MANAGING HEALTH CARE SUPPLY CHAIN: TRENDS, ISSUES, AND SOLUTIONS FROM A LOGISTICS PERSPECTIVE

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Abstract

The U.S. healthcare industry is a large enterprise accounting for over 14.1% of the national economic output in 2001. It has been under pressure for cost containment and providing quality health care services to consumers. Its record of investing heavily on development of sophisticated drugs and diagnostic systems does not match that of technologies to manage its day-to-day operations. In order to achieve improved performance, healthcare supply chain must be efficient and integrated. The driver for this integration is logistics and supply chain management. This paper describes trends, issues and some solutions for logistics management for Health Care Supply Chain with concepts drawn from Industrial Engineering, and Operations Research disciplines applied to specific domains. A healthcare supply chain template utilizing E-commerce strategy is presented. Use of simulation, optimization, and information sharing techniques are demonstrated to optimize purchasing and inventory policies.

(Keywords: Health Care Supply Chain, Health Care Logistics, e-Health Care)

1. Introduction

The US healthcare industry accounted for 14.1% of the U.S. economic output in 2001 (URL: http://www.cdc.gov/nchs/data/hus/tables/2003/03hus112.pdf). Various studies of this industry point to lack or failure of basic quality-control procedures, and misalignment among consumer needs, payers and provider services, as primary causes for building waste into industry management practices.

Pressures on the industry have fostered innovation in the design of services and organizations. Most of the innovations have targeted cost reductions in key functions, including logistics. The industry must find a flexible delivery enterprise that has substantial capital and is capable of efficient operations. This means effective management of a broad range of processes with diverse measures, from medical outcomes to cost of tissue paper. Healthcare sector of US economy faces several challenges, such as cost containment, outdated information management systems, and mergers and/or acquisitions.

The need to cut costs and compete has led to mergers and acquisitions in healthcare industry. Such consolidations have created new organizations made up of very different entities which are not as integrated as they should be. Due to competition, it has become imperative that enterprises seamlessly and efficiently provide and manage services (including purchase and delivery of supplies to the final user) across entities and continuum of care, both now and in the future.

The principal participants in the US healthcare supply chain include: manufacturers (drugs, medical equipment, and hospital medical supplies), distributors, medical service providers, medical groups, insurance companies, government agencies (such as, Health and Human Services), employers, government regulators, and users of healthcare services.

This paper describes trends, issues and some solutions for logistics management in Health Care Supply Chain with concepts drawn from Industrial Engineering (IE), and Operations Research (OR) disciplines applied to specific domains. A healthcare supply chain model utilizing E-commerce strategy is presented. Use of simulation, optimization, and information sharing techniques are demonstrated to optimize purchasing and inventory policies.

The rest of the paper is organized as follows. Section 2 lays the foundation of supply chain as a business strategy, describing concepts, key issues and approaches to problem solving in supply chain management. Section 3 makes the case for a Health Care supply chain emphasizing the need for it, strategic drivers, key issues and opportunities that exist for it to be a viable alternative for businesses. An E-Health Care supply chain model is presented in Section 4. The rationale behind this model and its various
components is described. Section 5 presents a methodology for applying IE and OR techniques to potential Health Care supply chain problems using the proposed model. The paper concludes with suggestions of possible problem areas where the proposed framework can be suitably applied as a future task, described in Section 6.

2. Supply Chain Management: Concepts, Key Issues, and Approaches to Problem –Solving

Supply chain has been defined as a system of suppliers, manufacturers, distributors, retailers, and customers where material typically flows downstream from suppliers to customers (except for reverse logistics) and information flow in both directions. Supply chain management involves managing a connected series of activities, which is concerned with planning, coordinating, and controlling movement of material, parts, and finished goods from supplier to customer. For this to occur, material, financial, and information flows are managed as decisions are made at strategic, tactical, and operational levels throughout the supply chain. Supply Chain Management issues span a large spectrum of a firm’s activities, at these levels (Simchi-Levi et al., 2003). Table 1 summarizes decisions made at these levels.

<table>
<thead>
<tr>
<th>Decision-Making Level</th>
<th>Timeline</th>
<th>Type of Decision Made</th>
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<tbody>
<tr>
<td>Strategic</td>
<td>5 to 10 years</td>
<td>Investment on plants and capacities. Introduction of new products. Creation of a logistics network.</td>
</tr>
<tr>
<td>Tactical</td>
<td>3 months to 2 years</td>
<td>Inventory policies to use. Procurement policies to be implemented. Transportation strategies to be adopted.</td>
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The above decisions are made in order to address some of the following common issues facing the supply chain management activity:

Distribution Network Configuration. This issue deals with selection of warehouse locations and capacities, determining production level for each product at each plant, and finalizing transportation flows between plants and warehouses so as to maximize production, transportation and inventory costs. It is a complex optimization problem dealing with network flows and capacity utilizations. This issue relates to healthcare related manufacturers and suppliers in a healthcare supply chain.

Inventory Control. This issue deals with stocking levels at various levels in the supply chain. Demands from level-to-level are considered in making this decision. This is a decision problem, solution to which involves using forecasting, inventory management, and simulation and optimization algorithms. Healthcare providers, suppliers as well as manufacturers deal with this issue in a healthcare supply chain.

Supply Contracts. This issue deals with setting up relationships between suppliers and buyers in the supply chain through establishments of supply contracts that specify prices, discounts, rebates, delivery lead times, quality, returns, etc. etc. This approach differs from traditional approaches because its central focus is on minimizing the impact of decision made at not just one level in the supply chain, but on all its players. This is a decision problem, solution to which could range from a simple Linear Programming problem to a complex Game Theory algorithm. A healthcare provider will be setting up these contracts with a distributor or directly with a manufacturer.

Distribution Strategies. This issue deals with decisions pertaining to movement of goods in the supply chain. Among the strategies available are direct shipment, cross-docking involving transshipments and load consolidation. The objective is to minimize warehousing (storage) and transportation costs. Solutions to this problem involve Network Algorithm utilizing Linear, and Non-Linear programming techniques in deterministic and stochastic environments. A healthcare provider will have to make decisions about warehousing or direct shipment to point of usages of various supplies.

Supply Chain Integration and Strategic Partnering. One of the key issues in managing supply chain is its integration. Information sharing and joint (or collaborative) operational planning are basic ingredients to solve this issue. Implementation of Collaborative Planning, Forecasting and Replenishment (CPFR) as carried out by Wal-Mart retail stores in their supply chain, aided by information sharing through common software platforms such as the Enterprise Resource Planning (ERP) are viable strategies. In a healthcare supply chain, it would mean CPFR among the healthcare provider, supplier and the manufacturer of healthcare related items.

Outsourcing and Procurement Strategies. An important issue to consider is what to manufacture internally and what to buy from outside sources. One of the problems to be dealt in making these decisions is identifying risks associated with these decisions and minimizing them.
Another issue to consider is the impact of Internet on procurement strategies and what channels to utilize (public or private portals) when dealing with trading partners. In arriving at the decision whether to outsource or buy, various optimization models may be utilized to balance risk and payoffs. Once this decision has been made, use of appropriate information technology component such as, Internet portals, and procurement software plays a key role in these decisions. An example of this issue in healthcare supply chain may be the decision to prepare the meals for inpatients in house versus delivering meals already prepared in the centralized kitchen of a catering company.

Information Technology and Decision Support Systems. One of the major issues in supply chain management is the lack of information for decision-making. Information technology plays the vital role in enabling decision-making throughout the supply chain. Some of the key ingredients of information technology in supply chain are – use of Internet and Web-based service portals, integrated information / knowledge within ERP software, and decision-support systems that utilize proven algorithms for various strategic, tactical and planning problems in specific industry domains.

Customer Value. Supply chain must be measured by its ability to deliver value to the end customer, the patient. This may be in the form of price, quality, service levels, and perceived value. Solutions based on Statistics and OR can be employed to – measure quality of product, and reduction of lead time to enhance service rates.

3. Health Care Supply Chain: The Need, Drivers, Issues, and Opportunities

Why supply chain management for Health Care Industry? There are a number of reasons why Health Care industry needs to look at how they manage their supply chain. The main ones -- cost and risk. According to Bradley (2000), “how well or badly the health care supply chain is managed is a major factor in health care costs”. During the mid 1990’s, the Efficient Healthcare Consumer Response (EHCR) (EHCR, 2000) performed its own major supply chain study. They found out that the health care supply chain inefficiencies contributed $11 billion (or 48%) out of the total annual costs of $23 billion. Their report described that the health care supply chain was centered around distributors, resulting in little contact between manufacturers and hospital materials managers. Contract negotiations tended to be adversarial. Providers achieved lower costs, but these costs were not driven out of the system, just pushed lower in the supply chain. They encouraged the health care industry to adopt the concept of “collaborative planning, forecasting and replenishment (CPFR)”, used by retail chains such as, Wal-Mart. The main idea is to avoid excess inventory through accurate forecasting, utilizing one commonly agreed to demand data among various supply chain partners (Anonymous, 2000).

Health Care Supply Chain Drivers. The factors that are driving the call for efficiency in health care supply chain are based on common business sense realizing that considering the size of the industry, even small-scale efficiencies can have potentially large dollar impact. Some of the key drivers are described below (URL: http://www.cisco.com/warp/public/779/ibs/solutions/supply/v/vertical/).

- **Fragmented supplier base.** With 26,000 medical suppliers, managing vendor relationship costs significant time and money for the buyer. The goal should be to consolidate purchases so as to buy majority of products from one source.
- **Reduced government subsidies** have created the necessity to control costs. In addition, the Health Insurance Portability and Accountability Act of 1996 (HIPAA) regulations have created the urgency for providers to address security and electronic transactions issues, resulting in additional cost of doing business.
- **Supply chain inefficiencies.** As mentioned earlier, according to the Efficient Health Care Consumer Response (EHCR) study, approximately $23 billion is spent on the U.S. health care supply chain annually. Streamlining the ordering process and reducing number of supplier relationships can eliminate approximately $11 billion in costs.
- **Managing core competencies.** An efficient supply chain frees up time for health care professionals to focus on their core competency of delivering quality patient care.
- **Internet based purchasing.** This enables supplier consolidation, reduced ordering costs, and a common purchasing platform for hospital networks.
- **Common data standards.** Adopt and promote uniform industry data standards for supply chain transactions over the Internet. The formation of “E-Standards Work Group” is an industry wide initiative for this purpose (URL: http://www.neoforma.com/corp/news_and_events/pres s_room/2000/estandards.html).
- **Standardization of product purchases in the supply chain.** Standardization of hospital supplies for their impact on (a) purchase volume, (b) ordering and tracking, (c) storage space, (d) resource allocation, and (e) economies of scale through group purchasing power (Vermond, 2000).
Integrated Supply Chain Process: Key Issues and Opportunities. There is now a greater awareness in the Health Care industry that there are significant payoffs through efficient management of the health care supply chain, whose processes incur avoidable costs in following areas (URL: http://www.oha.com/oha/perspec.nsf/0/3d488bb0d512a8ea85256abf005cce2e?OpenDocument):

- Transportation from a production plant to a regional distribution center;
- Distribution center operations;
- Outbound freight;
- Wholesale distributor’s receiving and warehousing operations;
- Wholesaler distributor’s mark-up for information processing and customer service;
- Transportation to the care provider; and
- Inventory.

Integrated supply chain processes would transform this disjoint string of activities into streamlined, cost effective processes characterized by substantial standardization, integration, and optimal service placement (Brennan, 1998). In order to successfully integrate the supply chain processes, five supply chain management areas need to be met or exceeded, as per the results of study published by Pricewaterhouse Coopers (URL: www.eMarketer.com), and summarized in Table 2.

Table 2. Supply Chain Management Applications and Potential Savings for Health Care in the US, 2000 (as a % of procurement costs)

<table>
<thead>
<tr>
<th>Supply Chain Management Area</th>
<th>Potential Benefits</th>
<th>Percent of Procurement Cost</th>
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<tbody>
<tr>
<td>Demand management</td>
<td>Minimized duplication, planning system, demand-driven ordering (clinical guidelines, etc.)</td>
<td>2% to 4%</td>
</tr>
<tr>
<td>Order management</td>
<td>Consolidated purchasing, paperless order management (EDI, Internet)</td>
<td>2.5% to 4%</td>
</tr>
<tr>
<td>Supplier management</td>
<td>Supplier consolidation, optimal direct-from-manufacturer implementation, compliance with GPO agreements</td>
<td>0.5% to 2%</td>
</tr>
<tr>
<td>Logistics management</td>
<td>Consolidated service center, integrated transport network, capacity utilization</td>
<td>0.5% to 2%</td>
</tr>
<tr>
<td>Inventory management</td>
<td>Automated point-of-service distribution, replenishment, non-stock items, reduction in SKUs</td>
<td>0.5% to 1.5%</td>
</tr>
<tr>
<td>Overall cost-savings from Supply Chain Management</td>
<td>6% to 13.5%</td>
<td></td>
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</tbody>
</table>

Source: Pricewaterhouse Coopers, 2000
(URL: http://www.emarketer.com/images/chart_pdfs/020001-021000/020410.pdf)

For the Health Care Supply Chain, these supply chain management areas are elaborated below:

Demand Management. Managing consumption of clinical resources is key to controlling demand and reducing the number of supplies that move through the supply chain process. Three practices need to be implemented in this regard: 1) demand needs to be forecast and a plan implemented to facilitate fulfillment of supplies on a periodic basis, 2) standardization of supplies so as to deliver them as a single unit of inventory, and 3) development of clinical guidelines to define supply requirements for key patient groupings.

Order Management. Initiating effective order management practices:

- Establishing standard order management processes.
- E-procurement through Web or electronic data interchange.
- Implementation of electronic product numbering and tracking process.

Supplier Management. Some of the key ingredients of an effective supplier management process are as follows:

- Reducing the number of suppliers that provide product to the healthcare system.
- Establishing and participating in group purchasing contracts to take advantage of discounts and rebates.

Logistics Management. Integrated logistics management that exploits efficiencies offered by consolidation of shipments, utilization of service centers and transportation network, and cross-docking in transportation of goods.

Inventory Management. Reducing the storage space, minimizing stock keeping units and their stocking levels, and maximizing inventory turnover rates can achieve integrated management savings. One of the key enabler of this policy is reducing variability among common products through standardization initiatives.

4. E-Health Care Supply Chain: Business Trends, Initiatives, and Model

E-Healthcare can be described as the transition of healthcare business and patient-related processes and transactions into the Internet-delivered electronic information superhighway. The concept of e-health as it evolves, refers to the use of Web-enabled systems and processes to accomplish some combination of following objectives: cut costs or increase revenues, streamline operations, improve patient or member satisfaction, and
contribute to the enhancement of medical care (Bose, 2003).

According to a study published by Forrester Research, the Internet healthcare industry in the U.S. will become a $370 billion business by 2004. Firms will organize around a healthcare e-business network that will serve consumers, providers, distribution chains and payers (Dembeck, 2000). According to this study, “Eight percent of retail health sales will move online.” Health e-tailers such as Rx.com and Vitamins.com will experience retail growth to $22 billion in 2004. The real growth in e-healthcare, however, will be in the business-to-business segment, which the study predicts will soar to $348 billion in 2004. As online business trade gains momentum, 17 percent healthcare business transactions will move online by 2004.” Forrester’s analysis of the consumer e-Commerce healthcare market projects healthy growth in on-line trade for -- non-medication health and beauty aids, over-the-counter non-prescription drugs, natural health cures, and prescription drugs.

According to this study, both large institutions and small medical practices will turn to Net players, such as Embion.com, Medicalbuyer.com and Medibuy.com to simplify procurement of medical supplies, thereby driving Internet efficiencies into the distribution chain. As a result, the study predicts that cost-conscious hospitals will move 24 percent of their purchasing online by 2004. Meanwhile, as more doctors get connected to healthcare networks, 12 percent of private practices will conduct their procurement online by 2004.

E-Health Care initiatives. In the healthcare industry, web-enabled applications under development include products for: claims handling; physician practice management systems; online prescriptions; and electronic clinical and financial data interchange for hospitals, physicians, pharmacies, managed care organizations and commercial and hospital laboratories. Other applications include: patient-centered systems; solutions for chronically ill patients; finance and accounting programs for hospitals and other health agencies; medical supply purchasing; health and medical web portals; managed care organization provider directories; health promotion and disease prevention; provider credentialing; risk management; case management; and practice management.

The move to Internet-based programs and services should result in savings for employers, insurers, managed care organizations and government-sponsored programs because of the significant cost-saving opportunities, such as better price comparisons, lower inventory costs, and more efficient health system-wide communications, patient information management and billing and claims handling (Nugent 2000). There are a number of companies engaged in e-healthcare efforts - AmericasDoctor.com, Health-Central.com, The Health Network, MedicalRecord.com, PlanetRx.com, Shared Medical Systems, etc. Hospital-sponsored Web sites, e-mail and discussion groups are becoming part of health care organizations’ Information Technology (IT) functions.

E-Health Care Supply Chain Model. The emergence of digital business value chains in the healthcare industry will lead to a trend for its supply chain management. The technology that is already available to integrate Web front-end interactions with back-office systems include, packaged Web modules, “middleware” and tools to build customized transaction systems, Web-based EDI, Web-based electronic marketplaces, and many electronic catalogs. This type of network connection allows the consumer to go directly to the system of choice to design, configure, and arrange for shipment or availability of the final product or service of choice. This ability is the result of an Extranet, linking partners in supply chain to necessary information on-line. An Intranet is used to link technologies, business processes, and organizational constituencies into a network that can display its offerings to consumers over the Internet.

Figure 1 depicts a representative model of US e-Healthcare Supply Chain proposed in Kumar and Chandra (2001), showing linkages and flow (material and information) between various business entities. The principal participants in the US healthcare supply chain include: manufacturers (drugs, medical equipment, and hospital medical supplies), distributors, medical service providers, medical groups, insurance companies, government agencies (such as, Health and Human Services), employers, government regulators, and users of healthcare services.

5. Implementing the E-Health Care Model: An IE/OR Perspective

For improving supply chain effectiveness, a decision support system that integrates information technology with Industrial Engineering and Operations Research techniques is described below. It is built upon a generic methodology proposed by Chandra and Grabis (2002), which emphasizes commonality of general structure of problems (such as identified in Table 2) across various industry domains. The unique differences that are, however, found in specific problem for a particular industry (for example Health Care supply chain) can be represented by parameters that uniquely set it apart from other problems (in other industry domains).
General approach. The decision support system consists of two integral parts—information support system and decision modeling system. The methodology consists of a number of consecutive tasks including definition of the supply chain management problem, generation of alternative supply chain configurations, decision modeling and final decision making as depicted in Figure 2. The main tools utilized in order to accomplish these tasks are supply chain process model, modeling database, decision modeling system and supply chain knowledge library. The modeling methodology is built around a unified representation of the supply chain modeling problem. This representation can be transformed in a number of different formats suitable for accomplish different modeling tasks. An implementation of the decision support system is developed on the basis of standard specialized software tools. An Enterprise Resource Planning software (SAP/R3, developed by SAP Inc., Germany) provides data storage support. ARIS (developed by IDS-Scheer Inc., Germany) is used in process modeling. MS Excel (developed by Microsoft Inc., USA) is used as a core component of the decision model. It invokes packages such as LINGO (developed by LINDO Systems, USA) and ProMODEL (developed by Pro Model Inc., USA) for solving of specific Linear Programming and Simulation modeling tasks, respectively.
For the Health Care industry, a supply chain management problem may pertain to supplier selection, demand management, order management, inventory control issues etc., as described in an earlier Section. Alternative supply chain configurations may identify a supply chain representation that recognizes availability of alternative health care suppliers, based on criteria such as lower cost, quality, material specifications, etc. A decision model will comprise of a problem representation, problem-solving algorithm(s) and parameters associated with the specific problem under study. A process model for a selected health care supply chain configuration will explicitly define processes (or activities) for all business entities such as, manufacturers of medical supplies, component manufacturers, wholesalers/distributors, health care providers, and patients (along with their characteristics captured as attributes and associated variables and parameters), from supply to demand stages. A health care supply chain knowledge library will represent the knowledge captured for supply chain configurations specific to a problem domain. This knowledge can be reused when problems with similar features are encountered in the future.

The unified representation of the supply chain problem assures data integrity. Modeling results are stored in the supply chain modeling database and are available to aid solving supply chain modeling problems with similar properties. Sharing of the modeling database over the Internet provides supply chain members with access to data. Utilization of generic decision models reduces modeling resource requirements and allows direct comparison of multiple configurations.

5.1. Modeling methodology

The proposed methodology systematically evaluates a specific problem by designing, modeling, and analyzing it according to its context in relation to the total enterprise represented by a supply chain entity. The step-by-step problem evaluation adopted in this methodology is described below.

Process model & modeling database. An initial state of modeling is either a current supply chain, which should be reconfigured, or a product or service specification, for which a supply chain is needed. The initial state generally is described in an informal manner. A supply chain kernel provides the template describing data requirements for the formal supply chain problem definition. Supply chain models are developed using the kernel data. Development of a supply chain process model is the next step of supply chain modeling. The process model provides an exhaustive representation of the general supply chain management problem. It provides input data for other supply chain models. Therefore, construction of the process model follows a set of rules elaborated to provide a consistent and generalized representation of the supply chain (Chandra and Marukyan 2002), which can be transformed in other required data processing formats. The process model describes the initial supply chain management problem referred to as the base configuration. The process model development is accompanied by creation of a supply chain modeling database. This database is used to store and disseminate the definition of the supply chain modeling problem and modeling results. The database is created using a template of the standardized supply chain modeling database model (Chandra and Chiiov 2001). The database is created using data extracted from the process model.

Tentative configurations. The proposed supply chain modeling methodology is primarily aimed at dealing with a class of problems involving supply chain reconfiguration. This includes evaluation of alternative supply chain configurations generated using information from the suppliers’ database. Tentative configurations are stored in the supply chain modeling database, where they are identified as alternative configurations to the base configuration.

Decision modeling. Selected tentative supply chain configurations are evaluated using the decision modeling system. The decision modeling system emulates consequences of adoption of particular supply chain configuration and management policies. Each tentative configuration representing the supply chain modeling problem is retrieved from the decision modeling database. The relational representation of the supply chain modeling problem is transformed into a format readable by decision
model components. This format uses incidence matrices to represent the supply chain modeling problem. A simulation model is a major part of the decision modeling system. The simulation model is designed using the generic modeling approach (Chandra et al. 2000, and Chandra and Grabis 2001), which is particularly well suited to deal with modeling of variety of supply chain configurations. Each configuration is evaluated under a number of different scenarios. A scenario describes different supply chain management policies, environmental and system parameters. Obtained results are stored in the database.

**Decision making & knowledge accumulation.** After the decision modeling process is completed with all tentative supply chain configurations, the modeling database stores a large number of alternative solutions to the initial supply chain management problem. A management problem is to find a decision to be implemented. The problem is exacerbated by the fact that not all factors can be adequately represented in models and several solutions may yield similar performances. This decision making can be assisted by utilization of an enterprise knowledge library.

If the decision modeling process is repeated routinely, then enterprise level supply chain modeling knowledge is accumulated in the modeling database. This accumulated knowledge is used to create the knowledge library, which stores information about management problems solved, alternative configurations considered, obtained modeling results, implemented decisions and implementation appraisal. The decision implementation appraisal is the crucial step to assure usability of accumulated knowledge. New decisions can be matched to stored decisions and those which are likely to yield unsatisfactory implementation results, can be filtered out using the appraisal criterion. The knowledge library is built utilizing the concept of supply chain ontology described in Chandra and Tumanyan (2002).

**6. Conclusions**

This paper has provided a comprehensive discussion on various aspects surrounding the need, efficacy, design, modeling, and implementation of a Health Care Supply Chain. It has been proposed that the Health Care industry can achieve efficiency in their operations through adoption of technologies, standards and practices, and proven models and methodologies developed in the IE/OR fields which have been successfully applied in many diverse industries for managing supply chain logistics. The model and methodology proposed in this paper should be validated with specific problems encountered in the Health Care industry in managing supply chain logistics. It is the next logical step planned to extend this research.

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