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16. Abstract

This report investigates the impacts of Information and Communication Technologies (ICT) and the Internet on logistics operations. The major contributions are: 1) an overview of the Internet growth during the past five years, as it relates to electronic commerce 2) a conceptual framework that assesses the impact of ICT on supply chain operations, 3) two modeling schemes representing no information sharing (NIS) and information sharing (IS) scenarios among multiple retailers and one supplier, and 4) cost reductions achievable through information sharing in a two-echelon supply chain where the supplier adopts a Vendor Managed Inventory (VMI) policy.

Reported statistics concerning Internet growth show large discrepancies, reflecting different traffic measurement methodologies adopted by various companies and agencies. Advantages and disadvantages of currently used techniques are presented. Trends in the development of electronic business-to-customer (B2C) and business-to-business (B2B) commerce sectors are discussed, and various forecasts are compared to actual observations where applicable.

A major industry affected by ICT is the logistics industry. A framework reflecting the transformation of logistics operations into supply chain management with real-time information and collaboration is presented. The framework reflects the shift in logistics operations towards strategies that allow faster reaction to customer demand changes facilitated by technological advancements and collaboration among various parties. These policies include Merge-In-Transit (MIT), Time Definite Delivery (TDD), postponement strategy, and VMI. Advantages and disadvantages of logistics relational settings and operations are discussed.

Finally, cost reductions achievable through information sharing among multiple retailers and one supplier are quantified. Simulation experiments are developed to model a setting with no information sharing (NIS) based on the Economic Order Quantity (EOQ), which is contrasted to a scenario with information sharing (IS) based on a VMI policy. Heuristic algorithms are applied to solve both problems. Results, based on randomly generated instances, show that the main benefit to retailers is a major decrease in stock-out costs. The major benefit for the supplier is the reduction in the so-called bullwhip effect, which translates into a decrease in inventory holding cost. Finally, although the number of visits from the supplier to retailers increased significantly, the transportation cost decreased in almost all cases reflecting the use of more efficient routes by the supplier when bundling retailers' demands.

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Impact Of Electronic Commerce on Logistics Operations:

A Focus on Vendor Managed Inventory Strategies

by

Mouhamad Y. Rabah

Hani S. Mahmassani

SWUTC/02/167227-F

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EXECUTIVE SUMMARY

This study investigates the impacts of Information and Communication Technologies (ICT) and the Internet on logistics operations. The major contributions are: 1) an overview of the Internet growth during the past five years, as it relates to electronic commerce 2) a conceptual framework that assesses the impact of ICT on supply chain operations, 3) two modeling schemes representing no information sharing (NIS) and information sharing (IS) scenarios among multiple retailers and one supplier, and 4) cost reductions achievable through information sharing in a two-echelon supply chain where the supplier adopts a Vendor Managed Inventory (VMI) policy.

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TABLE OF CONTENTS

LIST OF FIGURES

x

LIST OF TABLES

CHAPTER 1: INTRODUCTION

INTRODUCTION TO ELECTRONIC COMMERCE

Electronic commerce consists of electronic transactions (sales of products, exchange of information, transfer of funds…) between either businesses and consumers (B2C), or businesses only (B2B). Supported mainly by the Internet, electronic commerce has experienced rapid expansion during the past five years, impacting many industries. Across these industries, electronic commerce is enhancing competition, removing time and space constraints, and allowing companies to reach a larger customer base all over the world, at any time. The impacts of electronic commerce, coupled with developments in information technology, vary across industry sectors. Although many impacts can be directly observed, the "business value" created by these developments remains to be determined.

In the B2C sector, electronic commerce is thought to increase customer satisfaction by providing access to frequent product updates, a private and convenient shopping experience from home or work, and responsive customer support through electronic mail, instant messaging, or possibly web-based telephony. Electronic transactions have also resulted in cost reductions to businesses, which are reflected in lower transaction costs to consumers. For example, the cost of a typical banking transaction is $1.07 in a bank's branch versus $0.01 using the Internet. The fee charged for a brokerage transaction is $150.00 using a full service broker, compared to an average of $10.00 (and still decreasing) using an Internet broker (Andersen Consulting, 1999).   However, issues including security, privacy of transaction records, ease of ordering and need to see and touch the object that is being bought have offset these benefits, proving that not all electronic business models are profitable.

In the B2B sector, electronic commerce is thought to facilitate collaboration among companies, information sharing, and strategic partnerships. Companies are collaborating together to reduce costs, increase revenues, and improve operations. Electronic information exchange eliminates paperwork and is faster than conventional media. Strategic partnerships may be reflected in marketplaces that contribute to improving efficiency and increasing the revenues of participants. Development and application of new technologies are intended to help companies achieve better control of their business processes through tracking devices that help companies improve their level of service, and delivery processes. Electronic commerce is claimed to decrease the cost of many types of business transactions; these include periodic communications with customers and suppliers, ordering costs among companies, and transaction of digital information.

An important industry and business activity impacted by electronic commerce is the logistics industry, the main focus of this research. The main impact of technological developments on logistics operations is their further evolution and transformation into globally integrated Supply Chain Management (SCM). The main components of SCM include demand planning, fulfillment strategy, and supply planning.

The Internet provides a medium through which coordination could be achieved at low cost and supply chains could be forged quickly and connected through desktops. Electronic commerce is allowing lower interaction and collaboration costs, less expensive and easier access to information among companies, their customers, and their trading partners. Supply chain management, coupled with responsive distribution systems, provides tighter control over inventories. With timely flow of accurate information, rapidly selling items can be ordered and supplied to meet demand, while costly overruns are reduced. In supply planning, electronic commerce is expanding the scope and reach of companies by opening them to new suppliers, allowing them create mutually successful arrangements with suppliers and evaluate sourcing options (Andersen Consulting, 1999). Seventy percent of companies were forecasted to use e-commerce for transactions with suppliers by the end of year 2000 (KPMG, 1998); no official reports are available yet to verify or update the percentage.

In "State of Logistics Report", Delaney (1998) reports that American companies, during 1997, spent $862 billion dollars (10% of US GNP) on supply activities including " the cost of movement, storage, and control of products across the supply chain". As the margin of decreasing manufacturing costs narrowed, companies in the 1990's saw the necessity of decreasing costs through supply chain management and improvement of logistics operations. Trying to quantify cost reductions in logistics operations through information technologies is a major motivation for this research. Moreover, new technological developments have altered fulfillment strategies, requiring faster, more reliable, and less expensive delivery policies. These strategies include merge-in-transit operations, postponement policy, home-end delivery, and Vendor Managed Inventory (VMI) strategy. These policies are intended to help companies achieve better customer level of service, at lower costs. Developments in electronic commerce have been taking place at a rapid pace, in a dynamically changing environment. As researchers continue to grapple with its likely impacts, no definitive comprehensive framework has been successfully elaborated to assess the impacts of electronic commerce on supply chain and logistics operations. Developing this framework is another motivation for this research.

OBJECTIVES

The principal objective of this research is to develop a framework that addresses the transformation of the traditional supply chain into a multidimensional virtual one, while focusing on the impacts of information technologies and the Internet on logistics operations in multi-echelon supply chains. The framework will help manufacturing, distribution, and supply chain companies assess various logistics strategies by comparing their advantages and disadvantages. Finally, the research focuses on the impacts of electronic commerce and information technologies on VMI strategy. Quantifying these impacts into cost reductions achievable for companies implementing VMI is the main objective. This is achieved by comparing two scenarios: the first represents no information sharing among multiple retailers and one supplier, whereas the second assumes information sharing among these parties under a VMI setting. This is accomplished through the development of two sets of simulation experiments that quantify cost reductions achievable through ICT in multi-echelon distribution channels. The proposed models

quantify reductions in inventory levels, transportation costs, and demand variability (as reflected in the so-called bullwhip effect, discussed in Chen et al., 1999). Results serve as the basis for providing recommendations for distribution companies collaborating in multi-echelon supply chains.

OVERVIEW

Chapter 2 presents a comprehensive review of Internet traffic measurement techniques, growth, and the increase in the B2C and B2B activities. The chapter discusses Internet traffic measurement methodologies currently used and focuses on their differences; these differences are the main cause for variations in reported results among several companies. Moreover, the chapter presents the growth of the Internet population, usage, and gender characteristics changes from 1995 to 2000, coupled with forecasted growth. Finally, growth in the B2C and B2B sectors is discussed, accompanied by the impact of an economic slowdown on these two sectors during the year 2000-2001. Chapter 3 presents a conceptual framework that focuses on the transformation of the traditional supply chain into a digital, virtually forged one. The framework subdivides the Internet into five distinct categories and discusses the impact of each on supply chain operations, focusing on their interaction with the transportation industry. Moreover, new logistics trends and relational settings among supply chain parties are presented. In addition, the advantages and disadvantages of these new policies enabled by information technologies are discussed. Chapter 4 proposes two simulation experiments that quantify cost reductions achievable through VMI with the use of technological developments. The simulations model two settings reflecting no information sharing (NIS) and information sharing (IS) among multiple retailers and one supplier. The results, based on randomly generated instances, reflect variations in inventory, transportation, stock-out, and ordering costs experienced by the retailers and the supplier when shifting from a NIS to an IS policy. Finally, chapter 5 summarizes the findings of this work, and presents future research directions.

CHAPTER 2: LITERATURE REVIEW

INTRODUCTION TO THE INTERNET

Although the Internet gained widespread popularity in the 1990's, it has been in existence for more than 30 years. "ARPANET", funded by the U.S. Department of Defense in 1969, represented the first version of the Internet. The main objective was to develop alternate routes for transferring data between computer ports as a fault-tolerant, survivable defense mechanism in the event of nuclear attacks. In the 1970's, the Internet was used for sharing information between academic research sites, mainly via electronic mail. In 1983, the Transmission Control Protocol/Internet Protocol (TCP/IP) facilitated and standardized information sharing between different network users. However, the major Internet development was the introduction of the World Wide Web in 1992 by Tim Berners-Lee, a researcher at the European nuclear research facility in Geneva. The World Wide Web protocol introduced the idea of hyperlinks that allowed users to access data on computers all over the world by transferring from one port to another. Attracted by its ease of use, companies and agencies took notice of the importance of this new channel in facilitating communication and allowing cost savings, and hence felt compelled to gain a presence on the network. Since 1993, Internet growth has followed an exponential rate. The following sections discuss the Internet's population growth, usage characteristics, and growth of the B2C and B2B sectors. Before discussing these statistics, it is useful to understand available Internet traffic measurement techniques, and different methodologies adopted by various companies. Differences in measurement procedures and interpretation are often a major reason behind differences in the reported data.

TRAFFIC MEASUREMENT TECHNIQUES

In order to understand the behavior and performance of current networks, determine their level of service, identify users, and plan for future expansions, Internet traffic flow should be measured. Current measurement techniques differ by information provided, technology adopted, and drawbacks. Flow measurement technologies are comprised of meters, meter-readers, and managers. Meters observe passing packets, classify them into groups (user application, host, network), gather usage data and store the latter in a flow table. A reader collects data from various meters. The manager is responsible for controlling the two devices by sending information about flow specification, control parameters, and sampling techniques to the meter, whereas the reader receives information concerning meters to be monitored, frequency of data collection, and types of flows to be collected (Awduche et al., 2001). Table 2.1 summarizes current measurement techniques, and their drawbacks (Diem, 1997; O'Shea et al., 1997).

Traffic measurement procedures may be either passive or active in tracking Internet traffic in virtual networks. Passive measurements seek to characterize traffic in the network under study without interfering with or otherwise affecting the traffic carried by the network during the measurement period. However, it may be difficult to extract some characteristics of interest from the collected data. Passive techniques take the form of workload analyses (per packet or byte), which rely on collecting link traffic information using routers, switches, or other devices positioned at specific locations within the network (Claffy, 1999). Passive monitoring tools provide information about packet size distribution, packet arrival patterns, general traffic data including traffic sorted by application, origin and destination matrices, and the ability to separate between user traffic growth and traffic growth per user (Claffy et al., 1999).

TABLE 2.1: COMPARISON OF INTERNET TRAFFIC MEASUREMENT TECHNIQUES

Techniques	Examples	Description	Drawbacks
On-Site Programs	Service Centric Measurement or "Click Stream Analysis"	§ On site programs installed on the clien company's server § One of the earliest techniques § Calculate and log on-line traffic while providing appropriate channels § Information includes: hits, pages, visits, users (optional), and sessions.	§ High probability of inaccurate results, and data gathered could be affected by technological failures § The method decreases the number of clients that the server registers causing problems to the heuristics developed for the site § Number of page impressions could be overstated § Impossibility of separating multiple clicks by a user from those by different users § Demographic characteristics are not always available, thus bias
Off-Site Programs	On-line Surveys	§ Surveys published over the web to analyze Internet use, and users § A third party performs traffic analyses, hence providing more credible data (for potential advertisers)	§ Bias that might exist in the demographic characteristics of people responding to these surveys (self-selection bias) § Almost impossible to project accurate demographic characteristics
	PC Meter Precise User Centric Measurement	§ A passive tracking system that is installed at randomly selected households and that is able to monitor every activity related to the computer, specifically Internet use § Provides complete demographic characteristics about users	§ Cost § Self-selection bias; could be adjusted but not eliminated § Intrusive, thus invading privacy § No way to determine if site has increased awareness about a certain product

On the other hand, active techniques are performance-based methods that collect network properties by generating traffic needed to make the measurement. Unlike passive techniques, the generated flow interferes with already existing traffic, which might induce unintended effects. Active procedures provide traffic flow characteristics including 1) flow type (web, email, etc), 2) sources and/or destination of flow, 3) traffic exchange points, and 4) delay characteristics (time for information transfer).

These types of measurement approaches allow Internet sites to keep track of their traffic growth, traffic characteristics and performance (Monk et al., 1997). Finally, many companies adopt "user-centric" measurement techniques that include face-to-face interviews, diaries, telephone research, and computer-assisted telephone surveys, in addition to the approaches listed in Table 2.1. Companies using PC meters analyze Internet traffic users' characteristics and statistics by observing a random sample of Internet users and keeping track of their online activities. An example is the methodology adopted by MediaMetrix, described hereafter (Coffey, 1999).

First, a sample is selected using Random Digital Dialing (RDD) and corresponding mail matching is executed. If mail is applicable, people are contacted via mail by sending brochures. If the person accepts to join, he/she is directed to the website "E-trends" where he/she must create a user name and a password, download the meter, and fill the demographic characteristics of the household. The remaining persons are contacted by phone and, upon consent, are directed to the same website through the phone. Each personal computer (pc) in the household should have the meter and people are provided additional incentives for installing the meter at work. Next, the general demographic characteristics of the people surveyed are analyzed. General weighing procedures are determined through Iterative Proportional Fitting (IPF), and are applied at the individual level. Individuals are counted in the tabulations if they have used the Internet at least once/month, and if the meter has been measuring pc use for at least 21 days of the month.

Weighing is performed on each subset of the tabs, and is applied to avoid reporting unduplicated reach across home and work locations. The sample is segmented by people accessing the net from home, from work, and from both locations. Furthermore, the selected households are continuously contacted to ensure that any new pc is metered. Whenever a page is accessed, its URL is counted if it has successfully loaded into the browser. The installed meter can capture the following information:

- Machine status: On/Off
- Active Status: if the machine is on, time usage statistics. Sixty seconds after no usage, the machine is considered to be idle. After any movement, the meter continues accumulating the time for viewing a certain page.
- User identification: after any 30 minutes of idle time, users are asked to re-identify themselves by their ID and password
- Application in focus: only the activity in focus is metered and not the one in the background.
- WWW page viewing in a browser: the URL is recorded
- Information updates: periodically, the household members are asked to update their demographic characteristics.

Finally, the meter should be installed on all computers used by the individual, even at work. Usage at work is measured on the respondent's primary machine, and when no more than two other people regularly use it. Other companies adopt very similar procedures for keeping track of Internet traffic growth. However, due to different count and/or monitoring procedures, one often notices variations in reported results. Whenever these statistics show large discrepancies, further investigation should be

performed to try and determine the most reasonable. Some of these discrepancies are presented in the following sections.

INTERNET GROWTH STATISTICS

In order to better understand the Internet's impact, one should investigate its growth over the past few years. The following paragraphs discuss the growth in Internet users, usage statistics, and gender characteristics of people accessing the web. Observed and forecasted numbers are presented.

Internet Population Growth

"The usefulness of a network equals the square of the number of its users" (Metcalfe's law). This law applies to the Internet sector whose impact and potential economic significance have been growing at a fast rate with the increase in the number of users. Many companies have been tracking the growth of the Internet user population, which has been a rapidly moving target at best. Both definition and measurement of worldwide Internet population are still evolving concepts, and thus companies are reporting various statistics because of differences in the adopted methodologies. Figure 2.1 shows the numbers presented by one such company, Commerce Net (2000b), of the worldwide Internet user population growth from 1995 through 2000, with forecasted annual values through 2003.

However, numbers reported by different companies show large discrepancies. In 1999, Computer Economics reported that the online population is expected to be 213 million in 2001, and will increase to 350 million in 2005, whereas the Computer Industry Almanac reported that Internet population reached 259 million in 1999, is expected to attain 349 million at the end of 2000, 490 million in 2002, and finally to exceed 765 million by the end of year 2005 (Commerce Net, 2000d). The growth presented in Figure 2.1 reflects an average annual compound rate increase of 57.25% from 1995 to 2000, which is then forecasted to drop to 14.76% from 2000 to 2003. Using the Computer Industry Almanac data, we obtain an annual compound rate increase of 17% from 2000 to 2005. This decrease in the percentage growth reflects a postulated slowdown and a leveling-off the Internet penetration worldwide. This is due, in part, to saturation in certain markets, lack of sufficient technological infrastructure in others, and possible political and/or cultural obstacles in other countries. Because of these differences, it is useful to subdivide the Internet population growth into different areas of the world.
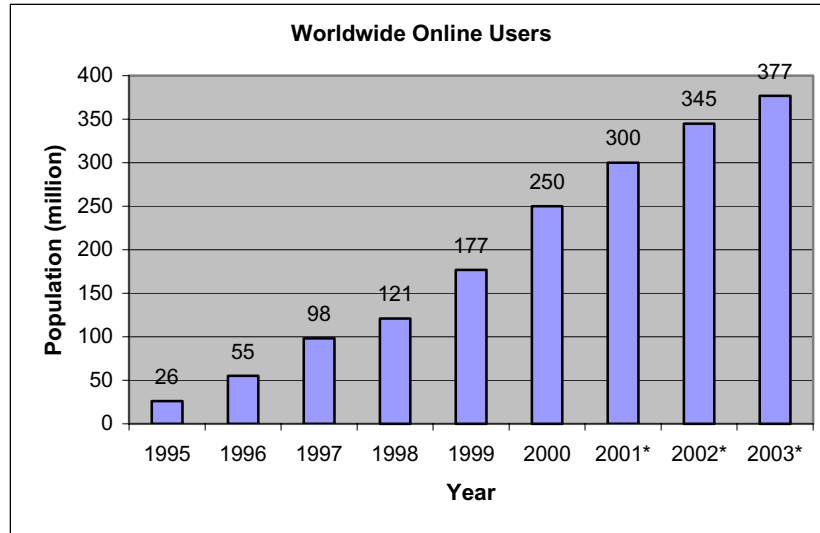
Figure 2.1: Observed (through 2000) and forecasted (2001-2003) worldwide internet population growth (Commerce Net, 2000b)

The U.S. remains the leading country in the development of Internet related technologies, and in the growth of the digital economy. Figure 2.2 depicts growth in the percentage of the population that is using the net in the U.S. from 1995 through 2000, and forecasted trend through 2005 (Commerce Net, 2000c). The figure reveals a decrease in the growth rate over the past two years, suggesting further slowdown in upcoming years as saturation is approached. The latter reflects the fact that there may be certain portions of the general population that are averse to adoption of new technologies, or are not able to afford the required equipment. Moreover, when interpreting Internet population growth, it is important to distinguish between people that are using the Internet, and those who are actually using the World Wide Web (*www*). Some people use the Internet as a telecommunication network without accessing the *www*; these activities include e-mail, education networks, and exchange of information through intranets. Business transactions through e-mail and Electronic Data Interchange (EDI) constitute a different category of electronically facilitated business thus commerce that is executed via the *www*. Use of the *www* implies usage of the Internet, but the reverse is not true. Comparison between the respective growth trends of these two types of uses is presented in Figure 2.3 (Commerce Net, 2000a). Note that Internet user population figures include the *www* usage numbers.

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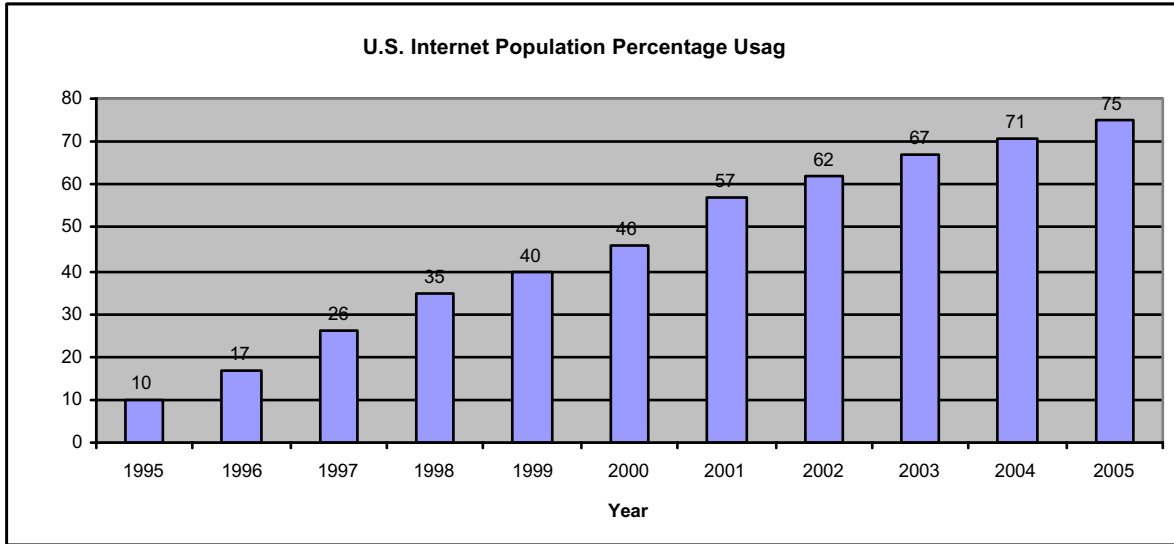
Figure 2.2: Observed (through 2000) and forecasted (2001-2005) percentage growth for U.S. citizens using the Internet (Commerce Net, 2000c)
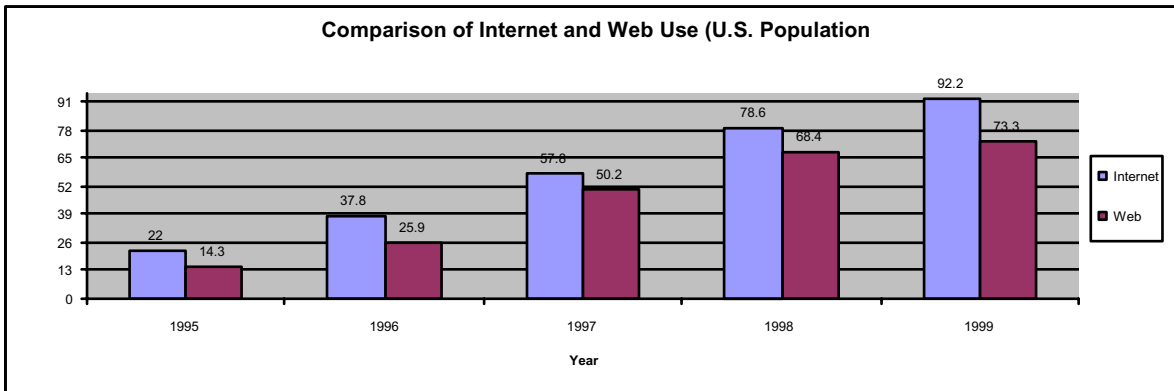
Figure 2.3: Observed growth of the U.S. population using the internet and using the world wide web (Commerce Net, 2000a)

Finally, while the growth of the Internet penetration has been faster in the U.S. and Canada compared to other parts of the world, the gap appears to be narrowing. In 1995, the U.S. represented 75 % of the total Internet population. This percentage decreased to 38% in 1998 (NUA, 2000), and is expected to decrease to 27% by the end of year 2005 according to the Computer Industry Almanac (Commerce Net, 2000d). In November 1999, Newsbytes Asia reported that there were 43.6 million online users in Asia. This population was forecasted to reach 228 million in 2005, with 37.6% in China (Commerce Net, 2000d). According to the Computer Industry Almanac, the number of Chinese users is expected to surpass the number of U.S. users by 2010 (Commerce Net, 2000d). European countries are also experiencing fast growth rates. In August 1999, The Computer Industry Almanac estimated that there will be 98.5 million online users in Western Europe by the end of 2000, and in November 1999 they expected that Western Europe would occupy the second place after North America by 2005 (Commerce Net, 2000d). Latest reports by The Computer Industry Almanac (2001) showed that at the end of year 2000, the U.S. Internet population reached 134.6 million, followed by Western Europe at 73.7 million

(missed forecast of 98.5) and then Japan with 33.9 million; the worldwide Internet population was estimated at 413.7 million. The same source forecasts that worldwide Internet users are expected to reach 673 million by end of 2002, and over 1 billion by end of 2005; The U.S. Internet population is expected to top 214 million by the end of 2005 (Computer Industry Almanac, 2001).

Internet Usage Statistics

In order to understand how the Internet is impacting the economy, it is important to understand what Internet users are mostly interested in, and how much time they are spending on the net. The following section discusses these trends and their implications.

According to MarketFacts reports (Upsdell, 1999), users are mostly (1) gathering news or information, (2) using e-mail, or (3) conducting research. Shopping is ranked in the 8th position. According to Forrester Research, factors that affect whether a user will revisit a site include the quality of the content, ease of use, speed of download, and frequency with which the site is updated. Coupons and incentives rank in the sixth position and purchasing capabilities (for example ease of purchase on the site) in the ninth (Upsdell, 1999). Moreover, one of the most important services that the Internet has provided is e-mail. This telecommunication medium is allowing people to substitute traditional communication methods with a cheaper, faster and more reliable alternative; 97% of Internet users take advantage of e-mail. In 1998, there were 77 million e-mail users in the U.S., sending 246 million e-mail messages/day. These numbers are expected to rise to 131 million users and 576 million messages/day by the year 2002 (Corp.Mail, 1999). Moreover, e-mail is apparently the preferred mean of personal communication, and has become the most widely used form of business communication. The forecasted growth is expected to occur because of e-mail's low cost compared to other traditional direct marketing alternatives. Thus e-mail use and growth is expected to accompany the growth of online advertising revenues, predicted to reach 7.7 billion in 2002 according to Jupiter Communications (Corp.Mail, 1999). Online advertising revenues were $4.6 billion in 1999 (Cyber Atlas, 2000c), and reached $6.9 billion in 2000 according to Competitive Media Reporting (Cyber Atlas, 2001c). However, due to a slowdown in economic activity, the percentage growth is expected to decrease in 2001, with Internet advertising revenues estimated to reach $8.1 billion according to Myers Reports (Cyber Atlas, 2001b). On the other hand, even with this decrease in spending, the amount in 2001 is expected to surpass the $7.7 billion forecasted in 1998 to be reached by 2002.

Another aspect of Internet growth is the relative split between access from home and access from work. Figures 2.4 and 2.5 describe the observed trends of access time/month for these two sectors according to NielsenNet Ratings (Cyber Atlas, 2000b). From-home access time/month has increased in the year 2000 compared to 1999. While monthly fluctuations are present, the average trend reflects a general increase in the time spent over the last 15 months. More time is spent on the Internet from work than from home, however this time exhibits much greater fluctuation than access time from home. The number of sessions/month ranged from 16 to 19 for home access, and between 37 and 43 for at work access.
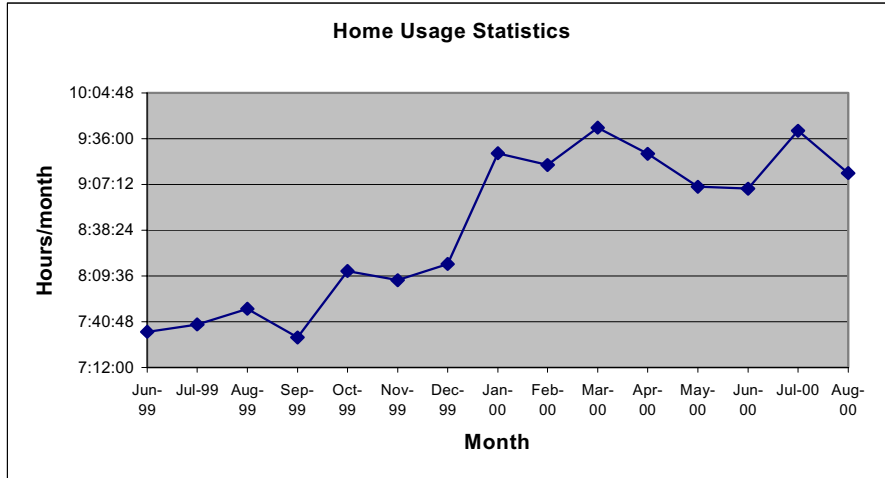
Figure 2.4: Monthly from-home internet use (Cyber Atlas, 2000b)
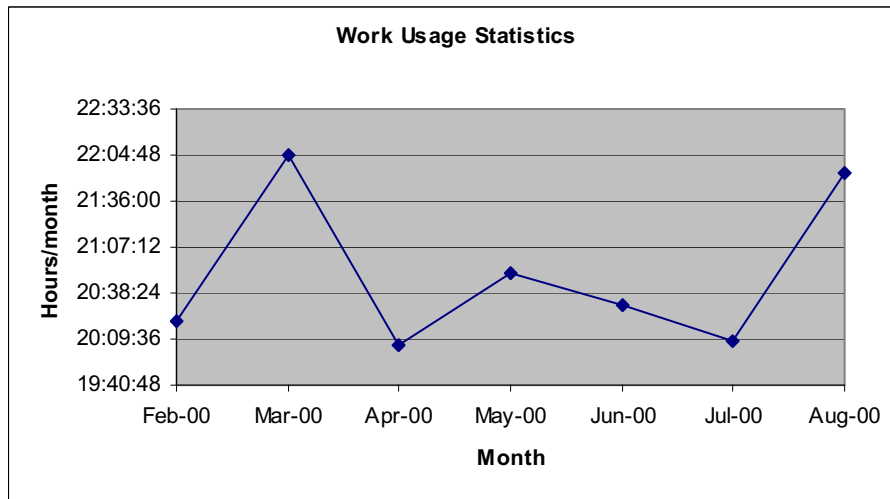
Figure 2.5: Monthly at-work internet use (Cyber Atlas, 2000b)

However, Commerce Net (1999) reported an increase in the number of people who access the web from home compared to work. Data collected in 1999 showed that 72 million people accessed the Internet from home compared to 46 million from work. Moreover, the survey indicates a decrease in the number of people who use the Internet for work purposes only; the corresponding percentages decreased from 15 in June 1998 to 12 in April 1999. As the number of hours spent per month increases, it is expected that the Internet will have greater impact and more profound implications on various industries. Keeping track of this growth is essential for assessing the Internet's impact. Moreover, separation between home access and work access is important. Home access increase is more likely to affect the B2C sector, whereas work access increase is more likely to reflect an increase in the B2B sector. The

forecasted growth in total e-commerce activity (Figure 2.6), and its impacts, subdivided into the B2C and B2B sectors, are discussed following a brief review of internet users' gender characteristics.

Growth of e-Commerce
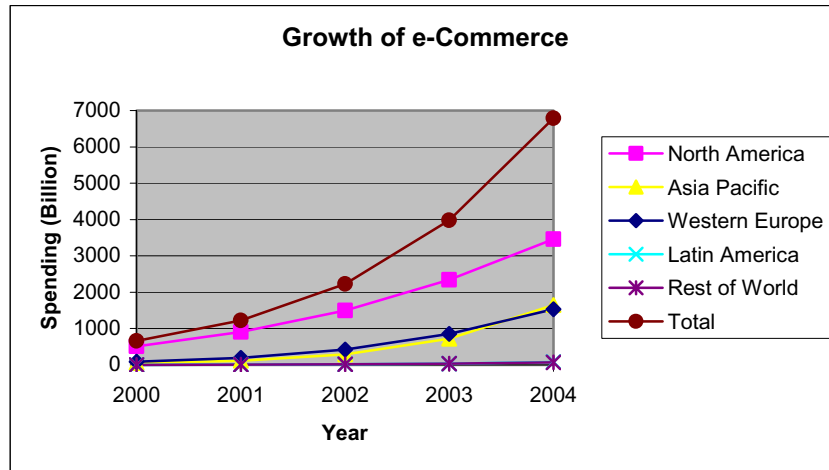
Figure 2.6: Forecasted growth of worldwide electronic B2C And B2B (Forrester Research, 2000b)

INTERNET USERS' GENDER CHARACTERISTICS

Although early U.S. Internet users were mostly male, the growth in the number of female users has been accelerating in the last two years. Some of the reported studies do not show a high percentage increase from 1995 to 1998 (Figure 2.7). On the other hand, over the last two years, most studies report that the female Internet audience has been catching up with its male counterpart. According to a January 2000 NielsenNet Ratings report (2000), the percentage of female Internet users reached 50 % of total Internet users by the end of 1999, and for the first time surpassed the male percentage in May 2000 to reach 51% of total Internet users. Moreover, according to a survey by NFO Interactive (2000), 56% of first time buyers over the net during the 1999 Christmas season were female. The surge in female users and buyers has helped in the growth of the e-clothing industry, as 26.4% of female online shoppers buy clothes online, whereas only 6.6% of male online shoppers do the same. This is an example of future trends that might evolve in the beauty, health and life style industries. In "Global Online Retailing" (Ernst & Young, 2000), it was reported that online shoppers were 50% female by the end of 1999.

Use of Internet by Gender

Year	Male (%)	Female (%)
1995	70	30
1996	68.6	31.4
1997	59.46	40.54
1998	64.2	35.8
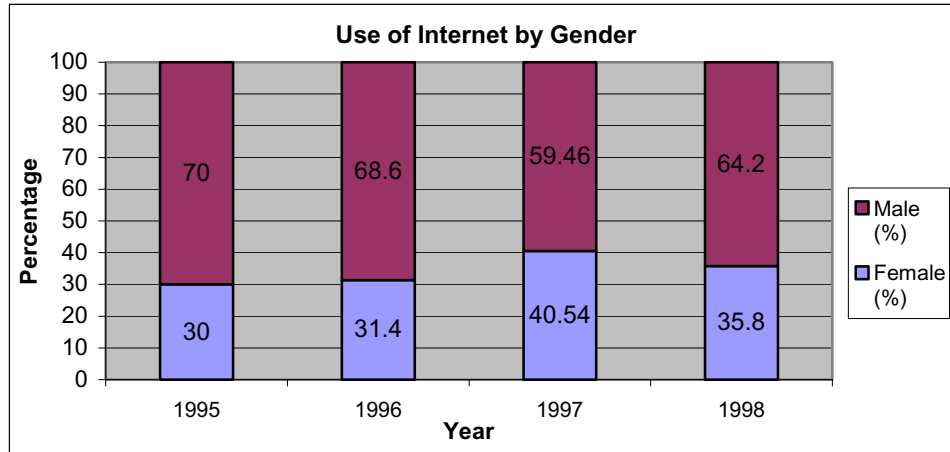
Figure 2.7: Percentage Of Female and Male Internet Users From 1995 to 1998 (Source: Various)

ELECTRONIC B2C COMMERCE GROWTH

Business-to-Customer (B2C) commerce refers to trading that takes place between companies and individual customers. In 1999, the U.S. and Canada accounted for 40% of worldwide Internet users. These users represent 60% of total US household purchasing power, 51% of which have bought online, which translates to over 41 million. In 1999, the B2C sector reached $17 billion and was estimated to double in 2000; B2C is estimated to top $100 billion in 2003 with an average spending amount of $1,033 compared to $500 dollars in 1999 (Cyber Atlas, 2000a). In March 2000, the U.S. Bureau of the Census reported that in the fourth quarter of 1999, 0.64% of retail sales were completed online accounting for $5.3 billion (Mesenbourg, 1999). Figures from other sources ranged from $4 to $14 billion (U.S. Department of Commerce, 2000). According to the NRF/Forrester Online Retail Index, online sales in 2000 culminated at $44.9 billion beating the estimates of 1999; furthermore, reported sales in January and February 2001 were $3.0 and $3.4 billon respectively, compared to $2.8 and $2.4 billion in 2000, thus reflecting a continued growth in the online sales industry (Forrester Research, 2001). Many consulting and Internet companies are keeping track of the progress of electronic commerce. Published reports examine sales growth, activity at electronic retailers (e-tailers) sites, and commodities' sales. The following paragraphs discuss Internet shopping penetration, "Internet Marketing" versus "Internet Shopping", and activity at e-tailers.

PC and Internet Shopping Penetration

According to Ernst & Young's report "Global Online Retailing 2000", 53% of the US households have computers, 34% of the households are connected to the Internet and 50% of these households have purchased online, or 17% of the total US households (Ernst & Young, 2000). However, these trends are not observed in other countries (Table 2.2).

TABLE 2.2: PC AND INTERNET SHOPPING PENETRATION (ERNST & YOUNG, 2000)

	US	Canada	Australia	UK	Italy	France
% Households with PC's	53	56	47	41	14	26
% Online	34	39	22	29	5	14
% Shoppers	17	9	5	10	1	2

One notes that Canada has the closest trends to the United States. The second highest percentage of Internet shoppers is in the UK. On the other hand, according to Scarborough Research, a survey of 85,000 randomly selected US adults conducted in 64 markets found that 54% of the people who have a personal computer have no Internet connection, and 75% of those who have Internet connection have not purchased online (Cyber Atlas, 1999). These results are somewhat different from those presented by Ernst &Young but this could be explained by the different sourcing strategy, and sectors analyzed. Trying to increase the percentage of online shoppers is a major boost for the B2C sector.

"Internet Marketing" vs. "Internet Shopping"

In the B2C sector, there is a distinction between "Internet Marketing" where a customer browses a company's web site but completes his/her purchases using conventional methods, and "Internet Transactions"(or Internet shopping) where the customer executes the entire purchase through the Internet (KPMG, 1998).

A report by the U.S. Department of Commerce (2000) emphasizes the growth of "Internet Marketing" in the car and health care industry. Among online shoppers the percentage that use the Internet to search for a new car increased from 25% in 1998 to 40% in the first quarter of 1999, and is expected to top 65% by the end of 2000 (J. D. Powers & Associates, 1999). J.D. Powers and Associates also report that only 2.7% of people who bought a car in the first quarter of 1999 apparently completed the purchase through the Internet. Another fast growing sector is the health industry. With 17,000 healthcare sites, the number of U.S. adults searching for health information was expected to increase from $24.8 million in 1999 to over $30 million in 2000 (Goldman et al, 2000). Jupiter Communications (2000) reported that 45% of online consumers access the net for health information. Currently, 32% of online consumers shop for health products on the web, and the health care industry is estimated to approach $370 billion in online transactions by 2004 (Jupiter Communications, 2000). Table 2.3 presents most commodities marketed through the Internet and those purchased using the Internet.

It is noted that although shopping for cars and car parts ranks in the first position (reflecting their high price), the amount purchased is negligible. The highest percentage for amount purchased compared to amount shopped is for the books' category with 73%. The amount marketed for the software category is not available.

TABLE 2.3: COMMODITIES MARKETED AND SHOPPED OVER THE INTERNET (LIEB, 1999)

Category	Amount Marketed (Million)	Amount Shopped (Million)
Cars/Car Parts	18.2	-----------
Books	12.6	9.2
Computers	12.4	5.4
Clothing	11.6	4.5
CDs/Videos	11.4	7.2
Software	----------	4.0

Finally, Internet shopping is mainly substituting for traditional retail buying rather than augmenting it. In August 1999, a report published by Jupiter Communications (1999) found that 6% of online shopping that occurred in 1999 consists of incremental sales that would not have occurred otherwise, and this figure is likely to increase to 6.5% by 2002. Moreover, Internet shopping affects transportation traffic flow. Greenfield Online (2000) found that 39% of people who are connected to the net have reduced their trips to stores and malls because they are able to complete some of their purchases over the net. However, estimating substitution versus new demand purchases is fraught with methodological difficulty.

E-Tailers Activity

E-tailers have been ranked according to different criteria. Some companies have ranked them according to the number of unique visitors, the percentage of respondents shopping at a site accompanied by the average amount spent at each site (the average depends on the type of products the site offers), and according to the revenues of each site. Different companies have reported different traffic measurements, largely due to different data inquiry methodologies (Table 2.4).

TABLE 2.4: TRAFFIC MEASUREMENT AT TOP E-TAILERS IN NOVEMBER 1999

	Unique Users (000's)[1]		Unique Users (000's)[2]	Unique Byers (000's)[2]
Amazon	14,765	**Amazon**	13,836	1,805
Bluemountainarts	12,742	**Buy.com**	5,822	876
AOL Shopping	11,110	**eToys**	5,101	403
EBay	10,529	**Barnesandnoble**	5,643	362
Barnesandnoble	5,838	**iprint**	2,217	331
EToys	4,911	**Drugstore**	1,451	316

1: Source: Media Metrix, 2000
2: Source: PCDataOnline, 2000

Although there are some differences in the results, we note that both report approximately the same number of unique visitors for Amazon.com. In fact, Amazon was reported to be the favorite e-tailer to shop at (Ernst & Young, 2000). According to Harris Interactive (1999), 10% of total Internet sales in the B2C sector occurred at Amazon. Table 2.5 presents the percentage of total Internet sales made through Amazon in five different categories; for example, 61.5% of all books sold on the Internet are sold at Amazon. However, the average amount of money spent at Amazon is not the highest with $128/purchase; the highest average is observed at Best Buy with $233/purchase for the product types it sells.

TABLE 2.5: AMAZON SALES (HARRIS INTERACTIVE, 1999)

Category	% Sales made at Amazon
Books	61.5
Music & Video	24
Electronics	8.3
Toys	7.6
Auction	3.6

In the last two years, many traditional retailers have opened online stores to compete with e-tailers. Moreover, many e-tailers were forced to close their sites due to losses, lack of funding, and unsuccessful business models. Latest reports show that these traditional retailers are gaining online market share, capturing four out of the top ten web retailers' positions. Table 2.6 presents the top five web retailers in January 2001 according to PC Data Online (Cyber Atlas, 2001d). Finally, if we consider all the websites -not e-tailers only- then until the end of 1999 AOL has captured most of the Internet revenues with $4,777 million since 1985. Amazon ranks third with $1,015 million (Andersen Consulting, 2000).

TABLE 2.6: TOP FIVE WEB RETAILERS AMONG US HOME USERS IN JANUARY 2001 (CYBER ATLAS, 2001D)

Web Site	Projected Buyers (000)	Overall Reach (%)	Unique Users (000)	Buy Rate (%)
Amazon	2,330	23.6	22,934	10.2
Barnesandnoble	638	7.2	6,998	9.1
Ticketmaster	636	5.6	5,473	11.6
Half	567	8.7	8,396	6.8
Jcpenny	545	4.1	3,967	13.7

ELECTRONIC B2B COMMERCE GROWTH

In the past few years, companies have been increasing their spending targeted towards improving their B2B infrastructure. In February 1999, IDC (1999a) reported that corporate businesses are likely to increase their Internet spending from $85 billion to $203 billion in 2002. Companies were reported to be mainly interested in improving their "Internet sales and marketing applications", "Internet commerce procurement and order management applications", and "Internet commerce customer service and support applications". The corporate spending towards these three applications increased by 154% in 1998 and was expected to grow by 280% in 1999 to reach $1.7 billion. "Internet commerce procurement and order management" –mostly related to logistics operations- is expected to reach $8.5 billion in 2003; this is expected to represent 65% of the total amount spent by companies towards B2B applications (Forrester Research, 1998). New releases by International Data Corporation report that companies' spending towards marketplaces alone will increase from $5.2 billion in 2000 to $17 billion in 2005, thus beating forecasts made in 1998 (Cyber Atlas, 2001f). The following paragraphs discuss the growth in the B2B sector, and the expansion of the B2B marketplaces.

Growth of the B2B Sector

Worldwide Internet commerce was expected to exceed $1 trillion in 2001, and to approach $3 or $3.2 trillion in 2003 according to IDC (1999b) and Forrester Research (1998) respectively. *The Industry Standard* reported that forecasts for 2003 regarding the U.S. B2B transaction value ranged between $634 billion and $2.8 billion (Lawrance, 2000); variations in the reported numbers lie in the inclusion of transaction value executed over EDI. In February 2000, Forrester Research (2000a) reported that U.S. B2B is likely to reach $2.7 trillion in 2004. More recent forecasts by Giga Information Group report that B2B sales through Internet marketplaces, EDI, Internet electronic trading networks (ETNs), Internet company-to-company links, extranets and private e-markets are likely to surpass $5.2 trillion in 2004 (Cyber Atlas, 2001a), beating Forrester Research estimates made in 2000. Moreover, Gartner INC. recently reported that the recent slowdown in the economic activity is not expected to hinder the growth of the B2B market, which will top $8.5 trillion in 2005. They also mention that B2B sales exceeding $433

billion in 2000, are predicted to attain $919 billion in 2001 (lower than $1 trillion previously forecasted), then $1.9 trillion in 2002, $3.6 trillion in 2003, $6 trillion in 2005, and finally total $8.5 trillion in 2005 (Cyber Atlas, 2001e).

B2B Marketplaces

According to Forrester Research, electronic marketplaces are likely to capture 53% of all online business trade. It is expected that 70% of online trade relating to computing and electronics, shipping and warehousing, and utility industries will be conducted through marketplaces (Forrester Research, 2000a). Internet marketplaces are growing fast because they are 1) facilitating communication among companies, 2) speeding up transaction time, 3) reducing transaction costs and 4) expanding companies' horizons through the reach of new customers in the virtual world. The *Economist* (2000) reported the existence of 750 worldwide-networked marketplaces in March 2000. The importance of marketplaces is that it is tying people together and helping them achieve better deals and higher commerce activity. According to Forrester Research (2000a), "71% of business buyers and sellers will at least try online marketplaces", and it is estimated that the value of marketplaces' transactions will soar from $54 billion in 2000 to $1.4 trillion in 2004. Table 2.7 summarizes the advantages of marketplaces and obstacles that face their advancement (Business Week, 2000).

TABLE 2.7: ADVANTAGES OF MARKETPLACES AND OBSTACLES ENCOUNTERED (BUSINESS WEEK, 2000)

Advantages of Marketplaces	Obstacles Facing Marketplaces
- Gather people into one place that increases the chances of trading and commerce	- Trying to attract a sufficient number of partners split between buyers and sellers
- Better prices through the ability to negotiate with multiple suppliers	- Buyers and sellers want to join most important marketplace
- Expanding the supply chain horizon of collaborating partners	- Suppliers' fear of control by industry leaders such as car-makers in Covisint
- Reduce reaction time to market changes	

To overcome the obstacles, electronic marketplaces are offering new services to increase their revenues; they are encouraging collaboration among partners. On the other hand, an analysis by Gartner INC. reports that electronic marketplaces faced difficulties in 2000, and accounted for only a small fraction of total B2B activity, which grew significantly in 2000 (Cyber Atlas, 2001e). The same report predicts that marketplaces will not have a substantial effect on B2B until 2003. Finally, ActiveMedia Research reported that most companies do not anticipate that online business will ever surpass their offline business;

however, they think cutting costs will be a major drive behind the creation of marketplaces (Cyber Atlas, 2001e).

CONCLUSION

Standardized Internet traffic measurement techniques are yet to be developed in order to overcome large discrepancies between reported statistics. Most of the reported results depend on the methodologies adopted by different companies; judjment must be exercised in interpreting reported statistics. To date, most forecasts for the Internet population in the U.S. have been surpassed, whereas predictions for Western Europe have missed the mark in 2000, in which Internet users were expected to reach 98.5 million but culminated at 73.7 million. The U.S. population is anticipated to further increase in the upcoming five years, however at a lower percentage growth than other countries especially Western, Europe, Japan, and China.

Growth is also noted in the B2C and B2B sectors. In 2000, electronic B2C commerce transactions were valued at $44.9 billion, exceeding forecasts of $34 billion. However, due to an economic slowdown spanning part of the year 2000 ad 2001, many e-tailers were forced to close after being faced with losses, lack of funding, and unsustainable business models. These were partly replaced by conventional retailers who moved online and seized market share; currently four out of the top ten web retailers are conventional ones. In the B2B sector, expansion was also noted, but numbers missed expectations in 2000, which could be attributed to the slowdown in economic activity. Although many marketplaces closed due to a lack of participants, their number is expected to increase in upcoming years, mainly by helping companies achieve cost reductions rather than higher revenues. Finally, one of the most impacted industries is the transportation and logistics industry. Impacts of Internet, new technologies, business-to-customer, and business-to-business on logistics and supply chain management operations are the main focus of Chapter 3.

CHAPTER 3: CONCEPTUAL FRAMEWORK OF IMPACTS OF INFORMATION TECHNOLOGIES AND ELECTRONIC COMMERCE ON LOGISTICS

INTRODUCTION

According to the Council of Logistics Management (2001) "logistics is the process of planning, implementing and controlling the efficient, effective flow and storage of goods, services, and related information from point of origin to point of consumption for the purpose of conforming to customer requirements". In recent years, logistics operations have evolved into Supply Chain Management. According to Metz (1998), "Integrated Supply Chain Management (ISCM) is a process oriented, integrated approach to procuring, producing, and delivering products and services to customers". ISCM scope includes the sub-suppliers, suppliers, internal operations, trade customers, retail customers and end users, and it covers the management of materials, information and fund flows.

The major factor that affected business logistics during the 1980's was the move towards internal integration, accompanied by the emergence and growth of third party logistics firms. The main contribution of Information and Communication Technologies (ICT) was the compression of the supply chain and the increase in information sharing to reduce inventory. This led to the emergence of new production and logistics strategies, such as the Distribution Resource Planning (DRP) and the Just –In-Time (JIT) strategies.

In the 1990's, the main forces that shaped business logistics are (1) globalization, (2) demographic forces, (3) information and communications technologies, (4) competition, (5) government regulations, and (6) environmental considerations. Globalization is noticeable in the greater role that international logistics and third parties with specialized skills play. Second, companies must cope with consumers demanding much higher level of service and companies are turning to outsourcing as a way to cope with possible labor turnover. Third, the main features of ICT in the 1990's is the Internet that is allowing "direct buying", and the emergence of powerful modeling tools to exploit the wealth of consumer and business data in the supply chain. Fourth, due to increased competition, supply chain optimization is necessary. Finally, government regulations are allowing new cross-border and trade agreements that are dramatically changing the operational landscapes of operating firms (Mahmassani, 1998).

Information and communication technologies offer tools that improve the operational performance of individual functions such as monitoring and tracking devices. They also increase customer satisfaction through tools such as easy ordering and status checking. In addition, they facilitate integration across the supply chain, and enable strategic alliances between shippers, carriers, and carrier users. Finally, they allow new business strategies and new channels to customers. Some of the new logistics strategies enabled by ICT are Vendor Managed Inventory (VMI) strategy, where the supplier knows when and how much of its products to store at a major distributor or retailer. Second, Merge-In-Transit (MIT) policy where the carrier or the third party provider assembles the demanded product for final delivery from its

various incoming components. Third, Time Definite Delivery (TDD), which ensures synchronous deliveries to multiple destinations by managing transport providers, service levels, and shipment release time. Fourth, the Freeze Point delay, where the final product assembly is left as close as possible to the point of final consumption by the end-consumer.

Subsequent sections discuss new technological developments with logistics applications, present a framework for changes in information and goods flow channels, analyze impacts of ICT and e-commerce on logistics operations focusing on Vendor Managed Inventory, and concludes by presenting further areas that should be investigated.

ADVANCES IN LOGISTICS TECHNOLOGIES

Advances in performance, decrease in prices of information systems and computers (Figure 3.1), expanded communication capabilities, wider availability of powerful software, and easier access to databases accompanied the widespread use of computers and IT, including newer applications such as the control of logistics functions on factory floors, in warehouses, and in the linkages to customers and suppliers.

Price Declines in Computers Have Accelerated Since 1995

(log scale; index 1987 Q1=100)
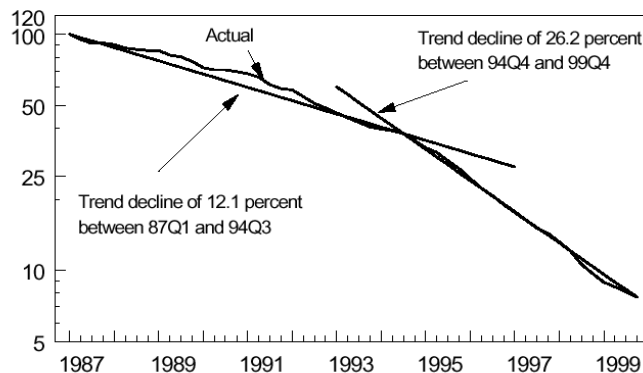
Source: U.S. Bureau of Economic Analysis

Figure 3.1: Price declines in computers over the last twelve years allowing higher use of information technologies

In the logistics area, applications focus on the use of information to forecast usage, control replenishment, efficiently operate warehouses and shipping terminals, organize and schedule vehicle operations, manage inventories, procurement, and material flows. These advances have motivated the development of powerful software and decision support systems to help companies in (Simchi-Levi et al, 2000a):

- Logistics network design

- Inventory deployment and management

- Distribution management

- Fleet management

- Production Planning

- Demand planning and forecasting

- Procurement/purchasing: managing supplier databases, sending bid requests, tracking information, order and shipment status

- Warehouse control system and transportation management that improves customer service performance

- Information sharing: order entry, requisition, and bill of materials

NEW INFORMATION AND GOODS FLOW CHANNELS

To maintain a competitive market position, companies have sought to optimize operations while meeting customers' higher level of service expectations. These higher levels of service could be achieved through the adoption of new information technologies (software), information sharing, collaboration, and outsourcing some of the internal functions. Traditional flow channels were comprised of linear exchanges of information and goods among the various parties that form the links of the chain. Collaboration across the supply chain was limited, and end-customers would obtain their products from retailers. Electronic commerce is allowing end-customers, whether individuals or firms, to order electronically from any collaborating party. Advances in technology, and the Internet have created new channels for information flow, goods flow and new partnerships across the supply chain, which are impacting logistics operations (Figure 3.2).

As shown in the flow chart, the Internet plays the role of a single point of contact facilitating information exchange, and opening new channels for goods flow. It is a form of a Client/Server computing platform where information is retrieved from ports distributed all over the world. Technologies that are allowing information exchange along these new channels include: 1) e-mail, 2) online order forms and documents, 3) electronic payment, 4) Electronic Data Interchange (EDI) and 5) Enterprise Resource Planning (ERP) which are transactions that integrate manufacturing, financial and other systems (Simchi-Levi et al, 2000c). Choice among these technologies depends on cost of implementation and the goals set by contributing firms. Internet tools (such as e-mail, online order forms, and electronic payments) offer the cheapest way of information exchange and are helping small firms become more competitive. The Internet contributors are divided into five categories:
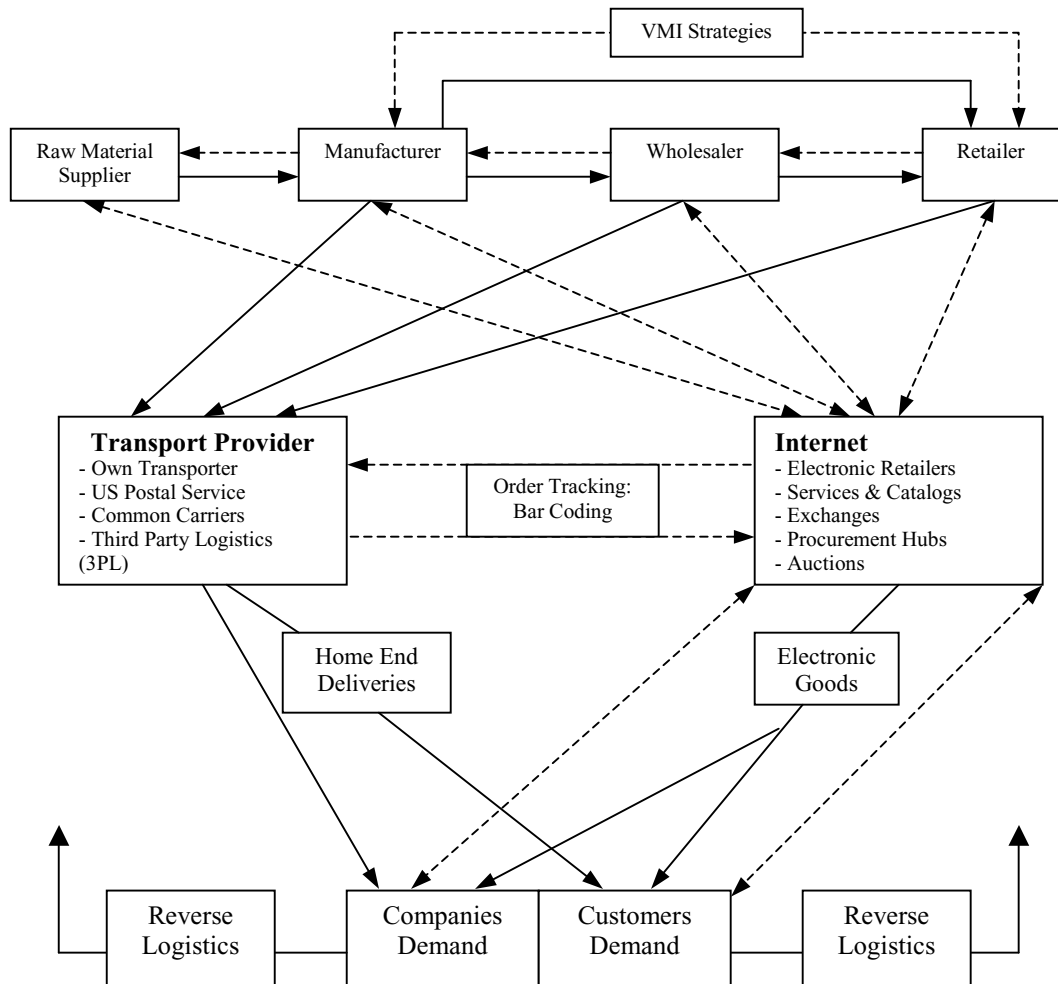
Figure 3.2: Transformation of the traditional supply chain into a virtually connected one

- Electronic Retailers: These channels focus on the B2C sector. Sales at these sites are mainly substituting for the conventional sector. They provide all types of consumer commodities. Some of them are virtual entities, whereas others have a physical presence also. As mentioned in Chapter 2, in the last two years, many bricks and mortar retailers have expanded their operations by moving online. These parties are regaining market share from e-tailers, many of whom where forced to shut down due to infeasible business models among other reasons. An example of e-tailers is Amazon.

- Services and Catalogs: These sites act as intermediaries providing information and digitizing catalogs for firms. They facilitate the shopping experience for customers by providing information sharing, advertisement, and cost comparison between products. The main revenue stream for these sites is online advertising, a sector that encountered a slowdown during the

year 2000-2001, but is still experiencing a high growth rate (Section 2.3.2). An example is Yahoo.

- Exchanges: The objective of these sites is to help different parties meet and settle on prices for negotiated commodities by providing explicit information about the products. Currently, all types of commodities are being exchanged, and sites have various rules governing such exchanges. These sites help companies reduce or clear unwanted inventories by selling them at reduced prices. An example is eBay.

- Procurement and collaboration hubs: These sites are mainly involved in B2B relations. Procurement hubs are clusters of organizations that have set their procurement site over the net and attract suppliers to join in. Collaboration hubs not only offer a transaction medium but also help participating partners complete their projects from the design phase to the distribution stage. B2B marketplaces are growing fast and are likely to affect logistics operations by increasing the operational efficiency of collaborating parties, and speeding up reactions to market changes.

- Auctions: These sites form an evolving class of sales channels for many industries, including consumer items. These could be buyer or seller oriented. Sites include Adauction and EWanted, a reverse auction site where sellers bid down their price to make the sale. Many marketplaces are auctioning truck capacities, freight movement, inventory surplus, and inventory storage. These auctioning sites are likely to affect logistics operations by improving capacity usage and allowing better information sharing. Examples of leading sites include nte.net, logistics.com, and transplace.com.

These five categories affect strategic relations among various parties and logistics operations, subjects discussed in the following sections.

LOGISTICS RELATIONS CHANGES

Channels representing goods flow are affected by the digital economy. Traditionally, goods were shipped in sequence from the supplier, to the manufacturer, to the wholesaler, to the retailer and finally to the customer. As shown in the flow chart (Figure 3.2), demands could be directly satisfied by either of the participating parties. Manufacturers, wholesalers, and retailers could be directly selling to the customers/companies through the Internet. Moreover, we are seeing several relationships developing across the supply chain. Types of coordination that are improving firms operational planning include:

- Buyer-Vendor relations: Collaborating parties invest in material handling through data technologies such as EDI. This type of relations tries to achieve higher customers' level of service by decreasing stock-outs while cutting down inventory costs; moreover, collaborating parties try to improve on demand forecasting strategies. An example of such relations is Vendor Managed Inventory.

- Production-Distribution relations: This type helps collaborating parties determine vehicle routing, machine scheduling, and inventory buffers. These relations increase the efficiency of

distributing to Distribution Centers (DCs), retailers, plants and sometimes directly to customers. These relational settings focus on improving the fulfillment strategies adopted by companies. An example is Merge In Transit policy.

- Multi-level inventory coordination across the supply chain which help to accelerate order processing, decrease inventory levels, and increase customer satisfaction. These strategies focus on the supply-planning phase. Companies try to coordinate their production schedules with the customers' demand.

These partnerships in the supply chain are based on information sharing, technology sharing, and process integration. They help decrease the uncertainty in planning, increase the level of control, and improve the efficiency of operations. For example, Chen et al. (1999) have highlighted the effect of information sharing in reducing the bullwhip effect, which describes the increase in demand variability as one moves up the supply chain. However, forging into a relational setting is not very easy and faces many obstacles. Table 3.1 summarizes the advantages and drawbacks of partnerships.

TABLE 3.1: ADVANTAGES AND DRAWBACKS OF PARTNERSHIPS

	No Partnership	Relational Setting	Drawbacks
Duration	One time	Long term	Conflicts
Information Exchange	Little	Multiple way sharing	Fear of information sharing
Transferability	Easy	Very difficult	
Focus	Profit focus	Supply Chain Focus	Each party wants the biggest portion
Planning and Goals	Short term	Long term	Conflicts
Risks	Individual	Shared	

Another collaboration milestone is the choice of the transport provider. As noted in the presented framework, any firm has the option of choosing its goods transport mode. It could be using its own fleet, the United States Postal Service (USPS), common carriers such as Ryder and FedEx, or a Third Party Logistics (3PL) provider. A firm's choice among these alternatives depends on its nature and objectives. Companies interested in maintaining control over their distribution usually operate their own fleet. Others interested in fast delivery with higher flexibility to market changes are expected adopt common carriers. USPS, for example, possesses a distribution channel set for home-end deliveries, and is likely to capture the highest market share relating to that sector. On the other hand, fast courier transporters (FedEx, UPS) are set to deliver to business districts. Finally, firms lacking the internal resources to manage logistics operations resort to 3PLs. These 3PLs are broadening their scope of operation by introducing logistics solutions where they offer to manage their customers' supply chain (example: UPS Logistics). The company's choice of a transport and logistics provider should depend on its reliability, relationships

record, fleet size, and ability to adjust to market changes. Finally, firms usually engage in partial or full outsourcing of some of their operations because resources are not available internally, function is difficult to manage, risks are shared, service quality is improved, cost reductions are achieved, and advanced technologies become within reach.

In the previous paragraphs, new relational settings, made possible and cheaper with the adoption of ICT and the Internet, were introduced. The following section focuses on the impact of ICT and e-commerce on logistics operation changes

LOGISTICS OPERATIONAL CHANGES

This section discusses impacts of ICT on logistics operations, focusing on management and control protocols, order entry systems, freight transportation, home-end deliveries, and Vendor Managed Inventory policy.

Management and Control Protocols

The purpose of management and control systems is to monitor and plan the production operations, physical supply channels and distribution systems. In recent years, inventory control systems have evolved and become more sophisticated. An example is Manufacturing Resource Planning (MRP), which could be applied in manufacturing, warehousing, and transportation activities. The benefits of such systems lie in the timeliness and level of detail they provide in determining requirements for assemblies, component parts, raw materials and schedules of production; this helps in increasing the efficiency of cost accounting, activity reporting and productivity of tracking systems. Other applications that help in increasing the efficiency of warehouse operations include computer generated pick lists, stock location labels, online inventory location information, and online inventory status information.

Order Entry System

Online order entry systems reduce the time a company requires to fill an order, and delivery time to a customer (lead time), and thus improve customers' level of service. These systems are helping companies achieve more accurate and efficient transmission of data thus improving their order tracking and order information activities, which allow for order consolidation and reductions in transportation costs. Moreover, as an order for a product is placed it could be directly forwarded to manufacturers, thus speeding up the production process.

Some companies have started to take advantage of online ordering systems to improve their customers' level of service, and reduce mistaken orders. Using online ordering, Alliant Foodservice was able to reduce their ordering mistakes from 3/1000 to 2/1000 in approximately one year; the goal is 0.4 errors per thousand. Moreover, the company was able to reduce the "supply-shortage" mistakes from 7.5 to 4/1000. Finally, returns decreased from 14 to 3/1000, and the goal of the company is 0.3 returns per thousand cases (Business Week, 2000).

Freight Transportation

E-commerce is affecting transportation freight movement by reducing the flow of certain materials and increasing the transport of other commodities. The effect of the Internet on the freight transportation sector includes its impact on 1) Just-in-Time patterns and trends, 2) current and prospective NAFTA flows, 3) intermodal freight movements, 4) urban goods movement distribution, 5) inland movements of goods moving in foreign trades, 6) travel and tourism requirements, both intercity and international, and 7) major new trade corridor flows (Romm et al., 1999). In the following paragraphs, general insights into the effect on the transport of goods are presented, separating between business-to-consumer and business-to-business sectors.

First, possible reduction of the total amount of freight transportation caused by the B2C sector could be explained by:

- Electronic materialization of many goods
- Elimination of personal transportation because electronic shopping might displace an object that would have been shipped anyway.
- Elimination of business transportation in some cases, where the retailer would choose the best distribution center to ship from.

On the other hand, B2C related transportation could increase because of:

- More freight being transported
- Probable inefficiency in distribution systems of e-tailers
- Increase in international imports, which leads to an increased demand for transportation.

Possible increase of the total amount of freight transportation caused by the B2B sector could be explained by:

- Increase in globalization and international trade among companies
- Move towards customer driven production policies, which might increase the frequency of shipments to retailers in order to reduce inventory levels
- Adoption of faster delivery modes such as trucks and airplanes

However, the increase in business related transportation is likely to be offset by the decrease caused by:

- Increase in collaboration among supply chain parties, which helps in bundling demands
- Increased access to customers' demand information, which is reducing unwanted inventory at retailers' shelves
- Reduction in mistaken orders, which eliminates unneeded delivery trips
- Increase in auctioning activity that helps in filling empty spaces on transportation modes in a more dynamic market.

Home End Deliveries

Competition between the U.S. Postal Service and express delivery companies is not only caused by differences in price, reliability and speed, but also convenience and ease of use. The Internet is

playing a major role in convenience and ease of use. Shipping companies are offering online tracking information and shipping transactions to facilitate billing procedures for their customers (Lyon, 1997). With the increase in electronic commerce (section 2.4), express delivery companies (ex: FedEx) are facing more complex problems (compared to business deliveries) of delivering to homes (Caruso, 1998). A major problem facing express companies is the expansion of their network coverage in a cost effective manner. Another problem is their operation schedule. Most of their delivery trucks run during regular working hours, during which most people are not available at home. Thus delivery companies have to either keep the package at the front door, or try to redeliver later. In the first case, theft and fraud are a major problem; in the second case, the cost of redelivering becomes very high and thus not profitable. These factors are the main cause of high cost incurred in home delivery by express companies, who might find it not feasible to enter this sector. However, USPS is the main delivery company that has the infrastructure for home-end deliveries, and is likely to capture the highest market share.

Vendor Managed Inventory

Under a VMI strategy, the supplier takes responsibility for the inventory levels of participating customers. Many companies have implemented VMI to keep track of customers' demand in order to try and reduce their inventory levels while increasing customers' level of service. An advantage of VMI is that it has usually resulted in an increase in retail sales by reducing stock-outs at retailers' sites. Another advantage is the reduction in the supply chain costs such as inventory costs; moreover, manufacturing costs are likely to decrease by optimizing the production plans since the customers' demand information is available to the supplier (KPMG, 1996). The particular model adopted under a VMI strategy depends on the industry itself, and the characteristics of the companies involved. A conceptual model representing the information exchange between customers and supplier in VMI is presented in Figure 3.3. Some of the measures that are adopted by collaborating parties to keep track of the performance of VMI strategy are:

- Increase in product turnover at the supplier and retailers
- Inventory levels at retailers and supplier
- Increase in sales at the retailers
- Productivity change of sales people and inventory managers
- Distribution/operation cost including truck utilization, reduction in paper work, reduction in returns, personnel costs, and depreciation
- Customer satisfaction including service levels and product freshness

Technology developments (EDI, bar-coding, internet) are facilitating the implementation of VMI strategy, though further adoption faces some strategic and operational obstacles. Strategic obstacles include the distributors' reluctance to provide information up the supply chain to prevent possible direct relations between the manufacturer and the customer. Operational obstacles include employers' fear of loosing their jobs, and companies fear of change in operational strategies, which may lead to loss of power. Finally, although integration and relationships between trading partners could improve customer satisfaction while increasing sales and decreasing the operating costs along the supply chain, VMI

strategy is not always a beneficial situation. Some of the benefits and drawbacks of VMI are summarized in Table 3.2.

Customer Process
Sales Forecasting

Information Transfer
→

Supplier Process
Set up Planning System:
Production
BOM
Lead Time
Safety Stock

Update Price ← Pricing

Inventory/Inventory Monitoring → Update Inventory Records & Evaluate Replenishment

Schedule Receiving Dock ← Set up replenishment order: product, qty, price

Confirm Shipment → Delivery

Payment → Confirmation

Figure 3.3: Information exchange under a VMI setting

TABLE 3.2: BENEFITS AND DRAWBACKS OF VMI STRATEGY

Benefits	Drawbacks
Improves relationships and cooperation along the supply chain	Vendor's administrative costs increase
Easy to implement and provides considerable benefits over existing performance	Not efficient with volume discounts and special pricing
Increases customer service level and reduces stock-outs	Complicates delivery system at start
Reduces overall supply chain costs by reducing stock-outs and lowering inventory levels because of the smoother demand	Retailer risks loss of control/flexibility
Increases sales	Minimal benefits to manufacturer until a good portion of its distribution process is through VMI.

Finally, implementing VMI is likely to help firms shift from a "Push" to a "Pull" supply strategy, where the customers' demand drives the delivery operations. The offset between advantages and drawbacks of VMI is the major motivation behind the analysis presented in chapter 4. Quantifying cost reductions achievable through information sharing when applying a VMI policy in a two-echelon

distribution channel is the main focus of next chapter. Moreover, identifying the benefits to retailers and supplier separately is another contribution of this work.

CONCLUSION

This chapter has discussed ways in which information and communication technologies and electronic commerce are impacting logistics operations. In the preceding sections, we noted that some of the technological advancements that are helping improve the level of service are real time shipment tracking devices, EDI, and Direct To Store strategies, which help in delivering the products faster and with lower transportation, warehousing, and handling costs. Through better logistics operations, firms could achieve faster response time, lower inventory levels, improved order accuracy, better information management, and cost savings from improved efficiency.

Finally, we notice that the impacts discussed imply that demands for goods movement will be driven by the final consumers' demand; the time between final demand and the upstream flows will be shortened considerably, and in the long run, there will be a convergence between freight demand and individual consumption through a variety of channels. This explains the move towards a Pull System driven by the customer versus a Push system. Future research directions include analyzing the impact of ICT on each of the discussed changes. This includes researching how to incorporate effect of technology on VMI strategy in theoretical models, developing new logistical policies for home-end deliveries, and assessing the change in freight movement. The following chapter focuses on the impacts of ICT on VMI, and quantifies cost reductions achievable through information sharing among multiple retailers and a supplier in a two-echelon distribution channel.

CHAPTER 4: COST IMPACTS OF INFORMATION SHARING THROUGH VENDOR MANAGED INVENTORY STRATEGY

INTRODUCTION

Vendor Managed Inventory (VMI) is a logistics distribution strategy where the supplier manages the inventory at customers' sites and decides on replenishment policies, subject to stipulated levels of availability and service. The supplier benefits by reducing its inventory levels, reducing customers' demand variability, and improving routing strategies; customers benefit by reducing resources dedicated to manage inventories, and by decreasing their stockouts thus increasing their revenues. VMI is made possible by installing technological equipment at participating sites to allow the supplier to keep track of the demand and inventory level at the customers. The decrease in the technological cost of applicable technologies, such as Electronic Data Interchange (EDI) and the Internet, has accelerated the adoption of these strategies across several industries. VMI is at present implemented mainly in the petrochemical and food distribution industries. The objective of the supplier in VMI is to decide on distribution tactics that will minimize the inventory and transportation costs across the supply chain. Primary decisions involved are 1) delivery time instants to the retailer, 2) quantity of product to ship to each retailer on his delivery date, and 3) daily routing of the vehicles. These decisions are constrained by the service level that should be maintained at retailers' sites, inventory capacity at supplier and retailers, and transportation capacity of the vehicles. Thus, applying a VMI strategy requires that the supplier solve an integrated transportation and inventory management problem.

Many researchers have investigated these integrated problems, and several models that capture these scenarios are found in the literature. Harris (1913) proposed the classical EOQ model, which determines a constant shipping frequency, and the quantity to be ordered for each delivery. This quantity is determined taking into consideration the inventory holding cost and the fixed ordering cost incurred by the retailer per delivery. The model has been applied in Blumenfeld *et al.* (1985), and Burns et al. (1985). Bertazzi et al (1997) further improved the proposed models by constraining the shipments to a given set of discrete frequencies; this eliminated some infeasible solutions obtained by previous models (from a practical point of view).

However, from the 1980's, researchers have mainly approached integrated inventory and vehicle routing problems by solving the Inventory Routing Problem (IRP). The IRP consists of finding distribution strategies for a supplier in order to optimize the system's inventory and transportation costs, while minimizing stock-outs or maintaining a pre-assigned customer level of service. The IRP solution determines which customers should be visited in a specified planning horizon, and optimal routing solutions to the supplier's fleet (usually reduces to a Vehicle Routing Problem (VRP)). Major research work started to emerge in the 1980's. Researchers first focused on solving the IRP for a single product being distributed from one warehouse/supplier to several retailers/customers; this work was mainly applicable in the petrochemical and industrial gas industries. Due to the complexity of the problem (which

includes the VRP, known to be NP-Hard), most research focused on minimization of distribution costs over the short-term (finite horizon). Variants of proposed solution techniques for the IRP include the length of the planning horizon that is considered. Most of the early work focused on solving the IRP for a single day. Later, the problem was extended to several days. The main difference in these two categories lies in the customer selection procedure, and the manner in which long-term effects of short-term decisions are included in the problem solution. The IRP could be modeled and solved as an exact mixed integer formulation; however, due to its complexity, it is usually solved using heuristics, especially for large problems.

Although several researchers have investigated VMI using several proposed models, none of the available research appears to have addressed the decrease in costs achievable across a supply chain by shifting from a non-collaborative environment (Scenario 1: no information sharing; a model is proposed based on the EOQ concept), and a collaborative environment (Scenario 2: information sharing; a model is proposed based on a VMI strategy). The objective of this research is to quantify cost reductions achievable through information sharing under a VMI setting compared to conventional replenishment strategies. The chapter focuses on variations in transportation, ordering, stock-out, and inventory holding costs at the supplier and retailers. In addition, we illustrate the reduction in the bullwhip effect defined in section 3.4, by examining the variability in the demand experienced at the supplier level.

The remainder of this chapter is organized as follows. Section 2 discusses previous literature related to the IRP. Section 3, describes the problem of interest. Section 4 discusses the simulation experiments designed to analyze system operation under the no information sharing and information sharing scenarios. In Section 5, computational results are shown and analyzed. Finally, Section 6 summarizes the important findings of this research, and presents future research directions.

LITERATURE REVIEW

This section discusses selected studies that provide the principal backbone for this analysis, helping to set the underlying framework. The first part of the section presents an overview of work relating to the IRP, whereas the second part focuses on the research published by Bertazzi, Paletta, and Speranza (1999), which was adopted as part of modeling the VMI setting.

Due to the complexity of the general IRP (long-term dynamic stochastic setting), almost all of the research work available in the literature has concentrated on solving the short-term version. Most of the early work has focused on solving the short-term IRP covering a single day (Ferdergruen and Zipkin, 1984; Golden et al, 1984; Chien et al, 1989). Later, this problem was expanded to span several days (Dror et al., 1985; Dror and Ball, 1987; Trudeau and Dror, 1992; and Huang et al., 1997). The main difference between the various approaches lies in the customer selection procedures and incorporation of long-term effects of short-term decisions. Other research work investigated the asymptotic behavior of proposed simple policies (Anily and Federgruen, 1990; Gallego and Simchi-Levi, 1990; Anily and Federgruen, 1993; Bramel and Simchi-Levi, 1995). Table 4.1 presents a chronological ordering of previous research work regarding the IRP, characterized along four principal dimensions.

The four dimensions shown in the table reflect the major variations in the formulation and solution assumptions adopted by the researchers. First, the time horizon considered is either long, short, or reduced. In practice, the objective is to maximize profit (minimize cost) over the long run, and some researchers have explicitly modeled this problem. Others have solved the IRP over a short time horizon, disregarding the long-term effects of short-term decisions. Some researchers have adopted a finite planning horizon methodology, over which a "short-term" problem is solved, however the costs are specified to incorporate some long-term effects. The second dimension consists of the assumption made regarding the demand. While in practice, the supplier does not always know customers' demand in advance, because the latter is usually stochastic, many researchers have considered a deterministic demand setting to reduce the complexity of the problem. Third, most researchers have assumed that multiple customers could be visited in a single route; however, some have adopted direct delivery strategies, which eliminate the routing problem. Finally, to facilitate the solution of the IRP, some researchers have assumed that the availability of vehicles is unlimited, which in most cases is not particularly realistic in practice.

Bertazzi et al. (1999) analyzed a distribution problem where a product must be replenished from a supplier to multiple retailers. They analyze the variation in total costs across the supply chain when the objective function (corresponding to different decision makers) is altered. One of the objective functions analyzed is to minimize the total cost across the supply chain, which represents a VMI setting where the supplier makes the replenishment decisions and is responsible for the transportation fleet. The supplier must determine delivery time instants for the retailers so that they do not stock-out, and must route

TABLE 4.1: IRP VARIATIONS TACKLED BY RESEARCHERS

Reference	Horizon	Demand Setting	Number of Retailers/Route	Vehicles
Federgruen and Zipkin 1984	Short	Stochastic	Multiple	Limited
Golden et al. 1984	Short	Bounded	Multiple	Limited
Burns et al. 1985	Short	Deterministic	Single, Multiple	Unlimited
Dror et al. 1985	Short	Deterministic	Multiple	Limited
Dror and Ball 1987	Reduced	Stochastic	Multiple	Limited
Chien et al. 1989	Reduced	Deterministic	Multiple	Limited
Anily and Federgruen 1990	Long	Deterministic	Multiple	Unlimited
Gallego and Simchi-Levi 1990	Long	Deterministic	Single	Unlimited
Trudeau and Dror 1992	Reduced	Stochastic	Multiple	Limited
Anily and Federgruen 1993	Long	Stochastic	Multiple	Unlimited
Minkoff 1993	Long	Stochastic	Multiple	Unlimited
Huang et al. 1997	Reduced	Stochastic	Multiple	Limited
Campbell et al. 1998	Short	Deterministic	Multiple	Limited
Kleywegt et al. 1999	Long	Stochastic	Single	Limited

vehicles accordingly. Since finding the exact solution is NP-hard, the authors propose a heuristic algorithm divided into two steps: "Start", to find an initial solution, and "Improve", to improve the solution. The solution is obtained by finding the shortest path along an acyclic network. The arcs in the network exist if they do not violate imposed constraints; the weights on these arcs vary according to the objective function considered. Results based on sixty randomly generated instances showed that minimizing the transportation cost produced solutions that were the closest (among other objective functions considered) to the solution that minimizes the total cost; moreover, the cost structure was also similar (Bertazzi et al., 1999). The heuristic proposed by the authors is used in the present analysis to model the information-sharing scenario, with the objective of minimizing the sum of all costs. The heuristic algorithm is further explained in Section 4.4.

PROBLEM DESCRIPTION

In this section we formally describe the problem under consideration. The main objective of the analysis is to quantify cost reductions achievable through information sharing in a two-echelon distribution system. In order to achieve this objective, two different scenarios are modeled: 1) no information sharing, and 2) information sharing.

Input Parameters

The parameters assumed to be given in the problem are:

- *n: Number of retailers, $i \in I = \{1, …, n\}$*
- *0: Supplier*
- *H: Number of days in the planning horizon, $t \in T = \{0, 1, …, H\}$*
- *VC: Vehicle capacity of the supplier*
- *r_{it}: Demand for retailer i in day t, $i \in I$, $t \in T$*
- *μ_i: average daily demand for retailer i, $i \in I$*
- *σ_i: Standard deviation of the daily demand for retailer i, $i \in I$*
- *h_i: Inventory holding cost at retailer i/unit/time unit, $i \in I$*
- *h_0: Inventory holding cost at the supplier/unit/time unit*
- *INVR0 (i): Starting inventory level at retailer i, $i \in I$*
- *INVS0: Starting inventory level at the supplier*
- *TRC (i, j): Transportation cost from i to j; $i, j \in I' = I \cup \{0\}$*
- *SO_i: Stock-out cost/unit, $i \in I' = I \cup \{0\}$*
- *K: Ordering cost for each retailer*
- *ATC: Average transportation cost charged to the retailer per delivery*
- *L_i: Lead time, $i \in I' = I \cup \{0\}$*
- *z_i: level of service parameter; $i \in I' = I \cup \{0\}$*

No Information Sharing

We consider a logistics network in which a product must be shipped from a supplier *0* to a set of retailers *$I=\{1, 2, … , n\}$* over a specified time horizon *H*, with discrete time instants *$t \in T = \{1, 2, …, H\}$* (corresponding to days). Each day a variable quantity *r_{it}* is consumed at retailer *$i \in I$.* The random demand *r_{it}* is assumed to be normally distributed with a daily mean *μ_i,* and a standard deviation *σ_i, $i \in I$;* demands are assumed to be identically independently distributed (iid) over days, and across retailers. Each retailer *$i \in I$* defines an ordering policy *(s_i, S_i)* where *s_i* is the re-order level, and *S_i* is the order up to level. This ordering policy is dependent upon the level of service that retailer *i* chooses, its daily demand characteristics *(μ_i, σ_i),* fixed ordering cost *K* incurred by the retailer per order, fixed transportation cost *ATC* charged by the supplier to the retailer per delivery, and finally the fixed and deterministic lead time *L_i,* thus we obtain,

$$s_i = L_i \times \mu_i + z_i \times \sigma_i \times \sqrt{L}_i \qquad\qquad (1)$$

and,

$$S_i = max\ (Q_i,\ L_i \times \mu_i) + z_i \times \sigma_i \times \sqrt{L}_i \qquad\qquad (2)$$

$$Where:\quad Q_i = \sqrt{2(K + ATC)\mu_i\ /\ h_i} \qquad\qquad (3)$$

In equations 1 and 2, z_i is a parameter that represents the level of service that retailer $i \in I$ adopts. The first term of equation 1 is the expected demand during lead-time L_i, whereas the second term is the safety stock that retailer i should keep in order to cover for deviations from average demand during lead-time L_i (Simchi-Levi, 2000b). Had there been no fixed costs incurred per order or delivery, S_i would have been equal to s_i. However, since retailer $i \in I$ incurs a cost $K+ATC$ per visit, the term Q_i is introduced in equation 2. This term is based on the EOQ concept; it balances between the fixed cost per unit time and the inventory holding cost per unit time. If in day $t \in T$ the inventory level at retailer $i \in I$, $INVR_{it}$, is below s_i, an order is placed to the supplier and the retailer is scheduled to be visited on day $t+L_i$. let QD_{it} be the quantity to be delivered to retailer i on day t, then QD_{it} is either equal to S_i if the retailer is visited on day t, or equal to zero otherwise. Finally, if a retailer $i \in I$ is not able to satisfy the demand r_{it}, then it places an urgent order on day t, and is visited on day $t+1$.

In this case, the supplier has no information about the retailers' customer demand. The supplier receives daily orders from the retailers, aggregates the demand, and accordingly adopts an (s_0, S_0) policy, under which the supplier sets a high level of service to avoid stock-out. The supplier does not incur any fixed costs per replenishment and thus S_0 becomes equal to s_0, as mentioned in the previous paragraph. The level s_0 is dependent upon the average demand μ_0, and its standard deviation σ_0, experienced by the supplier. Assuming that the supplier's lead-time is one day, we obtain,

$$S_0 = s_0 = \mu_0 + z_0 \times \sigma_0 \qquad\qquad (4)$$

Where, z_0 corresponds to the level of service adopted by the supplier. If the inventory level at the supplier on day t, $INVS_t$, drops below S_0, the supplier is replenished a quantity, $SPLY$, equal to S_0 on day $t+1$.

Deliveries from the supplier to retailers can be executed in each time instant $t \in T$ using a vehicle of a capacity VC, able to satisfy the daily requirements of all retailers. In each tour, the vehicle can visit several retailers, i.e., routing is allowed. The transportation cost TRC_{ij} from each node i to each node j, with $i, j \in I' = I \cup \{0\}$ is given. Thus the transportation cost incurred by the supplier on day t, TCS_t is equal to the sum of the arc costs of the route developed for day t. The total transportation cost incurred by the supplier becomes equal to,

$$TTCS = \sum_{t \in T} TCS_t \qquad\qquad (5)$$

Note that the total transportation cost for the system, $TTCS$, is determined for a given replenishment plan, resulting from a set of retailer ordering decisions. The quantities ordered depend on the average transport cost ATC charged by the supplier to the retailer. This ATC is obtained by dividing the total cost $TTCS$ by

the number of visits over the horizon of interest. This introduces the need to determine the transport cost jointly with the retailer decisions. The interdependence introduced in this formulation is addressed through an iterative scheme in the solution methodology, which ensures mutual consistency between the average transport cost used in the ordering decisions, and the resulting actual transport cost for the routing problem.

An inventory holding cost h_i, is charged per unit per day at the retailer i, $i \in I$. Knowing that the level of inventory at retailer i at the start of day t is equal to that of day t-1, minus the consumption in day t-1, plus what is delivered in day t, that is

$$INVR_{it} = INVR_{it-1} - r_{it-1} + QD_{it} \qquad\qquad (6)$$

the total inventory cost charged to retailer i is,

$$TINCR_i = \sum_{t \in T'} INVR_{it} \times h_i, \; where \; T' = \{1, ..., H+1\} \qquad\qquad (7)$$

The time horizon was extended by one day to include the cost of the inventory charged on the last day. The starting inventory $INVR0_i$, $i \in I$ is given.

An inventory holding cost h_0 is charged to the supplier, who incurs a total inventory cost,

$$TINCS = \sum_{t \in T} INVS_t \times h_0 \qquad\qquad (8)$$

where the starting inventory level at the supplier on day t is equal to that of day t-1, minus what was shipped on day t-1, plus what is replenished on day t, that is,

$$INVS_t = INVS_{t-1} - \sum_{i \in I} QD_{it-1} + SPLY_t \qquad\qquad (9)$$

A stock-out cost per unit of shortage, SO_i, $i \in I$, is charged to retailer i if it cannot satisfy its daily demand. Thus the stock-out cost incurred by retailer $i \in I$ on day $t \in T$ is,

$$
\begin{aligned}
SOCR_{it} &= (r_{it} - INVR_{it}) \times SO_i & if \; r_{it} \rangle INVR_{it} \\
&= 0 & otherwise
\end{aligned}
\qquad\qquad (10)
$$

Similarly, the supplier incurs a stock-out cost per unit of shortage SO_0, which may or may not be the same as the cost incurred by the retailers. In the experiments presented in the next section, we assume SO_i = SO_0 = SO, $i \in I$, for convenience. The stock-out cost incurred by the supplier 0 on day t is then given by

$$
\begin{aligned}
SOCS_t &= (\sum_{i \in I} QD_{it} - INVS_t) \times SO_0 & if \sum_{i \in I} QD_{it} \rangle INVS_t \\
&= 0 & otherwise
\end{aligned}
\qquad\qquad (11)
$$

The objective of the problem is to determine the inventory, ordering, stock-out, and transportation costs incurred by all the parties along the time horizon considered. Another objective is to correctly model

the interdependence between the transportation cost incurred by the supplier and the average transportation charge that is incurred by the retailer, and use an iterative scheme for its solution. The information sharing scenario is described next.

Information Sharing

The same logistics network is considered. In this scenario, the retailers do not decide on their replenishment strategy. They collaborate with the supplier by providing full information or access to their inventory levels and daily customer demand. The retailers benefit by eliminating ordering costs, and stock-out costs, for which the supplier becomes responsible. At the start of the planning horizon, the supplier, knowing the average daily demands μ_i and their standard deviations σ_i, $i \in I$, adopts a replenishment strategy that minimizes the total transportation and inventory costs at all collaborating sites. In this policy, the supplier assumes a daily constant demand at each retailer, $DMND_i = \mu_{i\ +}\ z_i \times \sigma_i$, where z_i corresponds to the same level of service adopted by the retailer in the first setting. This demand corresponds to the average daily demand, plus a margin to account for the stochastic nature of the demand. The supplier plans the delivery schedule to the retailers' sites so that they do not stock-out. Whenever a retailer is visited, it is replenished to the maximum inventory level, $max_i = s_i = L_i \times \mu_i + z_i \times \sigma_i \times \sqrt{L_i}$; furthermore, retailers' daily inventory is kept above a minimum level, $min_i = \mu_{i\ +}\ z_i \times \sigma_i$. Each day, the supplier is replenished a quantity that equals the sum of the demands that occurred on the previous day. Finally, since the demands at the retailers are random and normally distributed, the supplier follows the replenishment policy developed at the start of the planning horizon unless a retailer stocks out. In this case, the supplier is responsible for the stock-out costs, and the retailer must be replenished on the next day. The supplier profits from this strategy by reducing the demand variability, thereby decreasing the inventory holding cost. In both cases, it is assumed that the transportation, inventory holding, stock-out, and ordering costs are given. Moreover, the network (for the routing subproblem) is assumed to be complete and symmetric. The flow chart describes the decision policies involved in both scenarios (Figure 4.1). To evaluate the performance of the No information sharing scenario versus the information sharing one, two sets of simulation experiments were developed that represent each of the two settings.
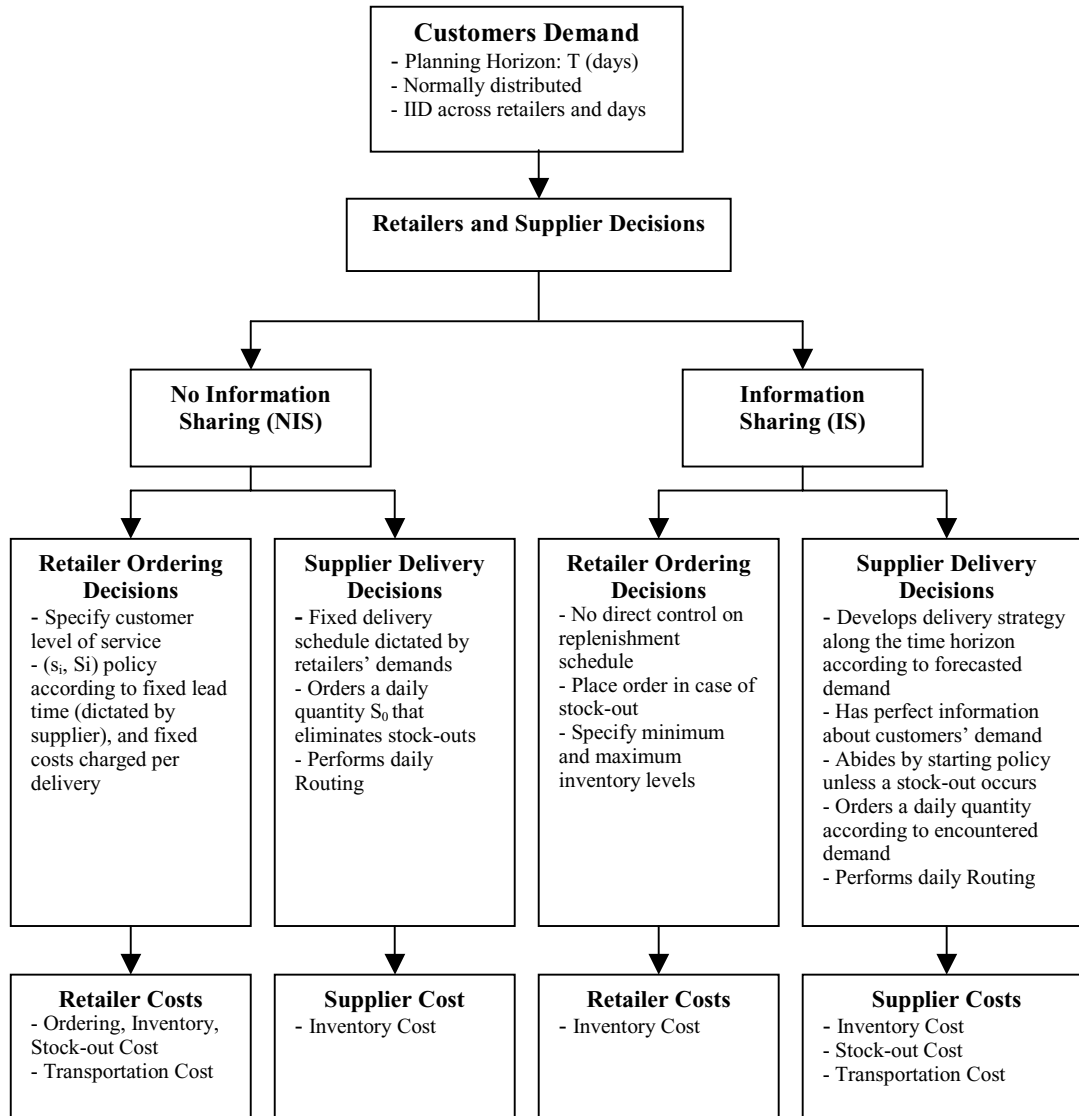
Figure 4.1: Comparison of policies under no information sharing and information sharing scenarios

STRUCTURE OF THE SIMULATION EXPERIMENTS

No Information Sharing

We describe the framework that was developed to represent the no information sharing scenario. A simulation model composed of seven steps is proposed to solve the problem described in the previous section.

Step 0: *Initialize the process by setting the initial inventory level at the supplier and at the retailers.*

Set initial ATC =$(\sum_i 2 * H * TRC_{0i} / (1.5 * L))/i$.

Step1: *Calculate (s_i, S_i) for $i \in I$ and S_0. For each retailer, determine the daily inventory level, $INVR_{it}$, and place an order if it is below s_i. Accordingly, determine the delivery schedule Y_{it}, equal to* 1 *if retailer i, $i \in I$ must be visited on day t, $t \in T$, and 0 otherwise. Calculate the fixed ordering and transportation costs charged to the retailers. Moreover, compute the daily inventory holding and stock-out costs.*

Step 2: *Determine the daily inventory level at the supplier, $INVS_t$, taking into consideration its daily supply, and the quantity that it ships.*

Step 3: *According to Y_{it}, insert each retailer in the route R_t developed for day t. Each retailer that must be visited on day t is inserted separately using a "cheapest cost" insertion heuristic (see Rosenkrantz et al., 1977). Let TCS(t) be the cost of R_t.*

Step 4: *Improve the transportation initial solution by applying a two-branch exchange algorithm (see Lin, 1965). Develop the route RI_t by removing a retailer from the initial solution and then reinserting it. Let TCSI (t) be cost of the new route. If TCSI (t) < TCS (t), keep the new solution. Repeat for all scheduled retailers, for all days, until no further improvement is achieved.*

Step 5: *Compute the average transportation cost incurred by the supplier per delivery: ATCS = Total transportation cost/Number of visits. Check for convergence. If ATCS<ATC≤1.005ATCS, Go to Step 7; otherwise, ATC = 0.75*ATCS + 0.25*ATC, and return to Step 1.*

Step 6: *Output retailers costs including inventory holding, stock-out, ordering and transportation. Output supplier inventory holding cost.*

Step 1 determines the delivery schedule for each retailer according to the adopted (s_i, S_i) policy. Whenever a retailer's inventory drops below s_i, it places an order quantity S_i that becomes scheduled to be delivered in exactly L_i days. Whenever a retailer stocks out, it places an order S_i in the same day, which becomes set to be delivered the next day. Furthermore, this step calculates the ordering and transportation costs that are incurred by each retailer along the time horizon. These cost are directly proportional to the number of visits. It also generates the inventory holding cost, and the stock-out cost incurred by the retailers. Step 2 of the simulation focuses on the costs incurred by the supplier. The supplier is set to abide by the delivery schedules of his customers. Accordingly, the daily inventory level at the supplier site is determined, and the inventory holding cost incurred is computed. Step 3 focuses on forming the daily transportation routes for the supplier. Each retailer that is scheduled to be visited on day t, is inserted in the route using the "Cheapest Insertion" heuristic (see for example Rosenkrantz et al., 1977). After constructing the initial solution for daily routes by inserting all retailers that must be visited, a 2-branch exchange improvement heuristic (see for example Lin, 1965) is employed in Step 5, thus improving the transportation cost. This step is repeated until no further improvement is achieved. The output of this step determines the daily transportation cost incurred by the supplier, and the routing that it should adopt to minimize the transportation cost. Step 6 checks if the transportation cost used to generate retailers' ordering decisions is within 0.5% (i.e. 0.005) of the actual transportation cost incurred by the supplier. If not, *ATC* reset to a new value, which is a linear combination of the initial value and the latest cost of the solution to the routing problem.
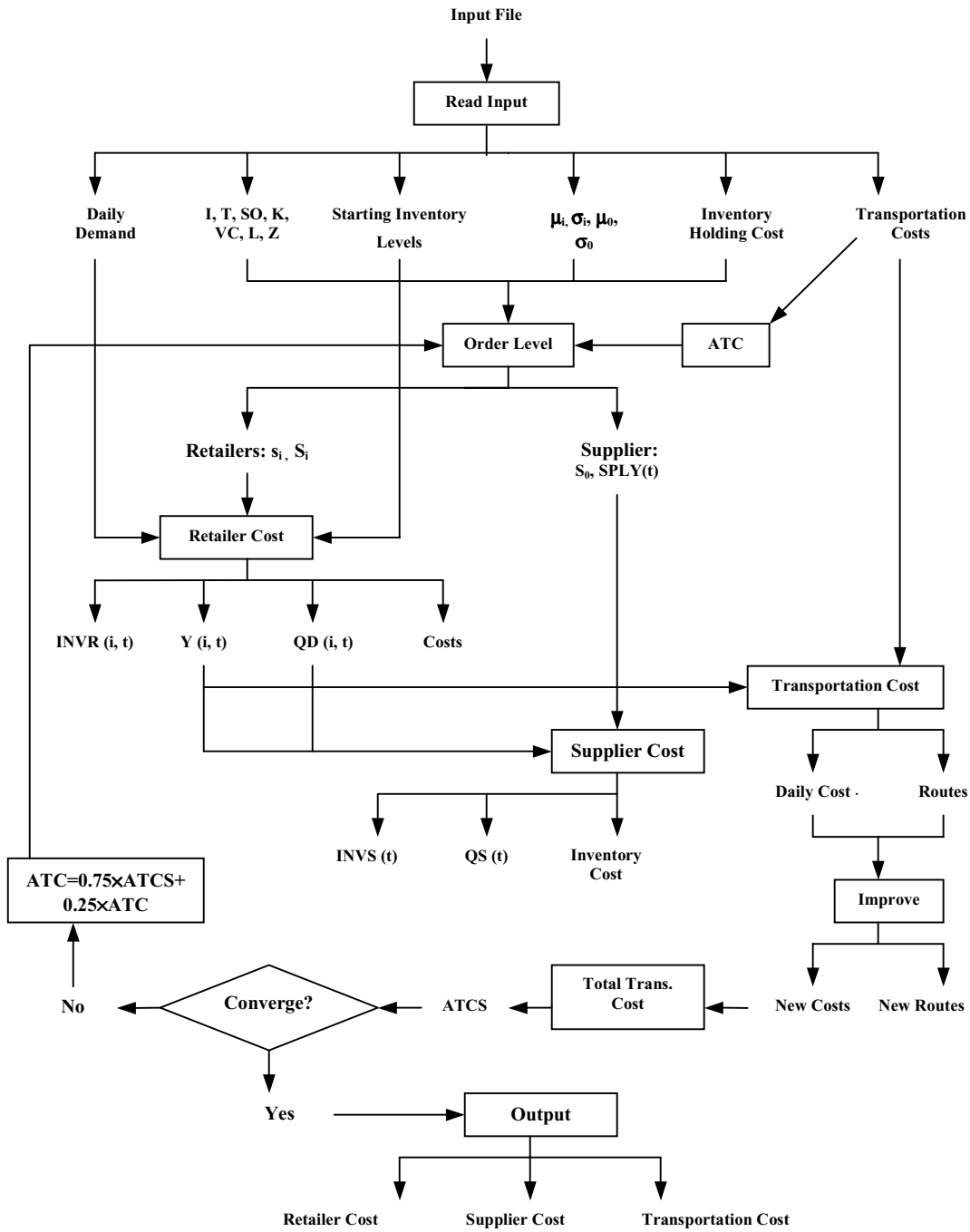
Figure 4.2: Modeling framework for the no information sharing scenario

Quantities to be delivered, S_i are recomputed for all retailers, and the problem is reiterated. After convergence, total costs for retailers and supplier are outputted. The simulation experiment was implemented in Fortran. Figure 4.2 presents an overview of its structure.

Information Sharing

The simulation approach developed to model the VMI strategy is composed of two main steps. The first step determines, at the start of the planning horizon, the shipping strategy that must be adopted by the supplier to minimize total costs across the supply chain. This is modeled using the formulation developed by Bertazzi et al. (1999), with the objective of minimizing systemwide costs. Their solution procedure is a heuristic composed of two steps: "*Start*", which generates an initial solution, and *"Improve"*, which improves the initial solution. In each iteration, the procedure *Start* inserts a retailer into the solution. This is achieved by creating an acyclic network for each retailer, where each node of the network represents a day of the planning horizon. An arc between any two nodes $k \in T$, *and* $j \in T$ *in* the acyclic network for retailer $i \in I$ exists if it is possible to visit retailer i on day j, given that the previous visit is on day k, without violating capacity constraints, and stock-out constraints at the supplier and retailers (no stock-outs are allowed). The weights on these arcs vary according to the objective function analyzed. In this case, these weights include the increase in the retailers' inventory cost, the increase in transportation cost, and the decrease in the supplier's inventory costs if the specified retailer is visited on a day j, and previous visit was at k. Whenever a retailer is visited, it is replenished to the given maximum level; the quantity that is shipped is dependent on the demand that occurred on days k to j-*1*. In this case, we assume that the supplier plans according to a constant daily demand at retailers' sites that corresponds to the same level of service adopted by the retailer in the non-collaborative setting. For example, if retailer i had assumed a 95% level of service, the supplier assumes that the retailer's daily consumption is $q_i = \mu_i + z_{0.05} \times \sigma_i = \mu_i + 1.65 \times \sigma_i$. Furthermore, the delivery schedule for each retailer is found by solving for the shortest path along the respective acyclic networks. After inserting all retailers and constructing the initial solution, procedure *"Improve"* is applied. The method removes a retailer from the solution then reinserts it in an attempt to improve the total cost of the solution. The procedure is repeated until no further improvement is achieved. The main output of the procedure from the standpoint of our strategy is the delivery schedule produced by the heuristic, which represents the starting policy for the supplier.

The second step of the approach takes as input the delivery schedule produced in step 1. The problem is then modeled using the same basic procedure described for the no information sharing scenario, with the major difference that the replenishment dates for each retailer are now predetermined. The problem is simulated using the same random, normally distributed demands introduced in the first setting. The supplier follows his original plan unless a retailer stocks out. In that situation, the retailer is visited the next day, after which the original schedule continues to be followed. Whenever a retailer is visited, its inventory is filled to the maximum level. Another difference is that the supplier knows the retailers' customers daily demands, and plans the replenishment strategy accordingly. The problem is simulated on a daily basis along the time horizon, and associated supplier and retailers' costs are computed. These costs are compared to the ones obtained in the first scenario.

SIMULATION EXPERIMENTS AND RESULTS

The main objective behind this analysis is to quantify cost reductions achievable through information sharing in a two-echelon distribution system composed of one supplier and multiple retailers. We seek to answer the following questions: 1) What is the benefit for retailers of adopting a VMI strategy in terms of inventory, ordering, and stock-out costs? 2) What is the benefit for the supplier in terms of the decrease in inventory holding cost? and 3) How important is the reduction in the bullwhip effect (Chen et al., 1999) through information sharing? We describe next the system features specified in the simulations, the principal factors that were varied across experiments, and performance descriptors considered in the analysis. Finally, simulation results based on randomly generated instances are analyzed.

Simulation Experiments

The logistics network considered in all the experiments consists of 50 retailers *(n=50)* served by a common supplier. Moreover, the logistics network is assumed to be symmetrical and complete, where the transportation cost between any two parties is randomly uniformly generated in the interval [10-1000]. All retailers are assumed to observe an average daily demand μ_i in the interval [50-150] (uniformly distributed), with a base coefficient of variation, COV_i, uniformly generated in the interval [0.1-0.3]; the daily demand at retailer i on day t, r_{it}, is a truncated normally distributed random variable with mean μ_i and standard variation $\sigma_i = COV_i \times \mu_i$ (negative and high positive values are eliminated). The inventory holding cost h_i, $i \in I$, is uniformly generated in the interval [0.5-1]. The starting inventory level at the retailers, $INVR0_i$ is equal to $g_i \times s_i$, where g_i is randomly uniformly generated in the interval [1, 2] in order to eliminate first day clustered ordering. The starting inventory level at the supplier, $INVS0$ is equal to S_0. The stock-out cost per unit of shortage is equal to \$10 at retailers and the supplier; however, in all the generated instances, the supplier adopts a 99% level of service $(z_{0.01}=2.33)$ in order to virtually eliminate stock-outs. Finally, all the experiments were simulated along a time horizon $H = 30$ days, whereas the lead-time L_i, $i \in I$, is equal to 5 days.

In addition to the information versus no information scenarios, the experimental factors under investigation in the simulations are: 1) inventory holding cost at the supplier, h_0, 2) coefficient of variation, *COV*, of the daily demand 3) level of service at retailers, *LOS*, and 4) fixed ordering cost K incurred by a retailer. First, the inventory holding cost at the supplier is likely to affect the frequency of shipments to the retailers' sites in the information sharing setting, and thus the cost components of the solution and the associated total cost are likely to be altered. A supplier with low inventory holding cost is likely to decrease his shipments to retailers in order to minimize the total cost, whereas the opposite is likely to occur in case of a high inventory holding cost, thus increasing the inventory cost at the retailers' sites. Three values for h_0 were used in the simulations: 1) low, $h_{0l} = 0.67 \times h_0 = 0.5$, 2) base, $h_0 = 0.75$, and 3) high, $h_{0h} = 1.33 \times h_0 = 1.0$.

Second, two intervals were considered for the retailers' demand coefficient of variation, *COV*. The reference interval was introduced in the preceding paragraph, whereas a setting with higher demand

variability was also simulated with *COV* randomly generated in the interval [0.1-0.6]. An increase in the demand variability is likely to increase the inventory cost at retailers and supplier due to an increase in the safety stock that each party should maintain. Moreover, it is likely to affect the number of stock-outs that occur along the time horizon.

Third, two values for the level of service, *LOS*, adopted by retailers were used: 95% ($z_{0.05}$ = 1.65, reference case), and 96% ($z_{0.04}$ = 1.75). The higher level of service represents retailers with high value items. These retailers usually keep a high safety stocks in order to avoid stock-outs, which affect their revenues considerably. The stock-out charge, *SO*, was not altered because no optimization was employed, and thus the increase in total stock-out cost is proportional to the change in *SO*. The results will help in comparing how adopting VMI strategies is likely to affect each category.

Fourth, two values for the retailers' ordering cost are used: *K = 10* (base case), and *K = 1000*. A high ordering cost affects the order-up to level that retailers adopt in the no information sharing setting, and thus decreases the frequency of orders placed by retailers. This increases the bullwhip effect, which is likely to increase the inventory cost at the supplier. Many retailers incur high ordering costs because their ordering systems are not streamlined within the company, and with the supplier. New technologies allowing electronic ordering and streamlining are likely to decrease the ordering costs substantially, thus becoming a major benefit for these types of companies. In the simulated instances, it is assumed that ordering costs are completely eliminated when shifting to an information sharing setting, and thus this cost component is eliminated from our performance measures considered, discussed next.

Four principal system descriptors are analyzed in the comparison between the no information sharing and information sharing scenarios. First, the change in the inventory cost at retailers is analyzed. In the first scenario, this cost is mainly dependent upon the level of service that retailers adopt and the lead-time assumed, whereas in the second scenario, it is controlled by the supplier's shipment frequency. Second, the change in the supplier's inventory cost is investigated. The supplier is likely to benefit from knowing the retailers' customer demands by eliminating the bullwhip effect, thus inducing a decrease in its cost. Third, variations in the stock-out costs are explored. Stock-out costs are a major concern for companies in competitive market environments, where a stock-out might result in the loss of a customer to other companies. Information sharing is likely to improve customers' level of service. Finally, variations in the transportation costs are examined. These costs are likely to be affected by the number of trips performed by the supplier in both scenarios.

In addition to the four cost components, system performance is also examined in terms of the associated variability in demand experienced at the supplier level under the two information scenarios. In particular, we examine the elimination of the bullwhip effect through the standard deviation of the demand distribution at the supplier. All the presented costs were monitored daily along the planning horizon; however, total costs are reported. For each of the aforementioned scenarios, five data sets have been randomly generated (Table 4.2), amounting to a total of sixty simulated instances; the obtained average and standard deviation for each statistic are reported. Analysis of these results is presented in the following subsections.

TABLE 4.2: EXPERIMENTAL FACTORS AND GENERATED INSTANCES; NIS AND IS CORRESPOND TO NO INFORMATION SHARING AND INFORMATION SHARING

Scenario	Parameter Values				Number of Generated Instances		Total Instances
	h_0	COV	LOS	K	NIS	IS	
Base Case	0.75	0.1-0.3	95%	10	5	5	10
Low h_0	0.50	0.1-0.3	95%	10	5	5	10
High h_0	1.00	0.1-0.3	95%	10	5	5	10
High COV	0.75	0.1-0.6	95%	10	5	5	10
High LOS	0.75	0.1-0.3	96%	10	5	5	10
High K	0.75	0.1-0.3	95%	1000	5	5	10

Sensitivity Analysis

In this section, we analyze how the solutions obtained varied according to changes in the input parameters presented in the previous subsection. It is important to note that each random instance has been analyzed under two scenarios: no information sharing (NIS) and information sharing (IS). In both cases, the total cost *(TC)* is composed of retailers' inventory cost *(IR),* ordering cost *(OCR)*, stock-out cost *(SOR)*, supplier inventory cost *(IS)*, stock-out cost *(SOS)*, and the transportation cost *(TRC)*. Since the adopted level of service at the supplier's site is 99%, no stock-outs were encountered in both settings eliminating *SOS* from the remainder of our analysis. Table 4.3 allows us to compare how variations in the input parameters affected the total cost and its components.

TABLE 4.3: AVERAGE TOTAL COST AND ITS COMPONENTS FOR THE DIFFERENT COMBINATIONS OF INPUT PARAMETER VALUES*

Parameters		Setting	Average Costs (Standard Deviation in parentheses)					
			IR	OCR	SOR	IS	TRC	TC
h_0	0.5	NIS	430,356 (25,470)	20,700 (158)	45,893 (4,690)	238,794 (20,942)	47,848 (16,951)	783,590 (46,352)
		IS	545,019 (27,631)	0 (0)	44 (99)	194,800 (14,228)	41,611 (8,769)	781,474 (31,492)
	0.75	NIS	430,356 (25,470)	20,700 (158)	45,893 (4,690)	358,191 (31,413)	47,848 (16,951)	902,987 (55,573)
		IS	554,877 (25,470)	0 (0)	44 (99)	292,526 (21,079)	39,505 (6,594)	886,952 (47,469)
	1.0	NIS	430,356 (25,470)	20,700 (158)	45,893 (4,690)	477,588 (41,884)	47,848 (16,951)	1,022,385 (68,366)
		IS	556,210 (32,134)	0 (0)	0 (0)	384,878 (25,910)	41,496 (4,626)	982,584 (48,737)
COV	0.1-0.3	NIS	430,356 (25,470)	20,700 (158)	45,893 (4,690)	358,191 (31,413)	47,848 (16,951)	902,987 (55,573)
		IS	554,877 (25,470)	0 (0)	44 (99)	292,526 (21,079)	39,505 (6,594)	886,952 (47,469)
	0.1-0.6	NIS	506,120 (37,249)	20,000 (1,172)	42,986 (4053)	345,974 (37,749)	48,115 (17,502)	963,195 (39,487)
		IS	622,732 (41,611)	0 (0)	2,054 (4,526)	279,536 (51,207)	57,897 (2,059)	962,219 (80,924)
LOS	95%	NIS	430,356 (25,470)	20,700 (158)	45,893 (4,690)	358,191 (31,413)	47,848 (16,951)	902,987 (55,573)
		IS	554,877 (25,470)	0 (0)	44 (99)	292,526 (21,079)	39,505 (6,594)	886,952 (47,469)
	96%	NIS	437,787 (25,377)	20,580 (239)	42,629 (4,591)	351,505 (35,447)	47,934 (17,149)	900,435 (64,620)
		IS	553,594 (21,247)	0 (0)	0 (0)	293,157 (20,188)	39,915 (7,021)	886,666 (36,596)
K	100	NIS	430,356 (25,470)	20,700 (158)	45,893 (4,690)	358,191 (31,413)	47,848 (16,951)	902,987 (55,573)
		IS	554,877 (25,470)	0 (0)	44 (99)	292,526 (21,079)	39,505 (6,594)	886,952 (47,469)
	1000	NIS	479,766 (19,718)	185,400 (6,804)	30,520 (4,743)	342,724 (15,068)	46,735 (17,520)	1,085,135 (18,983)
		IS	554,877 (25,470)	0 (0)	44 (99)	292,526 (21,079)	39,505 (6,594)	886,952 (47,469)

* *IR*: Retailers inventory; *OCR*: Retailers ordering; *SOR*: Retailers stock-out; *IS*: Supplier inventory; *TRC*: Transportation; *TC*: Total Cost

As discussed in the preceding subsection, four parameters have been altered: Inventory cost at the supplier h_o, coefficient of variation *COV*, level of service at the retailers *LOS*, and finally the ordering cost *K*. Furthermore, in all the IS scenarios, the ordering cost was eliminated to reflect one of the advantages of the VMI strategy. The table is organized as follows. Each row corresponds to a class of instances; the first column refers to the analyzed parameter, the second presents its values, the third column specifies the setting, and the last six columns present associated costs.

First, the effect of the supplier's inventory unit holding cost h_0 is analyzed (h_0 = 0.5, 0.75, 1.0). In all cases, the inventory cost at the retailers represented the main component of the total cost. As the inventory holding cost at the supplier increased, the inventory cost at the retailers increased in the IS setting, whereas it did not change in the NIS setting. Since the supplier manages the retailer's inventory in the IS scenario, it tends to ship more as its inventory holding cost increases. On the other hand, with NIS the supplier has no control on the replenishment schedule and must commit to the retailers' orders, which are not affected by the increase in h_0. It is also noticeable that the stock-out cost, *SOR,* is almost eliminated in the first two instances, and no stock-outs occurred in the last instance. This is explained by the fact that the retailers are more frequently replenished in the last scenario, thus eliminating stock-outs, one of the main advantages of VMI and IS. The inventory cost at the supplier decreased in all instances, reflecting the advantage of a VMI strategy where the supplier has access to the consumers' daily demand. In the instances considered, the percentage decrease in the supplier inventory cost accelerated with the increase in h_0, reflecting a higher shipping frequency to retailers' sites. The same could be noted for the percentage decrease in total cost. Finally, the highest coefficient of variation for the reported average total cost is 0.07, which reflects robustness in the reported results.

In the next category, the impact of an increase in daily demand variability (reflected in the coefficient of variation) is analyzed. As expected, the inventory level at the retailers increased in both settings (NIS and IS). Greater demand variability requires retailers to keep a higher safety stock level, which increases their inventory cost. On the other hand, the inventory cost at the supplier decreased since it ships larger quantities to the retailers. One interesting result is that the total stock-out cost decreased under no information sharing (NIS) though one might have expected it to remain approximately the same since the same level of service is adopted. This phenomenon could be due to the higher safety stock associated with the randomness in the demand, and the use of a truncated normal distribution for daily demands (hence diminishing potentially extreme cases). Furthermore, it is important to note that in the IS setting the stock-out cost was the highest among all other instances, and that the decrease in total cost was smaller; this implies that demand variability could affect the performance of the VMI strategy negatively, and the supplier might have to change the starting policy to eliminate stock-outs and improve cost performance.

As expected, when retailers adopt a higher level of service (larger *z* value), their inventory cost in the NIS case increased, ordering cost decreased, and their stock-out cost decreased, whereas the supplier's inventory cost decreased for the same reasons mentioned in the preceding paragraph. In the IS setting, the results were not too sensitive to this factor, resulting in only a slight decrease in the inventory cost at the retailers and a small increase in the supplier's inventory cost, coupled with elimination of

stock-out costs. Moreover, the decrease in total cost was not too meaningful when the 96% policy was adopted because the supplier has to maintain a higher (than the 95% case) level of service at retailers' sites in the IS case.

In the last set of generated instances, the effect of high ordering cost is investigated. In the NIS setting, higher ordering cost increases the total inventory cost at the retailers since a larger quantity is ordered to balance between the ordering and the inventory holding cost. Stock-out cost decreased because of the high inventory levels that cover up for the stochastic nature of the demand. Furthermore, an increase in retailers' ordering cost decreases the supplier's inventory cost since larger quantities are shipped to the retailers, and fewer orders are received. Finally, because no ordering cost is incurred in the IS case, the corresponding results did not change. This implied better performance under the VMI strategy, with a larger decrease in the total cost. The following subsection discusses the variation in the total cost and its components across all simulated results.

Analysis of Variation in Cost Components

In this section, cost reductions achievable through information sharing are analyzed. First, focus is directed towards the total cost and its structure. Second, we investigate each cost component separately, and identify potential advantages for each party of applying a VMI strategy.

Total Cost Analysis. Total cost reductions were achieved in all the generated instances. Improvements varied between 0.1% and 18.26% (Figure 4.3). The lowest decrease is noted under the high demand variability scenario (COV = 0.1-0.6), which is expected since the supplier is following its initial, a priori strategy, which assumes a constant daily demand at the retailers' sites. The highest saving is achieved under the high ordering cost scenario (K = 1000). This is also expected since in the NIS setting ordering cost represented about 17% of the total cost, whereas this cost element is eliminated under the IS scenario. Note that the scenario definitions follow Table 4.2. For example the high ordering cost scenario is one where K = 1000 with all other parameter values at their base case level (h_0 = 0.75, COV = 0.1-0.3, LOS = 95%).

Different levels of demand variability (Figure 4.4) and of the ordering cost (Figure 4.5) present the respective percentage of each cost component (total cost is 100%). The retailers' inventory cost represented the most important component of the total cost, and experienced the largest percentage increase when IS is adopted (relative to NIS). Apart from the ordering cost, the stock-out cost experienced the largest percentage decrease, followed by the supplier's inventory cost. Moreover, when shifting to an IS setting, the percentage of the transportation cost increased under high demand variability, whereas it decreased in the low variability setting. Actually, under high demand variability, the VMI strategy performed the worst with respect to reduction in stock-out cost. High variability requires the supplier to schedule urgent deliveries, and thus diverge from its original policy, inducing higher transportation costs. Finally, in Figure 4.5, one could notice that the percentage of the supplier cost increased in the IS setting, although it decreased in all other instances; this is caused by the elimination

of the ordering cost that constituted a high percentage in the NIS scenario; the supplier cost actually decreased as shown in Table 4.3.
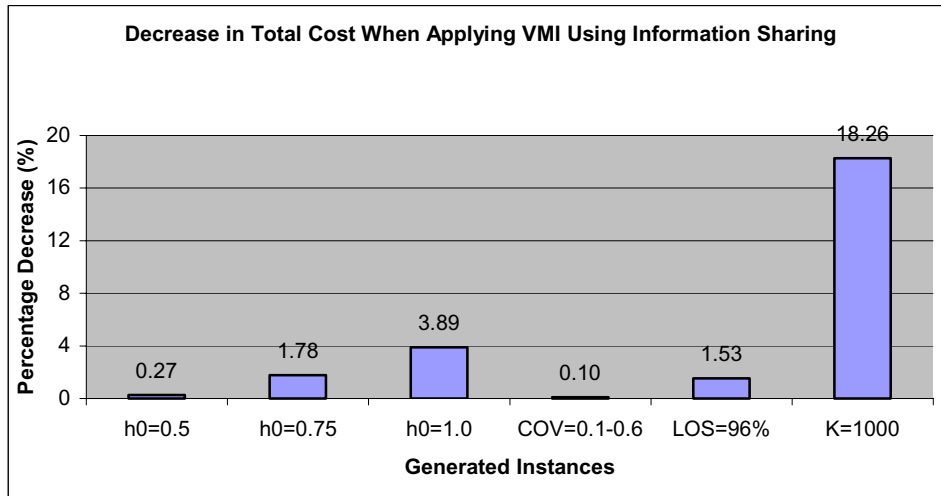

Figure 4.3: Percentage decrease in total cost when shifting from non-collaborative to collaborative environment; $h_0 = 0.75$ corresponds to the base case
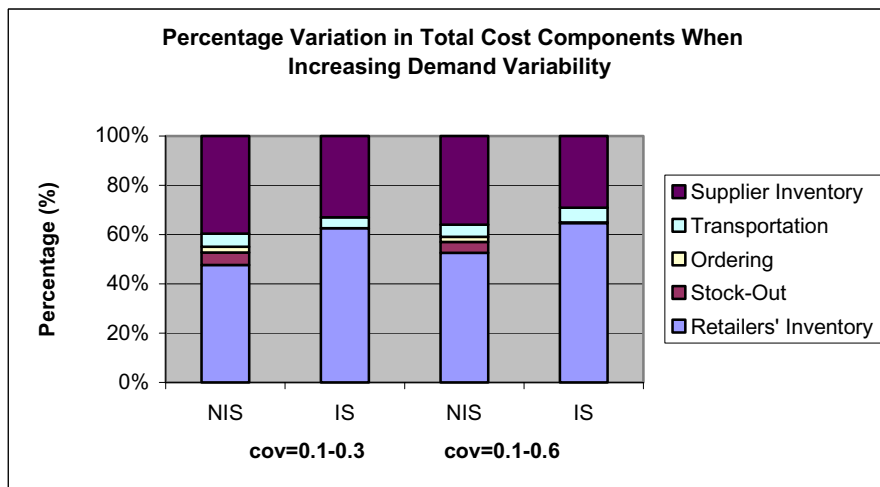

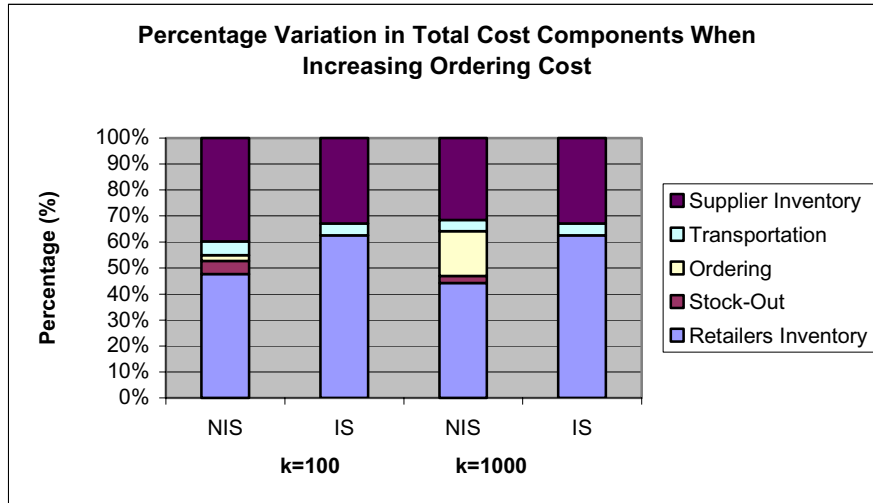Figure 4.4: Effect of demand variability on composition of total cost

Percentage Variation in Total Cost Components When Increasing Ordering Cost

Figure 4.5: Effect of ordering cost on composition of total cost

Analysis of Variation of Total Cost Components.   Although adopting a VMI strategy decreases the total cost across the supply chain, it is important to examine the benefit for each collaborating party. In this subsection, we analyze the three major components of the total cost: 1) retailers' inventory cost, 2) supplier's inventory cost, and 3) transportation cost.

Figure 4.6 presents the variation in the retailers' inventory cost when applying a VMI strategy compared to the NIS scenario. Increase in this cost is observed across all instances. The percentage increase varied between 15.66% and 29.24%. This rise in cost is caused by a higher shipping frequency that the supplier adopts in order to reduce its own inventory cost, and eliminate stock-outs at retailers' sites. Moreover, this increase in the retailers' inventory cost is justified by the assumption made in the IS scenario where the maximum inventory level at retailer i is taken to be equal to s_i *(computed using L_i)*, thus keeping the inventory level high. In order to reduce this jump in cost, the supplier could assume a lower upper limit (for example using a 2-day lead time), thus decreasing the inventory cost at the retailers. However, this strategy is likely to increase the probability of stock-outs at its customers, thereby increasing its cost. A decision should be taken according to the associated value of the product being shipped, and to the variation in stock-out and inventory costs. Moreover, it is important to note that the lowest increase in retailers' inventory cost is noted for retailers with high ordering charge. By adopting new technologies, these retailers can reduce these costs and speed up their processes while achieving higher accuracy levels. Finally, although this rise in cost is a disadvantage for retailers, it is compensated by the elimination of the ordering and stock-out costs. Another advantage of adopting a VMI strategy is that retailers can decrease their resources dedicated to manage inventories, and thus further reduce their operating costs.
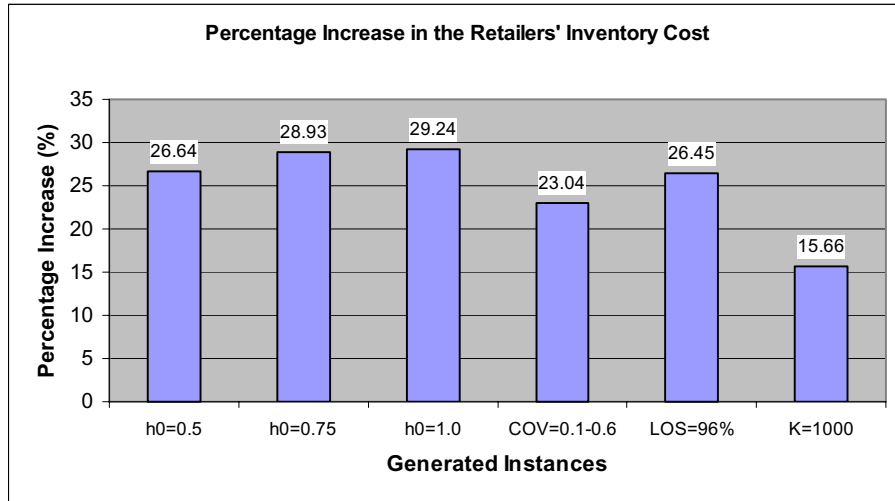
Figure 4.6: Percentage increase in retailers' inventory holding cost when shifting from a no information sharing to an information sharing setting; $h_0 = 0.75$ corresponds to the base case

The supplier's decrease in inventory holding cost varied between 14.65% and 19.41% (Figure 4.7). Information sharing, where the supplier directly accesses the retailers' customers demand and plans its replenishment policy accordingly, primarily drives this decrease in cost. The information sharing process decreases the variability of the demand observed by the supplier (discussed in the following section), thus lowering its safety stock levels. Moreover, the higher shipping frequency to retailers' sites decreases the amount of inventory available at the supplier and thus decreases its holding cost. However, this reduction in cost is diminished by stock-outs and transportation costs for which it becomes responsible. Finally, another aspect that must be examined by the supplier is the technology costs that it should invest to be able to track the retailers' inventory levels; however, these costs are decreasing and are likely to be overshadowed over the long run by VMI benefits.
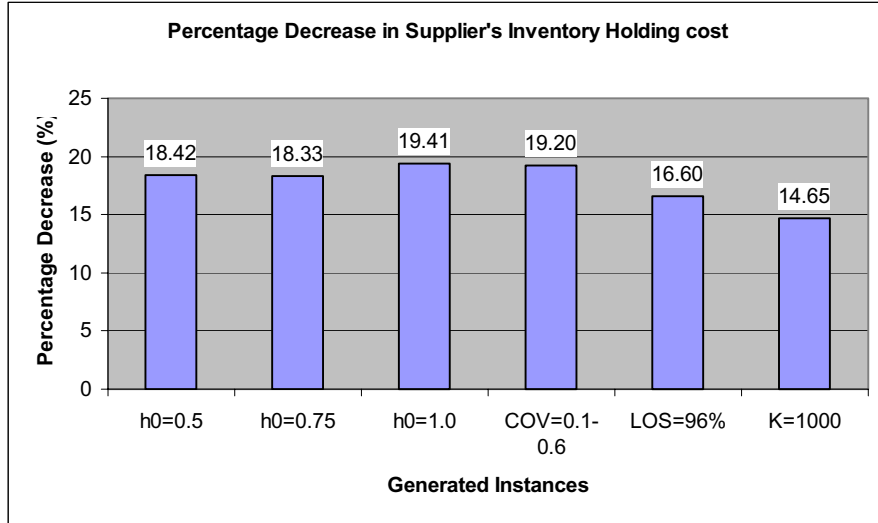
Figure 4.7: Percentage variation in the supplier's inventory holding cost when applying a VMI strategy; h_0 = 0.75 corresponds to the base case

Finally, analyzing the change in the transportation cost, we notice that it has been reduced in all instances other then the one with high demand variability, under which it increased by 20.33% (Figure 4.8). The percentage decrease varied between 13.04% and 17.44% on all tested instances.
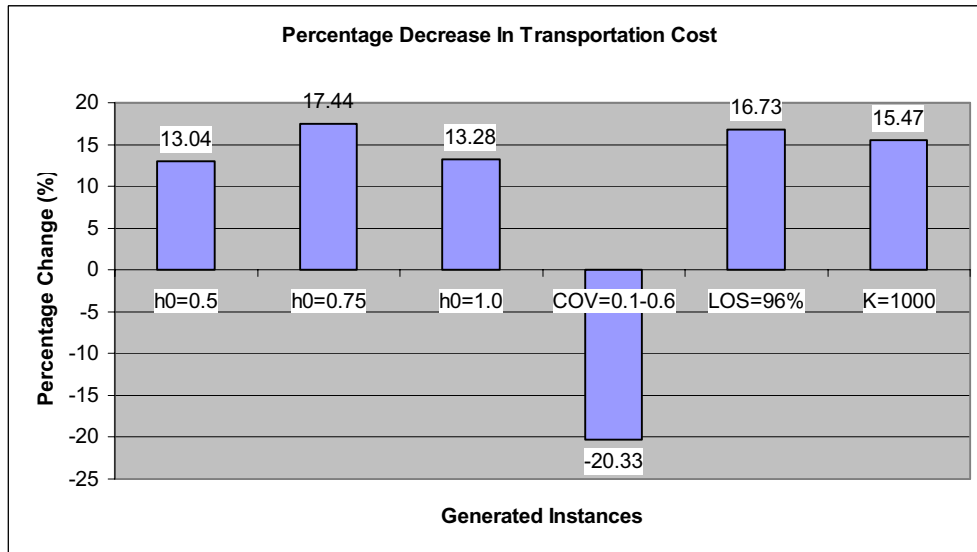
Figure 4.8: Percentage change in the transportation cost when shifting from no information sharing to information sharing scenario; h_0 = 0.75 corresponds to the base case

However, when applying a VMI strategy, the number of visits made by the supplier to retailers along the time horizon of interest at least doubled compared to the NIS setting (Table 4.4). The percentage increase in the number of visits fluctuated between 121.55% and 225.55% corresponding to

the instances with lowest inventory cost at the supplier ($h_0=0.5$) and high demand variability (COV=0.1-0.6) respectively. In the first case, since the supplier is minimizing the total cost in the VMI setting, the increase in the supplier's shipment frequency is the lowest among other cases, because it has a lower inventory cost than the retailers. On the other hand (as mentioned before), when the demand variability is high, stock-outs that induce urgent deliveries occur at a higher frequency. This requires the supplier to deviate from its initial schedule, thereby experiencing the highest percentage increase in the number of visits. Finally, although the number of visits more than doubled in the five other experiments, the transportation cost decreased, reflecting the advantage of a VMI strategy where the supplier bundles its customers into efficient routes, which lowers its transportation cost.

Table 4.4: INCREASE IN THE NUMBER OF VISITS MADE TO THE RETAILERS WHEN ADOPTING A VMI STRATEGY; $H_0 = 0.75$ CORRESPONDS TO THE BASE CASE

Generated Instance	$h_0=0.50$	$h_0=0.75$	$h_0=1.00$	COV=0.1-0.6	LOS=96%	K=1000
Number of Visits Using NIS	207	207	207	200	206	185
Number of Visits Using IS	459	475	506	650	459	459
Percentage Change	121.55	129.47	144.35	225.55	123.03	147.36

Decrease in Demand Variability

As discussed earlier, the bullwhip effect, or the increase in demand variability as one moves up the supply chain, decreases when the supplier, who becomes able to monitor the customers' demand directly, collaborates with the retailers. This reduction helps the supplier enhance its replenishment strategy, avoid inventory stockpiling, and improve customer level of service. Table 4.5 presents the increase in standard deviation of the demand observed by the supplier compared to the one observed by retailers when no information is shared between these two parties.

TABLE 4.5: INCREASE IN THE DEMAND'S STANDARD DEVIATION EXPERIENCED BY THE SUPPLIER WHEN OPERATING IN A NIS SETTING; $H_0 = 0.75$ CORRESPONDS TO THE BASE CASE

Generated Instance	$h_0=0.75$	COV=0.1-0.6	LOS=96%	K=1000
Standard Deviation of Demand Observed by Retailers	984.63	1577.34	996	984.63
Standard Deviation of Demand Observed by Supplier	1899.85	2061.79	1990.5	1873.11
Percentage Change	92.95	30.71	99.85	90.24

As expected, the lowest increase in the standard deviation occurred in the case with high demand variance (COV=0.1-0.6). For the remaining instances, the standard deviation increased between approximately 90% and 100%. This increase requires the supplier to keep a higher safety stock level, which increases its inventory cost. When the supplier shifts to a collaborative environment with the retailers, it eliminates this upsurge in the standard deviation, thus reducing its inventory holding cost.

Moreover, if the supplier has direct relations with the manufacturer, observing customers' demand could help them improve their production schedules, since they can eliminate the bullwhip effect. This helps the collaborating parties achieve a production plan that better matches supply and demand, which eliminates unnecessary inventory at the retailers' sites.

CONCLUSION

In this chapter, an analysis of the cost reductions achievable when applying a VMI strategy in a two-echelon supply chain composed of one supplier and multiple retailers has been presented. To answer the questions of interest, two models were proposed where the first one represents no information sharing scenario and the second one models an information sharing setting. Results, based on randomly generated instances, showed that reductions in total cost are achievable; however, changes in the cost components are not proportional for all collaborating parties. Retailers' inventory cost increased in all the generated instances. The main advantages for retailers was identified as the elimination of their ordering costs, stock-out costs, and decrease in their resources for inventory management. Moreover, the shift to a VMI setting increased the customers' level of service, which is likely to increase retailers' revenues. On the other hand, the supplier benefited by reducing the variability of the demand that it observes, thus achieving a lower inventory holding cost. Furthermore, the supplier was able to bundle customers' demand in order to achieve lower transportation costs in most cases. These gains were slightly offset by stock-out costs for which the supplier becomes responsible.

Finally, it is important to note that the increase in the retailers' inventory holding cost might be caused by the policy adopted by the supplier under a VMI setting. In the studied policy, it is assumed that whenever a retailer is visited, it is replenished to its maximum level (computed based on the starting lead time, 5 days in our case). However, since the supplier has direct information about the retailers' customer demand, a policy where the maximum replenishment level is calculated based on a reduced lead-time is thought to decrease retailers' inventory cost, but increase transportation and stock-out costs. A sensitivity analysis studying the effect of different policies adopted by the supplier on the total cost components represent future research directions. Moreover, in the studied problem, it is assumed that the supplier follows the delivery schedule developed at the start of the planning horizon. Adopting a rolling time horizon where the supplier updates its policy according to daily demands observed at the retailers' sites could be developed in future work. These policies are thought to better portray real life operations, and improve on the obtained solutions.

CHAPTER 5: SUMMARY OF RESULTS AND CONCLUSION

This research analyzes the impacts of Information and Communication Technologies (ICT) on logistics and supply chain operations. In Chapter 2, an overview of Internet growth, focusing on Internet users, usage statistics, gender characteristics, business-to-customer (B2C) and business-to-business (B2B) commerce, is presented. Chapter 3 discusses how new ICT and the Internet are reshaping the traditional supply chain and transforming it into a virtually connected one. A framework illustrating this change is presented with emphasis on the Internet channels that are affecting the transportation sector and logistics operations. New relations among supply chain parties and the emergence of new logistics operations are analyzed, focusing on Vendor Managed Inventory (VMI) strategies. Chapter 4 quantifies cost reductions achievable through information sharing among multiple retailers and a supplier that manages a VMI strategy, compared to a no information-sharing scenario. Two simulation experiments are performed to quantify changes in inventory, transportation, stock-out and ordering costs at the retailers and supplier.

SUMMARY OF RESULTS

Before analyzing the growth of the Internet sector, Internet traffic measurement techniques adopted by various companies were investigated. The overview showed that companies adopt different methodologies to keep track of the increase in the activity of several sectors, and thus report different results. The methodologies could be grouped into on-site and off-site techniques; the advantages and disadvantages of each are contrasted in Chapter 2. Results relating to the Internet population showed that the U.S. has the highest percentage among worldwide users; however, its rate of growth has been falling behind other countries such as China. The growth rate of Internet users in the U.S. is expected to level off in upcoming years, while it continues to rise in foreign countries, where the present penetration rate is much lower than in the U.S. The growth of Internet users has directly impacted the B2C and B2B commerce sectors. The B2C sector reached $44.9 billion in transactions in 2000, beating estimates made at the end of the year 1999. The main development in the B2C sector during the last two years was the move of traditional retailers towards the online market. These retailers seized market share from e-tailers, many of who were forced to shut down due to lack of funding, a slowing economy, and unsustainable business models. The value transacted in the B2B sector during the year 2000 was approximately ten times larger than the B2C sector, and reached $433 billion. The growth of the B2B sector is expected to be larger than that of B2C in upcoming years, reaching around $8.5 trillion in 2005 by some estimates. A growing industry in the B2B sector is online marketplaces. However, due to a slowdown in the economy at the end of 2000, business through B2B marketplaces represented only a small fraction of total B2B activity, and many closed their operations. The main effect of these marketplaces is in improving efficiency of operations and decreasing reaction time to market changes; their effect is forecast to grow starting in 2003.

Chapter 3 presented an analysis of the impacts of ICT and the Internet on logistics and distribution activities. First, the adoption of ICT has been on the rise due to the decrease in technology prices, with the Internet providing a relatively inexpensive platform for information sharing, thus enhancing the competitiveness of small companies. Advances in and adoption of new technologies has transformed logistics operations into supply chain management, which consists of demand forecasting, supply planning, and fulfillment strategies. An effect of ICT and the Internet in the 1990's on logistics operations is the expansion of Just-In-Time (JIT) strategies to more complicated and efficient policies including Vendor Managed Inventory (VMI), Merge-In-Transit (MIT), Time Definite Deliveries (TDD), and Freeze Point Delay (FPD). These strategies have been enabled by the development of advanced Decision Support Systems (DSS) that allow companies to optimize their supply chain operations. Another major impact of the Internet on logistics operations is the transformation of the traditional supply chain into a virtually forged one. The Internet sectors that are affecting transportation and logistics operations are grouped into five categories: 1) electronic retailers, 2) services and catalogs, 3) exchanges, 4) procurement and collaboration hubs, and 5) auctions. These sectors are increasing the operating efficiency of logistics companies, decreasing costs of information sharing, and promoting collaboration among firms. Types of coordination include buyer-vendor relations, production-distribution relations, and multi-level inventory coordination; however, most of these relational settings face obstacles. Moreover, the increase in information sharing and collaboration among companies has increased market competition, which is pushing companies to outsource some of their internal functions. Furthermore, it is noted that ICT are 1) improving the performance of management and control protocols, 2) increasing the efficiency of order entry systems, 3) affecting freight transportation, 4) boosting the home-end delivery sector, and 5) increasing the adoption of VMI strategy by firms. Finally, all these changes in logistics operations are pushing companies to adopt supply chain strategies based on a Pull System (goods' movement is driven by the final consumers' demand) instead of a Push System. Currently, corporations' ultimate goal is to achieve a convergence between goods' production schedules and consumers' demand so as to eliminate unnecessary material, while satisfying consumption.

In chapter 4, cost reductions achievable through information sharing in a two-echelon distribution system comprised of multiple retailers and one supplier are presented. This is achieved by modeling two scenarios. The first assumes no information sharing among the retailers and the supplier. The retailers adopt an optimal (s_i, S_i) policy according to fixed ordering and transportation costs charged by the supplier, and according to a fixed lead-time, whereas the supplier adopts a different (s_0, S_0) policy according to retailers' demands observed by the supplier. In the second scenario, retailers share information (VMI setting) with the supplier who becomes responsible for the replenishment strategy and for stock-outs. The analysis focuses on variations in inventory, transportation, ordering and stock-out costs at the supplier and retailers. Results from sixty randomly generated instances are summarized into the following effects of information sharing under VMI:

- Substantial decrease in the inventory holding cost at the supplier site because it has daily information of the retailers' customers demand, and orders its supplies accordingly.
- Elimination of stock-out costs at the retailers in almost all cases.

- Increase in inventory holding cost at the retailers because of higher shipping frequency applied by the supplier. This increase is associated with the replenishment policy at the retailer (fill to maximum). Alternate policies present future research directions, and are likely to decrease inventory costs at the retailers, however they might induce an increase in stock-out costs.

- Although the supplier makes more visits to the retailers under the VMI strategy, transportation cost decreased in all cases except one. These cost savings result from the supplier's ability to bundle the retailers' demands into more efficient routes, and thus compensate for the increased frequency. The single instance where transportation costs increased was under a scenario of high demand variability where the supplier was forced to send urgent deliveries to the retailers (caused by stock-outs), hence deviating from its efficient routing policy.

- Information sharing reduces the bullwhip effect, which is the increase in demand variability as one moves up the supply chain. The main beneficiary of this decrease is the supplier who reduces its safety-stock levels accordingly. This decrease in demand variability is likely to become more significant as we extend our analysis to multi-echelon supply chains (future research direction).

In all the instances, total cost across the supply chain was reduced. The reduction varied between 0.1% and 18.26%, with an average of 4.31%. These reductions are likely to increase with alternate policies such as the adoption of a rolling horizon by the supplier, and the decrease in the maximum level at the retailers, ideas that represent future research directions of interest to the author.

FUTURE RESEARCH

Future research directions include a standardization of the traffic measurement techniques by researchers and companies in order to eliminate differences among reported results. Other research directions that are pertinent to the logistics industry include the analysis of different strategies for home-end deliveries and reverse logistics, two sectors that have been increasing at a fast pace accompanying the growth of the B2C sector. Furthermore, an expansion of the problem described in chapter 4 is to be developed. This includes a sensitivity of the increase in stock-out costs with respect to a decrease in the maximum inventory level at retailers applied in the information sharing case. Finally, an expansion of the supply chain to a three-echelon distribution channel is another topic of interest.

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