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CHAPTER ONE

Supply Chain Information Systems

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CHAPTER 1

Supply Chain Information Systems

The ability to access global production and services has revolutionized business. Supply chain networks move inventories of various kinds from source to consumption. Being able to work with producers around the world provides opportunities to balance low cost with risk mediation. While logistics usually is associated with moving material, supply chains today can include intangibles such as services as well as inventories of goods. Using the Internet enables linking together supply chain networks in practically any business application, production, or service.

Organizations, such as Dell and Hewlett-Packard, have operated collaborative supply chains with each partner focusing on a few key strategic activities. Supply chains also include organizations, such as the military and nonprofit organizations like the Red Cross and Red Crescent. In the retail arena, Wal-Mart has been very successful in the past in linking thousands of sources with their millions of customers. Organizations such as Bank of America have viewed their service operations as key to their success and evaluated their entire service supply chain seeking to apply the same general principles as lean manufacturing, focusing on providing maximum value at minimum overall cost. Information systems are needed to make these supply chains work.

Supply Chain Management

Supply chain management (SCM) became a common term in the 1980s, heavily influenced by Japanese manufacturing processes like those developed by Toyota, such as just-in-time (JIT) and lean manufacturing. In the 1990s electronic data interchange (EDI) made it possible to coordinate chains of organizations worldwide. This enabled the integration of

participant supply chain elements into cooperative components sharing information and enabling coordinated planning, operations, and monitoring of performance. There was a focus on core competencies, abandoning the vertical integration of Standard Oil, U.S. Steel, and Alcoa and replacing it with linkages of independent organizations specializing in what they did best. This encompassed the entire product process to include design, manufacture, distribution, marketing, selling, and service. Agile supply chains, such as Motorola and Panasonic, are flexible, enabling changing the set of partners for given markets, regions, or channels, accessing the specific price or quality mix that enable organizations to be competitive.

Original equipment manufacturers (OEMs) shifted from making products to become brand owners. These brand owners needed to know what was going on across their entire supply chain, with the need to control from above rather than from within. Standard Oil in 1900 desired to control everything from within, seeking to own all elements in their supply chain. Conversely, Nike doesn't make shoes anymore. They coordinate activities from design to retail through communication supported by a variety of information systems linked across their supply chain.

Supply Chain Processes

Collaboration across supply chains requires the integration of all supply chain activities. This requires a continuous flow of information. Key supply chain processes include the following:

- Product development
- Procurement to include outsourcing or partnerships
- Manufacturing
- Physical distribution
- Customer relationship management (CRM)

Product development can be obtained by linking customers and suppliers. Customers can express their needs (desires), while the supply chain organization can contribute what is possible. Communication enables identification of a product with a competitive life cycle.

Procurement (sourcing) involves the selection of supply chain members. This can be for specific products or services, so that an organization like Wal-Mart might have literally millions of temporary sourcing arrangements. A stable supply chain will have relationships benefiting all parties. Outsourcing refers to procuring sources outside the OEM organization. Outsourcing is broader, however, in that it can refer to obtaining any part of a tangible product or intangible service. Information systems can use EDI and web links to communicate rapidly, enabling effective cost and risk management. Procurement generally involves obtaining materials and components. Outsourcing enables many opportunities to develop a more cost-efficient (or lower risk) supply chain. This comes at the cost of requiring significantly more coordination.

A *manufacturing* process can be developed based on what the OEM organization selects as the best combination of cost and risk over the total product life cycle. Manufacturing processes should be flexible to respond to changes in market conditions. The activities of planning, scheduling, inventory, transportation, and coordination across the supply chain require software coordination.

Physical distribution involves moving products (or services) through the supply chain, ultimately reaching customers. The specific routing is referred to as a channel in marketing and can include a variety of transportation media to move goods. In a service context, the channel can involve the routing of who a customer interacts with to get the service desired.

CRM is the management of the relationships between the providing organization and its customers. Customer service provides information from the customers and has the ability to give customers real-time information on product availability, price, and delivery.

Linking independent elements to work together to deliver goods and/or services is flexible and enables rapid change to comply with new circumstances that are commonly encountered in contemporary business. By expanding beyond the core organization, a need to monitor performance is needed. Some of the key measures of effective SCM include cost, service, productivity, use of assets, and quality. This is often implemented through monitoring customer perceptions, and identifying best practices as benchmarks to evaluate supply chain performance.

Supply Chain Information Systems

Many software applications are available for each step in the supply chain process. Many vendors specialize in particular steps supporting part of any one of the six elements given earlier. Each supply chain organization will find that they are best served by various combinations of these software products. Furthermore, as technology evolves, new software is developed to serve specific needs as information systems continue to evolve.

A SCM stream can be divided into three main streams: product, information, and finances.

- *Product*—Goods moving from sources through manufacturing processes and ultimately on to a customer, to include services such as customer returns.
- *Information*—Transmitting orders and updating delivery status.
- *Financial*—Credit terms, payment schedules, shipment, and contractual relationships.

Because of advances in manufacturing and distribution systems, the cost of developing new products and services is dropping and time to market is decreasing. This has resulted in increasing demand, local and global competition, and increasing strain on supply chains. SCM software links suppliers to databases that show forecasts, current inventory, shipping, or logistics timeframes within the customer organization. By giving this access to suppliers, they can better meet their customers' demands. For example, the supplier can adjust shipping to make certain that their customers have the inventory necessary to meet their customers' needs. They also can monitor unexpected supply chain disruptions to organize alternative routing. Suppliers can download forecasts into their own manufacturing systems to automate their internal processes as well.

Planning applications and execution applications are the two primary types of SCM software:

- *Planning applications* are capable of generating improved plans through use of mathematical algorithms.

- *Execution applications* enable tracing goods, managing materials, and exchanging financial information.

A number of supply chain systems have evolved over the decades. The first was materials requirements planning (MRP). This was extended to include planning schedules (often labeled MRP-II). Enterprise resource planning (ERP) systems seek to integrate all organizational information systems, although of course companies will always have special needs outside of an ERP. Nonetheless, ERP systems support much of supply chain activity, to include financial transactions with sources and customers, inventory dealings with sources, forecasting to support planning, MRP to support assembly operations, and many other activities. The trend is for many functions that used to be outside the ERP to be offered as modules within ERP. One case in point is advanced planning system (APS) software. There also have been systems marketed as warehouse management systems (WMSs), transportation management systems (TMSs), manufacturing execution systems (MESs), and the more general logistics management systems, targeted for specific industries such as the military and/or construction. The 21st century has seen a continued expansion of ERP systems to include additional functionality, such as CRM and SCM systems as part of the enterprise information system (EIS). There also are other uses of information technology available to support supply chains, such as online marketplaces.

Materials Requirements Planning

The term *MRP* is used as a general term to include all MRP versions, namely, MRP-I (i.e., materials requirements planning), Closed-loop MRP (i.e., MRP-I with capacity planning and shop floor management), and MRP-II (i.e., Closed-loop MRP integrated with the other functions such as finance and marketing).[1] The concept of an integrated information system took shape on the factory floor. Manufacturing software developed during the 1960s and 1970s, evolving from simple inventory tracking systems to MRP software. MRP at its core is a time-phased order release system that schedules and releases manufacturing work orders and purchase orders, so that subassemblies and components are available at

the assembly station when they are required. Some of the benefits of MRP are reduction of inventories, improved customer service, and enhanced efficiency and effectiveness. MRP software allows a plant manager to plan production and raw materials requirements by working backward from the sales forecast, the prediction of future sales. Thus, the manager first looks at marketing and sales forecasts of demand (what the customer wants), the production schedule needed to meet that demand, calculates the raw materials needed to meet production, and projects raw materials purchase orders to suppliers. For a company with many products, raw materials, and shared production resources, this kind of projection is impossible without a computer to keep track of various inputs.

EDI, the direct computer-to-computer exchange of standard business documents, allows companies to handle the purchasing process electronically, avoiding the cost and delays resulting from paper purchase order and invoice systems. SCM began with the sharing of long-range production schedules between manufacturers and their suppliers.

The MRP system should provide four basic items of information: when to place order, how much to order, who to order from, and when the items need to be on hand. MRP systems are used to acquire or fabricate component quantities on time for both internal purposes and sales and distribution. MRP is a planning instrument geared exclusively to assembly operations. Each manufacturing unit informs its suppliers what parts it needs and when it requires them. The main aim for the evolution of MRP was to tackle the problem of *dependent demand*, that is, determining how many of a particular component is required knowing the number of finished products.

The next stage of MRP-II evolution was JIT methodology in the late 1980s. MRP-II (manufacturing resource planning) is a method to plan all resources for a manufacturer. A variety of business functions are tied into MRP-II systems, including order processing as in MRP, business planning, sales and operations planning, production plans, master production scheduling, capacity requirements planning, and capacity planning. MRP-II systems are integrated with accounting and finance subsystems to produce reports including business plans, shipping budgets, inventory projections, and purchase plans. A major purpose of MRP-II is to integrate primary functions (i.e., production, marketing, and finance) and other functions,

such as personnel, engineering, and purchasing into the planning process, to improve the efficiency of the manufacturing enterprise.

Many within the operations management field consider ERP as a natural extension of MRP-II. The APICS Association for Operations Management definition for ERP is a method for the effective planning and control of all resources needed to take, make, ship, and account for customer orders.[2] There is at least some truth to this view, but ERP systems are even more comprehensive than simply on manufacturing operations. ERP systems are found in practically all types of large organizations, to include chemical facilities and even universities. MRP-II functions are covered by production planning and other ERP modules.

Advanced Planning Systems

Computer technology makes it possible for improvements at both the cost and value ends of the supply chain. Demand uncertainties can be better managed through improved inventory demand forecasting, reduction of inventories, and improved transportation costs through the optimization of coordinated activities across the supply chain. APSs provide decision support by using operational data to analyze material flows throughout the supply chain. This supports the business functions of purchasing, production, and distribution through the entire spectrum of planning. Purchasing is supported by planning and MRP. Production is supported by strategic, master, and production planning as well as short-term scheduling. Distribution is supported by distribution planning and transportation planning. These planning systems interact, enabling the management of demand across the supply chain. A recent list of APS products includes the following:

- Adexa
- i2
- JDA (acquired Manugistics)
- Logility
- Webplan (Kinaxis)

In addition, each major ERP software has options to support advanced planning through modules. APSs use historical demand data as the

basis of forecasts that are used to manage future demand. However, in order to optimize systems, a certain level of stability is required. John D. Rockefeller was able to manipulate demand for petroleum products over 100 years ago, obtaining the stability he needed. Demand manipulation is still possible in some markets today but is much more difficult. The idea of supply chain optimization is more difficult to implement in conditions of constant product innovation, highly volatile global demand, and increased product customization (such as applied by Dell and other computer vendors allowing customers to custom design their computer systems online). This turbulent market environment makes it difficult to obtain extensive pertinent demand history. It is easy to collect data, but demand changes too rapidly to take advantage of it for extended periods of time.

Warehouse Management Systems

WMSs provide the functionality of tracking parts throughout a supply chain. Systems such as HighJump Software and RedPrairie Corp (now part of JDA Software Group's supply chain management product line) offer tools using electronic input such as bar code scanning to track material through the supply chain system, maintaining accurate information flow to parallel physical flow. Radio-frequency identification (RFID) technology provides another form of electronic data input to WMSs. The example case at the end of the chapter provides some idea of what WMSs do.

Manufacturing Execution Systems

MESs appeared in the mid-1990s, evolving as all other supply chain information technology. Original focus was to manage demand on manufacturing organizations with respect to quality, standards, cost reduction, schedule, and ability to react to change. With time, functions have emphasized support traceability. MES functionality now integrates support to most manufacturing execution processes from release of production orders to finished goods delivery. MES also triggers supply chain replenishment upstream (telling sources that replenishment inventory is needed). These systems use a common user interface and data system to

integrate support to multiple locations or organizations within a supply chain. An MES offers the following functionalities:

- Scheduling
- Process management
- Document control
- Data collection or acquisition
- Labor management
- Quality management
- Production unit dispatch
- Maintenance management
- Product tracking
- Performance analysis
- Resource allocation and tracking

An MES can interact between the organizational ERP and the shop floor, taking production orders from the ERP and allocating machines and labor to tasks or products. Real status from the shop floor in turn is passed on to the ERP to update resource availability, track products and inventory, and record production. Logistics functions in the ERP include plant production scheduling, shipping, and inventory. The MES translates that to execution in the form of dispatching, detailed production scheduling, and tracking material.

Transportation Management Systems

TMSs provide software support at an affordable level to control shipping. A variety of alternative sources are available to increase visibility and generate more efficient solutions to move material in an increasingly complex environment involving many risks (piracy, war, regulations). Functionality provided includes transportation mode planning, optimization models, and workflow management.[3]

TMS software can be obtained from vendors, some of whom are listed here:[4]

- Accuship
- EPICOR

- HighJump (acquired Pinnacle)
- IBM (acquired Sterling Commerce and others)
- Infor
- JDA (acquired Manugistics)
- UPS Logistics Technologies

This list does not include the full-scale ERP vendors, such as Oracle and SAP, who also have TMS functionality. The list demonstrates the volatility of the industry, showing a number of acquisitions (and not showing a number of other acquisitions of TMS vendors that have been acquired). Other means of TMS acquisition include in-house development, hosting by an ASP, or software as a service. Firms also have options with respect to software within specific branches of the organization, or enterprise-wide support.

Enterprise resource Planning

In the early 1970s, business computing relied on centralized mainframe computer systems. Today, it is reported that 80 percent of Fortune 500 firms use ERP systems to manage operations.[5] These systems proved their value by providing a systematic way to measure what businesses did financially. The reports these systems delivered could be used for the analysis of variance with budgets and plans, and served as a place to archive business data. Computing provided a way to keep records much more accurately, and on a massively larger scale than was possible through manual means. But from our perspective at the beginning of the 21st century, that level of computer support was primitive.

Business computing systems were initially applied to those functions that were easiest to automate, and that called for the greatest levels of consistency and accuracy. Payroll and accounting functions were an obvious initial application. Computers can be programmed to generate accurate paychecks, considering tax and overtime regulations of any degree of complexity. They also can implement accounting systems for tax, cost, and other purposes because these functional applications tend to have precise rules that cover almost every case, so that computers can be entrusted to automatically and rapidly take care of everything related to these functions.

Prior to 2000, ERP systems catered to very large firms, who could afford the rather high costs of purchasing ERP systems. Even focusing on a selected few modules would typically cost firms $5 million and up for software. After 2000, demand dropped, in part because firms were often concerned with Y2K issues prior to 2000, which motivated many ERP system acquisitions. Demand noticeably dropped off after 2000 came and went. Vendors reacted in a number of ways. First, the market consolidated, with Oracle purchasing PeopleSoft (who had earlier acquired JD Edwards). Microsoft acquired a number of smaller ERP software products, consolidating them into Microsoft Dynamics, which caters to a smaller priced market, thus serving a needed gap in ERP coverage for small businesses. Notably, SAP advertises that they can serve small business too. But it appears that they are more valuable in the large-scale enterprise market. There, in addition, are many other systems to include open sourced ERP systems (at least for acquisition) like Compiere in France. Many countries, such as China, India, and others, have thriving markets for ERP systems designed specifically for local conditions, although SAP and Oracle have customers all over the globe.

Enterprise information systems (EIS) is appearing as a term for the addition of what used to be independent add-on software such as SCM systems and CRM to the core ERP. This trend manifested itself initially when Oracle purchased Siebel Systems, the leading CRM provider. SAP responded by acquiring their own CRM, and both vendors have added SCM functionality within their systems as well. The difference between ERP and EIS is primarily marketing semantics, so we will use ERP for both older and newer versions. One trend among ERP vendors is to expand their functionality to provide services formerly supplied by supply chain vendors such as Manugistics and i2 Technologies.[6] SAP has introduced mySAP.com, which is open collaborative system integrating SAP and non-SAP software. SAP APO supports supply chain activities, such as forecasting, scheduling, and other logistics-related activities. PeopleSoft has Enterprise Performance Management to support decisions at many levels. JD Edwards products have support for planning and execution. Oracle's 11i advanced planning and scheduling system was designed to automate customer, supplier, and firm interactions. Vendors are moving toward greater integration of supply chain products.

The ERP concept is not applied merely for the manufacturing environment but for all kinds of enterprises. Early ERP systems focused on manufacturing, although they quickly expanded to support all sorts of organizations. ERP facilitates enterprise-wide integrated information systems covering all functional areas and performs core corporate activities and enlarges customer service. ERP is a business management system that seeks to combine all aspects of the organization. It is capable of taking care of planning, manufacturing, sales, and marketing. The concept is to integrate legacy systems within a coordinated integrated system. Typically, an ERP system uses database systems, which are integrated with each other.

Common ERP Features: An ERP system is not merely the integration of diverse enterprise processes mentioned earlier but also can possess key characteristics to meet the requirements. Features often found in an ERP include the following:

- *Best business practices*—Incorporation of processes evaluated as the best in the world
- *Comprehensive*—Integrating as many business computing functions as possible, with a single database
- *Modular*—An open system architecture allowing incorporation of those modules needed for the organization
- *Flexible*—Capable of response to changing enterprise needs, to include Open DataBase Connectivity
- *External linkage*—Capable of linking external organizations, especially within supply chains

Among the many reasons to adopt an ERP, they offer an integrated system shared by all users rather than a diverse set of computer applications, which can rarely communicate with each other, and with each having its own set of data and files. ERP provides a means to coordinate information system assets and information flows across the organization. The main benefit is the elimination of suborganizational silos that focus on their own problems rather than serving the interests of the overall organization. On the downside, ERP systems impose one procedure for the entire organization, which requires everyone

to conform to the new system. ERP systems are thus less flexible. But the benefits of integration are usually much greater than the costs of conformity.

Data can be entered once, at the most accurate source, so that all users share the same data. This can be very beneficial because shared data is used more and by more people, which leads to much more complete and accurate data. As errors are encountered, users demand corrections, but this is limited because a set of procedures are needed to insure that changes do not introduce new errors. This makes it harder to make corrections, but again, this added inconvenience is usually well worth the gains of data integration.

ERP systems also can provide better ways of doing things. This idea is the essence of best practices, a key SAP system component. The downside to best practices is that they take a great deal of effort in identifying the best way to proceed with specific business functions, and that they often can involve significant change in how organizational members do their work. Further, as with any theory, what is considered best by one is often not considered best by all.

ERP systems are usually adopted with the expectation that they are going to yield lower computing costs in the long run. Ideally, adopting one common way of doing things is simpler and involves less effort to provide computing support to an organization. In practice, savings are often not realized, due to failure to anticipate all the detailed nuances of user needs, as well as the inevitable changes in the business environment that call for different best practices and computer system relationships. Training needs are typically under-budgeted in ERP projects. Furthermore, these training budgets don't usually include the hidden costs of lost productivity as employees cope with complex new systems. Table 1.1 recaps these pros and cons of ERP systems.

The key rationales for implementing ERP systems are:

- *Technology*—More powerful, integrated computer systems with greater flexibility and lower IT cost.
- *Business practices*—Implementation of better ways of accomplishing tasks yielding better operational quality and greater productivity.

Table 1.1 ERP Pros and Cons[7]

Factor	Pro	Con
System integration	Improved understanding across users	Less flexibility
Data integration	Greater accuracy	Harder to make corrections
Best practices	More efficient methods	Imposition of how people do their work
		Less freedom and creativity
Cost of computing	More efficient system planned	Changing needs
		Under-budgeted training expense
		Hidden costs of implementation

- *Strategy*—Cost advantages can be gained through more efficient systems leading to improved decision making, more business growth, and better external linkages.
- *Competitive advantage*—If an organization's competitors adopt ERP and gain cost efficiencies as well as serve customers better, organizations will be left with declining clientele, competitive advantage will also arise from providing better customer service.

The motivations for ERP adoption were examined by three studies using the same format. Mabert et al. (2000) surveyed over 400 Midwestern U.S. manufacturing organizations about ERP adoption. Olhager and Selldin (2003) replicated that study with 190 manufacturing firms in Sweden. Katerattanakul et al. (2006) again replicated the survey, this time in Korea. These studies reported the following ratings with respect to motivation for implementing ERP (see Table 1.2).

Initially, the fear of Y2K was a major concern. The Swedish survey was later than the one in the United States and that might explain the lower rating for this item in the Swedish study. The later Korean study did not ask about this dated issue. The U.S. response was actually neutral (only slightly higher than 3), but Y2K clearly was a factor in ERP adoption in the mid- to late-1990s. However, more important reasons were always present. In the first two studies, replacing legacy systems received a high positive response. The desire to simplify and standardize systems had the

Table 1.2 Reasons for implementing enterprise resource planning[8]

Reason	United States	Sweden	Korea
Replace legacy systems	4.06	4.11	3.42
Simplify and standardize systems	3.85	3.67	3.88
Improve interactions with suppliers and customers	3.55	3.16	3.45
Gain strategic advantage	3.46	3.18	3.63
Link to global activities	3.17	2.85	3.54
Solve the Y2K problem	3.08	2.48	NA
Pressure to keep up with competitors	2.99	2.48	2.94
Ease of upgrading systems	2.91	2.96	3.55
Restructure organization	2.58	2.70	3.33

Note: Rating scale from 1 (not important) to 5 (very important).

Source: Extracted from Mabert, Soni, and Venkataramanan (2000), Olhager and Selldin (2003), Katerattanakul, Hong, and Lee (2006).

second highest rating in the first two studies and had the highest rating in the later Korean study.

There were two other reasons that received relatively high ratings in the United States (a bit lower in Sweden). These were to improve interactions with suppliers and customers, which is one way to gain strategic advantage. The supply chain aspects of ERP have led vendors to modify their products to be more open, although work is needed in this direction (and seems to be proceeding). Linking to global activities was slightly positive in the U.S. survey, more negative in the Swedish study, and relatively higher in the Korean study.

Three other potential reasons received low ratings in both studies. Pressure to keep up with competitors received neutral support in the U.S. study. The ease of upgrading systems is a technical reason that received neutral support both in the United States and in Sweden. Restructuring the organization was rated lower.

From these studies, we infer that ERP systems are an important means to upgrade the quality of information systems. They can provide organizations with coordinated systems that have higher-quality data. Once the kinks are worked out, this information may be available in a more

responsive way. Not all evidence indicates lower costs, but most evidence does indicate higher-quality information systems.

ERP and SCM: Originally ERP tools were not considered for SCM and thus, the information flow between various members of the supply chain was slow. This was because until the late 1990s the concentration of organizations was on improving the internal efficiency alone. Organizations, however, soon realized that although internal efficiency is important, its benefit would be limited unless complemented by increased efficiency across the supply chain. They also realized that, accurate flow of real-time information across the supply chain was the key to success in the emerging business climate, which was characterized by rapid advances in technology, shorter product life cycles, and so forth. Therefore, organizations started integrating ERP applications with SCM software. This ensures that efficiency was achieved across the supply chain, including a seamless flow of information. ERP became a vital link in the integrated supply chain as it serves as the integrated planning and control system.

In summary, ERP applications help in effectively delivering SCM in the following ways:

- *Data sharing*: They can create opportunities to share data across supply chain members, which can help managers in making better decisions. They also make available wider scope to supply chain managers by providing access to much broader information.
- *Real-time information*: ERP systems can provide real-time information, which can be of great help in supply chain decisions. For example, ordering raw materials can be based on the inventory details provided by the ERP systems.

Web-based technologies have revolutionized the way business is conducted and SCM and ERP are no exceptions. In order to leverage the benefits offered by this new technology enabler, ERP systems are being *web-enabled*. The Internet allows linking websites to back-end systems like ERP and providing connections to host of external parties. The benefits of such a system are that customers have direct access to the supplier's ERP system and the vendors in turn can provide real-time information

about inventory, pricing, order, and shipping status. The Internet, thus, provides an interface between ERP system and the supply chain members allowing real-time flow of reliable and consistent information. To illustrate a benefit of web-enabling ERP, such a facility allows customers to go online and configure their own products and get price information and immediately get to know whether the configured product is in stock or not. This is made possible because the customers' request directly access the ERP systems of the suppliers.

WMS using RFID[9]

Warehousing is a component of most supply chains, storing inventory until it is moved to the next stage. Warehousing operations include inventory storage, order product mixing, cross docking, and customer service. Within inventory management the specific tasks of storage and retrieval and inventory control are tasks of importance. A number of WMS software vendors are in the market, offering tools to manage warehouse operations. Current technology such as RFID is often incorporated within these systems.

Wang et al.[10] reported the implementation of a digital warehouse management system (DWMS) using RFID. This application was in China, applied specifically to managing the supply chain of tobacco, which has a much larger market in China than in the United States. The user was the Wuhan Tobacco Corporation, which had over 100 warehouses storing thousands of different products. The RFID-DWMS reported was installed in a distribution center warehouse. This DWMS consisted of four components: a digital shelf manager, a reader adapter, a storage or retrieval manager, and an event processor manager. Implementation involved the following six stages:

1. *Warehouse process analysis* was the first step. The Chinese government required that all tobacco products have a barcode that communicated with a government database. The warehouse operation involved the receipt of new products, a storage assignment made by an operator relying on experience, and the transportation of the item to its designated storage location. When products were distributed from the warehouse, two operators scanned the barcode as items left and a

quality control person monitored the results to ensure that barcode information was correct. At the end of each day, a manual inventory of products in the warehouse was conducted. A business process reengineering analysis was conducted to recommend improvements to this set of processes.

2. *Requirements analysis* evolved from interviews with warehouse managers and operators. Warehouse managers needed more racks for storage capacity and RFID tags to store barcode information and enable improved operations. They also had to maintain operator records and needed a visual display of all warehouse information and current inventory reports. The requirements of warehouse operators were an automatic assignment of storage or retrieval actions, a guide map to show them where they had to go, and an alert if an operation did the wrong thing.
3. *Warehouse layout design* was accomplished to most efficiently lay out drive-in racks. Forklift crashes were minimized by fixing RFID readers in the receiving space linked with the DESM software. Data collection and tag writing were performed by a barcode scanner and RFID reader at the same time. When forklifts passed a second reader in the warehouse, data were collected in real time. This required RFIDs with readability at a distance. Forklifts had a touch-screen computer linked to the DWMS database.
4. *System design* included a human resources management subsystem for personnel. It also included stock-in and stock-out subsystems to maintain real-time inventory data. A digital shelf map gave the manager a visual view of all warehouse inventory with statistical report capabilities.
5. *Forklift guidance* was driven by the touch-screen computer on each forklift. Retrieval was driven using last-in-first-out. Operators were given guide maps to make it easy to see locations.
6. *Rule management* gave a rules maintenance platform that allowed addition, modification, and deletion to the rulebase. Priorities for storage and retrieval could also be specified.

Implementation involved some issues. Barcode data needed to be compressed into a new data format. A digital pallet held 30 boxes.

Barcode data included a 32-digit number containing company name, production area, date, and specification, as well as a serial number to uniquely identify each box. A system was applied to provide a check to obtain data reliability. Additionally, both storage and retrieval operations were reengineered for efficiency.

The RFID-DWMS improved operations in four ways:

1. Inventory was visualized.
2. Storage/retrieval assignment was automated.
3. Forklifts were automatically guided.
4. Loading time was reduced.

The system reduced required manpower by half. Average loading time was cut from 50 minutes to 18 minutes. Loading and unloading efficiency was improved, and finally, inventory accuracy was increased from 80 to 99 percent. Thus, the WMS was highly successful. Wang et al. gave the following lessons learned:

- Top management support is the most important factor in successful implementation.
- A prototype system for testing is needed for expensive innovative technology.
- The type of RFID technology used needs to be carefully selected, trading off cost and functionality needed.
- The decision to tag items or pallets is important, again trading off cost for detailed accuracy.
- Systems should be designed to be as flexible as possible.

Conclusion

In the past, vertical integration was a way to gain efficiency in supply chains. Today, vertical integration doesn't work as well, because specialty organizations have developed to perform specific tasks very efficiently. Efficiency is gained today through supply chains linking specialists throughout the vertical business hierarchy.

A number of software systems are available to support supply chains. This chapter reviewed MRP, APS, and ERP. Online market place software was briefly described as an example of other software support. ERP systems were initially focused on integrating internal operations. Their high investment cost and often rigid procedures made them barriers to effective supply chain linkage. However, recent trends show movement toward more open systems that allow closer coordination across supply chains. One way to accomplish this efficiency would be through all elements in a supply chain adopting the same ERP vendor products, as well as software enhancements. However, this is not economically viable for most supply chain components. Many suppliers may not have the millions necessary to invest in technology adopted by the core company in the supply chain.

Other approaches are toward open ERP software. APSs were originally developed to enhance the ability of firms to deal with other organizations in their supply chain. More recently, the trend among ERP vendors is to provide this functionality within their products, especially through Internet technology. Lean manufacturing is another philosophy related to gaining efficiency in production operations. While the concepts of lean manufacturing initially seem in conflict with the idea of ERP, there have been imaginative developments allowing ERP systems to support lean manufacturing.

ERP deployment, management, and evolution are significant operational concerns in today's cost-conscious business climate. The performance of enterprise applications designed to streamline ERP processes and operations is dependent on the fundamental network infrastructure. Companies should take a holistic view of their mission, critical applications, and networking environments and include best-in-class networking solutions.

Enterprises have long made flamboyant statements about getting closer to their customers and streamlining operations. ERP, CRM, and SCM applications and the organizations implementing them are in part, *bringing teeth* to those superior intentions. It is not a trouble-free process, however. In reality, the highly publicized failures of these initiatives have in some minds brought concern about these applications and their possible benefits. However, more and more organizations are moving

ahead with these initiatives, and the successful organizations will gain from higher margins, better customer relations, and improved back-office operations.

The core idea of ERP is complete integration of an organization's computing system. Despite obvious advantages to vendors of each adopting organization installing the entire suite of modules offered, however, only about half of the implementations seem to be of this nature. It is very common for organizations to select only a few of the available modules, which makes great sense because not every organization needs every module vendors develop. In fact, vendors seem to recognize this through their recent emphasis on products tailored to specific industry.

Organizations may have other very important reasons to implement ERP products differently than the vendors' design. A very important one is that full system implementation is very expensive. By selecting particular modules, organizations can cut initial implementation costs significantly. Although vendors might argue that in the long run this might be ineffective than full implementation now, in practice information systems projects rarely go as planned, nor do they tend to stay within originally planned budgets. Thus, organizations reduce risk greatly by trying particular modules first, often seeing how the new system is digested by the organization, before plunging to additional modules.

There is also a difference in the difficulty of implementing different modules. Financial and accounting modules are typically installed first, as they involve the most structured application. This makes it easier to implement, and easier for the organization to digest. Other modules such as materials management and planning also tend to work well. Conversely, support to less structured environments, such as sales and marketing, tend to be more problematic.

Outline of the Book

Chapter 1 introduces various information systems available to support supply chain operations. Chapter 2 describes the key supply chain process of MRP and its relationship to ERP systems. Chapter 3 further elaborates the ERP options, to include APS as an available module or as a standalone system. Chapter 4 discusses the relationship of business process

reengineering with these integrated systems. Chapter 5 presents a systematic selection technique. Chapter 6 describes the issues in implementing such systems, along with the demonstration of project management in the supply chain software context. Chapter 7 summarizes three issues in implementing these systems.

Notes

Chapter 1

1. Ptak and Smith (2011).
2. Manetti (2001).
3. Moser and Ward (2008).
4. Gonzalez (2007).
5. Saenz de Ugarte, Artiba, and Pellerin (2009).
6. Olson and Kesharwani (2010).
7. Olson (2004).
8. Mabert et al. (2000); Olhager and Selldin (2003); Katerattanakul et al. (2006).
9. Wang, Chen, and Xie (2010).
10. Wang et al. (2010).