LONGITUDINAL STUDY OF SUPPLY CHAIN INFORMATION SYSTEMS

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PREVIOUS RESEARCH

Production and logistics information systems have a long history of research [13, 14, 15, 22, 23]. A complete discussion of all studies performed would be too extensive for this article; however, there are two key areas that warrant examination. The first is the usage rates of various production and logistics information system tools. A series of research studies and related articles published from 1975 to 1995 were the source of background information [9, 10, 11]. The studies collected information on 25 critical capabilities and components of logistics information systems and provided the basic structure for the current research. A number of additional studies added to the longitudinal research in this area [10, 16, 21].

The second area of interest is the current trends in logistics and supply chain information systems. A number of relevant information technology innovations have emerged since the 1995 iteration of the survey [11]. Recent research has identified new types of supply chain management tools [12], inventory-related software [8, 17], functional execution systems for logistics and operations [20], and transportation and distribution software suites [1]. Enterprise resource planning (ERP) [2, 3, 18, 19] and electronic commerce (EC) are topics that warrant investigation [4, 5, 6, 21, 24] as well. These new tools and topics were added to the study for current analysis and could potentially be included in future longitudinal analysis.

METHODOLOGY

Research methodology supported two primary objectives. The first was to gather appropriate longitudinal data regarding the production and logistics components of supply chain information systems (SCIS). The other was to reach a wide variety of U.S. executives with supply chain responsibilities (inventory management, transportation, production, etc.) across a range of firm types. A broad cross-section of respondents would help increase the ability to generalize the research findings. Given these objectives, a mail survey was determined to be the most appropriate data collection instrument.

To ensure that the current study addressed the same issues as the first four iterations of the research—the growth of information systems in logistics and throughout the supply chain—the initial sections of the current questionnaire mirrored the previous questionnaires. The same questions were asked and they were presented in the same format as in the first four studies. The only change was the addition of a "current trends" section to gather data on new tools, techniques, and systems. This approach allowed the instrument to generate data not only for historical comparisons, but also for the analysis of new technologies.

The eight-page questionnaire was sent to 1,949 companies to ensure that a diverse audience was reached. These companies were chosen from membership databases and conference attendee lists of a number of relevant professional organizations. Consulting companies and academic institutions were excluded from the mailing list because they were not part of the target audience. The primary sources of potential participants were the membership database of the Council of Logistics Management and the attendee list of the Distribution Computer Expo.

Completed questionnaires were received from 265 people. After the undeliverable surveys were removed from the sample, the response rate was 13.6%. This appears to be an acceptable rate for a lengthy questionnaire at a time of reduced response rates for the

TABLE 1: Respondent Demographics

Demographic Category	Percent of Companies
Primary business	
Manufacturing	61.9*
Services (retailing, wholesaling, etc.)	25.4
Not indicated	12.7
Industry	
Consumer durable products	11.6
Food production and processing	9.7
Textiles	8.5
Chemicals	6.9
Electrical machinery and equipment	6.2
Third-party logistics	5.4
Drug	4.2
Paper, packaging and related	4.2
Other (six remaining categories)	6.9
Not indicated	35.1
Respondent titles	
Manager	24.7
Director	26.9
Vice president	23.7
CEO/president	2.3
Other/not indicated	22.4
Division annual sales**	
Under $100 million	75.7
Between $100 million and $1 billion	10.8
Above $1 billion	0.1
Not indicated	12.7

* Some areas do not add to 100% because of rounding.
** Because of the wide range of answers regarding annual sales, 1998 figures were validated using public records.

traditional mail survey [7]. A test of nonresponse bias (based on a test of public information of company demographics) found no significant difference between respondents and nonrespondents.

RESEARCH FINDINGS

Respondent Demographics

Given the large number of respondents, almost every type of business, industry, and size of company was represented in the results. Table 1 provides a breakdown of the respondents' organizations by those key demographic categories.

Demographic information indicates that the goal of diversity was achieved in terms of industry representation and respondent title. Although most respondents work for manufacturing firms, a sizable number of responses were received from service organizations. That allowed comparative analysis of the two respondent groups.

Historical Trends

The primary purpose of the study was to track the changes in information systems use for production, logistics, and other supply chain management functions. Thus, the first section of the survey focused on the relevant data elements captured by each company's information system. Twenty-five data elements regarding manufacturing, sales, logistics, and related areas were examined in accordance with the previous surveys. Respondents were asked whether their organizations' information system incorporated these 25 items. The data elements were grouped into functional areas for analysis and presentation.

The product-related data elements had the highest level of computerization, both in the current survey and throughout past studies. Companies are effectively incorporating product and production data into their SCIS. Furthermore, computerization in all areas grew steadily during the five iterations of the study, as indicated in table 2.

Automation of inventory- and warehousing-related data is far less uniform among respondents. Table 3 highlights extremely high levels of computerization of data related to inventory levels, open purchase orders, and back orders—key elements in the warehouse management system (WMS), ERP, and other SCIS being used today. However, there are a number of critical information needs that are not being provided by current information systems. In particular, cost measurements and related data elements are not being generated on a widespread basis.

This situation can create inventory management challenges and/or the need for manual control of warehouse activities. Although the typical company knows

TABLE 2: Percent of Information Systems Providing Product-Related Data

Data Element	1975	1982	1987	1992	2000
Product description	83	94	94	90	95
Master order file	24	89	90	93	97
Production costs	60	71	70	69	71
Packaging costs	34	41	45	47	56

TABLE 3: Percent of Information Systems Providing Inventory and Warehouse Data

Data Element	*1975*	*1982*	*1987*	*1992*	*2000*
Inventory levels	84	93	94	93	97
Back orders	74	74	75	78	85
Carrying costs	29	38	43	42	42
Stockout costs	7	10	15	17	14
Open order data	51	71	80	88	95
Deleted orders	41	69	71	80	81
Forecast sales	65	67	72	68	69
Storage costs	29	28	39	39	41
Handling costs	30	31	42	41	47

how much inventory is in a distribution facility, the information systems do not provide information regarding the associated costs of carrying or processing the inventory. This lack of cost knowledge may make it more difficult for organizations to effectively control warehousing costs, analyze supply chain tradeoffs, or make fully informed inventory decisions.

According to respondents, the computerization of transportation data by SCIS is common (table 4). In general, the automation of key information in this area grew steadily during the past five-year time period. However, the availability of transportation data via SCIS is not as high as the availability of product elements or top inventory elements. Although nearly all respondents' systems can produce order files and freight documents, a quarter to half of them do not provide key transactional data or support important financial capabilities. These organizations lack important transportation management system functionalities, which may reduce the efficiency of transportation operations, limit the ability to analyze performance, or make route/schedule/carrier selection analysis more manual.

In general, the current research revealed a continuation of positive historical trends. Of the 25 elements presented, 18 were included in SCIS to a greater degree than found in the previous iteration of the survey. One element (carrying cost) remained the same and one was included (stockout costs) to a slightly lower degree. Given the increasing reliance on information technology in production, logistics, and supply chain management, it would have been very surprising to uncover downward trends in data capture levels for additional data elements.

Without question, there remains ample opportunity to improve the use of SCIS to provide important production and logistics information. The low levels of data capture of inventory costs, warehousing storage and handling costs, and transportation operations create a key knowledge gap in many supply chains.

Cost control, supply chain efficiency, and customer service may suffer because of this dearth of data. Ultimately, SCIS that fail to include these elements may limit a company's ability to initiate and benefit fully from supply chain partnerships. Therefore, it would be highly beneficial for organizations to enhance the capabilities of their SCIS to provide additional cost and operational data.

Manufacturing Highlights

Differences between manufacturers and other types of companies (retailers, distributors, etc.) represented in the current study was an important area of examination. A comparison of the survey data was made

TABLE 4: Percent of Information Systems Providing Transportation Data

Data Element	*1975*	*1982*	*1987*	*1992*	*2000*
Carrier file	57	53	64	66	75
Freight rates	45	36	61	63	71
Transit times	35	30	35	37	52
Shipment schedules	34	51	57	59	70
Open order files	84	85	89	92	94
Manifest/BOL	49	55	70	71	83
Freight bill payment	51	56	62	63	71

using two statistical tests. (The tests, Pearson chi-square and Kendall's tau-c, were used to identify statistically significant findings. Findings with a *p*-value of less than .1 or .05 are discussed in this section.). The data were examined to identify divergences between the two groups for all the relevant survey questions.

There were a number of very important areas in which statistically significant differences existed between the two test groups (i.e., the *p*-value was less than .10) The first area dealt with some of the costs. Not surprisingly, manufacturers were statistically very much more likely to track production costs ($p = .000$). However, manufacturers were also more likely to gather data on packaging costs ($p = .001$) and handling costs ($p = .099$) than were nonmanufacturing organizations. No significant differences were found between the two groups for storage, inventory carrying, or stockout costs.

The second group of differences occurred in the evaluation of the importance of various types of information throughout the supply chain. The somewhat obvious finding was that manufacturers felt production planning information was more important than did nonmanufacturers ($p = .000$). The important finding was that manufacturers reported receiving better production planning information than did other types of companies ($p = .000$). Another area that manufacturers identified as more important was raw materials/work in process inventory management ($p = .000$). Finally, manufacturers highlighted the importance of intracompany transportation ($p = .028$) and outbound transportation ($p = .093$) more than did other respondents.

Current Trends

The study addressed emerging issues and current trends regarding SCIS. Respondents were asked to identify their current activities and/or future plans for using electronic commerce (EC) and ERP tools in their supply chain activities.

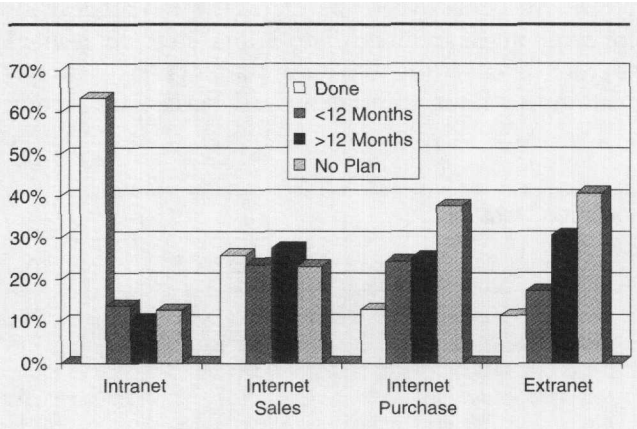

FIGURE 1: EC implementation levels and intentions

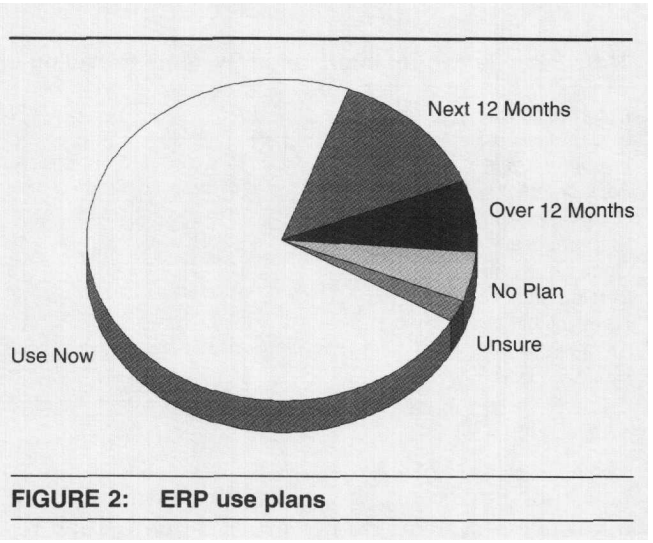

FIGURE 2: ERP use plans

EC was used to varying degrees depending on the application (see fig. 1). Many companies use EC to improve information sharing across the organization. More than 60% of respondents said that their company uses an intranet to communicate with internal customers. An additional 12% plan to install an intranet by the end of the year. However, the ability to share information with supply chain partners using new EC tools is much more limited. This was the least-used EC tool, with only about 10% of respondents currently employing the technique. It appears that electronic data interchange (EDI) continues to be the communication tool of choice.

EC-based transactions are also relatively low. Only half the respondents said they would provide Internet-based sales by the end of 2000. There was an even lower use of EC by respondents for sourcing materials and products. Less than 15% of the companies were placing orders via EC tools. It appears that EC, especially from the business-to-business transaction standpoint of manufacturing respondents, has not achieved widespread acceptance and implementation.

The other major tool of interest was the use of ERP. Respondents were asked whether their company currently uses an ERP program or intends to implement one in the near future. Figure 2 indicates that 72.3% of respondents have already implemented some portion of an ERP system. Another 13.3% said that their company planned to implement a system within the next 12 months. Only a small percentage of respondents reported no intention of implementing an ERP system.

Respondents were also asked to identify the types of ERP applications and subsystems they have installed

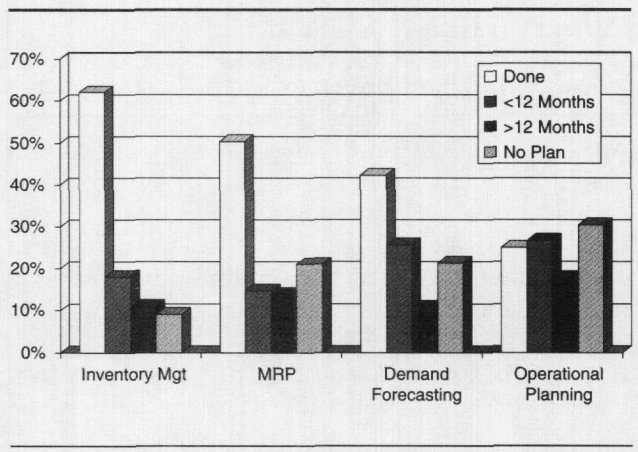

FIGURE 3: ERP subsystem implementation plans

or plan to install. The four most relevant areas to production, logistics, and SCM planning are identified in figure 3.

It appears that the manufacturing- and inventory-related ERP applications are gaining widespread use. More than 60% of respondents use an ERP program to manage inventory. Approximately 50% of the companies use ERP in conjunction with a material requirements planning (MRP) program.

Demand forecasting and operational planning aspects of ERP are not as widely used by respondents. Often, these areas require the involvement of and external information from supply chain partners. Trust/confidentiality issues and the lack of extranet capabilities may be slowing respondents' ability to use these ERP tools. Apparently, these and other information-sharing problems are expected to decline; one-third of respondents plan to implement both capabilities during the next 12 to 24 months.

Results indicate that both EC and ERP are emerging as valuable SCIS tools. However, it is apparent that respondents are not progressing at a uniform pace, and they are not choosing to adopt all subsystems. That is likely due to the various types of companies within the sample (i.e., manufacturers, distributors, retailers, etc.). Finally, it appears that the vast majority of companies will be using both EC and ERP to manage inventory and manufacturing operations in the near future.

Manufacturing Highlights

The data in the current trends section were also analyzed to determine whether there were any significant differences between manufacturers and the other types of respondent firms. The statistical tests and criteria employed for that analysis were similar to those used for between-group comparisons of the longitudinal data.

These tests revealed that manufacturers did not believe EC was as important as did nonmanufacturers ($p = .026$). Furthermore, manufacturers were much less likely to implement Internet-based sales ($p = .001$) or extranet systems to communicate with supply chain partners ($p = .040$) than were their nonmanufacturing counterparts.

On the other hand, manufacturers have taken the lead in some ERP activities. They believed that ERP was more important to the success of the company than did the other respondents ($p = .000$). That belief led to manufacturers being more likely to implement the ERP production scheduling and MRP than were nonmanufacturers ($p = .000$). However, manufacturers were no more likely to implement the other portions of an ERP system: logistics planning, human resource management, financial management, demand forecasting, or inventory management.

MANAGERIAL IMPLICATIONS

Benchmarking SCIS

The longitudinal data produced by the study provide benchmarking information for managers with supply chain responsibilities. A great many data regarding the level of computerization for the various tactical elements of SCIS are provided. Companies can compare themselves to the overall results to learn where they exceed, meet, or lag respondents in widely available production and inventory data capabilities of SCIS. They may also find opportunities to differentiate themselves by implementing some of the infrequently employed operational data elements—especially in the inventory cost, warehousing operations, and transportation transaction areas.

In the area of production the obviously high levels of computerization emphasize some early adoption of SCIS in this area. However, there still remain opportunities with the cost data. The second portion deals with inventory and warehouse data. Again, executives can use the longitudinal data to benchmark the current level of SCIS implementation within their organizations. As with production, there are significant opportunities to improve in the area of capturing cost data.

Similarities between these two areas present additional possibilities to supply chain management executives regarding customer service. The high levels in certain data information areas may set a baseline for meeting internal and external customers' requirements. Furthermore, as the level of cooperation be-

tween supply channel members increases, companies downstream may demand higher levels of information. Also, organizations able to effectively manage their own inventory and production data may be able to help downstream companies utilize vendor-managed inventory. This should improve relationships and sales with customers based primarily on the use of higher levels of SCIS. Companies with advanced SCIS can expect to gain competitive advantage with existing customers and attract new clients.

There are also upstream benefits to increasing SCIS beyond the level of competitive necessity. Companies with advanced data collection and distribution methods can provide suppliers with more and timelier information. The higher levels of SCI could help promote various tools and techniques such as Just-in-Time, total quality management, and cost reduction. The ability to enhance communication upstream should lead to an improved flow of materials and/or finished goods into the organization.

Another area of benefit from benchmarking SCIS is the flow of information between various business functions within the organization. The flow of internal information is necessary to ensure that a company operates efficiently. Implementation of the various systems that collect and share critical information between areas is necessary to place reorders, create accurate invoices, schedule transportation, mail marketing information, and so on. An increase in effective internal communication should allow the various business silos to interact more successfully.

The final opportunity for benchmarking involves transportation. The lower level of data collected by the SCIS in this area presents significant opportunities to provide higher levels of service to internal and external customers. The organization would benefit by offering customers higher levels of transportation information and additional selections in transportation options. Also, an improved SCIS could allow a company to control inbound transportation to the benefit of both the supplier and the controlling organization.

The longitudinal data provide supply chain managers with valuable insights into the need for robust supply chain information. The upward trends in data element capture indicate that organizations across the supply chain need this type of information and expect their partners to provide it. Companies upstream and downstream in the supply chain are implementing supply chain strategies that require accurate, timely, and tailored information. The SCIS must be able to produce the 25 basic elements discussed in this article as well as provide inventory visibility, cost knowledge, and planning capabilities.

Current Areas and Possible Trends

The information provided by the current trends analysis can be of value to the supply chain manager. Although some EC tools have not been widely embraced by respondents, their potential should not be underestimated. EC can provide the connectivity that is so vital to supply chain excellence. It can provide a standardized method to communicate with many different types of customers and suppliers as opposed to EDI, which is far more specialized. The limited adoption rates of extranets and transactional capabilities found by this research should not be viewed as a warning sign to avoid EC. Rather, results suggest that an opportunity still exists to create leading edge information-sharing capabilities within supply chains.

Also critical for SCIS is a method of standardizing the internal and external data. The Internet will help standardize the communication process, but the actual data needs usually vary by user. Employing ERP in some form can help reduce the variation this process creates by providing a standardized-data-warehouse type of approach.

Although most supply chain professionals have first- or secondhand knowledge of ERP disasters, providing information among users is an important goal of ERP. The standardization of data between various functions within a company by ERP can be carried over to the SCIS of other channel partners. The only limits on who may access the information are those placed by the host organization. Other ERP and software programs can read the data stored within the host ERP, which reduces the technical barriers to allowing access to data across the supply chain.

Managers can use the ERP information to better understand how respondents utilize these tools and when they plan to implement ERP tools. In addition to standardizing data, ERP provides valuable information to users across the supply chain. It is being widely employed to manage production and inventory activities, and the use of demand forecasting applications is poised to grow dramatically during the next year. Organizations must possess (or rapidly develop) the capability to feed information into these ERP systems and effectively use information they generate.

SUMMARY

The research discussed in this article provides a number of important findings useful to practitioners and academicians. The longitudinal analysis reveals that the upward trend in the computerization of production and logistics information continues. This finding highlights the importance to supply chain profession-

als of constantly upgrading and improving their organizations' SCIS to capture this type of information. Remaining current in the needs of internal and external information systems is an ongoing challenge that organizations must heed.

Although the longitudinal study findings support continuous improvement and investment in SCIS, it should be noted that across-the-board implementation is neither appropriate nor financially possible. Not a single respondent company collected all the data areas nor used all the system tools. Each respondent chose to implement a tailored set of system applications because of a lack of time, capital, or expertise. It is unlikely that other organizations can afford the resources to apply all the systems opportunities at this time. Every company must make a rational decision about which information system tools to employ. The findings should help supply chain managers and executives identify candidates for implementation.

Statistically significant differences were found to exist between manufactures' SCIS and that of other channel members. This finding presents opportunities for material suppliers. Companies that support manufacturing operations as customers must identify the key SCIS needs of this group. Furthermore, manufacturers must ensure that the SCIS differences do not negatively affect customers farther down the supply chain.

Finally, the research provided basic implementation information regarding the "newer" SCIS technologies that include EC and ERP. Both of these areas still hold tremendous potential in the business-to-business arena. They may become the most important part of communication within supply chain management during the next few years. Results suggest that companies are moving from a transaction focus of "should we sell/buy on the Web" to an information exchange focus of "how do we work with partners through the Web." Standardized ERP information and EC facilitating tools (e.g., extensible markup language) will likely serve to enhance, simplify, and increase electronic information sharing between supply chain partners.

In conclusion, the growth of logistics and production information systems as part of the SCIS continues throughout industry. Business leaders need to decide how to improve their operations and inventory management through effective use of these systems. The information contained in this article should provide valuable insight for those improvement initiatives.

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