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A COMPREHENSIVE FRAMEWORK FOR LOGISTICS & SUPPLY CHAIN MANAGEMENT OF LUBRICANTS

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Abstract

Logistics and Supply Chain Management (SCM) have experienced dramatic changes during the last ten years within a very competitive environment with continuously shorter life cycles and an increasing number and variety of SKUs (stock keeping units). The decision-making models used most often by industry and preached by academia have been proven inadequate to most of the manufacturing environments that we studied. In this paper, we first provide definitions and then summarize the unique challenges of supply chain management for chemical products and especially lubricants, present current realities and review past efforts. We demonstrate why the traditional inventory and distribution management paradigms used in the past are inadequate for addressing the new realities, by examining their basic assumptions. We further document the strategic role of variability in such environments. Subsequently, we present best practices and discuss the enhanced role of information flow and information technology. Finally, we outline the need for a new supply chain framework by identifying the unique challenges and opportunities that exist for both academia and industry.

Keywords: *Supply Chain Management, Lubricants, Logistics, EDI, XML, Supply Chain Collaboration*

1. INTRODUCTION

The dramatic changes of the last decade have outlined the need of comprehensive and sophisticated supply chain and inventory management tailored to the needs of industry. Manufacturers/producers began recognizing that their manufacturing and distribution policies were inefficient, exhibiting long cycle times, large lot sizes, low yield and long and very unpredictable lead times. Further, the length of time between placing an order and its due date (the order lead time) has been decreasing dramatically. Customers often expect same day service and even when they are willing to wait they expect to be quoted with accurate delivery lead times. In addition, the variety of products and part numbers that are requested has increased, while at the same time the life cycle of the products has shortened. These trends have placed enormous pressure on supply chains; companies that cannot meet these challenges will face tremendous difficulties within the confines of the new economy. The growth of e-commerce has further added to the increased demands of customers, the increased number of SKUs (stock keeping units), and at the same underscored the urgent need for a system-wide supply chain optimization. The decision-making processes and software tools used most often by industry and the methodological models and paradigms covered by academia have been proven incapable of addressing satisfactorily many practical real world environments.

There are many efforts in defining supply chain management (SCM) and logistics.It appears that each organization and practitioner cater definitions according to their needs. Most of these definitions are not concise, and rather cumbersome. We provide below our own definitions stemming with our more than fifteen year interaction with a large number of Fortune 500 companies and a large number of SMEs. Thus, supply chain management is an extended enterprise that integrates and co-manages all common flows, processes & resources of its trading partners and others to maximize stakeholder value for all. Further, we define logistics as the discipline that deals with the management of inventories (i) in motion, (ii) in process, and (iii) in wait.

Any comprehensive framework for SCM should take into account all four flows that materialize within a supply chain, namely: (i) information, (ii) product, (iii) process, and (iv) cash flows.

Within this environment, the necessity of managing inventories efficiently is critical. However, despite the dramatic changes that have occurred in manufacturing, warehousing and distribution the basic approaches practiced by industry and taught in academia today appear to have serious flaws. The classical paradigm of academic research and corresponding teaching has been misguided.

In this paper, we begin by summarizing the unique challenges of supply chain management first for manufacturers and then specifically for the petroleum industry and the production of lubricants, present current realities and review past efforts; we draw parallelisms between manufacturing and retailing throughout the manuscript. We then demonstrate why the classical inventory and distribution management paradigms used in the past are inadequate for addressing the new realities, by examining their basic assumptions. We further document the strategic role of variability in such environments; we present best practices and discuss the enhanced role of information flow and information technology. We also present briefly some of the core issues that we have been facing during our involvement with an international U.S. based apparel designer and marketer. Finally, we outline the need for a new supply chain framework by identifying the unique challenges and opportunities that exist for both academia and industry, while further discussing future trends.

2. INVENTORY AND SUPPLY CHAIN MANAGEMENT: BACKGROUND

The first mathematically based methods for controlling inventories developed at the beginning of the century focused on the tradeoff between fixed order cost and inventory carrying costs. These efforts led to the development of the well-known economic order quantity (EOQ) model that remains quite prevalent in industry today as the basis for many production planning and inventory control decision support systems. The next wave of research efforts began in the 1950s and modeled stochasticity in the demand process. Fundamental contributions on this arena include: (i) proof of optimality of (s,S) policies (Dvoretzky et al., 1953), (ii) formulation of the basic properties of multi-echelon systems (Bessler and Veinottt, 1966, Clark and Scarf 1960), (iii) development of multiple items models with resource constraints (Hadley and Whitin, 1963) and (iv) development and implementation of multi-item, multi-echelon models (Muckstadt 1973, Cohen et al., 1986, 1988, 1989, and specifically for repairable items Sherbrooke, 1968).

In addition, the manufacturing industry adopted materials requirements planning (MRP) as an integrated framework for purchasing, production and inventory control. Advances in information technology further facilitated the implementation of such models. U.S. manufacturing firms have shown a rapidly growing interest in commercial enterprise resource planning (ERP) products (such as e.g., SAP and Oracle) that are IT-based synchronized MRP “push” systems. This trend started in the early 1990s as companies looked to coordinate and standardize data transactions pertaining to planning, inventory, information and cash flow. However, in spite the surge of ERP products the reports on their performance are mixed so far. Leading supply chain software vendors like i2 Technologies, Manguistics, Chesapeake (acquired recently by Aspen Technologies), and Red Pepper (acquired by PeopleSoft) have made available products that integrate optimization modeling, heuristics (often very simplistic ones), computer and networking hardware, and database design. Specifecally, in the manufacturing sector, since the late 1970s, there has been a focus in implementing just-in-time manufacturing concepts for improving efficiency. KANBAN systems (and their more sophisticated hybrids) are information management systems that can be used for inventory replenishment and their usage has generally led to improved responsiveness, reduced cycle times, and reduced waste.

At the core of managing a DC that operates within a lean retailing environment is the warehouse management system (WMS); WMS is responsible for handling the enormous data processing needs associated with the thousand transactions occurring daily for incoming and outgoing systems. A WMS system can have a positive impact only if interfaces seamlessly with the corporate ERP systems and at the same time have the ability to interact with apparel manufacturers concerning incoming orders and retailers concerning outgoing shipments via EDI. It is our experience that when management employs WMS in isolation of the other components then results are quite inefficient. The vast majority of the WMS systems that we have encountered, contrary to their efforts in proving the opposite, they lack any intelligence (they are simply glorified databases) and at the same time any understanding of how they can affect inventory replenishment policies and in general how they fit in the entire supply chain puzzle by updating, reconciling and disseminating information. Further, management often lacks any knowledge of the shortcomings of the WMS in place and still depends on its interaction with the ERP system, which as we outlined earlier most of the times cannot capture effectively system variability.

While such improvements have resulted in better management of inventories, still the science of inventory management remains incapable of addressing satisfactorily many practical real world environments. Too much inventory exists wasting billions of dollars in investments and holding costs annually. Demand goes often unsatisfied for long periods of time for critical components because of the unavailability of the proper amount of inventory.

Many dramatic changes have occurred in the last decade that exacerbated the need of even more sophisticated and responsive to the needs of the industry inventory management. As customers started demanding better quality and service, manufacturers began recognizing that their manufacturing and distribution policies were inefficient, exhibiting long cycle times, large lot sizes, low yield, lengthy and very unpredictable lead times. Further, the length of time between placing an order and its due date has been decreasing dramatically. Customers often expect same day service and even when they are willing or they have to wait they expect to be quoted with accurate delivery lead times. In addition, the variety of products and part numbers that are requested has increased while at the same time the life cycle of the products has shortened. These last two trends have placed enormous pressure on supply chains; companies that cannot meet these challenges will face tremendous difficulties within the confines of the new economy. Indicatively, Singhal and Hendricks (ORMS Today, 2001) after searching for articles in the Wall Street Journal and Dow Jones News Service from 1989 to 1998 for news of supply chain problems, report that when a company announces supply chain malfunctions (such as part shortages, changes requested by customers, new product ramp/rollouts, production, development and quality problems) its stock priced tumbles nearly 9 percent and losses can be as great as 20 percent over six months (leading to an average reduction of shareholder wealth by $120 million or more per company).

Such market demand trends have changed forever the way that retailers and their manufacturers/suppliers manage their supply chains. Using standard performance measures such as inventory turns, it is evident that the way retailers manage their inventories lags behind other sectors, such as manufacturing. However, it is also true that retailers have to face unique challenges and complexities. For example, retailers have to maintain stock at many geographically dispersed areas and further they need to manage a very large number (often in the order of several hundred thousand) of SKUs (stock keeping units). Until recently, demand rates at the store level were reported only in aggregate form with significant delays and inaccuracies.

3. SUPPLY CHAIN MANAGEMENT FOR THE PETROLEUM INDUSTRY

The petroleum industry provides a wide spectrum of products among others, lubricants for engines, fuel for transportation, fertilizers, medicines, plastics, construction materials and clothing. The petroleum supply chain appears to follow the classical paradigm of “plan, source, make, move, and sell”. However, the petroleum supply chain is far more complex than the classical discrete part manufacturing supply chains. This complexity stems from incredibly complex manufacturing processes juxtaposed with highly interdependent operations.

Each of these operations has developed into prototype silos, that are separate business units, each with its own distinct objectives. Such silos include exploration and production, manufacturing, engineering and wholesale and retailing. We have often seen business units operating completely independent from each other myopically pursuing their own profitability at the expense of the overall success and profitability of the entire supply chain.

Especially the wholesale/retail silo poses displays unique characteristics that in their turn impose special demands on the relevant inventory management systems. As such, at any time, million of gallons of fuel products from a refinery may be in transit between the refinery and the terminals. This pipeline inventory can be transported by a variety of modes including trucks, pipelines and/or barges. Often, terminals can have warehouse facilities for storing packaged goods like lubricants and waxes. For effective decision-making, management should have full visibility of the inventory positions throughout their organization and the status of all shipments in real-time. They should further understand how the inventories and shipments should change to meet the projected demand.

4. THE NEED FOR COLLABORATIVE SUPPLY CHAINS

Many dramatic changes have occurred in the last decade that exacerbated the need for even more sophisticated and responsive approaches to supply chain and inventory management. As customers started demanding better quality and service, manufacturers began recognizing that their manufacturing and distribution policies were inefficient, exhibiting long cycle times, large lot sizes, low yield, lengthy and very unpredictable lead times. Further, the length of time between placing an order and its due date has been decreasing dramatically. Customers often expect same day service and even when they are willing or they have to wait they expect to be quoted with accurate delivery lead times. In addition, the variety of products and part numbers that are requested has increased while at the same time the life cycle of the products has shortened (for example, in the semiconductor industry governed by Moore's Law the capacity of semiconductors doubles now every twelve months).

4.1 The Strategic Role of Variability

Given all these improvements in both manufacturing and retailing why is it that we cannot provide consistently 100% on time delivery? There are many reasons why the service levels are poor but a prime reason has to do with the fact that variability of the demand over the reduced lead times is often too great and at the same time it cannot be estimated easily. Even more so the demand variability increases as one moves upstream in the supply chain leading to the bullwhip effect. Chen et al. (1999) present a synthesis of the factors that can cause bullwhip. We provide below a list of the major sources of variability and further comment on each of them based on our experience with both manufacturing and retailing:

The first such factor is demand forecasting; at the end of each period, the retailer observes the more recent demand, updates accordingly his/her demand forecast and then uses the updated forecast to update the target inventory level (assuming that a simple order-up-to inventory policy is followed). Exactly this practice of updating the forecast and the order-up-to point in each period results in increased variability in the orders placed by the retailer.

Lead times can magnify the increase in variability due to demand forecasting. For example, a formula that is commonly employed to calculate the order-up-to level in a period is: order-up-to level= expected lead time demand + a safety stock factor * the standard deviation of the lead time demand. Any changes in our estimates of the parameters of the demand process will be magnified by the lead time. Furthermore, the safety stock quantity in the above formula depends on knowing the upper tail of the probability distribution of the lead time demand and its standard deviation. Academicians often assume the demand to be normally, exponentially, Poisson or negative binomially distributed, leading to the development of analytically tractable models. However, estimating the distribution parameter values is often quite challenging in today's manufacturing and distribution environments. Further, the classical assumptions of stationary and independent demand from day to day and part-to-part is quite myopic for many real world environments.

Batch ordering further contributes to the manufacturer seeing a distorted and highly variable pattern of orders; if the retailer uses batch ordering, then the manufacturer observes a quite large order followed by periods of no orders. As the value of components and parts continues to drop and the cost of capital remains low, batch sizes will continue to be large throughout various stages of the supply chain.

Supply shortages can further lead to inflated orders from the retailer to the manufacturer (in anticipation of an item going in short supply).

Price variations like promotions and clearance sales can cause distorted demand patterns and increased variability in demand. The every day low pricing strategy practiced by leading retailers (such as Procter and Gamble) is an attempt to lower this variation by smoothing customer demand and eliminating price incentives.

Another cause of variability is due to the fact that in a very competitive environment products are often in and out of favor quickly, leading to dramatic swings in demand. Such variable demand patterns force the production system to respond either by producing to meet the high requirement promptly or by satisfying demand from inventories of either finished goods or partially completed subassemblies. Further, manufacturers tend to utilize a number of distribution centers (DCs) so that they can respond faster to orders placed by regional customers. However, this policy too burdens the system with more variability since the demand experienced at each warehouse has higher variability than the one experienced by the overall system. Forecasting consequently, becomes much less accurate as the number of DCs increases leading to increased inventories and reduced service levels.

Given all these sources of variability the production how do the current most production and inventories paradigms used throughout the industry fair? Material requirement planning (MRP) systems require as input a large amount of data including, bill of materials (BOM), historical demand, lead times, target safety stocks, current orders, backlogged demands, and work in process (WIP). Given these data MRP establishes desired production and inventory levels. First, a master production schedule (MPS) for finished goods is generated and then thorough a BOM explosion and using the provided lead times production requirements are computed for raw materials, components, and subassemblies. However, these plans are produced under the assumption of infinite capacity. Further, lead times are rarely known in advance, deterministic, and independent from part to part. Actually, the lead times act as surrogates for capacity and are a function of the product mix (types and quantities) that is currently being produced, the availability of the required equipment, tooling, and personnel.

Both MRP and distribution requirements planning falsely presume that safety stocks and inventories can be planned and balanced among all locations within the distribution network, thus ignoring the dynamic nature of the system that is due to randomness stemming from lot sizing rules, lead times, forecasting techniques and other managerial policies. More specifically, safety stocks are usually calculated using single item single locations models leading to policies like (Q,r), (s,S), or an order-up-to R policy. Even though there exist models that account for stochastic lead times they are seldom used in practice; even these models though, do not capture the complexities of today’s supply chains as described earlier. As it is well known from classical queuing theory models, capacity utilization, customer service levels and inventory requirements are interdependent and cannot and should be treated in isolation from each other. Consequently, it is impossible for any real world dynamic capacity constrained environment to manage inventories using the standard MRP type models that we presented above; items cannot be managed independently, since they compete demanding capacity and often common components, they have different demand patterns with different predictability, and different lead time requirements.

4.2 Trends in Relationships among Supply Chain Partners

These facts have placed enormous pressure on complex global supply chains; companies that cannot meet these challenges will face tremendous difficulties within the confines of the new economy. Companies that will survive and prosper will have to provide tight integration among the extended partners of their supply chain. Such integration include: (i) information integration, (ii) business integration, and (iii) decision-making integration. Thus, the final goal for SC partners is to develop tightly coupled information infrastructures, tightly coupled business processes and tightly coupled decision support systems (Muckstadt et al., 2001).

When information is integrated SC partners share demand (point of sales data, POS) information, demand forecasting, inventory levels, capacity plans, promotional plans, and shipment schedules (Lee and Whang, 1998). Coordination refers to the allocation of decision-making rights to the most qualified partner of the SC. For example, a company might decide to give up replenishment decision-making to its supplier. This is the basis of the practice known as vendor managed inventory (VMI) and other similar coordination initiatives such as CRP (Continuous Replenishment Program). All these coordination schemes presume a sufficient support from appropriate IT practices and tools, such as the ones presented in the next section. Finally, collaboration is further extended in business and decision-making processes. In that form of a relationship, the SC partners jointly plan their decisions in strategic and tactical levels.

Benefits of this type of collaboration enhanced by IT (e-collaboration) include: improved customer service, improved cycle times, lower inventory levels, improved profits, and lower IT infrastructure and adoption costs. On the other side, there are few risk of implementation considerations, such as the reliance on electronic medium with no hard copy backup, that software packages may need to be tailored, and the adoption rate of suppliers.

5. INFORMATION SHARING PRACTICES

So how does business collaboration actually work? In order to fully understand the potential impact that modern e-business systems can have on collaboration practices, we will briefly describe their operational aspects, focusing particularly on the communication between supplier and customer. There are three different phases in the evolution of communication: (a) Traditional communication means such as phone, fax, etc. (b) EDI messages as the main communication means. (c) An e-business system based on the Internet.

5.1 Electronic Data Interchange (EDI)

The benefits of collaboration policies though become more apparent when the communication between buyer and supplier is automated through the use of Electronic Data Interchange (EDI), which has become the standard for business to business (B2B) communication. EDI is the electronic interchange of structured and normative data between computers of organizations that are involved in some transaction (Heck, 1993). It is the paperless exchange of standardized business transaction documents between two trading partners; most commonly through a VAN (Value Added Network). The application system of the one company provides an in-house file. The communication system converts the in-house file into an EDI message, which is then communicated through a network and reconverted to an in-house file of the receiving application system of the other company. EDI messages are not meant to be humanly readable. They are coded transmissions designed to be quickly and accurately read by computer programs. The format of the documents is agreed to at a national or international level (depending on the EDI standard being used). For instance, the American National Standards Institute (ANSI) publishes a format commonly used in the US. There are several hundreds of different types of documents that can be sent, with hundreds of different codes each describing a particular parameter of the policy. Due to the very specific nature of collaboration relationships it is critical that each of the fields contained within each transaction be clearly defined and understood by both customer and supplier.

Despite the drive to standardize, there remain considerable issues with EDI communications; the majority of these issues stems from EDI's rigidity. The smaller partner within the collaboration scheme has to comply with the demands of the most powerful one. At the same time most of the times a specific partner does not collaborate only with a unique SC partner. Furthermore, companies aiming in taking advantage of the Internet's full potential need to be able to receive information sent electronically from suppliers and/or customers, and then pass it on their own systems without changing the format. EDI attempts to realize this but without great success (for example, we have not seen EDI implementations that allow seamless transfer of data without format changes).

5.2 Web-Enabled Business Systems

Despite the recent “bubble burst” the internet has been changing communications for ever, since it offers unique and efficient capabilities; it is ubiquitous, it works around the clock, is scalable, digital, fast, interactive, multi-exchange, multi-media and economical. Its development has been changing dramatically SCM as we know it, towards e-SCM. Elite companies that excel in e-SCM such as Dell Computers, Wal-Mart, eBay, Procter & Gamble, and Amazon.com clearly demonstrate e-SCM’s potential.

Lately, web-based communication systems have become available by IT companies and are gradually becoming adopted in numerous industries. Nevertheless, it is worthwhile noting that such web systems are novel and cutting-edge technology and most of the companies that are indeed implementing them are doing so as pilot programs. However, although there are very few reported data on these experiences, it is becoming evident that these new systems will have significant impact on collaboration policies.

A key component of these web-enabled communication systems is XML. Since 1996, companies started using Extensible Markup Language or XML to describe web pages. Like Hypertext Markup Language (HTML), XML is an open standard. XML describes the content of a web page in terms of the type of data that it contains, instead of the way the data should look and thus it dramatically facilitates sharing of information among partners. XML can be extended. Contrary to HTML, which has a limited array of tags for marking a document, XML users and developers can develop their own tags, as long as they document their explanation in a standard manner and attach this information to the document.

In order to better understand how web-enabled systems operate we briefly discuss a couple of cases that are running such systems. For example, BASF Corp. due to the severe inefficiencies in their VMI program, as described above, deployed a VMI application based on XML on a B2B integration platform. They created a web site that allows customers secure access to an inventory screen where they can communicate both on-hand balances and forecast information with the company. From this information, the system automatically generates a usage order for the company and a replenishment order based upon the on-hand and forecast data.

Similar practices – even though perhaps not so simple - can be found in other industries. In most cases suppliers and their key customers have realized significant reductions in inventory, increased inventory turns and decreased administrative costs associated with inventory replenishment. Naturally, there is still a degree of manual re-entry of data at some point in the process, yet the true extent of the benefits of web will not be fully realized until the customer’s data come directly over the web from one partner’s ERP system directly into the other partner’s system.

6. LESSONS FROM INDUSTRY, CHALLENGES AND FUTURE TRENDS

So will web-based applications provide just an incremental improvement on the benefits that EDI messages have brought about? Will there be anything so different that these web-systems will bring to further enhance the value of collaboration policies?

It is still very early to tell since there is very little experience reported from the companies that are actually implementing or even piloting web policies. Even in terms of the actual benefits that EDI adoption brought, there are few unequivocal research results (see e.g. Banerjee and Banerjee 1992, Anvari 1992, Ernst and Kamrad 1997, Heck 1993). Nevertheless what seems to be clear is that EDI can dramatically reduce the cost of processing documents like purchase orders and invoices. This is because the information can be moved directly from a database or ERP system to the trading partner (and vice versa) thus saving a lot of manual processing of the documents. Hundreds or even thousands of documents can be processed within a few minutes. Therefore EDI has an impact on the administrative costs associated with ordering and replenishment and hence the total inventory cost.

A preliminary analysis of the available literature seems to highlight a few features of web systems that might hold interesting implications for collaboration policies. These capabilities do not necessary imply that these web systems will definitely have these impacts, since their impact is case dependent. For example, trying to get suppliers of lower quality to perform better by making them responsible for a customer's inventory and by implementing a web system will certainly lead to failure. Also, attempting to improve a customer's inventory management by implementing collaboration policies through the web will certainly not help if the problem stems from poor MRP and/or production scheduling. In other words, collaboration is by no means a panacea for every SCM problem and furthermore a web-based system will not always be preferable to one based on EDI or even a manual communication. Each case has to be examined on its own merit.

We have witnessed the challenge phased by a major chemicals company that received a request from one of its largest customer to exchange XML documents for a critical business process within a period of few months. The vendor had to send to the customer electronic certificates of analysis for each canister that hey were shipping. Certificates of analysis are documents that used to demonstrate that a product has been manufactured in compliance with specs. Canisters are used to house and deliver hazardous industrial gases. The vendor had to rethink completely its existing EDI strategy. It became evident that the vendor could not respond to the client's demand using EDI since it s standards are very rigid. For example, one cannot add a new data element. Using EDI would have required the vendor to work through all of the data elements in the document. Instead, with XML the partners could agree on the data that they would be exchanging. As a result, the vendor's Web development team used the Microsoft Biztalk Server 2000 and Visual Basic to create a front end to their ERP to ERP solution. The total implementation took less than 2 months and to date the two partners have exchanged more than a dozen thousand documents via the Biztalk Server link including purchase orders, certificates of analysis and invoices. Finally, the venfor now encourages all its trading partners (suppliers, buyers) to exchange electronic documents employing this XML type solution.

7. SUMMARY AND CONCLUSIONS

As supply chain management transcends a plethora of classical academic disciplines, it if of no surprise that academia has been slow to react to the radical changes of the market in general, and of the supply chains in particular. Often, industry has surpassed academia in tackling efficiently the right issues in supply chain management; however, other times vendors have done a disservice to the community by not acknowledging and by not educating corporate users about the limitations of their developed products.

Current business and academic strategic and tactical paradigms are not well suited to handling the levels of uncertainty and risk that are present in today's supply chains. The need for a holistic, interdisciplinary approach beyond the traditional silos of supply chain players is now more evident than ever. Linked information systems, joint business processes and decision systems are necessary to further foster collaboration among SC partners. Information technology and especially web-enabled business systems hold significant potential for supply chain collaboration that further needs to be studied under the paradigm of maximizing total supply chain profitability..

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