Final Report for Period: 09/2009 - 08/2010 **Submitted on:** 10/11/2010
Principal Investigator: Keskinocak, Pinar . **Award ID:** 0400301
Organization: GA Tech Res Corp - GIT
Submitted By:
Keskinocak, Pinar - Principal Investigator
Title:
Collaborative Research: Intra- and Inter-Enterprise Collaborative Procurement

Project Participants

Senior Personnel

Name: Keskinocak, Pinar
Worked for more than 160 Hours: Yes
Contribution to Project:

Name: Marston, Lee
Worked for more than 160 Hours: No
Contribution to Project:

Name: Erhun, Feryal
Worked for more than 160 Hours: Yes
Contribution to Project:

Name: Gui, Luyi
Worked for more than 160 Hours: No
Contribution to Project:

Post-doc

Name: Yuksel Ozkaya, Banu
Worked for more than 160 Hours: No
Contribution to Project:

Graduate Student

Name: Ozkaya, Evren
Worked for more than 160 Hours: Yes
Contribution to Project:
In the first year of the project, Evren Ozkaya has worked with me for one semester on reviewing the literature and investigating how RFID can be used to facilitate collaboration between supply chain partners and how RFID technology can improve shelf space management.

In the second year, we established a collaboration with Intel Corporation which shifted our focus to the management of platform products, and in particular, the impact of information exchange between the customers and the manufacturer on the overall profitability of the firm and the match between demand and supply.

Name: Pekgun, Pelin
Worked for more than 160 Hours: No
Contribution to Project:

Name: Dachevskiy, Lev

Worked for more than 160 Hours: Yes

Contribution to Project:

Lev was hired to work on writing a case study about the collaboration between Ryder and Philips. We interviewed managers at Ryder and collected some information, unfortunately he decided to switch to another project before writing the case study.

Name: Xia, Shuangjun

Worked for more than 160 Hours: Yes

Contribution to Project:

Name: Privett, Natalie

Worked for more than 160 Hours: Yes

Contribution to Project:

Name: Heier, Jessica

Worked for more than 160 Hours: Yes

Contribution to Project:

Name: Gui, Luyi

Worked for more than 160 Hours: No

Contribution to Project:

Name: Stilp, Michael

Worked for more than 160 Hours: Yes

Contribution to Project:

Undergraduate Student

Technician, Programmer

Other Participant

Research Experience for Undergraduates

Organizational Partners

Intel Corporation

Ph.D. student Evren Ozkaya did internship at Intel in Summer 2007 and also worked there part time during Fall 2006. We now have continuing idea exchange and collaboration with our contacts at Intel.

Stanford University

This is a collaborative grant, with one PI from Georgia Tech and the other PI from Stanford University.

Other Collaborators or Contacts

We collaborated with the Centers for Disease Control and Protection (CDC). Our manin contact there is Sergey Sotnikov. Here is a quick snapshot of our research interests with Dr. Sotnikov. Public health is about delivery of population-based health services (immunizations, screening etc.)

Each US county has a health department charged with delivery of these services. Some of these health department establish partnerships with doctors, businesses etc to deliver these services. Partnerships are widely promoted in public health as a way of sharing limited resources, avoiding duplications etc. We are interested in investigating whether partnership relationships have any effects on ability of health departments to generate revenues.

1. Dr. Sergey Sotnikov
Economist and Senior Service Fellow
Division of Partnerships and Strategic Alliances
National Center for Health Marketing
Coordinating Center for Health and Information Services
Centers for Disease Control and Prevention (CDC)

Activities and Findings

Research and Education Activities:

The major research and education activities that we proposed and our progress on these activities are as follows:

QUANTITY DISCOUNTS AND DYNAMIC PROCUREMENT:
Proposal: Study how buyers should procure in the face of quantity discounts under demand uncertainty ? we will first study stochastic quantity discounts faced by individual buyers and use those results as building blocks in the collaborative scenario. Initially we will focus on a single product, and then extend our results to multiple related products. This part of our research will be an important step towards filling the void in the current literature on stochastic quantity discounts, particularly for multiple related products.

Progress: We have now completed this part of our research successfully and published the following papers:
? Erhun, F., P. Keskinocak, and S. Tayur, 2008. Dynamic Procurement, Quantity Discounts, and Supply Chain Efficiency. POMS, V. 17, N. 5, pp. 1-8.
? Erhun, F., P. Keskinocak, and S. Tayur, 2008. Dynamic Procurement in a Capacitated Supply Chain Facing Uncertain Demand. IIE Transactions, V. 40, N. 8, pp. 733-748.

COLLABORATIVE PROCUREMENT:
Proposal: (1) Develop and analyze models to understand the dynamics of horizontal inter-enterprise collaborative procurement under deterministic demand. We will study the underlying economics behind collaborative procurement among competitor firms, examine the effects of collaboration on buyer and supplier profitability, and derive conditions under which collaboration will be beneficial to each participant. (2) Develop and analyze models to understand the dynamics of intra- and inter-enterprise collaborative procurement under stochastic demand in a dynamic setting. We will study collaborative procurement as a potential tool for risk hedging and coordinated replenishment.

Progress: We have completed and published the following paper in Naval Research Logistics:
? Keskinocak, P. and S. Savasaneril. 2008. Collaborative Procurement among Competing Buyers. Naval Research Logistics, Vol. 55, No. 6, 516-540.

Kael Stilp, who has been supported in part by this grant, recently worked on the following topic (in collaboration with Luyi Gui, Edem Wornyo, and Ozlem Ergun):
In recent years global companies have switched the standard model of operation for their Information and Communication Technology (ICT) divisions, in charge of varying internal computer technology, to a model promoting global cooperation. This new approach replaces the previous notion of localized regions all acting independently. The centralization process allows more uniform technology deployments, economies of scale, and labor resources to be put to more effective use. The World Food Programme (WFP) currently operates under the old standard for ICT, as each country is responsible for its own ICT operations. While the new model offers clear advantages for efficiency and effectiveness, each country may have significantly different needs and budgets for the ICT operations, making implementation a difficult task. We study how these countries could share the costs of the centralized structure so that each country is willing to participate without incurring significant disadvantages. As ICT services are in the process of being cataloged by WFP we designed a mathematical model which assigns prices to these services while offering each country a unique percentage discount on the prices. This is used to control the expected budget that a country will incur within a year so that they may satisfy their expected requirements for ICT service while realizing a budget that does not exceed their budget were they operating independently. Thus, our primary task was identifying and implementing fairness considerations for all of the countries. We found that the model was susceptible to extreme pricing schemes when we used linear fairness constraints, such as maximizing the minimum expected percentage savings a country would receive. Based on observations of the structure of the model we expect this problem to be typical under similar variants of the model. To achieve more reasonable pricing schemes with little loss in overall efficiency we introduce quadratic objective functions. This change does not greatly impact the ability for the model to be solved quickly, yet also

prevents any prices from becoming extremely expensive or extremely cheap.

COLLABORATIVE SUPPLY CHAIN MANAGEMENT:
Proposal: Develop models and decision support tools for coordinating intra-enterprise collaborative procurement with logistics, to simultaneously optimize the 'net landed cost.'
Progress: As a step towards achieving this goal we completed a book chapter on Collaborative Supply Chain Management, which discusses many aspects of collaboration in supply chains, with examples from industry and academia, and provides possible future research directions in these areas:
? Erhun, F. and P. Keskinocak. 'Collaborative Supply Chain Management,' in Handbook of Production Planning. Edited by K. Kempf, P. Keskinocak, and R. Uzsoy, Kluwer International Series in Operations Research and Management Science, Kluwer Academic Publishers (To appear).

Proposal: a company can achieve significant benefits by coordinating the decisions of different functional areas, i.e., intra-enterprise vertical collaboration.
Progress: In many firms pricing and lead-time decisions are made in a decentralized fashion, primarily by marketing and operations departments, respectively. As such, in the following paper we analyze the inefficiencies that are due to the decentralization of these two decisions and explore coordination mechanisms.
* P. Pekgun, P. Griffin, P. Keskinocak (2008), 'Coordination of Marketing and Production for Price and Leadtime Decisions,' IIE Transactions, Vol. 40, No. 1, 12-30.
* IIE Transactions Best Paper Award - Scheduling & Logistics, May 2009.
* P. Pekgun, P. Griffin, P. Keskinocak, 'Decentralizing Price and Lead-time Decisions under Competition,' INFORMS, San Diego, CA, October 11-14, 2009.

Proposal: Development of case studies and games to aid in teaching concepts, issues and practices in this area, within the context of real-world applications.
Progress: We are currently working on the following case study.

O. Ergun, L. Gui, J. L. Heier Stamm, P. Keskinocak, and J. Swann, 2010. 'UPS - Salvation Army Collaboration Improves Haiti Relief Logistics.' Teaching case study. In preparation.

In response to the January 2010 earthquake in Haiti, the Salvation Army deployed UPS Trackpad? technology to facilitate the registry of residents in their refugee camps and to streamline the distribution of food and other items to those affected by the earthquake. The Trackpad? system was donated by UPS and specially adapted by the company and its partner vendor, Cardinal Tracking, to meet this need. The Salvation Army used barcode-imprinted cards, given to each of 4,000 families, and hand-held scanners to capture information such as the number of people in the household, the number of children, the family's location in the camp, and specific relief distributions they had received.

This case study will document the collaborative efforts of UPS and the Salvation Army, describe the ways that this collaboration improved the efficiency and effectiveness of relief operations, and provide opportunities for students to build analytical skills relevant to decision-making in collaborative scenarios. An interactive game, questions, problems, and teaching notes are being prepared to accompany the case narrative. The target audience for the case study includes undergraduate, graduate, and professional education courses in industrial engineering, operations research, logistics, and operations management.

In addition, we have developed the following game:

P. Keskinocak, S. Xia, 'Interactive Supply Chain Game,' classroom game. The primary goal of this game is to investigate the interplay between the supplier's inventory allocation mechanism and the customers' demand forecast and orders, i.e., to determine how customers revise their forecasts and orders in response to the supplier's allocation mechanism.

Findings: (See PDF version submitted by PI at the end of the report)

DYNAMIC PROCUREMENT:
Dynamic procurement, i.e., simple price-only contracts repeated over time (possibly with different prices), is a commonly observed practice in a vertical channel. Dynamic procurement minimizes potential capacity risks (supplier's or buyer's), spreads payments over a period of time, and may lead to lower prices due to decreasing costs over time. Dynamic procurement may also influence future prices. Based on a data analysis over a four-year horizon, a consulting firm for a major manufacturer of finished goods observed a strong indication that the

manufacturer was able to impact its raw material costs by using dynamic procurement. The consulting firm concluded that higher inventory levels at the manufacturer showed strong correlations with reduced sourcing costs on a per-unit basis. A likely reason that dynamic procurement helped to reduce prices was expressed by many of the manufacturer's purchasers as 'being able to walk away from the table.' We analyze this phenomenon and investigate the impact of timing of the decisions and of additional demand information on a supplier's pricing and a buyer's procurement decisions in a capacity procurement setting where the supplier and the buyer both engage in strategic decisions.

Dynamic Procurement, Quantity Discounts, and Supply Chain Efficiency: In order to establish the link between dynamic procurement and incremental quantity discounts, we study a model with a single supplier and a single buyer, who interact multiple times before the buyer sells her product in the end consumer market. Dynamic procurement, i.e., simple price-only contracts repeated over time (possibly with different prices), is a commonly observed practice in a vertical channel. A common justification for dynamic procurement is risk hedging. In a vertical setting we show that risk hedging is not necessarily the only justification for multiple trades. We derive a Pareto improving rationale for the use of additional trading periods in the case of deterministic demand and price-only contracts, where all participants (buyer, supplier, and end-consumers) benefit. The additional trading periods inherently create the equivalent of a non-linear pricing scheme, which makes the performance of the decentralized supply chain approach that of a centralized supply chain when the number of trading periods is sufficiently high.

Dynamic Procurement in a Capacitated Supply Chain Facing Uncertain Demand: In order to generalize our results under deterministic demand (see Dynamic Procurement, Quantity Discounts, and Supply Chain Efficiency), in an environment where a buyer procures capacity from a capacitated supplier through a price-only contract, we investigate the impact of timing of decisions and additional demand information on the supplier's pricing and the buyer's procurement decisions. As the selling season approaches, the buyer and the supplier have better information about the demand process. We question to what degree waiting until the demand uncertainty is resolved ? given that such an option is feasible ? is the best alternative for the supply chain partners. Our main model is a two period dynamic pricing/procurement game where the supplier sets wholesale prices dynamically; he sets the second period price after seeing the demand state as well as the buyer's first period procurement quantity. We also study two single period models (early commitment and no-commitment) based on the information available to the players prior to their decisions. For each model, we find the subgame perfect Nash equilibrium in a closed form and analyze the players' behaviors to determine the impact of the additional information and trading periods on their welfare. We also consider the supplier's optimal capacity decision. Several additional insights are obtained through numerical experiments.

Our main results are as follows: In the single period models, we observe that the supplier is better off under no-commitment, i.e., the additional demand information is beneficial for the supplier. However, the additional demand information does not always benefit the buyer and the supply chain. When the trade occurs in two periods and the supplier sets the prices dynamically, he is better off compared to the single period models. He can use the additional period and the additional demand information to control the prices more tightly. Depending on the demand state, prices may increase (advance purchase discount) or decrease (markdown) over time. The buyer may still prefer early commitment, but she is definitely better off under dynamic pricing/procurement compared to no-commitment. When the supplier chooses his capacity as well as the prices, for a wide-range of parameters, the dynamic game is the best alternative for all parties, including the end customers. Contrary to our intuition, we observe that more capacity is not always better for the supplier, even when it comes for free.

INTRA- and INTER-ENTERPRISE COLLABORATION:

The increasing importance of supply chain efficiency as a key competitive advantage has changed the nature of many intra- and inter-firm relationships from adversarial to collaborative in recent years. We have written a chapter on collaborative supply chain management and provide an overview of various collaborative concepts in supply chains, such as design and new product introduction, planning, forecasting and inventory management, production management, logistics, and procurement. We also discuss the role of information technology in collaboration. We provide several future research directions.

In terms of intra-enterprise vertical collaboration, in a paper with P. Pekgun and P. Griffin (published in IIE Transactions) we study a firm which serves customers that are sensitive to quoted price and leadtime, with pricing and leadtime decisions being made by the marketing and production departments, respectively. We analyze the inefficiencies created by the decentralization of the price and leadtime decisions. In the decentralized setting, the total demand generated is larger, leadtimes are longer, quoted prices are lower, and the firm's profits are lower as compared to the centralized setting. We show that coordination can be achieved using a transfer price contract with bonus payments. We also provide insights on the sensitivity of the optimal decisions with respect to market characteristics, sequence of decisions and the firm's capacity level.

In recent years, collaborative procurement emerged as one of the many initiatives for achieving improved inter-firm coordination and collaboration. In an article with S. Savasaneril (published in Naval Research Logistics), we adopt a game-theoretical approach to study the interaction between two firms who procure jointly, but produce independently and remain competitors in a product market characterized by price-sensitive demand. We study the underlying economics behind collaborative procurement, examine the effects of collaboration on buyer and supplier profitability, and derive conditions under which collaboration is beneficial to each participant. We find that a necessary and sufficient condition for a buyer to collaborate is to increase its sales. We identify the conditions that lead equal size buyers (i.e., consortia consisting of only large buyers or only small buyers) versus different size buyers to collaborate. We also determine the conditions that make collaboration profitable for the supplier, and show that rather than selling a large quantity to a single buyer, the supplier prefers to sell to multiple buyers in smaller quantities.

While the article with S. Savasaneril focuses on 'horizontal' collaboration, in another article with E. Ozkaya and J. Vandevate we focus on 'vertical' collaboration in the form of information sharing. Motivated by practices in the semiconductor industry, we investigate the value of demand information for platform products. In semiconductor industry, suppliers deliver multiple components to the OEMs at different times that are then assembled as a single platform (i.e. Personal Computer) by OEMs. We analyzed scenarios where we can use this component demand dependency on quantity and timing as advanced demand information to improve forecasting accuracy. Our approach investigates the benefits of this advanced demand information under stochastic demand scenarios using a Monte Carlo approach. We developed an integrated supply chain simulator to quantify the potential benefits of the resultant forecast improvement on Intel's global supply chain.

Training and Development:

The graduate students have taken courses in many related disciplines including game theory, behavioral economics, and data analysis. The graduate students attended conferences to further improve their understanding of the current research in their respective research areas. They have also presented their results at conferences which helped them disseminate their findings and develop their communication and presentation skills.

Secil Savasaneril, a former Ph.D. student, is currently a faculty member at Middle East Technical University, Ankara, Turkey. Evren Ozkaya, a former Ph.D. student now works for McKinsey & Co. While he was a Ph.D. student, Evren did an internship with Intel Corporation in the summer of 2006, and later a second internship with Intel Corporation to further deepen his knowledge and understanding of real-world practices, and graduated in 2008. Pelin Pekgun, a former Ph.D. student did and internship with Manugistics, Inc., graduated in 2007, and now works for JDA. Current Ph.D. students Shaungjun Xia and Michael Stilp successfully completed their comprehensive exams. Banu Yuksel Ozkaya, former post-doctoral fellow, is currently a faculty member in the Industrial Engineering Department at Hacettepe University, Ankara, Turkey.

Outreach Activities:

We have given talks at conferences, workshops, and seminars to disseminate our results.

1. P. Pekgun, P. Griffin, P. Keskinocak, 'Decentralizing Price and Lead-time Decisions under Competition,' INFORMS, San Diego, CA, October 11-14, 2009.
2. N. Privett, F. Erhun, P. Keskinocak, G. Shah, S. Sotnikov, 'Investigating the Effects of Partnerships on Local Public Health Agencies,' INFORMS, San Diego, CA, October 11-14, 2009.
3. E. Ozkaya, P. Keskinocak, J. Vande Vate, M. Waithe, 'Supply Chain and Logistics Planning of Platform Products: Value of Platform Demand Information,' INFORMS, Seattle, WA, November 4-7, 2007.
4. B. Yuksel Ozkaya and P. Keskinocak, 'A Model on Decentralized Dynamic Price and Lead-Time Quotation,' INFORMS, Pittsburgh, PA, November 5-8, 2006.
5. P. Keskinocak and S. Savasaneril, 'Collaboration Between Buyers During the Procurement Process,' XXV. National Operations Research and Industrial Engineering Congress, Istanbul,Turkey, July 2005.
6. P. Pekgun, P. Griffin,and P. Keskinocak, 'Coordination of Marketing and Production for Price and Lead-time Decisions,'MSOM Conference, Northwestern University, June 27-28,2005.

Two of our articles which were published in IIE Transactions were chosen as one of the two articles that were highlighted in the monthly 'Industrial Engineer' magazine:

? 'Dynamic Procurement Saves Money' Executive Summary Edited by C. Yano, Industrial Engineer Magazine, V. 40, N. 8, pp. 52-53, August 2008.
? Coordination of Marketing and Production for Price and Leadtime Decisions, Industrial Engineer Magazine (January 2008), by C. Yano

IE Magazine is distributed to all members of IIE.

I gave an executive short course on Supply Chain Collaboration in The Logistics Institute's executive education series in April 2006, in April 2007, and in April 2008.

I gave a 2-day executive short course (together with Esma Gel) on Supply Chain Management to Intel employees in Chandler, AZ in April 2006, and 1.5 hours of the course was dedicated to collaboration in supply chains. In March 2007, I repeated a similar version of the course at Diamax Industries in Atlanta, GA.

I taught a 2.5-day course on 'Supply Chain Management in the Humanitarian Sector' in the Executive Masters for Humanitarian Logistics Management, University of Lugano, Switzerland, April 12-14, 2010. One of the modules in this course focused on supply chain collaboration, both in the for-profit and the non-profit sectors.

Journal Publications

Erhun, F; Keskinocak, P; Tayur, S, "Dynamic procurement, quantity discounts, and supply chain efficiency", PRODUCTION AND OPERATIONS MANAGEMENT, p. 543, vol. 17, (2008). Published, 10.3401/poms.1080.005

Erhun, F; Keskinocak, P; Tayur, S, "Dynamic procurement in a capacitated supply chain facing uncertain demand", IIE TRANSACTIONS, p. 733, vol. 40, (2008). Published, 10.1080/0740817070174482

Pekgun, P; Griffin, PM; Keskinocak, P, "Coordination of marketing and production for price and leadtime decisions", IIE TRANSACTIONS, p. 12, vol. 40, (2008). Published, 10.1080/0740817070124534

Keskinocak, P; Savasaneril, S, "Collaborative procurement among competing buyers", NAVAL RESEARCH LOGISTICS, p. 516, vol. 55, (2008). Published, 10.1002/nav.2030

Books or Other One-time Publications

Feryal Erhun and Pinar Keskinocak, "Collaborative Supply Chain Management", (2010). Book, Accepted
Editor(s): K. Kempf, P. Keskinocak, R. Uzsoy
Collection: Production Planning Handbook
Bibliography: Kluwer

P. Keskinocak, "Collaborative key to disaster recovery", (2010). Trade magazine, Published
Collection: Air Cargo World
Bibliography: http://www.aircargoworld.com/Magazine/Departments/Viewpoint/

Web/Internet Site

Other Specific Products

Contributions

Contributions within Discipline:

Collaborative procurement emerged as one of the many initiatives
for achieving improved inter-firm coordination and collaboration.
In the paper with former Ph.D. student Secil Savasaneril, we adopt a game-theoretical approach to study the
interaction between two firms who procure jointly, but produce
independently and remain competitors in a product market

characterized by price-sensitive demand. We study the underlying economics behind collaborative procurement, examine the effects of collaboration on buyer and supplier profitability, and derive conditions under which collaboration is beneficial to each participant. We find that a necessary and sufficient condition for a buyer to collaborate is to increase its capacity utilization. We identify the conditions that lead equal size buyers (i.e., consortia consisting of only large buyers or only small buyers) versus different size buyers to collaborate. We also determine the conditions that makes collaboration profitable for the supplier, and show that rather than selling a large quantity to a single buyer, the supplier prefers to sell to multiple buyers in smaller quantities.

In her Executive Summary in IE Magazine, Yano describes the contribution of our work on dynamic procurement as follows: 'Common wisdom suggests that long-term contracts or buying in bulk to take advantage of quantity discounts saves money. But by committing to buy large quantities up front, a buyer gives up his negotiating power and ultimately pays more than if he had made periodic (dynamic) purchases under a series of [priceonly] contracts.' In addition, with our work on dynamic procurement, we establish the relation between quantity discounts and dynamic procurement.

Contributions to Other Disciplines:

To analyze the strategic interactions among different divisions within a firm or among multiple firms in a supply chain, we use game theory as the main tool of analysis. Hence, our research relates to the field of economics.

Contributions to Human Resource Development:

Over the past 3 years, I have supported several Ph.D. students who have worked on this grant. Pelin Pekgun and Evren Ozkaya graduated already and are both working in industry. I have also worked with post-doctoral fellow Banu Yuksel Ozkaya, who is currently a faculty member in the Industrial Engineering Department at Hacettepe University, Ankara, Turkey.

Contributions to Resources for Research and Education:

In an effort towards understanding the value of information in supply chain interactions between a manufacturer and its customers (who may also be manufactures), with Ph.D. student Shuangjun Xia we developed an Excel-based supply chain game. The preliminary versions of the game have been played and tested in graduate and undergraduate classes at Georgia Tech. We have also received feedback about this game from supply chain managers at Intel Corp.
We are now developoing theoretical models to analyze how different players would make decisions in 'ewuilibrium.' Our goal is then to comapare the results from the theoretical analysis with the behavior of human players.

Contributions Beyond Science and Engineering:

In the recent years, the PI's interests shifted towards societal applications of Operations Research and Management Science (OR/MS). In particular, she has established various collaborations with non-governmental organizations, which are a critical part of the American society as well as a growing sector of the national economy. They provide the opportunity for individuals to volunteer and give back to society, which has become a prominent part of American culture. They also provide a large amount of public goods that no one directly pays for but from which everyone reaps benefits, such as cleaner air and fewer people in prison. According to the Stanford Project on the Evolution of Nonprofits, 183,769 nonprofit organizations (0.7 nonprofits per 1,000 people) expend 686.5 billion and account for nearly 7% of the U.S. GDP (Gammal et al. 2005). In addition, the nonprofit sector employs 12.5 million people, which accounts for 9.5% of total employment in the United States (Jalandoni et al. 2002). Therefore, it is important to understand and improve the operations of nonprofit organizations.

Recently, we started a new project with the goal of providing quantitative evaluation of the effects of partnerships (collaboration) on revenue generating strategies and performance of local health departments (LHDs). Through the investigation of performance we aim to find ways to measure the effectiveness of the LHDs in order to explore the relationships between performance, revenues and collaboration. The goal is to create a map that will take into account the characteristics of an LHD to provide optimal strategies regarding the types and combinations of partnerships. The recent report from Institute of Medicine, 'The Future of the Public's Health in the 21st Century,' promotes partnerships as an important way to improve public health. The U.S. public health system is comprised of 3,000 LHDs, each servicing the population of individual counties. Each LHD provides a number of public health services, including immunizations, animal control, behavioral health, child health, chronic disease prevention, etc. There are expectations that by partnering with hospitals, doctors, community organizations, insurance companies, etc., local health departments may leverage additional financial resources for public health programs.

There are several ways how partnerships can effect revenue generation by LHDs. First, by partnering with other organizations LHDs can increase their chances of being financed through federal, state and nongovernmental organization grants (many grant applications require establishment of partnerships). Second, LHDs may cooperate with insurance companies and hospitals to increase clientele base and generate additional revenues from fee services. Third, cooperating with partners helps to avoid duplication in provision of services and unnecessary spending thus leading to lower LHD revenues. Fourth, outsourcing and contracting out of LHD services can also have negative effect on LHD revenues. The net effect of partnerships on LHD revenue is unclear. It is also unclear which types of partnerships or combinations of partnerships lead to higher revenues. Furthermore, revenues may not be indicative of performance and partnerships may be tied more to better performance, that is, better use of the revenue, as opposed to revenue itself. It is our goal to quantify the contribution of each of the partnership relationships or combination of partnership relations to revenue generation and performance.

Conference Proceedings

Categories for which nothing is reported:

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Collaborative Supply Chain Management*

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DRAFT: Comments welcome. Please do not copy, quote, or circulate without authors' permission.

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Contents

1 Introduction

The management of supply chains has become progressively more complex and challenging due to higher customer expectations for better service, higher quality, lower prices and shorter leadtimes; ongoing demand uncertainty; an increase in product variation; and shorter product life cycles. The increasing importance of supply chain efficiency as a key competitive advantage has changed the nature of many intra- and inter-firm relationships from adversarial to collaborative. An industry survey by Forrester Research reveals that 72% of firms say supplier collaboration is "critical to their product development success." [82] An AMR Survey at Microsoft Engineering and Manufacturing Executive Summit, which was conducted by the participation of CEO, CFO, CIO, Sr. VP of Fortune 1000 companies, shows that 58% of the participants consider collaboration as a "strategic necessity," while another 32% consider it to be "very important." 57% of the participants state that they are directly involved in leading effort [28].

1.1 What is collaboration?

According to Cohen and Roussel, collaboration is "the means by which companies within the supply chain work together toward mutual objectives through the sharing of ideas, information, knowledge, risks, and rewards." [33] Hence, collaboration requires that companies in a supply chain work actively together as one toward common objectives. Collaboration includes the sharing of information, knowledge, risk, and profits/benefits in an agreed-to consistent fashion for all participants, and entails understanding how other companies operate, how they make decisions, and what is important to them. Everyone involved must benefit or it is not true collaboration.

Collaboration can have many different facets (Figure 1). *Intra-enterprise* collaboration takes place in numerous areas, including procurement, product design, and logistics. For example, by replacing their decentralized purchasing functions with centralized procurement, many companies were able to reduce the associated administrative costs, better utilize their procurement managers' time, and more importantly, leverage their buying power with their suppliers, resulting in significant savings. Using centralized procurement, Dial Corp. was able to eliminate $100 million in total costs in five years (1996-2001) [83], Siemens Medical Systems cut its costs by 25% over a three year period (1998-2001) [27], and Fujitsu has detailed plans to reduce its spending on components and materials by approximately $3.85 billion over two years [97]. These examples illustrate *intra-enterprise horizontal collaboration* where a company coordinates or centralizes the activities of multiple entities which are responsible from the same function, e.g., purchasing. Alternatively, a company can achieve significant benefits by coordinating the decisions of different functional areas, i.e., *intra-enterprise vertical collaboration*. An example of intra-enterprise vertical collaboration is the "net landed cost" approach, where a company coordinates several functions, such as purchasing and logistics. Traditionally, purchasing's goal in many companies has been to pro-

	Intra-enterprise	Inter-enterprise
Vertical	• Manufacturing & Sales/Marketing • Manufacturing & Distribution • Design & Marketing & Manufacturing	• Supplier & Manufacturer (e.g., Toyota and its suppliers) • Manufacturer & Retailer (e.g., P&G and Wal-Mart) • Distributor & Retailer
Horizontal	• Procurement functions across multiple divisions (e.g., Dial Corp.)	• Multiple manufacturers (e.g., Covisint) • Multiple logistics providers (e.g., Transplace)

Figure 1: Different facets of collaboration

cure goods at minimum cost, without necessarily considering the impact of their decisions on the overall profitability of the company. Such cost focus sometimes leads to high-volume less-frequent purchases driven by trade promotions, resulting in excess inventory and increased logistics costs due to limited storage space. An extensive survey by Bain & Company shows that "the cost of excess inventory in stores, driven by 'silo' planning and misaligned trade promotions, amounts to more than 25 percent of annual sales." [34] The net landed cost approach eliminates such inefficiencies by coordinating the procurement decisions with other functions, such as inventory and logistics, throughout the enterprise [45].

Inter-enterprise collaboration occurs when independent companies work together, synchronize and modify their business practices for mutual benefits, thereby shifting the nature of traditional relationships from adversarial to collaborative [65]. As in the case of intra-enterprise collaboration, inter-enterprise collaboration can be *horizontal* where companies with similar characteristics, which are potentially competitors, collaborate on a particular business function, such as procurement. Examples include Covisint (founded by DaimlerChrysler, Ford, General Motors and Renault-Nissan) [3], and numerous group purchasing organizations in the health care industry [6]. Collaborative procurement helps the buyers to leverage more value-added pricing, service, and technology from their external suppliers than could be obtained individually [55, 64]. Alternatively, it can be *vertical*, where partners in a supply chain, e.g., a supplier and a manufacturer, collaborate to improve the overall efficiency of the chain.

1.2 Why do we need collaboration?

Supply chain management covers a whole spectrum of activities from product and process design to manufacturing, procurement, planning and forecasting, order fulfillment, and distribution.

Managing such complex systems requires complex tradeoffs. Many times the subsystems rely on local optimization. However, different entities in the chain may have different and often conflicting objectives. Moreover, the output of one system is the input of another system. Hence even though they are decentralized, supply chain activities are interconnected. Therefore, it is essential to consider the *entire* system and coordinate decisions (Figure 2).

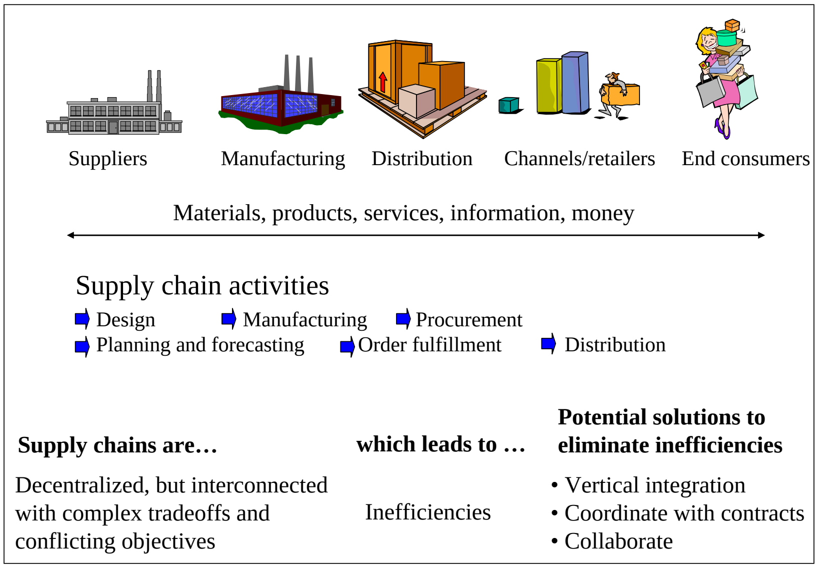


Figure 2: A typical supply chain

Given that each participant in a supply chain acts on self interest and does not necessarily have access to the same information (e.g., the retailer may have more information about the end consumer demand compared to the supplier), the individual choices of the participants collectively do not usually lead to an "optimal" outcome for the supply chain. That is, the total profits of a typical "decentralized" supply chain which is composed of multiple, independently managed companies, is less than the total profits of the "centralized" version of the same chain, if such a chain could exist and be managed optimally by a single decision-maker to maximize the entire chain's profits.

One possible strategy for reducing such inefficiencies is "vertical integration," where a company owns every part of its supply chain, including the raw materials, factories, and stores. An excellent example of vertical integration was Ford Motor Co. early in the 20th century [105]. In addition to automobile factories, Henry Ford owned a steel mill, a glass factory, a rubber tree plantation, an iron mine, and railroads and ships used for transportation. Ford's focus was on "mass production," making the same car, Model T, cheaper and faster. This approach worked very well at the beginning. The price of Model T fell from \$850 in 1908 to \$290 in 1924. By 1914, Ford had a 48% share of the American market, and by 1920 Ford was producing half the cars made worldwide. Vertical integration allows a company to obtain raw materials at a low cost, and exert more control over the entire supply chain, both in terms of leadtimes and quality. However, we do not see many examples of vertically integrated companies today. Why? Mainly because in today's fast paced economy, where customers' needs and tastes change overnight, companies which focus on core competencies and are nimble are more likely to stay ahead of competition and succeed. Hence, we see an increasing trend towards "virtual integration," where supply chains are composed of independently managed but tightly linked companies. Innovative practices, such as information sharing or vendor managed inventory (VMI), are successfully used by some companies such as Dell Corporation and Cisco Systems to get closer to virtual integration [68]. All of these steps companies take towards virtual integration fall under the umbrella of *collaboration*, which is the main focus of this chapter.

While companies increasingly believe in the potential benefits of collaboration, most are still reluctant to changing their supply chain practices, and in such cases it is desirable to design contracts (defining the terms of trade) or change the terms of the existing contracts, to align incentives and reduce inefficiencies. This is known as "supply chain coordination" and is discussed in Section 2. Similar concepts apply to independently managed divisions within a company as well. One should keep in mind that even though supply chain coordination is a step towards supply chain collaboration, it does not entail all benefits as well as complications that collaborative environments create.

In summary, collaboration may be as simple as sharing information, or as involved as joint product design (Figure 3). Supply chain activities with a high potential of benefiting from collaboration include new product introduction (planning, pricing, product design and packaging), procurement, logistics, replenishment planning and demand forecasting. We discuss each of these activities in some detail in the following sections.

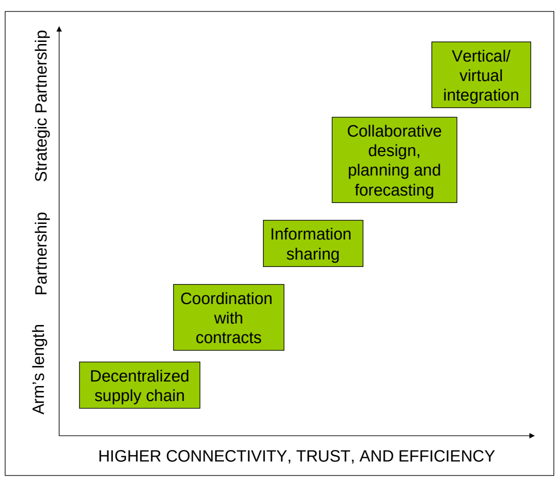


Figure 3: A spectrum of collaboration in supply chains

2 Intra-firm and Supply Chain Coordination through Incentives and Contracts

In a supply chain (SC), there are multiple firms owned and operated by different parties, and each of these firms take decisions which are in line with their own goals and objectives. Similarly, often times large firms consists of multiple "divisions," such as marketing, production, procurement, logistics, and finance, each having their own goals and incentives and focusing on different aspects of the firm's operations. As in all decentralized systems, the actions chosen by SC participants or different divisions of a firm might not always lead to the "optimal" outcome if one considers the entire system as one entity. That is, since each player acts out of self-interest, we usually see inefficiencies in the system, i.e., the results look different than if the system was managed "optimally" by a single decision-maker who could decide on behalf of these players and enforce the type of behavior dictated by this globally (or centrally) optimal solution.

In this section, we take a look at the nature of inefficiencies that might result from the decentralized decision-making within a firm or in a supply chain, and if and how one can design incentive mechanisms or contracts such that even though each player acts out of self interest, the decentralized solution might approach the centralized optimal solution. Such incentive mechanisms and contracts are useful if companies want to reduce inefficiencies in their supply chains without necessarily engaging in elaborate collaborative activities. For excellent reviews on supply chain contracts and coordination we refer the reader to Tsay, Nahmias and Agrawal [108] and Cachon [26].

2.1 Intra-firm Coordination

Examples of "disconnect" between different divisions (or functional units) or a firm are abundant. "It's a familiar scenario. Orders spike and manufacturing can't keep up. The people on the manufacturing floor blame purchasing for the production line shutting down because purchasing didn't buy enough materials and logistics didn't get the materials to the plant in time. Purchasing and logistics look at the sales organization and say they did not get any forecasting information to predict a big spike in demand so inventories could be built to cover the demand." [53]

In addition to communication inefficiencies between different divisions of a firm, inefficiencies or suboptimal decisions can also arise due to misaligned incentives. "Rewards and recognition systems misaligned with corporate objectives can result in behavior that is not anticipated or desired by management. These unanticipated actions may be personally beneficial to front-line sales reps, manufacturing floor managers or even senior executives, yet they move the company away from its overall goals or cause systemic harm." [93] In an executive roundtable at Tuck School of Business at Dartmouth, Steve Stone from Lowe's recalled an oversupply of lawn mowers pushed out to the stores in an effort to minimize distribution center inventory, only to have them linger unprofitably as Spring arrived unseasonably late [96]. Sysco's Kirk Drummond described situations where salespeople brought in huge last minute orders for next-day fulfillment without any advance warning to operations. Staples' Kevin Holian described an overenthusiastic promotion where merchants dramatically underestimated potential demand at a deeply discounted price point. Misaligned incentives also lead to conflicts in decision-making in an organization. For example, sales/marketing is often evaluated based on revenues or sales volume, whereas manufacturing is often evaluated based on cost or operational efficiency. When it comes to decisions such as quoting leadtimes to customers, marketing would prefer shorter leadtimes with the goal of attracting more customers whereas manufacturing would prefer longer leadtimes with the goal of completing the orders on time, without using overtime or other costly options, and to avoid delay penalties.

Pekgun et al. [79] study the incentive alignment between marketing and manufacturing in a setting where marketing is responsible from price and manufacturing is responsible from leadtime decisions. They find that coordination among these departments can be achieved with a transfer price contract with bonus payments. Under coordination, both production and marketing are better off, i.e., costs are lower and revenues are higher, leading to higher overall profitability for the firm. de Groote [37] studies product variety versus process flexibility in the marketing/operations interface. Balasubramanian and Bhardwaj [23] model a duopoly in which firms with decentralized marketing and manufacturing functions with conflicting objectives compete on the basis of price and quality. Teck and Zheng [107], Chatterjee, Slotnick and Sobel [30] and Erkoc and Wu [46] study the leadtime quotation problem within the marketing/operations interface.

It is crucial for a firm to adjust the incentives of different divisions so that they are better aligned with the firm's overall goals and strategy. While incentive alignment (or sharing information) by itself is not a cure for all inefficiencies that arise in a firm, it contributes significantly towards better processes and higher motivation for collaboration.

2.2 Supply Chain Coordination

To illustrate the inefficiencies that might result in a decentralized supply chain, we consider a simple stylized two-stage supply chain with one supplier and one retailer (Figure 4), where the retailer buys goods from the supplier and sells them in the end market.[1]

For simplicity, assume that (i) the supplier is uncapacitated, and has unit cost of production c, (ii) the retailer faces a market where the price is inversely related to the quantity sold, (iii) there

[1]The material in this section is based on Erhun and Keskinocak (2003). Interested readers may refer to [44] for a more detailed analysis.

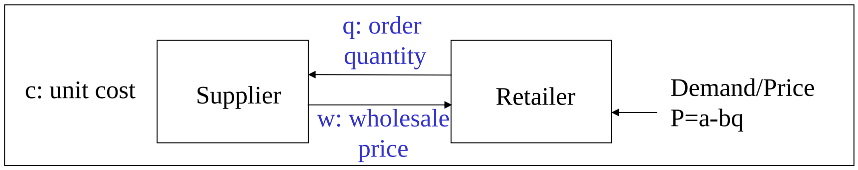


Figure 4: A simple supply chain

is a linear demand curve $P = a - bq$ where P is the market price and q is the quantity sold by the retailer, and (iv) all of this information is common knowledge[2].

First let us consider the simple *wholesale price contract* where the supplier charges the retailer w per unit. The supplier's and the retailer's profits are $\Pi_S = (w - c)q$ and $\Pi_R = (a - bq - w)q$, respectively. The supply chain's profits are $\Pi = \Pi_S + \Pi_R = (a - bq - c)q$. Note that the choice of w only indirectly affects the total SC profits, since the choice of w impacts the choice of q.

Decentralized Supply Chain (DSC): As in most real-world supply chains, suppose that the supplier and the retailer are two independently owned and managed firms, where each party is trying to maximize his/her own profits. The supplier chooses the unit wholesale price w and after observing w, the retailer chooses the order quantity q. The equilibrium solution for this decentralized supply chain is given in the second column of Table 1. In this contractual setting, the supplier gets two-thirds of the SC profits, the retailer gets only one-third. This is partly due to the first-mover advantage of the supplier.

Table 1: Wholesale price contract

	DSC	CSC
Supplier's wholesale price (w)	$w = (a + c)/2$	w
Retailer's quantity (q)	$q = (a - c)/4b$	$q^* = (a - c)/2b$
Market Price (P)	$P = (3a + c)/4$	$P^* = (a + c)/2$
Supplier's profit (Π_S)	$\Pi_S = (a - c)^2/8b$	$\Pi^*_S = (w - c)q$
Retailer's profit (Π_R)	$\Pi_R = (a - c)^2/16b$	$\Pi^*_R = (P - w)q$
Total SC profits (Π)	$\Pi = 3(a - c)^2/16b$	$\Pi^* = (a - c)^2/4b$

Now, let us consider a centralized (integrated) supply chain (CSC) where both the retailer and the supplier are part of the same organization and managed by the same entity.

Centralized Supply Chain (CSC): In this case there is a single decision-maker who is

[2]Note that in such a deterministic environment, the retailer will always purchase from the supplier exactly as much as he will sell in the market. The "common knowledge" assumption may imply some information sharing between the supply chain partners.

concerned with maximizing the entire chain's profits $\Pi = (a - bq - c)q$. The solution for the CSC is given in the third column of Table 1.

From Table 1 we see that the quantity sold as well as the total SC profits are higher and the price is lower in the CSC than in the DCS. Hence, both the supply chain and the consumers are better off in the CSC. What about the retailer and the supplier? Are they both better off, or is one of them worse off in the CSC? What is the wholesale price? How does the choice of w affect the market price, quantity, and the supply chain profits? A closer look would reveal that w has no impact on these quantities. Any positive w would result in the same outcome for the CSC because the firm would be paying the wholesale price to itself! However, the choice of w in the CSC is still very important as it determines how the profits will be allocated between the supplier and the retailer. We can interpret w as a form of transfer payment from the retailer to the supplier. What is the minimum w that is reasonable? For positive supplier profits, we need $w \geq c$. If we set $w = c$, the supplier's profits are zero whereas the retailer captures the entire supply chain's profits. What is the w that splits the SC profits equally between the retailer and the supplier? If we set $w = (a + 3c)/4$, $w - c = P - w = (a - c)/4$ and each party's profits are $(a - c)^2/8b$. Note that this is the same as the supplier's profits in the DSC. Hence, if the supplier and the retailer split the profits equally in the CSC, the supplier is at least as good, and the retailer is strictly better off than in the DCS.

In the DSC, the outcomes are worse for all the parties involved (supplier, retailer, supply chain, and consumer) compared to the CSC, because in the DSC both the retailer and the supplier independently try to maximize their own profits, i.e., they each try to get a margin, $P - w$ and $w - c$, respectively. This effect is called *double marginalization* (DM).

> "In a serial supply chain with multiple firms there is coordination failure because each firm charges a margin and neither firm considers the entire supply chain's margin when making a decision." [91]

In this stylized model, the profit loss in the DSC due to DM is 25% (also referred to as the DM loss). It is clearly in the firms' interest to eliminate or reduce double marginalization, especially if this can be done while allocating the additional profits to the firms such that both firms benefit. This simple model suggests that vertical integration could be one possible way of eliminating double marginalization. However, for reasons we discussed at the beginning of this chapter, vertical integration is usually not desirable, or not practical. Then the question is, can we change the terms of the trade so that independently managed companies act as if they are vertically integrated? This is the concept known as *supply chain coordination.* In this stylized model, the retailer should choose $q^* = (a - c)/2b$ in any coordinating contract.

One can easily think of some very simple alternative contracts to eliminate double marginalization:

Take-it-or-leave-it-contract: The supplier offers the following contract to the retailer: Buy q^* at the wholesale price $w = (a + c)/2$, or nothing. In this case the supplier's profit is Π^*, i.e., the supplier captures 100% of the CSC profits.

Marginal pricing: The supplier sets $w = c$. In this case, the retailer's profit is Π^*, i.e., the retailer captures 100% of the CSC profits.

Note that the take-it-or-leave-it contract would require a very powerful supplier whereas the marginal pricing contract would require a very powerful retailer. In practice, neither the supplier nor the retailer is so powerful in general to dictate such contract terms. Hence, we need to consider alternative contracts that coordinate the supply chain. In general, the following aspects are important in (coordinating) contracts [26]: (i) Profitability: Achieve profits close to optimum. (ii) Fairness and flexibility: Allow for flexible division of profits. (iii) Implementability: Should be easy and low-cost to administer.

Revenue Sharing Contract: In a revenue sharing contract, the retailer pays a unit wholesale price w to the supplier and shares a fraction $\alpha < 1$ of his revenues with the supplier. For the simple supply chain in Figure 4, one can show that the revenue sharing contract can coordinate the supply chain with a w lower than what is charged under the wholesale price contract, and α can be chosen such that both the supplier and the retailer are better off.

A well-known example of the revenue sharing contract has been implemented between Blockbuster and movie studios [102]. Blockbuster is a retailer, which purchases movies from the studios (suppliers) and rents them to customers. The supplier's wholesale price impacts how many videos Blockbuster orders and hence, how many units are eventually rented by customers. Before 1998, the price of purchasing a tape from the studio was very high, around \$65. Given that rental fees are in the order of \$3-4, Blockbuster could purchase only a limited number of videos and this resulted in lost demand; especially during the initial release period, where the demand was high (peak demand usually lasts less than 10 weeks), 20% of customers could not find what they were looking for on the shelf. Hence, the studio's high wholesale price impacted the quantity purchased by Blockbuster, and in turn, the revenues and the profitability of both firms. Seeing this problem, Blockbuster and the studios went into a revenue sharing agreement. According to this, Blockbuster pays only \$8 per tape initially, but then gives a portion (somewhere around 30 to 45%) of the revenues generated from that tape back to the supplier. Since this agreement reduces Blockbuster's initial investment in movies, it orders more tapes from the studio, hence, is able to meet more demand, generate more revenues, and give back a portion of those revenues back to the supplier. Blockbuster increased its overall market share from 25% to 31% and its cash flow by 61% using this agreement. This is clearly a win-win situation. The supplier might be better off even if he sells each unit below its production cost. A similar agreement is used between studios and theaters as well.

In case of multiple retailers, it turns out that coordination is not guaranteed under revenue sharing unless the supplier has the flexibility to offer different contracts to different retailers [26]. Unfortunately, such "discrimination" might not always be possible due to legal considerations. Another issue is the impact of such an agreement on the behavior of a retailer who sells competing goods and also sets prices. In such a case, the retailer may have an incentive to use the goods under revenue sharing agreement as loss leaders, to drive the traffic to the store and increase overall sales. Finally, revenue sharing loses its appeal if the revenues depend on the retailer's sales effort. For a retailer who is taking only a fraction of the revenues he generates, the incentive to improve sales goes down. While revenue sharing helps to ensure that the retailers buy and sell the "right" quantity, it hurts their sales effort. This is especially true in retail industries such as automobile sales, where a retailer's sales effort makes a big difference in the overall sales rate.

Buyback Contract: We observed that in the decentralized chain under wholesale price contract, the retailer orders less than the optimal quantity. This was mainly due to double marginalization. An additional reason for ordering less than the optimal quantity could be the risk of excess inventory. For example, consider a newsvendor type model, where there is a single selling opportunity and the seller needs to procure/produce before knowing the demand. This is the case for most fashion retailers, where products need to be ordered months in advance, due to long leadtimes, way before the demand is known and the actual selling season begins. Whatever is not sold at the end of the selling season is salvaged, and the retailer bears the cost of having excess inventory.

In a buyback contract, the retailer can return unsold goods to the supplier at the end of the selling season and get some money back. Specifically, the supplier purchases leftover units at the end of the selling season for \$$b$ per unit, where $b < w$. Buyback contracts allocate the inventory risk between the supplier and the retailer and motivate the retailer to purchase more than what he would in a typical wholesale price contract, which can benefit both the retailer and the supplier. Buyback contracts are commonly used in industries with perishable products and short product lifecycles, such as high-tech industry.

Two-Part Tariff: In a two-part tariff, the supplier charges a fixed fee F and a wholesale price w per unit. The following is an example of two-part tariffs from fractional aircraft ownership:

> "For travellers who value flexibility and the increased security of knowing everyone on the flight, there is a compelling incentive for opting for fractional ownership. ... Under NetJets' scheme, a one-sixteenth share of a small Cessna Encore, which seats seven passengers, costs \$487,500 plus a monthly management fee of \$6,350 and an occupied hourly fee of \$1,390 for each of the allotted 50 hours." [47]

For the simple supply chain in Figure 4, one can show that the two-part tariff can coordinate the supply chain with $w = c$, and the choice of F determines how the profits are allocated between the supplier and the retailer.

Quantity Discount Contract: In the examples we discussed above, we assumed that w is fixed per unit. However, in many applications suppliers offer quantity discounts.

> "We offer a quantity discount for orders of 10 pieces and more of the same products." (www.decor24.com)

> "Quantity discounts on miscellaneous accessories: 0 - 4 = 0%; 5 - 9 = 5%; 10 - 24 = 10%; 25 - 49 = 15%; 50 - up = 20%" (www.frye.com)

In quantity discount contracts, if the retailer purchases more units, the unit price goes down. Therefore, the supplier charges $w(q)$ where w is a decreasing function of q. Again, for the simple supply chain in Figure 4, one can show that the quantity discount contract can coordinate the supply chain with the appropriate choice of $w(q)$.

Our focus in this section was on incentive mechanisms or contracts which partially "align" the incentives of different players in a firm or a supply chain to achieve results which are better than in a purely decentralized setting. We restricted ourselves to environments where all players have access to the same information. However, this is rarely the situation in supply chains. Complex contract structures, which most probably will be renegotiated[3], may be required in environments with asymmetric information. Hence, contracts and incentive mechanisms that do not require a true collaboration may have limited effectiveness in complex supply chains. In the following section, we discuss collaborative practices which usually require more interaction among participants beyond setting contractual terms.

3 Supply Chain Collaboration

As we discussed earlier, supply contracts are one alternative to eliminate inefficiencies in supply chains. Yet another alternative is collaboration. One should note that collaboration is more than managing relations with written contracts. In the following sections we discuss collaborative activities that have a high potential of improving the performance of supply chains.

One useful tool for modeling analyzing collaboration among firms is cooperative game theory, which studies the outcomes when the firms come together and form coalitions. In the Appendix, we provide brief definitions of well-known terminology from cooperative game theory.

[3] Gartner Research [100] estimates that "80 percent of outsourcing relationships will be renegotiated during lifetime of contract."

3.1 Collaboration in Design and New Product Introduction

Reducing time-to-market and shortening product life cycles are commonly advocated as sources of competitive advantage [24, 25]. By launching new products faster than competitors, firms can rapidly respond to customer feedback, establish new standards, improve brand recognition, quickly introduce technical innovations, and capture a bigger share of the market, resulting in higher profits [110]. Following this trend, several companies in diverse industries have gained market share, increased profits, and built strong brands. For instance, Intel leapfrogged an entire technological generation in 2001 to maintain leadership in the semiconductor manufacturing industry; the company named its strategy One Generation Ahead [43].

Aberdeen Group reports that companies can reduce costs by nearly 18% by involving suppliers and procurement in new product development processes at design inception and development phase compared to companies delaying such collaboration until the product prototype phase. Early involvement speeds time-to-market (TTM) 10% to 20%. For example, Microsoft was able to launch the first generation of XBox in 16 months (6 months shorter than Sony's PlayStation 2), winning 3.6% market in 4 months by creating a collaborative environment with its manufacturing partner and nearly 200 component vendors [88]. General Motors (GM) saved $1 billion in IT expenses by reducing its TTM from 48 months to 18 months [84].

Even small steps such as information sharing enables improvements in the design and new product introduction by enabling standardization, eliminating repetition, and shortening the leadtime of the product without lowering the quality. Especially in industries, such as apparel, which are characterized by very short product lifecycles but long development cycles, such improvements are valuable. Boyd Rogers, VF's (the world's largest apparel maker) VP of supply chain and technology states that "It takes as long as nine months to design a new pair of jeans and get them on the shelves. ... If you look at the cycle times from design to retail shelf, about two-thirds is spent in product development." [104] According to Johnson [57], the biggest challenges in the apparel industry are: (1) Ensuring that everyone in the supply chain has an accurate and up to date description of the product. (2) Visibility to the entire product and sourcing team with a documented history of product changes. Long development times, combined with the above problems, create an excellent environment for collaborative design. "VF believes [collaboration on design and logistics], could save it $100 million a year and cut months off the time to get a new design to market." [104] An intra-enterprise communication through a Web-enabled system improves the design process by reducing the cycle times, reducing communication costs and errors, speeding time-to-market, improving pricing, and standardizing design process through templates of past designs [56, 104]. Collaboration brings additional improvements by combining the knowledge base of partners.

Without doubt, collaborative product design and new product introduction has its challenges.

Trust is a big issue - adversarial relationships may emerge due to lack of trust and failure to generate a win-win solutions. In that sense, partner selection is a key! According to Mentzer et al. “Not all partners and supply chain activities are created equal.” Hence, it is important to “choose those that will deliver the greatest benefits.” [73] Partners should be comfortable with the relationship as well as their roles and responsibilities within the relationship to make collaboration work. Yet another dimension is the availability of tools and processes to enable collaboration. With vendors such as UGS Corp., Dassault Systèmes, Agile Software, MatrixOne, and Parametric Technology, Product Lifecycle Management (PLM) suites provide such tools and processes. Already a multi-billion dollar industry, PLM is “quickly maturing as a major category of enterprise software.” [69]

3.2 Collaboration in Planning

Bullwhip effect, which refers to the phenomenon where the order variability amplifies as one moves upstream in a supply chain from retailers to distributors to manufacturers to suppliers (Figure 5), is one the well-documented sources of inefficiency in supply chains [66]. There are many factors that contribute to the bullwhip effect: Demand forecasting and inventory management, order batching, price fluctuation, and rationing and shortage gaming.

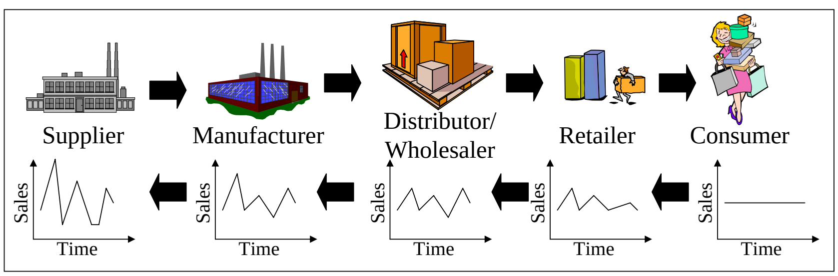


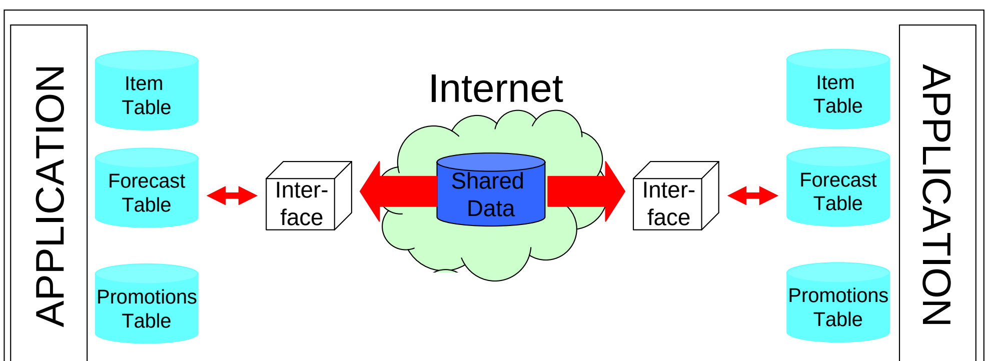
Figure 5: Bullwhip effect

In order to eliminate inefficiencies due to demand forecasting and inventory management, many supply chain partners now rely on collaborative processes such as Quick Response (QR), Collaborative Planning, Forecasting, and Replenishment (CPFR) and Vendor Managed Inventory (VMI). QR, which can be viewed as the simplest of all collaborative planning activities, entails suppliers receive Point-of-Sale (POS) data from retailers and use this information to improve forecasting, and to synchronize production and inventory activities. Well-publicized success stories of QR include Zara and Benetton. These companies, among others, successfully use QR to operate their effective and responsive supply chains. However, companies can take additional collaborative efforts to further improve their operations. For example, they can choose to participate in collaborative forecasting in order to arrive at an agreed upon forecast between all partners, which is the idea behind CPFR. This requires sharing of additional information on future demand, such as pricing, promotions, and release of new products. Finally, retailers may leave the inventory decision to suppliers as in VMI within agreed upon limits.

3.2.1 Collaboration in Forecasting

Collaborative forecasting is an iterative forecasting process in which all participants in the supply chain collaborate to arrive at an agreed upon forecast. It entails sharing of not only forecasts but also information about other factors which affect future demand, such as, pricing, promotions, and release of new products. Such an information sharing significantly reduces, but does not completely eliminate, the bullwhip effect [90].

CPFR is a standard set of processes and a protocol, developed by Voluntary Inter-Industry Commerce Standards Committee [10], for sharing a wide range of data over the Internet. It is a platform for negotiation before agreeing on a forecast (Figure 6). In one of the first CPFR pilots, Wal-Mart and Warner-Lambert eliminated 2 weeks of inventory and cut cycle times in half for Listerine. On a successful pilot from Nabisco and Wegmans, the total snack nut category sales went up from 11%, as opposed to a 9% decline for other retailers. In particular, Planters sales went up 40%, as the efficient replenishment enabled more promotions and discounting. The warehouse fill rate increased from 93% to 97% and inventory dropped by 18%. Henkel KgaA, a German-based household cleaners and home care products manufacturer, announced that from October 1999 to March 2000, number of forecasts with average error more than 50% declined from nearly half to 5% and number of forecasts with error rate of less than 20% grew from 20 to 75% as a result of a CPFR implementation [17].



ITEM NUMBER	RETAILER'S FORECAST	MANUFACTURER'S FORECAST	DELTA	TOLERANCE	OK?
567890001	1,200	1,150	50	100	√
567890002	14,000	9,000	5,000	2,000	X
567890003	330	350	20	50	√

Figure 6: CPFR: Shared Process and Data Model (Source: CPFR Committee [4])

The benefits of CPFR are numerous. For the retailers, the benefits include improved forecast accuracy, better store shelf stock rates and higher sales, lower inventories, better promotions planning, lower logistics costs, and lower process costs. For the suppliers, the benefits include lower inventory costs, smoother demand patterns, faster replenishment cycles, better customer service, and lower production planning and deployment costs [4]. Given these benefits, the academic literature on collaborative forecasting is flourishing [19, 20, 21, 60, 75]. Sheffi [89] provides a quick overview of the development of collaboration in supply chains and discusses the possible benefits of collaboration based on case studies focusing on CPFR.

In a series of papers Aviv [19, 20, 21] studies the potential value of CPFR in a cooperative supply chain using stylized models with a single retailer and a single manufacturer and shows that the benefits of collaborative forecasting depend on (i) the relative explanatory power of the supply chain partners, (ii) the supply side agility, and (iii) the internal service rate. He identifies cases where a partnership does not appear to be valuable to the manufacturer. Miyaoka [75] considers a decentralized two-stage supply chain with a single selling season and addresses the incentive issues associated with implementing collaborative forecasting. She introduces a concept that she calls Collaborative Forecasting Alignment (CFA) that aligns the parties' incentives so that demand information can be shared credibly with a simple transfer price agreement. Kurtulus and Toktay [60] investigate the conditions that favor the use of collaborative forecasting between a supplier and a retailer in a newsvendor setting. Both the supplier and the retailer can exert independent, costly effort to improve the quality of their local demand forecasts. The authors characterize the existence and stability conditions of an equilibrium in which both parties invest in improving the forecast quality as collaborative forecasting being sustainable.

An interesting research direction in CPFR is N-tier relationships, i.e., analyzing either multiple partners in one tier or multiple tiers of partners. Especially mechanisms that enable truthful information sharing for multiple partners in one tier would be valuable. Current practices would also greatly benefit from empirical research on the value, adoption, and success factors of CPFR.

3.2.2 Vendor-Managed Inventory

VMI, also called the Continuous Replenishment Program (CRP), is an agreement between a supplier and a buyer, which gives "the responsibility to maintain adequate inventory levels at the buyer's site" to the supplier [54]. Both the academic literature [12, 22, 38, 39, 40, 29, 32, 48, 58] and the implementations of VMI [49, 80] are growing at a steady pace.

VMI allows coordination of production and distribution between suppliers and retailers. There are several benefits of this type of coordination that are documented by successful implementations. One such success story is due to Campbell Soup Company. In early 1990s Campbell Soup Company was enjoying a stable business environment: only 5% of their products were changing every year and the demand was predictable. More than 98% of demand was satisfied from stocks of finished goods. Replenishment leadtime for new products was one month and the minimum market life cycle was six months. However, the company suffered from low margins and in 1991 implemented CRP. They started monitoring demand and inventory levels daily (via Electronic Data Interchange (EDI) links) and jointly decided on inventory policy and parameters with their retailers. As a result of these changes, inventory levels went down from 4 weeks to 2 weeks of supply, in-stock availability went up to 99.2% from 98.5%, and the company recognized the negative impacts of the overuse of price promotions [49, 54]. Wal-Mart and P&G, Kmart and First Brands, Inc., and Kmart and Whitehall Robbins, who have successfully incorporated VMI into their operations, have observed similar benefits [90].

One critical question in any VMI implementation is: Who owns inventory? There are different ways of handling this issue of ownership. Traditionally, in VMI implementations the retailer owned inventory. This creates obvious incentive misalignments between retailers and suppliers. Recently, we see a movement towards a consignment relationship where the supplier owns inventory until the goods are sold. Based on the Institute of Management and Administration's 2004 Inventory Management Report Survey, Mullen reports that "37.3 percent of respondents shift inventory ownership to suppliers via consignment agreements." In the list of top 10 best practices, the respondents ranked inventory consignment in third place in 2004 (up from fifth place in 2003 and tenth place in 2002) [76]. Wal-mart, for example, has such consignment relationships with some of its suppliers, including most of its grocery purchases [106]. As a part of the E-Chain Optimization Project (eChO), STMicroelectronics and one of its strategic partners implemented CPFR, based on VMI model with consignment. According to Peleg [80], "This resulted in a dramatic transformation of a superficial collaborative forecasting process to one that involves deep collaboration."

The clear benefits of VMI that we discussed above has created interest in academia as well. Mishra and Raghunathan [74] identify yet another benefit of VMI for the retailer by showing "that VMI intensifies the competition between manufacturers of competing brands [due to brand substitution] and that the increased competition benefits a retailer that stocks these brands [as manufacturers stock more inventory]." Çetinkaya and Lee [29] analyze a model that coordinates inventory and transportation decisions in a VMI setting. In their model, a vendor, who uses a certain kind of (s, S) policy, satisfies demands for several retailers in close proximity. In order to benefit from the scale economies in transportation, the vendor may batch orders. Hence, the vendor's inventory should take into account the replenishment frequency. The authors jointly compute the optimum replenishment quantity as well as dispatch frequency. Cheung and Lee [32] study the relative benefits of two VMI-initiatives, i.e., joint/coordinated replenishment systems and joint/coordinated replenishment systems with stock rebalancing, in a setting close to Çetinkaya and Lee's. The authors conclude that shipment coordination and rebalancing reduce costs as the number of retailers who can participate, i.e., many customers in close proximity, increases. In a related work, Altintas et al. [15] show that the increasing burden of transportation costs are forcing suppliers to eliminate transportation inefficiencies by motivating buyers to place full-truckload orders and suggest discount schemes that suppliers may use to moderate buyers ordering behaviors under different transportation costs.

Fry et al. [48] model a type of VMI agreement called a (z, Z) VMI contract. In a (z, Z) VMI contract inventory at the customer is reviewed periodically. If upon review, the inventory level is below z, then the supplier has to pay the retailer a penalty of b^-, and if upon review, the inventory level is above Z, then the supplier has to pay the retailer a penalty of b^+. The authors formulate a Markov decision process (MDP) in which the supplier makes three types of decisions: production quantity, outsourcing (expediting) quantity, and delivery quantity to the retailer. The retailer takes the supplier's optimal policy in the MDP into account, and chooses the values of z and Z that minimizes the retailer's expected cost. They show that there exist values of z, Z, b^-, and b^+ (that could be chosen by a central decision maker) that would optimize the overall supply chain performance. They also formulate a MDP model of a conventional retailer managed inventory (RMI) setting, in which the supplier has complete knowledge of the consumer demand distribution, the retailer's inventory level, and the retailer's ordering policy, thus modeling RMI with complete information sharing. They compare the overall performance of the supply chain under both settings numerically and show that the results are inconclusive. They find that VMI can lead to both significantly better or worse overall supply chain performance than RMI.

VMI implementations are not always successful, especially when communication and trust are not built into the partnership. Spartan Stores, a grocery chain, shut down VMI program just after one year. Buyers did not trust suppliers and spent no less time in ordering. Suppliers could not incorporate promotional information into forecasts, hence, delivery levels were unacceptably low during promotion times [90]. This example highlights a very common mistake in VMI implementations: unexpected demand changes need to be shared! Retailers should always keep in mind that because they no longer manage the inventory, inventory does not disappear from the supply chain. Hence, they should not expect suppliers to incorporate big swings in demand to their operations. As Mullen argues "In the long run, it is better ... to work with suppliers collaboratively to reduce inventory throughout the supply chain. This effort can lead to a long-term, mutually beneficial partnership." [76]

3.3 Collaboration in Production Management

Collaborative Production Management (CPM) – an application of collaborative concepts to the factory floor – includes intra- and inter-enterprise collaboration and real-time information sharing on "production planning, finite scheduling, material and recipe management, data collection, document control, lot and work order tracking, plant floor and enterprise system interfacing, messaging and alarming, performance analysis, genealogy, dispatching and workflow management" [94]. It thus "synchronizes, executes, tracks, reports, and optimizes manufacturing processes" [95].

One of the dimensions of CPM is collaborative scheduling. According to a manager of Military Technology and Operations at a multinational aerospace manufacturer "In order to reduce production cost and customer lead time, it is very important to coordinate daily manufacturing schedules closely between our own plants and those of our suppliers. Since our suppliers typically have different objectives from ours, conflicts often arise and have to be resolved through scheduling coordination." [51]

In a series of papers, Hall and his colleagues study the benefits and challenges of coordination within supply chain scheduling models. Hall and Potts [52] and Dawande et al. [36] analyze conflict and cooperation issues arising in an arborescent supply chain[4]. In Hall and Potts's model, a supplier makes deliveries to several manufacturers, who also make deliveries to customers. In Dawande et al.'s model a manufacturer makes products which are shipped to customers by a distributor. Hall and Potts show that cooperation between a supplier and a manufacturer may reduce the total system cost by at least 20% or 25%, or by up to 100%, depending upon the scheduling objective. Dawande et al. argue that the ideal schedule of the manufacturer and the distributor (determined by cost and capacity considerations) are in general not well coordinated, which leads to poor overall performance. Hence, Dawande et al. consider the extent to which one decision maker's cost is larger than optimal when the other decision maker imposes its optimal schedule. The authors show that the cost of conflict can be eliminated and the parties benefit from cooperation when the dominant player agrees not to use its individually optimal schedule. The authors recommend a perfectly equitable split of the surplus, when the parties accurately and continuously share all cost data in a verifiable way. Alternately, they recommend negotiation for a transfer payment from the dominated player to the dominant player. Chen and Hall [31] study the same issues in an assembly system where suppliers provide parts to a manufacturer who performs a nonbottleneck operation for each product and demonstrate computationally that the cost saving realized by cooperation between the decision makers is significant in many cases in assembly systems as well.

According to the ARC Advisory Group, the CPM for discrete manufacturing market will more than double and hit $1.4 billion by the end of 2010 [99]. The benefits of CPM are significant: reduced errors, increased production rates, improved capacity utilization, increased equipment reliability, improved efficiency and productivity of staffing, improved responsiveness to demand changes, improved quality, and continuous improvement. In order to achieve these benefits, CPM should integrate with business, engineering, and maintenance systems.

[4] In arborescent supply chains, each player has only one supplier but can act as a supplier to one or many players.

3.4 Collaboration in Transportation

"Transportation continues to be the biggest component of overall logistics cost and accounts, on average, for 6% of a company's annual expense budget. ... Technology and shipper-carrier collaboration are opening new doors to cost/price reductions in all areas of the transportation process - procurement, planning, execution and monitoring." [77] Hence, collaborative practices have seen an increased adoption in the transportation industry in recent years.

To transport the shipments of different shippers, a carrier often has to reposition its assets, e.g., trucks in case of a trucking company and containers in case of an ocean carrier. A recent industry report estimates that 17% and 22% of all truck movements in the U.S. are empty for large and small carriers, respectively, resulting in approximately 35 million empty miles monthly and a loss of billions of dollars [18]. These repositioning costs are reflected in the prices paid by the shipper, and eventually translate to higher prices of the goods sold in the market, impacting the entire economy. To reduce these costs, shippers and carriers can get together and collaborate on managing the timing and frequency of the shipments to better utilize the truck capacity of a carrier. Examples of such collaborative logistics networks include Nistevo, Transplace, and One Network Enterprises. By participating in collaborative activities through these networks, a number of companies such as General Mills, Georgia-Pacific, and Land O'Lakes were able to identify cost efficient routes and realize considerable savings (Figure 7). For example, Georgia-Pacific's percentage of empty movements decreased from 18% to 3% after forming collaborative partnerships with other companies in the Nistevo Network, where each 1% reduction in empty moves corresponds to $750,000 savings annually [103].

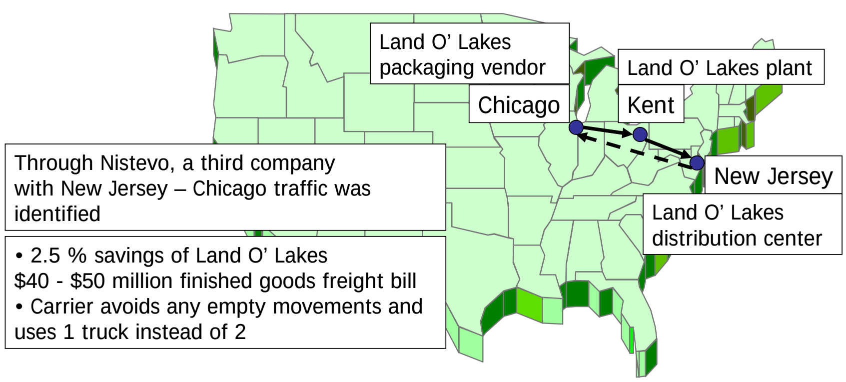


Figure 7: Collaborative routing example from Nistevo Network

For similar reasons as in trucking, collaboration has also been embraced by the sea-cargo industry. Repositioning empty containers is very expensive: According to ROI Container Cargo Alliance (July 2002) a 10% reduction in equipment and repositioning costs can potentially increase profitability by 35-50%. Several ocean carriers have formed alliances (e.g., Sea-Land and Maersk share vessels in the Atlantic and Pacific oceans), which allow them to realize economies of scale, extend customer base, and increase asset utilization (reducing empty container moves) while providing customers with more frequent sailings and faster transit times [13].

There are several important issues that need to be addressed for achieving successful collaborative transportation: (1) How to form routes to reduce empty moves? (2) How to share costs among the different participants? (3) How to establish trust among the participants and overcome cultural differences? The third question is of utmost importance, since collaborative networks cannot exist without trust and agreement among participants. For example, Kellogg's and General Mills, major competitors in food manufacturing, send most of their products to the same stores and could greatly benefit from sharing truck capacity or routes, however, they were not able to collaborate because of cultural roadblocks [103]. While we acknowledge the importance of trust, our focus in this section will be primarily on analytical approaches which can help answer the first two questions.

Generating Collaborative Tours: Identifying tours to minimize asset repositioning costs in a collaborative logistics network can be challenging, especially as the size of the network (i.e., the number of participants and the number of lanes) grows. Adding to the challenge are the existence of various timing constraints, including the following: (1) dispatch time windows, i.e., the time interval in which the load to be moved should be dispatched to arrive at its destination on time, and (2) Department of Transportation Hours of Service regulations, which limit driving and duty hours of truck drivers.

Ergun et al. [42] discuss optimization methodology that can be used in the identification of repeatable, dedicated truckload continuous move tours, which is relevant for companies that regularly send truckload shipments and are interested in collaborating with each other. Considering the constraints mentioned above, they focus on the Time-Constrained Lane Covering Problem (TCLCP), which is defined as follows: For a given set of lanes, find a set of tours covering all lanes such that the total duration of the tours is minimized and the dispatch windows are respected.

Given the large size of practical instances, Ergun et al. [42] focus on developing an effective and efficient heuristic for TCLCP. They implement a greedy heuristic that generates a large number of time-feasible cycles (potentially all) and greedily selects a subset of those cycles to cover the lanes based on some criterion measuring the desirability or attractiveness of a cycle. After all lanes are covered they perform a local improvement step to improve the solution. They test their methods on randomly generated test problems and also conduct a case study for a group purchasing organization to assess the potential value of collaborative transportation procurement for individual member companies. In the case study, a typical all-member instance for a single week involves about 750 locations and 5500 lanes. The potential savings due to continuous moves are estimated to be in the order of 9-10%. They observe that the smaller the dispatch window width the smaller the savings, due to the increased chance of waiting time between two consecutive moves.

Sharing costs/savings among collaborators: One of the most challenging aspects of collaboration is devising "fair" mechanisms to allocate the costs/savings among the participants such that the resulting collaborative arrangement is sustainable. According to Kevin Lynch, the President and CEO of Nistevo Corporation, "The key to understanding Collaborative Logistics lies in recognizing how costs are distributed in a logistics network." [67] In a recent paper, Ozener and Ergun [78] discuss desirable properties of cost allocation mechanisms in collaborative transportation[5].

In current practice, collaborative networks allocate benefits proportionally to the base cost (cost before collaboration) of the participating shipper's lanes. That is, the savings (the difference between the total base cost and the total cost of the collaborative tours) are distributed based on the percentage of the base cost each shipper has contributed to the collaborative transportation network. The example in Figure 8 (based on Ozener and Ergun [78]) shows that although such "proportional cost allocation" schemes are easy to implement, they are not fair from a game theoretic point of view. In this example, suppose that the cost of covering a lane is equal to 1. If only shippers A and B are in the network, the total cost of covering the lanes is 2, and the proportional cost allocation method allocates a cost of 1 to each shipper. With the addition of the new shipper C, the total cost of covering the lanes in the network becomes 4, and a cost of $\frac{4}{3}$ is allocated to each shipper. However, with this allocation, it is easy to see that shippers A and B (or A and C) are better off collaborating on their own with a total cost of 2. Therefore, the proportional cost allocation in this case is not fair and the *grand coalition* that consists of all the shippers in the network could be replaced by a subgroup of its members[6]. Note that the only allocation where the grand coalition is not threatened by any subgroup of its members is the allocation of $(0, 2, 2)$ to shippers A, B and C, respectively. Since shipper A creates a positive value for the other two shippers, it is charged less than B and C. However, charging shipper A nothing makes A a *free-rider* which may not be desirable in a collaboration. Furthermore, in the only fair allocation, where the grand coalition is maintained together, both shippers B and C are allocated their stand alone costs, so being in a collaboration brings no positive value for these two shippers. This simple example illustrates some of the challenges in finding a robust mechanism for allocating costs and savings in a collaborative framework.

As our simple example indicates, a cross monotonic cost allocation, i.e., an allocation where any member's benefit does not decrease with the addition of a newcomer, may not exist in the core

[5]Ozener and Ergun [78] use well-known terminology from cooperative game theory that we summarize in the Appendix.

[6]Ozener and Ergun [78] note that due to the costs associated with managing collaborations, limited rationality of the players and membership fees, a sub-coalition might not be formed even though it offers additional benefits to its members. Therefore, relaxing the stability restriction in a limited way might be acceptable for a cost allocation method.

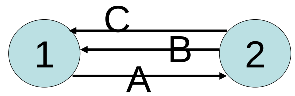


Figure 8: Cost sharing in a simple collaborative network

of the shipper collaboration problem. Hence, increased synergies due to addition of new members to a coalition do not necessarily create additional benefits for the participants. Therefore, Ozener and Ergun [78] study cross monotonic and stable allocations that recover a good percentage of the total cost, even if not the entire cost.

A collaborative game where the players compensate each others' costs with side payments, is called a *transferable payoffs* game. A collaborative game is called a *non-transferable payoffs* game if positive transfers between members of the collaboration are not allowed. In the shippers' collaboration problem, seeking a cost allocation method which distributes the total transportation costs corresponds to a transferable payoffs game, whereas seeking an allocation which only distributes the asset repositioning costs corresponds to a non-transferable payoffs game. To ensure that each shipper pays at least its original lane cost (i.e., to avoid the situation in the example in Figure 8 where shipper A pays nothing), allocations with non-transferable payoffs are of interest. Furthermore, it is desirable that each shipper is guaranteed an allocation less than its stand alone cost so that being a member of the collaboration offers a positive benefit. Ozener and Ergun [78] show that when either of these two restrictions is imposed, it is not possible to have a budget balanced and stable cost allocation for the shippers' collaboration problem. Hence, they relax the efficiency and stability properties in a limited way and develop allocations with the above two restrictions.

Despite its challenges, collaboration can offer tremendous benefits to its participants. In addition to reducing transportation costs, collaborative logistics can also lower inventories and at the same time eliminate stockouts resulting in lower inventory holding costs and better customer service. Consider AIT, a leading distributor of industrial products in North America, which operates 450 service centers that sell maintenance, repair and operational industrial products to large and small manufacturers. By sharing truck space with its partners, AIT has seen its dedicated freight charges drop by nearly 30%. In addition, since deliveries are now made daily (due to shared truck capacity) rather than weekly as it was before, service centers do not have to carry as much safety stock and can order products as late as 5 p.m. to be delivered the next day. As a result, customer service has improved and the need for the company's service centers to hold safety stock inventory has declined by 15% to 20% [103]. As we see in this example, in addition to reducing the transportation costs, collaboration also helped the company to reduce leadtimes and increase delivery frequencies, resulting in better demand forecasts and allowing the company to better match demand and supply with less inventory in a timely manner.

Traditionally, supply chain partners focused their attention on controlling and reducing their own costs to increase profitability, but now they realize that a system-wide collaborative focus offers opportunities that are not possible to achieve by any one company alone. Collaborative transportation not only reduces the shipping costs for the participants, but can also result in major cost savings due to lower inventory levels, shorter leadtimes, lower stockouts, and better customer service.

3.5 Collaboration in Procurement

Collaborative procurement emerged as one of the many initiatives for achieving improved intra- and inter-firm coordination and collaboration.

With intra-enterprise vertical and horizontal collaboration, a company streamlines and coordinates its procurement functions which can lead to significant savings. For example, by aggregating its spending, Lucent reduced the number of invoices that amount to less than $1,000 by 23% in 2003, according to Joe Carson, chief procurement executive. In addition, Lucent has reduced its supplier base by about half, placing a larger part of its spend with fewer suppliers to leverage its buying power [98]. Similarly, by simplifying its supply base, working closely with its key suppliers, leveraging its buying power with those suppliers across the different business units, and developing a system for implementing innovative cost-savings ideas, Dial Corp. was able to lower its purchasing costs by $100 million in five years [83].

Inter-enterprise vertical collaborative procurement, i.e., collaboration between buyers and suppliers has been successfully adopted by companies with world-class procurement practices. According to Purchasing Magazine, using supply base rationalization and partnering with key suppliers, world-class procurement organizations incur procurement costs that are 20% less than typical companies (0.68% of procurement spending vs. 0.85%) and operate with nearly half the staff (44.9 staff per $1 billion of spend vs. 89.2) [101]. One of the best known examples of collaborative intra-enterprise procurement is between Japanese auto makers and their suppliers, which are based on long-term purchasing relationships, intense collaboration, cross-shareholding, and the frequent exchange of personnel and technology [14]. Quoting a senior executive to Ford, GM, Chrysler, and Toyota: "Toyota helped us dramatically improve our production system. We started by making one component, and as we improved, [Toyota] rewarded us with orders for more components. Toyota is our best customer." According to Ahmadjian and Lincoln [14], Toyota and Honda have built great supplier relationships by consistently following six steps: they understand how their suppliers work, turn supplier rivalry into opportunity, monitor vendors closely, develop those vendors' capabilities, share information intensively but selectively, and help their vendors continually improve their processes.

Inter-enterprise horizontal collaboration in procurement has also seen much interest and success in recent years. This practice is also known as cooperative purchasing, group purchasing, and consortium purchasing, where two or more independent organizations (potential competitors) with similar products or services, join together, either formally or informally, or through an independent third party, for the purpose of combining their requirements for the purchase of materials, services, and capital goods.

Group purchasing is not a new concept; cooperatives and other non-profit organizations (mainly educational and social) have practiced it for many years. There are numerous examples of co-operatives and for-profit firms making purchases such as office equipment and supplies, tooling, software, engineering and consulting services, air freight, and other items through purchasing consortia. Group purchasing has been especially prevalent in the healthcare industry, perhaps because decreasing supply expenses plays an important role in increasing the already low profit margins and offers a unique competitive advantage. The Group Purchasing Organizations (GPO) Directory [6] contains information on more than 700 GPOs and multi-hospital systems which own, manage, or provide purchasing services to hospitals. Some of the other industry sectors where big group purchasing organizations exist are telecommunications, transportation and services.

One of the major benefits of collaborative procurement for buyers is reduced purchasing costs due to the quantity discounts offered by the suppliers. Through collaborative procurement "... co-customers can present a single face to suppliers. They can combine orders, make life easier for the supplier and reduce their own costs. When the supplier has to process only one order rather than several, it gets a larger volume and can respond with lower prices." [72] For example, Transplace [9], an Internet-based global logistics alliance formed by six of the largest U.S.-based transportation companies, offers shippers and carriers efficiencies and cost savings from combined purchasing power on items such as fuel, equipment, maintenance and repair parts, insurance, and other services. Under its Fuel Program, Transplace negotiates the price of fuel with suppliers of petroleum products, allowing member carriers to procure fuel at lower prices at designated fuel stops across the country. In a quantity discount scheme, the supplier sets price break(s) [63] or uses continuous pricing [61, 62, 35]. Dolan [41] provides a thorough analysis and categorization of the studies on quantity discounts.

The extent of actual cost savings due to collaborative procurement may lead potential members of group purchasing programs to question whether it is actually worth joining such a program, i.e., whether the savings will justify the efforts on reshaping the purchasing process. The supplier has parallel concerns: Does the potential increase in sales volumes justify offering lower prices to GPOs? In particular, under what market conditions (such as the demand structure and uncertainty, number of buyers and suppliers in the market, the size and market power of the participants, uncertainty in supply availability and quality, etc.) is collaboration beneficial to each participant? These questions become particularly important when the collaborating buyers are competitors in the end market [50].

Despite its increasing adoption in practice, the effects of collaboration on buyer and supplier profitability has not been studied systematically. Mathewson and Winter [71] study a problem where a group of buyers negotiates and makes a contract with a group of suppliers to get lower prices. In turn, the buyer group gets supplies only from the contracting group which implies a trade-off between low price and low product availability. Authors conclude that as the number of suppliers increases, the buyer group is more likely to benefit from contracts and the formation of buyer groups might be welfare increasing or decreasing depending on the model's parameters. Spiegel [92] addresses production sub-contracting between two rival firms operating at the same horizontal stage in the supply chain. He shows that this arrangement, if it occurs at all, always increases production efficiency. Anand and Aron [16] study the optimal design of an online business-to-customer group-buying scheme under demand uncertainty. In their model, the buyers arrive and demand single units, and as the number of units demanded increases the price drops. The demand function is not known to the supplier before he decides on price-quantity tuples. Under this setting, the supplier's benefit from group-buying increases as demand heterogeneity (the difference in the slopes of the demand curves of the buyers) increases. Furthermore, group-buying outperforms single pricing when the goods are produced after total demand is realized under scale economies.

Keskinocak and Savasaneril [59] study collaboration in a business-to-business (B2B) setting, where buyer companies participate in group purchasing for procurement, but produce independently and remain competitors in the end market. When the buyers are uncapacitated (and identical in terms of costs), they show that buyers and end consumers are better off under joint procurement as compared to independent procurement, and rather than selling a large quantity to a single buyer, the supplier is better off by selling smaller and equal quantities to both buyers. Next, they consider the case of different size buyers, i.e., buyers with different capacity availability. Intuitively, one might think that a "large" buyer would have less incentive to collaborate with a smaller buyer on procurement, since the large buyer already has enough volume to obtain a good price from the supplier. The "small" buyer, on the other hand, might prefer to collaborate with a large buyer, since it will obtain additional price breaks due to the volume of the large buyer. Given these conflicting incentives, one might expect that joint procurement would occur mainly among roughly equal size buyers (in terms of capacity and purchase volume). However, the authors find that depending on the market characteristics, collaboration may occur among different size buyers. Furthermore, depending on the capacity of the large buyer, the small buyer may not always be willing to collaborate.

4 Role of Information Technology in Collaboration

In the last two decades, we have witnessed tremendous changes in how enterprises manage their intra- and inter-enterprise operations. Up until the 1990s, the main focus of companies was on improving cost and quality. During 1990s, with the development of ERP systems – which are central repositories for information about an enterprise that facilitate real-time information exchange and transactions within and between enterprises – companies made a huge progress about completing their internal integration and started going beyond internal integration and integrating with their external business partners. Over the past decade, there has been considerable advancement on software products, such as instant messaging and virtual network computing, and enabling technologies, such as Meta Markup Language (XML), to further support collaborative processes. However, true end-to-end visibility and collaboration in supply chains can only be possible with the development of common data standards. According to Vinay Asgekar, and AMR Analyst, "Common data standards that are readily embraced can let leading companies truly achieve a streamlined extended supply chain." [87]

EDI is a "communication standard that enables the electronic transfer of routine documents between business partners." [109] EDI enables computers to talk to each other by sending standardized messages over (traditionally) a Value-Added Network (VAN) or (more and more) the Internet. EDI enables and fosters collaborative relationships. In addition, it minimizes data entry errors, secures message/data transfer, reduces cycle time, improves inventory management and increases productivity, and increases customer service. Based on an Aberdeen Group research, Roberts reports that "90 percent of all invoices among the Fortune 1000 are handled by electronic data interchange (EDI), but this accounts for less than 10 percent of all business invoices." Even though it is very mature (EDI has been around for more than three decades) and very secure (through the use of VAN), EDI is also very costly so "most medium-sized and smaller companies cannot afford" it [85]. Thus, the adoption of traditional EDI has been slower than expected. However, the XML/EDI framework and the Internet-enabled EDI are closing the gap.

RosettaNet, is a global consortium-based standards organization, which develops a common XML-based platform for communication to enable collaboration and automation of transactions in global supply chains [8]. RosettaNet defines business processes, semantics, and a framework for how data gets passed over the Internet. According to Joseph Matysik, Materials Manager at Intel Corporation, Assembly/Test Materials Operations "Intel has significantly extended its supply chain visibility and agility through its RosettaNet implementations and process re-engineering efforts." [87]. Among the benefits of RosettaNet (and such standards in general), one can count error-free forecast-to-cash procurement processes, reduction in manual transactions, reduction in contract costs, reduction in inventory levels, decrease in change orders, reduction in administrative costs, reduction in logistics costs, and reduction in planning time [8]. Other standards organizations include [81]: the AIAG (Automotive Industry Action Group) for the automotive industry [2], the WWRE (WorldWide Retail Exchange) for retailers and suppliers in the food, general merchandize[7], textile/home, and drugstore sectors [11], the AIA (Aerospace Industries Association of America) for the defense and aerospace supply chains [1], and the GS1 for global supply chains across industries [7].

In spite of all these advances in IT, the biggest mistake companies can make today is to view the new IT products and tools alone as a silver bullet. IT by itself is not enough to lead to successful collaboration. Firms must know how to use IT to reap the benefits of collaboration. Human contribution, through data analysis and information utilization, is where the true benefits of IT lie. Therefore, the enabling and supporting role of IT to collaborative processes can only be realized if the technology is employed effectively. When used effectively, IT enables collaboration by providing the necessary tools to make it feasible, such as real-time data transfer and automated communication. IT supports collaborative inter-organizational relationships by reducing the transaction costs and risks with automated process. Furthermore, IT provides the opportunity for outsourcing of processes between partners.

5 Concluding Remarks

Any improvement in the design of integrated and collaborative supply chains by better coordination between the parties is expected to have significant economic and social impacts. The advantages of a successful collaboration are numerous, including reduced inventory, increased sales, lower costs, increased revenue, better forecast accuracy, improved customer service, and more efficient use of resources. [4, 5, 33] In spite of these well-documented advantages, companies are still reluctant to open up their supply chains to collaboration. This fact is most obvious from the AMR Survey at Microsoft Engineering and Manufacturing Executive Summit: even though only 20% of the participants were concerned about trading partner acceptance, 44% had concerns about trading partner readiness [28].

There are excellent examples of companies such as Dell, Microsoft, Cisco, Wal-Mart, who have successfully implemented supply chain collaboration. Even though there is not a single recipe for such a success, there are several common factors that we observe:

- Collaboration is all about sharing: sharing of ideas, information, knowledge, risks, and rewards. In a collaborative environment, "the partners need to share both the pain and the gain." [73] Unless all parties benefit, it is not a true relationship.

- Collaboration should not be the new flavor of the month; companies should know why they

[7] WWRE is now a part of Agentrics LLC, due to a merger with GNX.

want to collaborate. Essentially, the relationship should fit with the partners' strategies, processes, and technologies [70].

- Many times companies do not effectively collaborate internally [33]. However, collaboration should start with intra-enterprise collaboration. Based on an AMR study, Sabath and Fontanella [86] argues that "Enterprises that have learned to collaborate internally are the most successful in creating collaborative relationships."

- It is of key importance to identify the partners correctly. Partners should trust each other and should be ready and willing to share practices, processes and information, even when this means sharing proprietary information [70, 5].

- The partners should have a clear understanding of "what is expected of them and others in the relationship" [73]. To enable this, the expectations should be set up-front clearly, which requires "a formal, documented front-end agreement that defines the scope (i.e, the steps, measures, terms, and protocols that define the nature of the collaboration) and goals (i.e, the specific benefits that the collaboration is expected to deliver) of the relationship." [5] Sabath and Fontanella [86] identify misaligned expectations and using different definitions as a cause of disappointment in collaboration. Unless all parties are open, committed, truthful, and have a stake in outcome, collaborations are doomed to failure.

- The scope and the goals of collaboration should be open to an evolving collaborative relationship. According to Langley, Jr., collaboration "must allow members to dynamically create, measure and evolve collaborative partnerships." [64] This will enable companies to learn and adapt, and create new opportunities for future collaborations.

- As with any implementation, targeting both short-term and long-term objectives is important. Matchette and Seikel [70] recommend maximizing "day-to-day performance" and using "performance measures that reflect the organization's overall business objectives." This will help people understand the dynamics and value of the relationship, and potentially increase commitment at every level.

- Making good use of information infrastructure and technology enables a smoother relationship. By itself, IT will not result in a successful collaboration; however, it is an *enabler* of collaboration [73]. Partners should "develop systems for timely reporting to enable faster, better-informed decision making about the collaboration." [70] When successfully combined with strategies and processes, IT creates an environment that fosters interaction and visibility.

While collaboration promises great value, most companies lack the vision on how it would change their business processes and impact key performance metrics such as inventory turns, sales, and margins. Currently available academic research on collaborative supply chain management is still at its infancy, and does not provide the most needed foundational insights on when and how collaboration would benefit the participants. Hence, there is a rapidly increasing need for a better understanding on how to transform businesses into collaborative partners in supply chains, and for professionals who can work with companies as they sooner or later go through such transformation.

Appendix

i. In a *budget balanced* or *efficient* cost allocation the total cost allocated to the members of the collaboration is equal to the total cost incurred by the collaboration. That is, a budget deficit or a surplus is not created.

ii. In an *approximate budget balanced* cost allocation at least α-percent of the cost is recovered and the budget deficit is distributed in some other way (for example as annual or initiation membership fees).

iii. In a *stable* or *fair* cost allocation no coalition of members can find a better way of collaborating on their own.

iii. The set of cost allocations which are budget balanced and stable is called the *core* of a collaborative game.

In a stable cost allocation, the grand coalition is perceived as fair and is not threatened by its sub-coalitions. Thus, stability is the key concept that holds a collaboration together.

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