	<b>96,875</b>	<b>506</b>	<b>86,935</b>	<b>183,810</b>
110	50	1,076	72,615	162	99,525	172,140
110	100	1,384	84,735	399	98,580	183,315
<b>110</b>	<b>105</b>	<b>1,486</b>	<b>86,938</b>	<b>493</b>	<b>96,872</b>	<b>183,810</b>
120	75	1,108	65,971	181	108,250	174,220
120	100	1,252	71,601	286	109,176	180,777
<b>120</b>	<b>116</b>	<b>1,501</b>	<b>77,500</b>	<b>506</b>	<b>106,310</b>	<b>183,810</b>

From Table 6.4, it can also be observed that increasing the buyback price always increases retailer profits and may also increase manufacturer profits. Also, the manufacturers can increase their profits by increasing the buyback price by a larger amount than they increase the wholesale price. As an example, the manufacturer makes a higher profit with a wholesale price of \$110 and a buyback price of \$100 than it does with a wholesale price of \$100 and a buyback price of \$60.

It can also be observed that as the wholesale price increases, it is optimal for the manufacturer to increase the buyback price as well. Another observation is that for a fixed wholesale price, as the buyback price increases, the retailer orders more and also returns more. Consequently, as the cost associated with returns increases, buyback contracts become less attractive because the cost of returns reduces supply chain profits. In this situation, holding cost subsidies can be used as an alternative to buyback contracts with similar outcomes.

## 6.6 Quantity Flexibility Contracts

In quantity flexibility contracts, the manufacturer allows the retailer to change the quantity ordered after observing demand. If a retailer orders  $Q$  units, the manufacturer commits to providing  $Q^+ = (1 + \alpha)Q$  units, and the retailer is committed to buying at least  $Q^- = (1 - \beta)Q$  units. Both  $\alpha$  and  $\beta$  are between 0 and 1. The retailer can purchase up to  $Q^+$  units depending on the demand observed. These contracts are similar to buyback contracts in that the manufacturer now bears some of the risk of having excess inventory. Because no returns are required, these contracts can be more effective than buyback contracts when the cost of returns is high. Quantity flexibility contracts increase the average amount the retailer purchases and may increase total supply chain profits [2, p: 245-246].

As in previous discussions, let  $v$  the unit production cost,  $c$  the unit wholesale price,  $p$  the unit selling price,  $s$  the retailer salvage value, and  $w$  the manufacturer salvage value. The manufacturer produces  $Q^+$  units and the retailer purchases  $Q^-$  units if demand  $D$  is less than  $Q^-$ ,  $D$  units if demand  $D$  is between  $Q^-$  and  $Q^+$ , and  $Q^+$  units if demand  $D$  is greater than  $Q^+$ . We thus obtain:

Expected quantity purchased by retailer:

$$Q = Q^- F(Q^-) + Q^+ [1 - F(Q^+)] + \mu [F_s[(Q^+ - \mu) / \sigma] - F_s[(Q^- - \mu) / \sigma]] - \sigma [f_s[(Q^+ - \mu) / \sigma] - f_s[(Q^- - \mu) / \sigma]] \quad (6.12)$$

Expected quantity sold by retailer:

$$D = Q^+ [1 - F(Q^+)] + \mu F_s[(Q^+ - \mu) / \sigma] - \sigma f_s[(Q^+ - \mu) / \sigma] \quad (6.13)$$

$$\text{Expected overstock at manufacturer} = Q - D \quad (6.14)$$

$$\text{Expected retailer profit} = pD + s(Q - D) - cQ \quad (6.15)$$

$$\text{Expected manufacturer profit} = cQ + w(Q^+ - Q) - vQ^+ \quad (6.16)$$

Based on the same figures as in the previous examples and using Excel, Table 6.5 provides the impact of different quantity flexibility contracts on supply chain profitability. All contracts considered are such that the salvage value is nil at both the manufacturer and the retailer and that  $\alpha = \beta$ .

From Table 6.5 we can observe that quantity flexibility contracts allow both the manufacturer and the retailer to increase their profits. It is often in the manufacturer's best interest to offer a quantity flexibility contract to the retailer. As an example, for the wholesale price of \$100, the manufacturer increases its own profits by offering a quantity flexibility contract where  $\alpha$  and  $\beta$  are equal to 0.2. Total supply chain profits also increase with quantity flexibility. As the manufacturer increases the wholesale price, it is optimal to offer greater quantity flexibility to the retailer.

Vendor-managed Inventories (VMI) is another approach to move the control of the replenishment decision from the retailer to the manufacturer. VMI can allow a manufacturer to increase its profits as well as profits for the entire supply chain by mitigating some of the effects of double marginalization.

**Table 6.5:** Order Sizes and Profits at the Manufacturer and the Retailer Under Different Quantity Flexibility Contracts

$\alpha$	$\beta$	Whole sale Price (\$)	Order Size	Expected Purchase (Retailer)	Expected Sale (Retailer)	Expected Profit (Retailer) (\$)	Expected Profit (Man.) (\$)	Expected Supply Chain Profit (\$)
0	0	100	1,000	1,000	880	76,063	90,000	166,063
0.2	0.2	100	900	944	916	88,775	83,642	172,417
0.2	0.2	100	1,000	1,000	955	90,933	88,000	178,933
0.2	0.2	100	1,100	1,047	978	90,889	91,515	182,404
0.4	0.4	100	1,000	1,000	987	97,456	86,000	183,456
<b>0.6</b>	<b>0.6</b>	<b>100</b>	<b>1,000</b>	<b>1,000</b>	<b>997</b>	<b>99,491</b>	<b>84,000</b>	<b>183,491</b>
0.7	0.7	100	1,000	1,000	999	99,801	83,000	182,801
0.2	0.2	110	1,000	1,000	955	80,933	98,000	178,933
0.4	0.4	110	1,000	1,000	987	87,456	96,000	183,456
<b>0.5</b>	<b>0.5</b>	<b>110</b>	<b>1,000</b>	<b>1,000</b>	<b>994</b>	<b>88,810</b>	<b>95,000</b>	<b>183,810</b>
0.2	0.2	120	1,000	1,000	955	70,933	108,000	178,933
<b>0.4</b>	<b>0.4</b>	<b>120</b>	<b>1,000</b>	<b>1,000</b>	<b>987</b>	<b>77,456</b>	<b>106,000</b>	<b>183,456</b>

## **CHAPTER 7. PROPOSED SUPPLY CHAIN CONTRACT MODEL**

Both buyback and quantity flexibility contracts help increase the total supply chain profit. However, there are two issues that need to be addressed. The first one is related to profit sharing, i.e., how to share the additional supply chain surplus thus generated. The second issue, the main weakness of the contracts discussed, is the fact that demand has not been correlated to the selling price. In this chapter we develop “Maximize Supply Chain Profit with Buyback and Quantity Flexibility Contracts and Profit Sharing with Demand as a Function of the Selling Price Model” to address these issues.

This chapter is organized as follows:

In Section 7.1, we analyze and then propose two solutions to address the issue of profit sharing for quantity flexibility contracts.

In Section 7.2, we develop a model to address the individual weaknesses of the models discussed by incorporating the price-sensitive demand into quantity flexibility contracts to maximize the total supply chain profit: Committed Deliveries using Quantity Flexibility Contracts to Maximize Supply Chain Surplus with Demand as a Function of the Selling Price.

In Section 7.3, we also develop a computer program to help simulate the system to find optimum contract parameters for the proposed supply chain contract model. The program is given in Appendix B.

Finally, in Section 7.4, we compare the existing and proposed models and emphasize the benefits of using the supply chain contracts with a price-sensitive demand function and profit sharing as a supply chain performance driver.

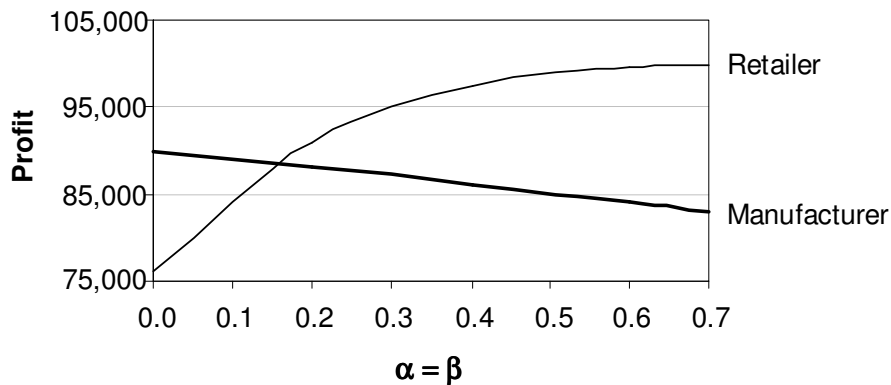
### **7.1 Profit Sharing while Maximizing the Supply Chain Surplus**

Table 7.1 partially duplicates Table 6.5 for cases where the wholesale price and order size are kept constant. As we previously observed, quantity flexibility contracts allow both the manufacturer and the retailer to increase their profits by increasing

the total supply chain surplus. However, the values of  $\alpha$  and  $\beta$  which maximize the expected supply chain profit may have an adverse affect on either the manufacturer or the retailer. As it can be observed from Table 7.1 and Figure 7.1, a quantity flexibility contract with  $\alpha$  and  $\beta = 0.6$  increases the total expected supply chain profit by more than 10%. However, the manufacturer's profit actually decreases by roughly 7% due to a much higher retailer's profit increase of 30%.

**Table 7.1:** Order Sizes and Profits at the Manufacturer and the Retailer with Constant Wholesale Price and Order Size

$\alpha$	$\beta$	Whole sale Price (\$)	Order Size	Expected Purchase (Retailer)	Expected Sale (Retailer)	Expected Profit (Retailer) (\$)	Expected Profit (Man.) (\$)	Expected Supply Chain Profit (\$)
0	0	100	1,000	1,000	880	76,063	90,000	166,063
0.2	0.2	100	1,000	1,000	955	90,933	88,000	178,933
0.4	0.4	100	1,000	1,000	987	97,456	86,000	183,456
<b>0.6</b>	<b>0.6</b>	<b>100</b>	<b>1,000</b>	<b>1,000</b>	<b>997</b>	<b>99,491</b>	<b>84,000</b>	<b>183,491</b>
0.7	0.7	100	1,000	1,000	999	99,801	83,000	182,801



**Figure 7.1:** Manufacturer and Retailer Profits

We will analyze and then evaluate two solutions to address this issue of profit sharing for quantity flexibility contracts. Our first solution will use  $\beta$  as the profit sharing parameter whereas the second solution involves the wholesale unit price the



manufacturer charges the retailer. In both cases, the selling price of the product and order size are kept constant.

### 7.1.1 Profit Sharing with $\beta$ as a Parameter

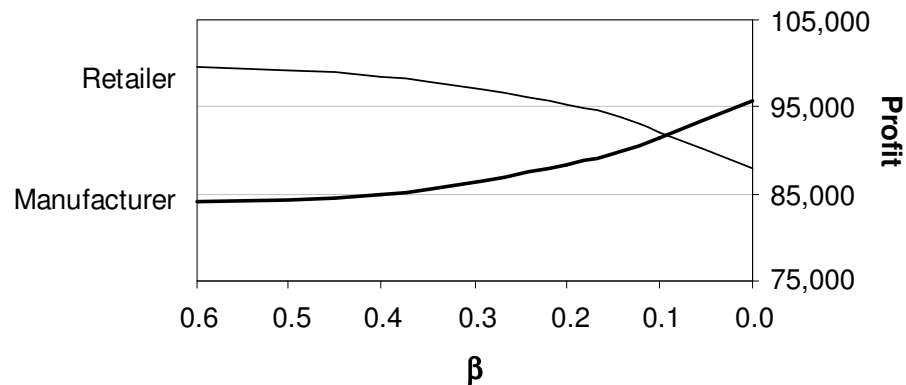
As discussed, in quantity flexibility contracts, the manufacturer allows the retailer to change the quantity ordered after observing demand. If a retailer orders  $Q$  units, the manufacturer commits to providing  $Q^+ = (1 + \alpha)Q$  units, and the retailer is committed to buying at least  $Q^- = (1 - \beta)Q$  units. Both  $\alpha$  and  $\beta$  are between 0 and 1. The retailer can purchase up to  $Q^+$  units depending on the demand observed. Quantity flexibility contracts increase the average amount the retailer purchases and may increase total supply chain profits. All contracts considered are such that the salvage value is nil at both the manufacturer and the retailer.

Since the expected quantity sold by retailer is a function of  $\alpha$  (Equation (6.13)) whereas the expected quantity purchased by retailer is a function of both  $\alpha$  and  $\beta$  (Equation (6.12)), we can move the unsold units inventory from manufacturer to retailer by decreasing  $\beta$  while keeping  $\alpha$  constant to guarantee the same total expected supply chain profit. Similarly, increasing  $\beta$  will move the unsold units from retailer to manufacturer. Therefore, using  $\beta$  as a parameter, the expected supply chain profit can be redistributed between the manufacturer and the retailer.

Table 7.2, generated using Excel, and Figure 7.2 show the impact of using  $\beta$  as a parameter on the distribution of the total expected supply chain profit. Setting  $\alpha = 0.6$  and  $\beta = 0.1$  will approximately redistribute the profit evenly between the manufacturer and the retailer. Similar approach can be used to distribute only the additional supply chain profit generated by using the quantity flexibility contract rather than distributing the total supply chain profit. The manufacturer can even guarantee a certain profit level to the retailer in exchange of freely setting  $\beta$ , i.e., moving the unsold units to the retailer. Finally, we assumed that all contracts considered are such that the salvage value is nil at both the manufacturer and the retailer. If the salvage value is different at both ends, then it has to be incorporated accordingly.

**Table 7.2:** Order Sizes and Profits at the Manufacturer and the Retailer with  $\beta$  as Profit Sharing Parameter

$\alpha$	$\beta$	Whole sale Price (\$)	Order Size	Expected Purchase (Retailer)	Expected Sale (Retailer)	Expected Profit (Retailer) (\$)	Expected Profit (Man.) (\$)	Expected Supply Chain Profit (\$)
0.6	0.6	100	1,000	1,000	997	99,491	84,000	183,491
0.6	0.4	100	1,000	1,010	997	98,473	85,017	183,491
0.6	0.2	100	1,000	1,043	997	95,212	88,279	183,491
<b>0.6</b>	<b>0.1</b>	<b>100</b>	<b>1,000</b>	<b>1,074</b>	<b>997</b>	<b>92,118</b>	<b>91,372</b>	<b>183,491</b>
0.6	0	100	1,000	1,117	997	87,777	95,714	183,491



**Figure 7.2:** Manufacturer and Retailer Profits  $\alpha = 0.6$

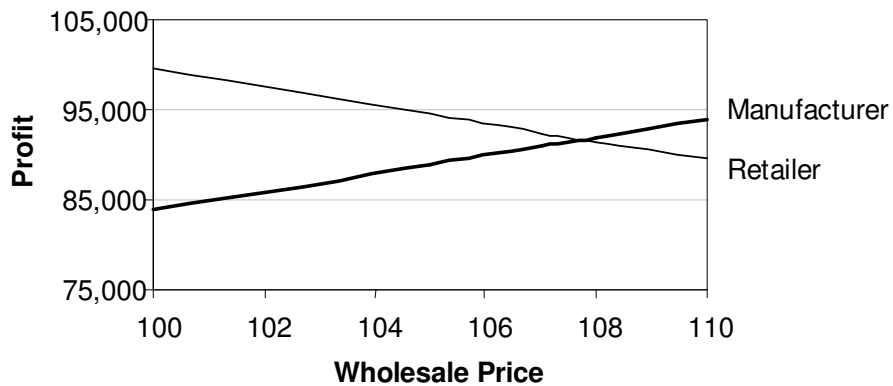
### 7.1.2 Profit Sharing with Wholesale Price as a Parameter

The use of wholesale price as a parameter can also achieve the same profit sharing objective in a similar way. Wholesale price, being an internal parameter within the manufacturing and/or replenishment cycle of the supply chain, has no effect on the total expected supply chain profit. It merely redistributes the total supply chain surplus between the manufacturer and the retailer. Table 7.3, generated using Excel, and Figure 7.3 show the impact of using the wholesale price as a parameter on the distribution of the total expected supply chain profit. Setting the wholesale price around \$108 will approximately redistribute the profit evenly between the manufacturer and the retailer. Again, similar approach can be used to distribute only

the additional supply chain profit generated by using the quantity flexibility contract rather than distributing the total supply chain profit. The manufacturer can still guarantee a certain profit level to the retailer in exchange of charging a higher wholesale price. Finally, a combination of using both  $\beta$  and the wholesale price as parameters can also achieve the desired profit sharing mechanism.

**Table 7.3:** Order Sizes and Profits at the Manufacturer and the Retailer with Wholesale Price as Profit Sharing Parameter

$\alpha$	$\beta$	Whole sale Price (\$)	Order Size	Expected Purchase (Retailer)	Expected Sale (Retailer)	Expected Profit (Retailer) (\$)	Expected Profit (Man.) (\$)	Expected Supply Chain Profit (\$)
0.6	0.6	100	1,000	1,000	997	99,491	84,000	183,491
0.6	0.6	105	1,000	1,000	997	94,491	89,000	183,491
0.6	0.6	107	1,000	1,000	997	92,491	91,000	183,491
<b>0.6</b>	<b>0.6</b>	<b>108</b>	<b>1,000</b>	<b>1,000</b>	<b>997</b>	<b>91,491</b>	<b>92,000</b>	<b>183,491</b>
0.6	0.6	110	1,000	1,000	997	89,491	94,000	183,491



**Figure 7.3:** Manufacturer and Retailer Profits  
 $\alpha = \beta = 0.6$

## 7.2 Committed Deliveries using Quantity Flexibility Contracts to Maximize Supply Chain Surplus with Demand as a Function of the Selling Price

We have so far seen that commitment strategies where demand is a function of the selling price can improve retailer's profit but are restricted with the Intracompany Interfunctional Scope: The Maximize Company Profit View. The Intracompany Interfunctional scope leads to each stage of the supply chain trying to maximize its own profits, which does not necessarily result in the maximization of supply chain surplus. Supply chain surplus is maximized only when all supply chain stages coordinate strategy together. On the other hand, we have also seen that the Intercompany Interfunctional Scope: The Maximize Supply Chain Surplus View which requires that each company evaluate its actions in the context of the entire supply chain can be achieved using buyback or quantity flexibility contracts and profit sharing where demand is normally distributed, but not a function of the selling price. Therefore both methodologies are limited in their respective scopes. Combining both methodologies, we will now develop a model for committed deliveries using quantity flexibility contracts to maximize supply chain surplus with demand as a function of the selling price.

As previously discussed, in quantity flexibility contracts, the manufacturer allows the retailer to change the quantity ordered after observing demand. If a retailer orders  $Q$  units, the manufacturer commits to providing  $Q^+ = (1 + \alpha)Q$  units, and the retailer is committed to buying at least  $Q^- = (1 - \beta)Q$  units. Both  $\alpha$  and  $\beta$  are between 0 and 1. Furthermore, let again  $v$  the unit production cost,  $c$  the unit wholesale price,  $p$  the unit selling price,  $s$  the retailer salvage value, and  $w$  the manufacturer salvage value. The manufacturer produces  $Q^+$  units and the retailer purchases  $Q^-$  units if demand  $D$  is less than  $Q^-$ ,  $D$  units if demand  $D$  is between  $Q^-$  and  $Q^+$ , and  $Q^+$  units if demand  $D$  is greater than  $Q^+$  where the demand  $D$  is a function of the selling price with linear elasticity defined as:

$$D = \mu(p) = d(a - p) / b \quad : a - b \leq p \leq a \quad (7.1)$$

We also assume that demand is again normally distributed with a mean  $\mu(p)$  and standard deviation  $\sigma(p)$ .

Substituting  $\mu(p)$  and  $\sigma(p)$  into Equations (6.12) to (6.16), we obtain:

Expected quantity purchased by retailer:

$$Q = Q^- F(Q^-) + Q^+ [1 - F(Q^+)] + \mu(p) [F_s[(Q^+ - \mu(p)) / \sigma(p)] - F_s[(Q^- - \mu(p)) / \sigma(p)]] - \sigma(p) [f_s[(Q^+ - \mu(p)) / \sigma(p)] - f_s[(Q^- - \mu(p)) / \sigma(p)]] \quad (7.2)$$

Expected quantity sold by retailer:

$$D = Q^+ [1 - F(Q^+)] + \mu(p) F_s[(Q^+ - \mu(p)) / \sigma(p)] - \sigma(p) f_s[(Q^+ - \mu(p)) / \sigma(p)] \quad (7.3)$$

$$\text{Expected overstock at manufacturer} = Q - D \quad (7.4)$$

$$\text{Expected retailer profit} = pD + s(Q - D) - cQ \quad (7.5)$$

$$\text{Expected manufacturer profit} = cQ + w(Q^+ - Q) - vQ^+ \quad (7.6)$$

Based on the same figures as in the previous examples, Tables 7.4 to 7.7, generated using Excel, show the impact of different quantity flexibility contracts on supply chain profitability where the demand is a function of the selling price. All contracts considered are such that the salvage value is nil at both the manufacturer and the retailer.

Again, let each product costs  $v = \$10$  to produce, including transportation, and the manufacturer plans to charge a wholesale price  $c = \$100$  per unit. For consistency and comparison, we will also use the same linear elasticity function parameters, i.e.,  $d = 1500$ ,  $a = 300$ ,  $b = 150$ , and for simplicity let  $\sigma(p) = 300$  constant.

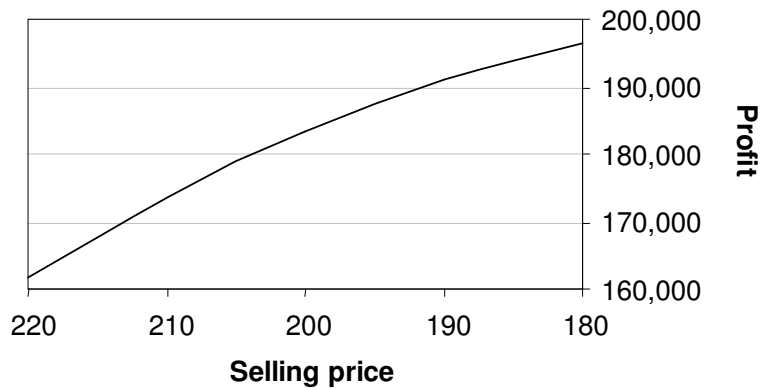
Table 7.4 and Figure 7.4 show the impact of selling price on the expected supply chain profit with  $\alpha = \beta = 0.6$  for a selling price range of \$180 to \$220.

Since demand is now treated as a function of the selling price, by lowering the selling price, the supply chain can expect a higher demand and potentially higher expected supply chain profit. Although the retailer's expected profit is maximized for a selling price of \$200 when the wholesale price is \$100 (as previously shown in Table 6.3), for the range of values considered, the supply chain's surplus is maximized when the selling price is set to \$180. The increase in expected sales (from 997 to 1,199) offsets the decrease in selling price (from \$200 to \$180) with a net increase of expected supply chain profit of approximately 7%.

Again profit sharing needs to be applied to convince the retailer to charge a lower price for the good of the entire supply chain.

**Table 7.4:** Order Sizes and Profits at the Manufacturer and the Retailer with Demand as a Function of the Selling Price  
 $\alpha = \beta = 0.6$

$\alpha$	$\beta$	Selling Price (\$)	Order Size	Expected Purchase (Retailer)	Expected Sale (Retailer)	Expected Profit (Retailer) (\$)	Expected Profit (Man.) (\$)	Expected Supply Chain Profit (\$)
<b>0.6</b>	<b>0.6</b>	<b>180</b>	<b>1,200</b>	<b>1,200</b>	<b>1,199</b>	<b>95,853</b>	<b>100,800</b>	<b>196,653</b>
0.6	0.6	190	1,100	1,100	1,099	98,721	92,400	191,121
0.6	0.6	200	1,000	1,000	997	99,491	84,000	183,491
0.6	0.6	210	900	900	896	98,101	75,600	173,701
0.6	0.6	220	800	800	793	94,466	67,200	161,666

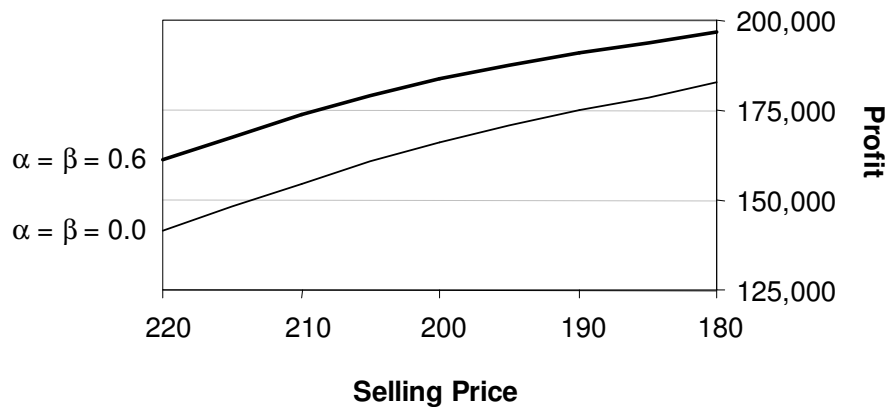


**Figure 7.4:** Supply Chain Profits  $\alpha = \beta = 0.6$

It should be emphasized that the additional supply chain surplus thus generated is not attributable only to the inclusion of demand as a function of the selling price but also to the quantity flexibility contracts as well. As it can be seen from Table 7.5 and Figure 7.5, the supply chain surplus generated is lower for all selling prices without using a quantity flexibility contract.

**Table 7.5:** Order Sizes and Profits at the Manufacturer and the Retailer with Demand as a Function of the Selling Price  
 $\alpha = \beta = 0$

$\alpha$	$\beta$	Selling Price (\$)	Order Size	Expected Purchase (Retailer)	Expected Sale (Retailer)	Expected Profit (Retailer) (\$)	Expected Profit (Man.) (\$)	Expected Supply Chain Profit (\$)
<b>0</b>	<b>0</b>	<b>180</b>	<b>1,200</b>	<b>1,200</b>	<b>1,080</b>	<b>74,457</b>	<b>108,000</b>	<b>182,457</b>
0	0	190	1,100	1,100	980	76,260	99,000	175,260
0	0	200	1,000	1,000	880	76,063	90,000	166,063
0	0	210	900	900	780	73,867	81,000	154,867
0	0	220	800	800	680	69,670	72,000	141,670

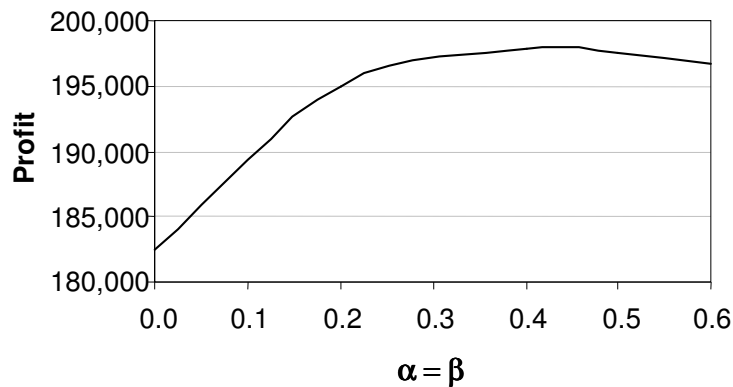


**Figure 7.5:** Supply Chain Profits with and without Contracts

For the selling price maximizing the total expected supply chain profit, quantity flexibility contracts can be further refined to increase the total supply chain surplus. This step is equivalent to using quantity flexibility contracts discussed in Section 6.6 where demand is set for a given selling price. Table 7.6 and Figure 6.10 show that, for a selling price of \$180, setting  $\alpha = \beta = 0.4$  maximizes the total expected supply chain profit.

**Table 7.6:** Order Sizes and Profits at the Manufacturer and the Retailer with Demand as a Function of Selling Price  
Selling Price = 180

$\alpha$	$\beta$	Selling Price (\$)	Order Size	Expected Purchase (Retailer)	Expected Sale (Retailer)	Expected Profit (Retailer) (\$)	Expected Profit (Man.) (\$)	Expected Supply Chain Profit (\$)
0	0	180	1,200	1,200	1,080	74,457	108,000	182,457
0.2	0.2	180	1,200	1,200	1,164	89,509	105,600	195,109
<b>0.4</b>	<b>0.4</b>	<b>180</b>	<b>1,200</b>	<b>1,200</b>	<b>1,193</b>	<b>94,745</b>	<b>103,200</b>	<b>197,945</b>
0.5	0.5	180	1,200	1,200	1,197	95,541	102,000	197,541
0.6	0.6	180	1,200	1,200	1,199	95,853	100,800	196,653



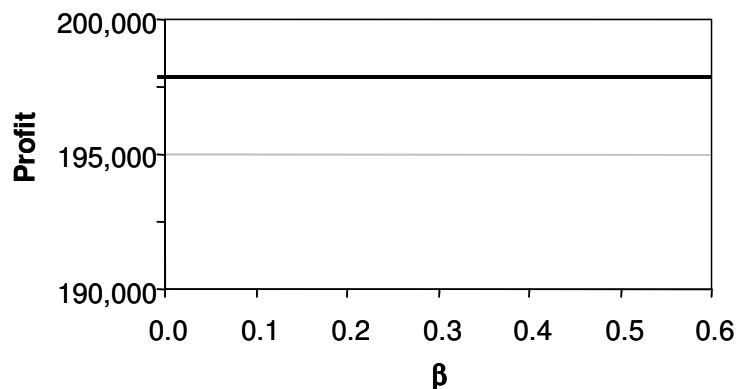
**Figure 7.6:** Supply Chain Profit  
Selling Price = 180



It should be noted that the selection of  $\alpha$  alone maximizes the expected supply chain profit since the expected quantity sold by retailer is a function of  $\alpha$  and not  $\beta$ . As it can be seen in Table 7.7 and Figure 7.7, the expected supply chain profit is constant for  $\alpha = 0.4$  regardless the value of  $\beta$ . However, since the expected quantity purchased by retailer is a function of both  $\alpha$  and  $\beta$ , we can move the unsold inventory from manufacturer to retailer by decreasing  $\beta$  while keeping  $\alpha$  constant to guarantee the same total expected supply chain profit.

**Table 7.7:** Order Sizes and Profits at the Manufacturer and the Retailer with Demand as a Function of the Selling Price and Selling Price = 180  $\alpha = 0.4$

$\alpha$	$\beta$	Selling Price (\$)	Order Size	Expected Purchase (Retailer)	Expected Sale (Retailer)	Expected Profit (Retailer) (\$)	Expected Profit (Man.) (\$)	Expected Supply Chain Profit (\$)
0.4	0.1	180	1,200	1,262	1,193	88,529	109,416	197,945
0.4	0.2	180	1,200	1,229	1,193	91,836	106,109	197,945
0.4	0.4	180	1,200	1,200	1,193	94,745	103,200	197,945
0.4	0.6	180	1,200	1,194	1,193	95,361	102,584	197,945
0.4	0.8	180	1,200	1,193	1,193	95,437	102,508	197,945

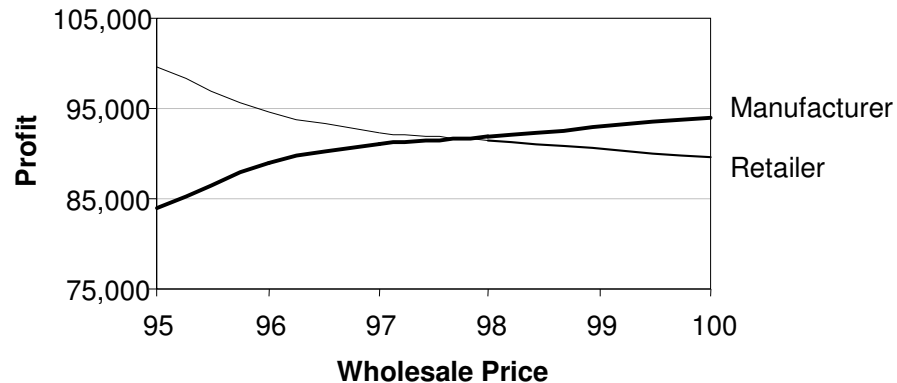


**Figure 7.7:** Supply Chain Profit Selling Price = 180  $\alpha = 0.4$

In order to compensate the retailer's profit decrease due to a lower selling price, hence a lower profit margin, profit sharing discussed in Section 6.7 needs to be applied. Table 7.8 and Figure 7.8 show the effect of using the wholesale price as profit sharing parameter. Decreasing the wholesale price the manufacturer charges the retailer from \$100 to \$96, thus increasing the retailer's profit margin, will approximately evenly distribute the total supply chain profit.

**Table 7.8:** Order Sizes and Profits at the Manufacturer and the Retailer with Demand as a Function of the Selling Price and Wholesale Price as Profit Sharing Parameter  
Selling Price = 180

$\alpha$	$\beta$	Whole sale Price (\$)	Order Size	Expected Purchase (Retailer)	Expected Sale (Retailer)	Expected Profit (Retailer) (\$)	Expected Profit (Man.) (\$)	Expected Supply Chain Profit (\$)
0.4	0.4	95	1,200	1,200	1,193	100,745	97,200	197,945
<b>0.4</b>	<b>0.4</b>	<b>96</b>	<b>1,200</b>	<b>1,200</b>	<b>1,193</b>	<b>99,545</b>	<b>98,400</b>	<b>197,945</b>
0.4	0.4	97	1,200	1,200	1,193	98,345	99,600	197,945
0.4	0.4	98	1,200	1,200	1,193	97,145	100,800	197,945
0.4	0.4	100	1,200	1,200	1,193	94,745	103,200	197,945

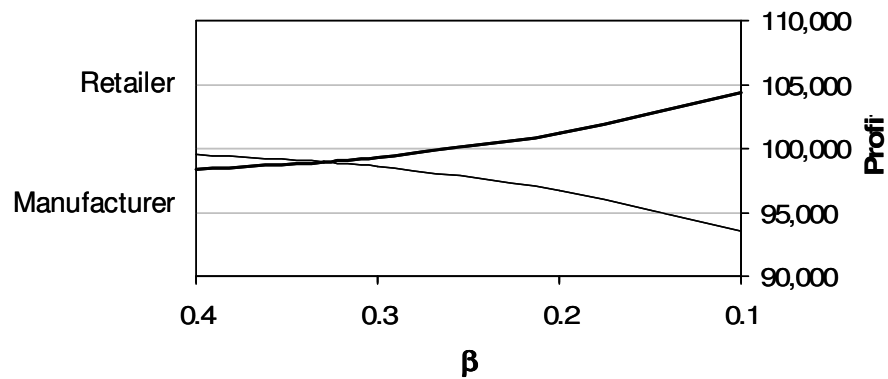


**Figure 7.8:** Manufacturer and Retailer Profits  
Selling Price = 180 and  $\alpha = \beta = 0.4$

Finally, as we stated, a combination of using both  $\beta$  and the wholesale price as parameters can also achieve the desired profit sharing mechanism. Table 7.9 and Figure 7.9 show the effect of using  $\beta$  to further refine profit sharing.

**Table 7.9:** Order Sizes and Profits at the Manufacturer and the Retailer with Demand as a Function of the Selling Price and  $\beta$  as Profit Sharing Parameter  
Wholesale Price = 96

$\alpha$	$\beta$	Whole sale Price (\$)	Order Size	Expected Purchase (Retailer)	Expected Sale (Retailer)	Expected Profit (Retailer) (\$)	Expected Profit (Man.) (\$)	Expected Supply Chain Profit (\$)
0.4	0.1	96	1,200	1,262	1,193	93,578	104,367	197,945
0.4	0.2	96	1,200	1,229	1,193	96,752	101,193	197,945
0.4	0.3	96	1,200	1,210	1,193	98,599	99,346	197,945
<b>0.4</b>	<b>0.35</b>	<b>96</b>	<b>1,200</b>	<b>1,204</b>	<b>1,193</b>	<b>99,158</b>	<b>98,787</b>	<b>197,945</b>
0.4	0.4	96	1,200	1,200	1,193	99,545	98,400	197,945



**Figure 7.9:** Manufacturer and Retailer Profits  
Selling Price = 180 and Wholesale Price = 96

Excel calculations for Table 7.9 are given in Appendix A.

### 7.3 Computer Program to Find Optimum Contract Parameters

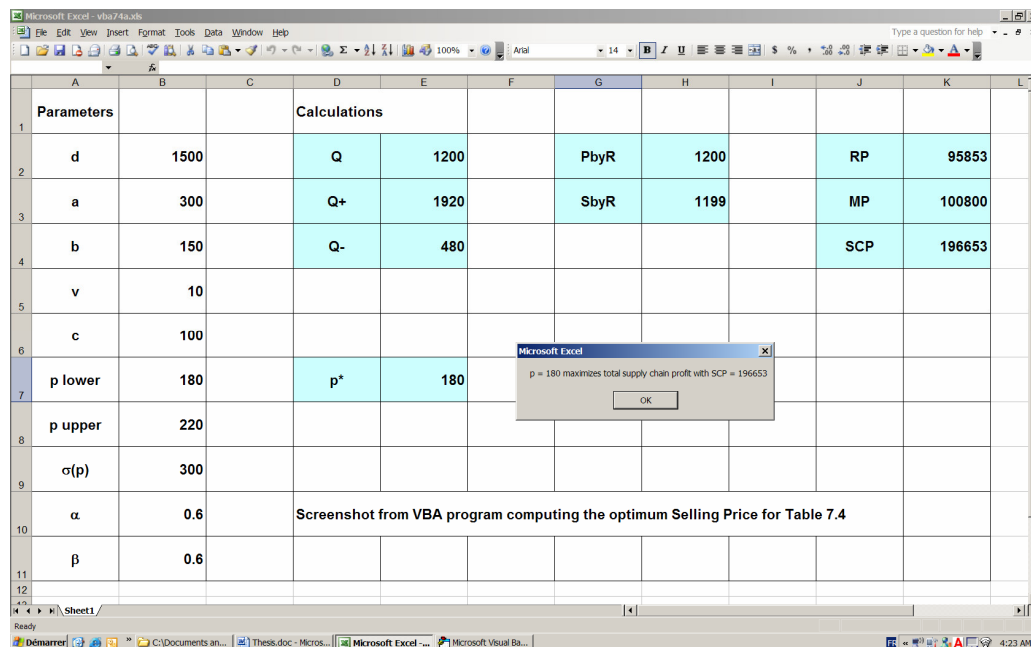
Calculations for Table 7.1 through Table 7.9 are carried out using Excel formulas for specific set of parameters. To simulate and calculate the optimum supply chain contract values for the entire system, we also developed a VBA (Visual Basic for Applications) computer program consisting of five procedures:

- Simulate\_p to compute optimum selling price,
- Simulate\_alpha to compute the optimum  $\alpha$  value,
- Simulate\_p\_alpha to compute optimum selling price and  $\alpha$  value simultaneously
- Simulate\_c to compute profit sharing wholesale price, and
- Simulate\_beta to compute profit sharing  $\beta$  value.

VBA computer program source code of the procedures is given in Appendix B

#### 7.3.1 Simulate\_p

Figure 7.10 shows the screenshot output of Simulate\_p to compute the optimum selling price for Table 7.4. For consistency and comparison, the selling price is restricted to a range of [180, 220] and  $\alpha = \beta$  is set to 0.6.



**Figure 7.10:** Screenshot from VBA program Simulate\_p (p [180, 200])

Figure 7.11 is a rerun of the same procedure Simulate\_p with unrestricted selling price. It should be noted that by removing the restriction, supply chain profit is now maximized at  $p = 158$  with  $SCP = 201,608$ . Initial input screenshot for is also given for completeness.

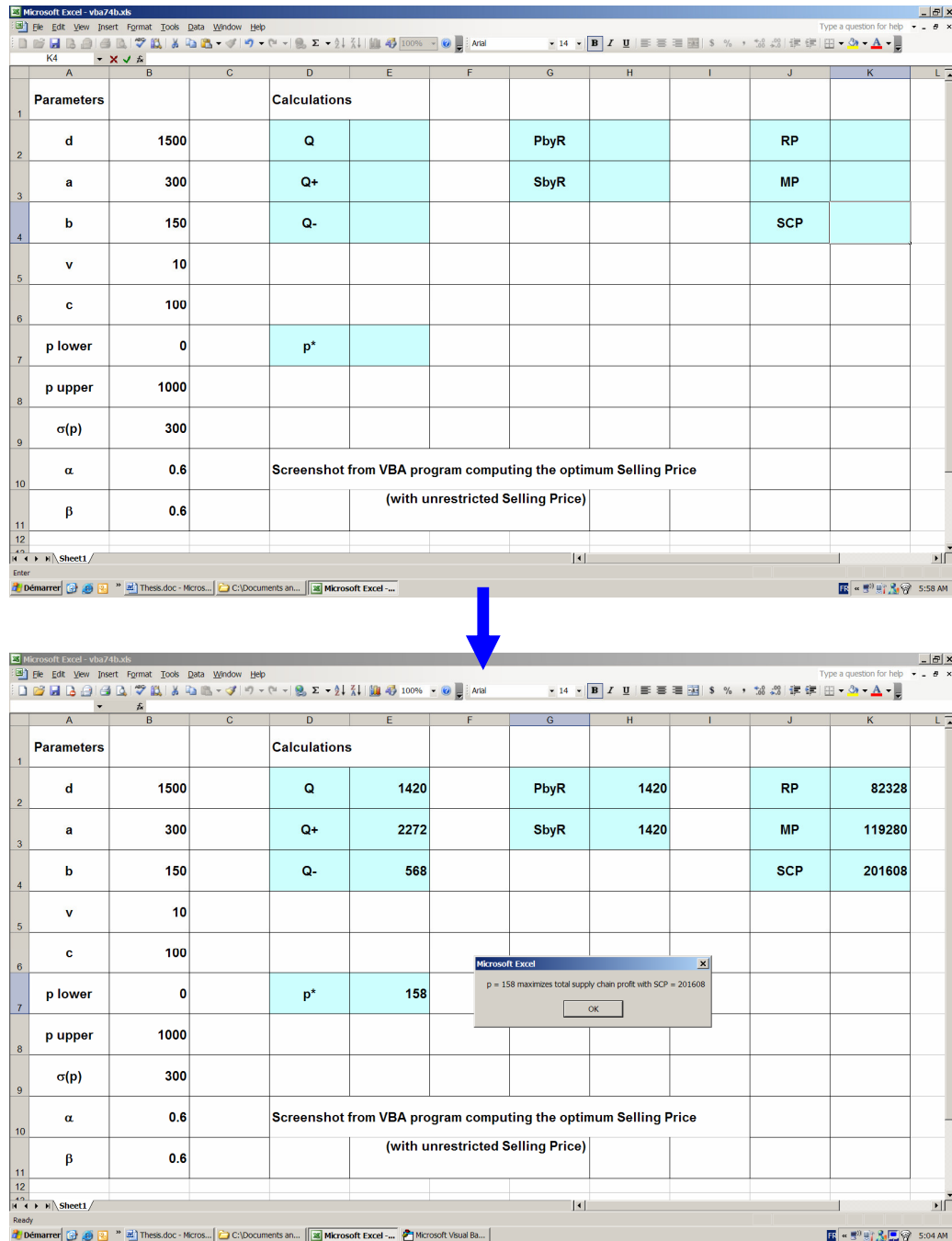
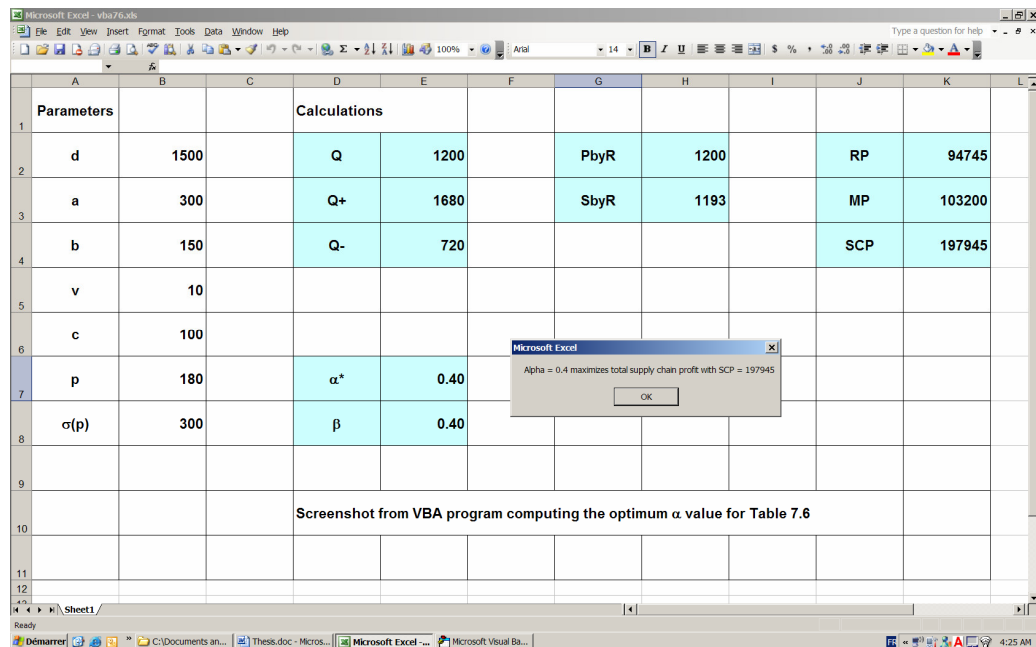


Figure 7.11: Screenshot from VBA program Simulate\_p (unrestricted p)

### 7.3.2 Simulate\_alpha

For the selling price maximizing the total supply chain profit, quantity flexibility contracts can be further refined by now setting  $\alpha$  to its optimum value. Figure 7.12 shows the screenshot output of Simulate\_alpha to compute the optimum  $\alpha$  value for Table 7.6. Again for consistency and comparison, the selling price is set to its optimum restricted value of 180.

The granularity for  $\alpha$  is chosen as 0.01 and  $\beta$  is set equal to  $\alpha$ . It should be noted that  $\beta$  has no effect on the expected supply chain profit but merely redistributes the total supply chain surplus between the manufacturer and the retailer.

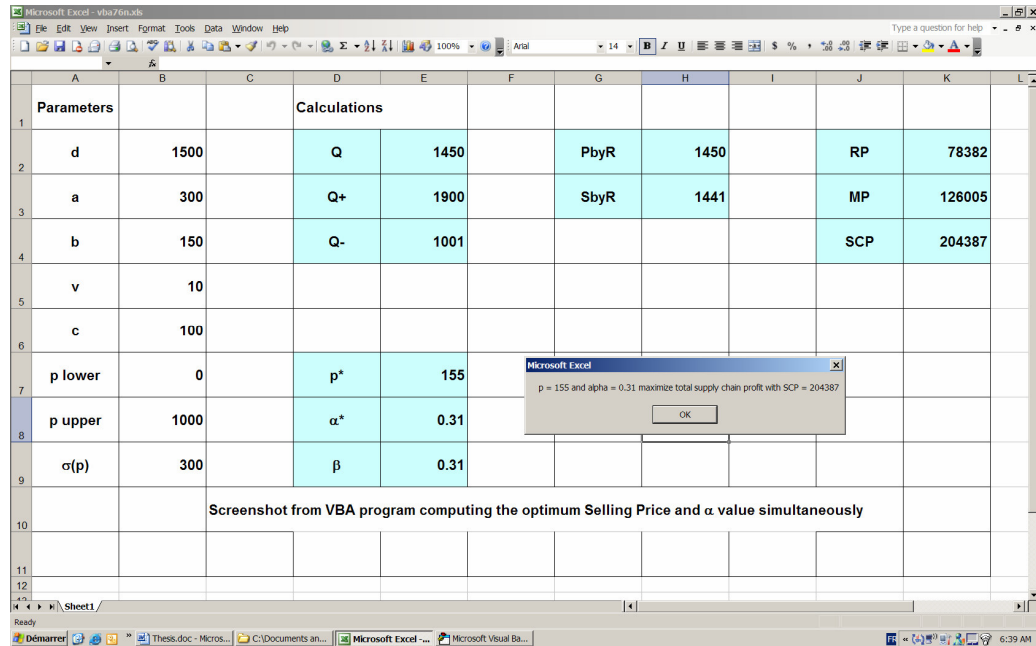


**Figure 7.12:** Screenshot from VBA program Simulate\_alpha

Simulate\_alpha needs to be run after Simulate\_p using its optimum selling price. However, optimizing the selling price first and then the  $\alpha$  value may only result to local maximums. Therefore, both the selling price and the  $\alpha$  value need to be simulated simultaneously. This is achieved by running the procedure Simulate\_p\_alpha.

### 7.3.3 Simulate\_p\_alpha

Figure 7.13 shows the screenshot output of simulate\_p\_alpha to compute the optimum selling price and the alpha value combination maximizing the supply chain profit with unrestricted selling price.



**Figure 7.13:** Screenshot from VBA program Simulate\_p\_alpha

### 7.3.4 Simulate\_c and Simulate\_beta

Once a supply chain profit maximizing selling price and its corresponding optimum  $\alpha$  value are computed, profit sharing can then be achieved by resetting the wholesale price and/or  $\beta$  value. Figure 7.14 and Figure 7.15 show the screenshot output of the procedures simulate\_c and simulate\_beta to compute the profit sharing wholesale price and profit sharing  $\beta$  value corresponding to Table 7.8, and Table 7.9 respectively.

Again for consistency and comparison, the selling price is set to its optimum restricted value of 180.

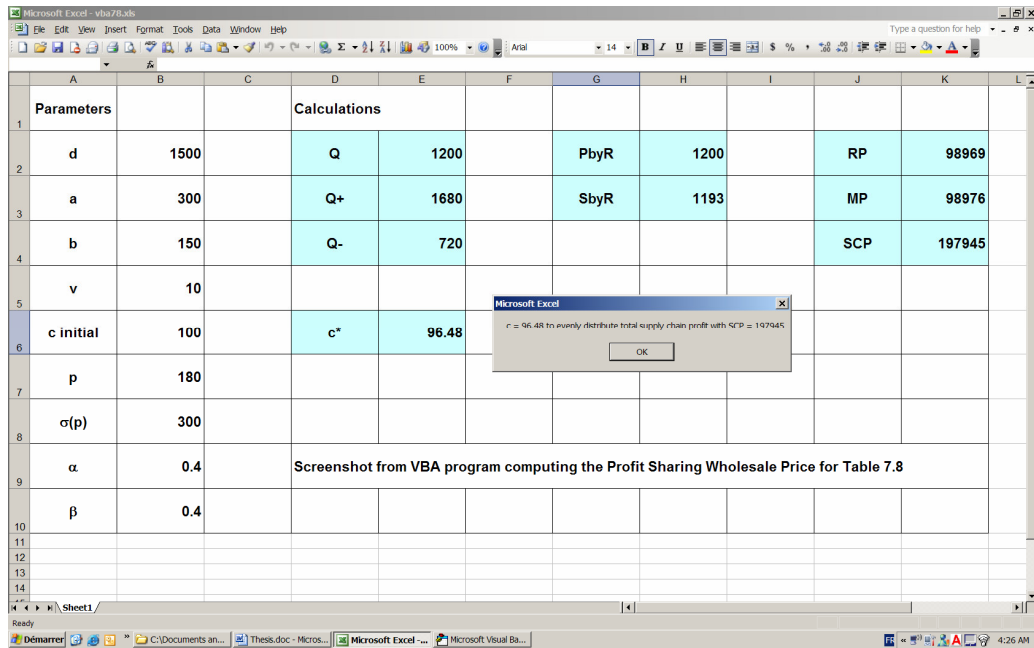


Figure 7.14: Screenshot from VBA program Simulate\_c

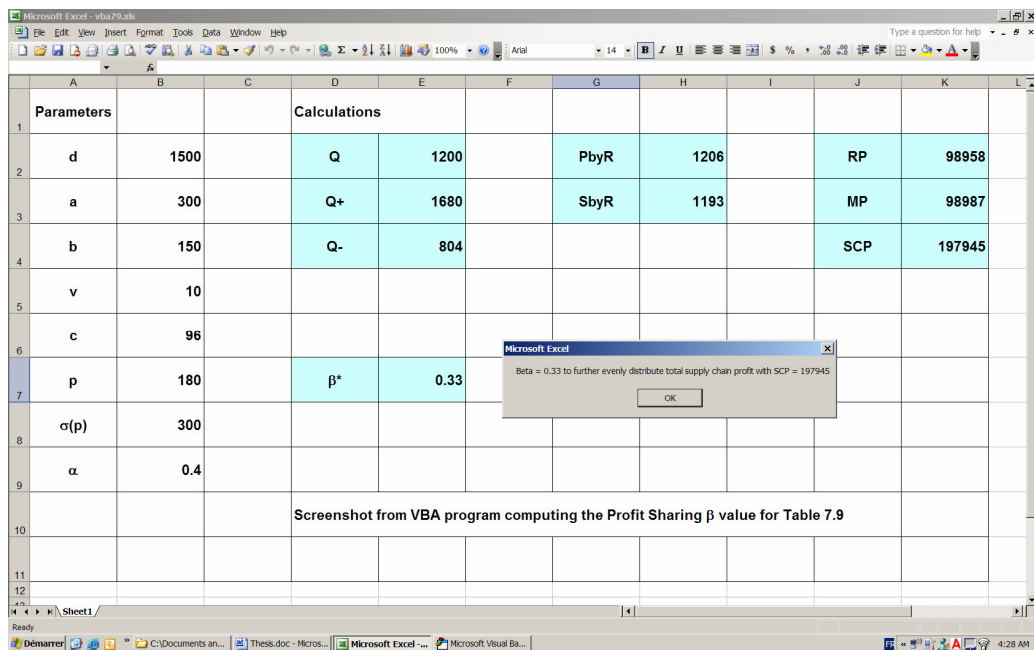


Figure 7.15: Screenshot from VBA program Simulate\_beta



## 7.4 Model Comparison

Table 7.10 summarizes the strength and weaknesses of the models discussed and developed.

**Table 7.10:** Strength and Weaknesses of the Models Discussed and Developed

Existing Models	Strength	Weaknesses
<p>Maximize Retailer Profit without/with Commitment Opportunity (Demand as a Function of the Selling Price)</p>	<ul style="list-style-type: none"> <li>• Correlates demand to selling price using elasticity demand functions</li> </ul>	<ul style="list-style-type: none"> <li>• Restricted with the Intracompany Scope, does not maximize total supply chain profit</li> <li>• Deals with only one segment of the supply chain</li> </ul>
<p>Maximize Supply Chain Profit with Buyback and Quantity Flexibility Contracts (Normally Distributed Demand)</p>	<ul style="list-style-type: none"> <li>• Increases total supply chain surplus</li> <li>• Intercompany scope, coordinates all stages of the supply chain</li> </ul>	<ul style="list-style-type: none"> <li>• Does not correlate demand to selling price, hence price insensitive</li> <li>• Does not address profit sharing</li> <li>• Buyback contracts do not include costs associated with returns</li> <li>• Quantity flexibility contracts do not differentiate salvage value in different segments of the supply chain</li> </ul>

**Table 7.10:** (cont.)

<b>Proposed Models</b>	<b>Strength</b>	<b>Weaknesses</b>
<p>Maximize Supply Chain Profit with Buyback and Quantity Flexibility Contracts and Profit Sharing (Normally Distributed Demand)</p>	<ul style="list-style-type: none"> <li>• Increases total supply chain surplus</li> <li>• Intercompany scope, coordinates all stages of the supply chain</li> <li>• Addresses profit sharing</li> </ul>	<ul style="list-style-type: none"> <li>• Does not correlate demand to selling price, hence price insensitive</li> <li>• Buyback contracts do not include costs associated with returns</li> <li>• Quantity flexibility contracts do not differentiate salvage value in different segments of the supply chain</li> </ul>
<p>Maximize Supply Chain Profit with Buyback and Quantity Flexibility Contracts and Profit Sharing (Demand as a Function of the Selling Price)</p>	<ul style="list-style-type: none"> <li>• Correlates demand to selling price using elasticity demand functions</li> <li>• Maximizes total supply chain surplus</li> <li>• Intercompany scope, coordinated all stages of the supply chain</li> <li>• Addresses profit sharing</li> </ul>	<ul style="list-style-type: none"> <li>• Buyback contracts do not include costs associated with returns</li> <li>• Quantity flexibility contracts do not differentiate salvage value in different segments of the supply chain</li> </ul>

As it can be observed from Table 7.10, the model we developed, “Maximize Supply Chain Profit with Buyback and Quantity Flexibility Contracts and Profit Sharing with Demand as a Function of the Selling Price Model” combines the strength of the existing models and addresses their main weaknesses.

## **CHAPTER 8. CONCLUSIONS AND DIRECTIONS FOR FUTURE RESEARCH**

In this dissertation we have explored several models addressing the implications of supply chain contracts in supply chain networks. Our work has focused on the decisions jointly made by a manufacturer and a retailer to determine the optimal level of product availability. The central theme in these models has been the notion of contracts that specify the parameters within which a retailer places orders and a manufacturer fulfills them in order to maximize the total supply chain surplus.

In Chapter 3, we looked at various supply chain stages, decision phases, cycles, and supply chain implementation with the objective of maximizing the overall value generated by the supply chain. In Chapter 4, we reviewed the supply chain performance in terms of a strategic fit to match supply chain's responsiveness with demand uncertainty along with major demand patterns, and the need of an Intercompany Interfunctional scope to maximize total supply chain surplus. We also looked at various supply chain drivers to achieve the balance between efficiency and responsiveness, and obstacles to achieve this strategic fit.

In Chapter 5, we reviewed the impact of information technology structure upon supply chain collaboration and how APS systems seek to integrate information and coordinate overall supply chain decisions.

In Chapter 6, we discussed two supply chain contract models. First, where a retailer facing price sensitive demand may obtain a discount by committing a fixed quantity over a finite horizon and second where a manufacturer offering buyback or quantity flexibility contracts may increase the total supply chain profit. We concluded that the first model incorporates demand as a function of the selling price but does not address the crucial issue of total supply chain surplus maximization. On the other hand, the second model, although it increases the total supply chain surplus, does not incorporate the demand elasticity.

We then developed in Chapter 7 a model to address the individual weaknesses of the models discussed by incorporating the price sensitive demand into quantity flexible contracts by determining the optimal level of product availability, as a function of the selling price, which maximizes the total supply chain profit. We also

proposed two solutions to the issue of profit sharing related to the additional supply chain profit. Furthermore, through numerical experiments, we showed that our model maximizes total supply chain surplus by incorporating demand elasticity and profit sharing. We also developed a computer program to help simulate the system to find optimum contract parameters.

We then summarized the strength and weaknesses of the models discussed with respect to our model and showed that our model, Maximize Supply Chain Profit with Buyback and Quantity Flexibility Contracts and Profit Sharing with Demand as a Function of the Selling Price Model, combines the strength of the models discussed and addresses their main weaknesses. We strongly believe that the supply chain contract models developed in this dissertation can be an integral part of any APS system.

### **8.1 Future Work**

The model presented here assumes that the supply chain consists of a manufacturer and a retailer. Future work should consider extending the supply chain to model suppliers and/or distributors as well.

Furthermore, the model assumes that the product is at maturity phase of its life cycle with a normally distributed constant/horizontal demand pattern. Future work should consider different demand patterns at different phases of the product's life cycle.

Although the model developed addresses major weaknesses of the other models, it does not include the costs associated with returns in buyback contracts. It does not differentiate salvage value in different segments of the supply chain for quantity flexibility contracts either. Future work should also consider addressing these issues.

For now, the integration of the supply chain contract models developed need to be implemented into APS software through customized development. The coordination through the supply chain can then be achieved by Collaborative Planning, Forecasting, and Replenishment (CPFR) processes. We sincerely believe and hope to see a supply chain contract module as an integral part of logistical information systems.

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## APPENDIX A. EXCEL CALCULATIONS

The following Excel functions are used to evaluate various normal distribution functions:

$$F(x, \mu, \sigma) = \text{NORMDIST}(x, \mu, \sigma, 1)$$

$$f(x, \mu, \sigma) = \text{NORMDIST}(x, \mu, \sigma, 0)$$

The following Excel functions are used to evaluate various standard normal distribution functions:

$$F_s(x) = \text{NORMDIST}(x, 0, 1, 1) \text{ or } \text{NORMSDIST}(x)$$

$$f_s(x) = \text{NORMDIST}(x, 0, 1, 0)$$

### A.1 NORMDIST

NORMDIST returns the normal distribution for the specified mean and standard deviation.

Syntax: **NORMDIST(x,mean,standard\_dev,cumulative)**

**X** is the value for which the distribution is evaluated.

**Mean** is the arithmetic mean of the distribution.

**Standard\_dev** is the standard deviation of the distribution.

**Cumulative** is a logical value that determines the form of the function. If cumulative is TRUE or 1, NORMDIST returns the cumulative distribution function; if cumulative is FALSE or 0, it returns the probability mass function.

If mean = 0, standard\_dev = 1, and cumulative = TRUE, NORMDIST returns the standard normal distribution, NORMSDIST.

The equation (cumulative = FALSE) is:

$$f(x; \mu, \sigma) = \frac{1}{\sqrt{2\pi}\sigma} e^{-\left(\frac{x-\mu}{2\sigma^2}\right)}$$

When cumulative = TRUE, the formula is the integral from negative infinity to x of the given formula.

## A.2 NORMSDIST

NORMSDIST returns the standard normal cumulative distribution function. The distribution has a mean of zero and a standard deviation of one.

Syntax: **NORMSDIST(z)**

**Z** is the value for which the distribution is evaluated.

The equation is:

$$f(z) = \frac{1}{\sqrt{2\pi}} e^{-\frac{z^2}{2}}$$

## A.3 Excel Calculations for Table 7.8

Excel calculations for Table 7.8 are shown in Figure A.1.

$\alpha$	$\beta$	$v$	$c$	$p$	$Q$	$Q+$	$Q-$	Purchase Quantity by Retailer (PbyR)	Sold Quantity by Retailer (SbyR)	Retailer Profit (RP)	Manufac. Profit (MP)	Supply Chain Profit (SCP)	$\mu$	$\sigma$	Fs(Q+)	Fs(Q-)	fs(Q+)	fs(Q-)
param	param	param	param	param	param	formula	formula	formula	formula	formula	formula	formula	param	param	formula	formula	formula	formula
0.4	0.1	10	96	180	1,200	1,680	1,080	1,262	1,193	93,578	104,367	197,945	1,200	300	0.94520071	0.34457826	0.11092083	0.36827014
0.4	0.2	10	96	180	1,200	1,680	960	1,229	1,193	96,752	101,193	197,945	1,200	300	0.94520071	0.2118554	0.11092083	0.28969155
0.4	0.3	10	96	180	1,200	1,680	840	1,210	1,193	98,599	99,346	197,945	1,200	300	0.94520071	0.11506967	0.11092083	0.19418605
0.4	0.35	10	96	180	1,200	1,680	780	1,204	1,193	99,158	98,787	197,945	1,200	300	0.94520071	0.08075666	0.11092083	0.14972747
0.4	0.4	10	96	180	1,200	1,680	720	1,200	1,193	99,545	98,400	197,945	1,200	300	0.94520071	0.05479929	0.11092083	0.11092083

$Q+$  =  $(1 + \alpha) * Q$   
 $G3$  =  $(1 + A3) * F3$

$Q-$  =  $(1 - \beta) * Q$   
 $H3$  =  $(1 - B3) * Q$

$Fs(Q+)$  =  $NORMSDIST(((Q+) - \mu) / \sigma)$   
 $P3$  =  $NORMSDIST((G3 - N3) / O3)$

$Fs(Q-)$  =  $NORMSDIST(((Q-) - \mu) / \sigma)$   
 $Q3$  =  $NORMSDIST((H3 - N3) / O3)$

$fs(Q+)$  =  $NORMDIST(((Q+) - \mu) / \sigma, 0, 1, 0)$   
 $R3$  =  $NORMDIST((G3 - N3) / O3, 0, 1, 0)$

$fs(Q-)$  =  $NORMDIST(((Q-) - \mu) / \sigma, 0, 1, 0)$   
 $S3$  =  $NORMDIST((H3 - N3) / O3, 0, 1, 0)$

$PbyR$  =  $(Q-) * NORMDIST((Q-, \mu, \sigma, 1) + (Q+) * (1 - NORMDIST((Q+), \mu, \sigma, 1))) + (\mu * (Fs(Q+) - Fs(Q-))) - (\sigma * (fs(Q+) - fs(Q-)))$   
 $I3$  =  $H3 * NORMDIST(H3, N3, O3, 1) + G3 * (1 - NORMDIST(G3, N3, O3, 1)) + (N3 * (P3 - Q3)) - (O3 * (R3 - S3))$

$SbyR$  =  $(Q+) * (1 - NORMDIST((Q+), \mu, \sigma, 1) + (\mu * Fs(Q+) - (\sigma * fs(Q+)))$   
 $J3$  =  $G3 * (1 - NORMDIST(G3, N3, O3, 1)) + (N3 * P3) - (O3 * R3)$

$RP$  =  $(p * SbyR) - (c * PbyR)$   
 $K3$  =  $(E3 * J3) - (D3 * I3)$

$MP$  =  $(c * PbyR) - (v * (Q+))$   
 $L3$  =  $(D3 * I3) - (C3 * G3)$

$SCP$  =  $RP + MP$   
 $M3$  =  $K3 + L3$

Figure A.1: Excel Formulas and Calculations for Table 7.8

## **VITA**

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