The impact of ERP on supply chain management: Exploratory findings from a European Delphi study

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Abstract

This article presents results from a Delphi study on the future impact of enterprise resource planning (ERP) systems on supply chain management (SCM). The Delphi study was conducted with 23 Dutch supply chain executives of European multi-nationals. Findings from this exploratory study were threefold. First, our executives have identified the following key SCM issues for the coming years: (1) further integration of activities between suppliers and customers across the entire supply chain; (2) on-going changes in supply chain needs and required flexibility from IT; (3) more mass customization of products and services leading to increasing assortments while decreasing cycle times and inventories; (4) the locus of the driver's seat of the entire supply chain and (5) supply chains consisting of several independent enterprises.

The second main finding is that the panel experts saw only a modest role for ERP in improving future supply chain effectiveness and a clear risk of ERP actually limiting progress in SCM. ERP was seen as offering a positive contribution to only four of the top 12 future supply chain issues: (1) more customization of products and services; (2) more standardized processes and information; (3) the need for worldwide IT systems; and (4) greater transparency of the marketplace. Implications for subsequent research and management practice are discussed.

The following key limitations of current ERP systems in providing effective SCM support emerge as the third finding from this exploratory study: (1) their insufficient extended enterprise functionality in crossing organizational boundaries; (2) their inflexibility to ever-changing supply chain needs, (3) their lack of functionality beyond managing transactions, and (4) their closed and non-modular system architecture. These limitations stem from the fact that the first generation of ERP products has been designed to integrate the various operations of an individual firm. In modern SCM, however, the unit of analysis has become a network of organizations, rendering these ERP products inadequate in the new economy.
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1. Introduction

After two decades of streamlining internal operations, boosting plant productivity, improving product quality, and reducing manufacturing costs, companies are focusing on supply chain strategies as the next frontier in organizational excellence. One reason for these initiatives may be the substantial cost reductions to be achieved from improving logistics performance. In Europe, logistics costs range from 6% to 15% of total turnover (AT Kearney, 1993). In the United States, American companies spent $670 billion on logistics and supply chain-related activities in 1993, corresponding to 10.5% of GDP (Kurt Salmon, 1993). Another reason appears to be the advent of the network economy (Castells, 1996; Arthur, 1996), which is triggering profound changes in the scope and impact of supply chain management (SCM). In this network economy, the totally vertically integrated business firm may be becoming the exception and ever changing networks of organizations the rule (Tapscott, 1996; Kelly, 1998; Fine, 1998). Markets are becoming more transparent, customer demands are being met in a more customized manner (Pepper and Rogers, 1999; Jensen, 1999) and, in general, the rate of change in the business world keeps increasing (Brown and Eisenhardt, 1998; Gleick, 1999). All these developments are having a profound impact on the ways in which supply chains of (extended) enterprises are to be managed.

The literature on new business models for the Internet age is growing rapidly (e.g., Chesborough and Teece, 1996; Downes and Mui, 1998; Malone and Laubacher, 1998; Porter, 1998; Tayur et al., 1998; Hagel and Singer, 1999). In particular, Fine (1998) is emphasizing that, as the business environment changes, supply chain *design* as opposed to supply chain *coordination* is becoming a core competency. His theory-building work is being followed up by empirical research confirming his findings (Mendelson and Pillai, 1999).

Interestingly enough, a second business-driven phenomenon, enterprise resource planning (ERP) is sweeping across industry at the same time. ERP, the logical extension of the material requirements planning (MRP) systems of the 1970s and of the manufacturing resource planning (MRP II) systems of the 1980s, is now a de facto standard in industry.

Two considerations make this simultaneous development very interesting. The first is that, although from a managerial decision making perspective the two trends are quite closely linked, they seem to be evolving independently in industry. ERP is a comprehensive transaction management system that integrates many kinds of information processing abilities and places data into a single database. Prior to ERP, this processing and data were typically spread across several separate information systems. For example, a firm could have separate systems for purchasing, order management, human resources, and accounting, each of which would maintain a separate data source. ERP would subsume these into a single seamless system. Researchers have pointed to information system fragmentation as the primary culprit for information delays and distortions along the supply chain (McAfee, 1998). Information delays and distortions, in turn, cause the famous bullwhip phenomenon (Forrester, 1961 and Lee et al., 1997). An ERP system could potentially enhance transparency across the supply chain by eliminating information distortions and increase information velocity by reducing information delays. Hence, there is reason to believe that ERP adoption could be associated with significant gains in supply chain effectiveness. But despite the presence of such close interactions, many supply chain improvement programs and ERP implementation efforts appear to be managed independently by different people.

The other reason why the simultaneous rise in the focus on ERP and SCM is so interesting is that academics appear to be far less interested in ERP

than they are in SCM. For instance, Fine (1998) does not even mention the term, despite the integrative potential of ERP systems. In fact, one can argue that very little academic research has been done on ERP, except for research on reasons for implementation and on the challenges of the implementation project itself (Upon and McAfee, 2000; McAfee, 1998; Austin and Nolan, 1999; Davenport, 1998). In the field of operations management, this is reminiscent of the academic treatment of MRP II and JIT, important industry phenomena of the past two decades. Little research was conducted on these phenomena and therefore few well-grounded recommendations could be provided in a timely manner to companies struggling with these complex undertakings (e.g., Burns et al., 1991, for MRP II and White et al., 1999, for JIT).

Our research is therefore aimed at rekindling academic initiatives focusing on the interactions between ERP and SCM. From the above historical perspective, it should be clear that, in an exploratory phase, we feel we should first listen to practitioners. What do experts from business, who recently have been or are currently going through ERP implementations, think about its strengths and weaknesses with respect to challenges in business and SCM? To address this question, we have set up a Delphi study with 23 Dutch supply chain executives, all working for European multi-nationals. From this study, it became clear that there are indeed close interrelations between SCM and ERP. Moreover, these interrelations are not all positive. Our exploratory findings suggest that ERP is seen as contributing to SCM in technical areas such as standardization, transparency, and globalization. Our experts also found that current ERP systems can be limiting progress in SCM from a strategic perspective because of their low flexibility and their typical single-company scope.

The remainder of the paper is organized as follows. Section 2 introduces our working definitions for SCM. Section 3 analyzes how ERP could be expected to support SCM initiatives. Section 4 describes the design of our Delphi study. The results from the Delphi study are presented in Section 5. These results fall in three areas: they reconfirm from a practice viewpoint the appro-

priateness of a dynamic perspective on current SCM trends, show how ERP can both support and limit these SCM trends, and give underlying reasons for the potentially limiting role of ERP here. We discuss these findings and their business and technology implications in Section 6. Section 7 concludes the paper.

2. Supply chain management in the network economy

We view a supply chain as a network consisting of suppliers, manufacturers, distributors, retailers, and customers (Fig. 1). At the operational level, this network supports three types of flows that require careful planning and close co-ordination:

- *material flows:* which represent physical product flows from suppliers to customers as well as the reverse flows for product returns, servicing, and recycling;
- *information flows:* which represent order transmission and order tracking, and which coordinate the physical flows; and
- *financial flows:* which represent credit terms, payment schedules, and consignment and title ownership arrangements.

The network, in turn, is supported by three pillars:

- *processes:* which embed the firm's capabilities in logistics, new product development, and knowledge management;
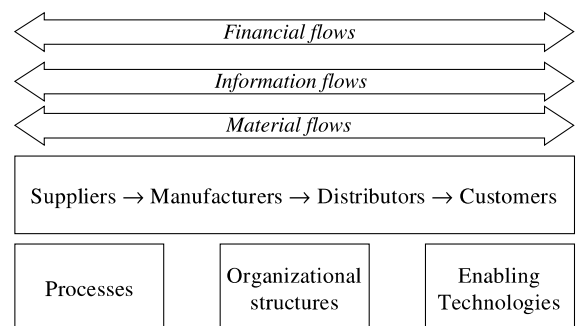
Fig. 1. An integrated model of the supply chain.

- *organizational structures*, which encompass a range of relationships from total vertical integration to networked companies as well as management approaches, and performance measurement and reward schemes; and
- *enabling technologies*, which include both process and information technologies.

Supply chains perform two principal functions (Fisher, 1997): the *physical* function of transformation, storage and transportation, and the *market mediation* function of matching demand and supply. While the physical function has been extensively studied within the production control and inventory management literature with a view to locally minimize cost, innovative approaches to the market mediation function were suggested only recently. These customer-oriented approaches, which focus on coordination in the entire chain, are classified in Fig. 2.

Supply chain design is concerned not only with the specification of customer zones, selection of manufacturing and distribution facilities, and allocation of product families to these sites, but also with the prioritization of the capabilities to be developed and retained internally, and the forging of new partnerships with other entities along a supply network. According to Fine (1998), supply chain design ought to be thought of as a dynamic process of assembling chains of capabilities and not just collaborating organizations.

This *dynamic* view is particularly important in a fast-evolving world where new products and emerging distribution channels necessitate a continuous review of supply chain design decisions. We will refer to the rate of change in products, processes, technologies, and organizational structures within an industry as that industry's *clockspeed*. Just like product design has an enormous impact on manufacturing performance, superior supply chain design offers significant payoffs in managing and coordinating supply chain activities.

This dynamic view may necessitate different perspectives (or mappings) for supply chain design. These perspectives include: organizational supply chain, capability supply chain, and technology supply chain (Fine, 1998).

- An *organizational* map shows all the entities in a company's extended supply chain and illustrates all value-adding activities performed by each organization along the chain.
- A focus on *technology*, on the other hand, traces the lines of dependency upstream to the suppliers and downstream to the customers, who provide and use, respectively, key technologies along the supply chain.
- Finally, a focus on *capability* aims at identifying the key business process capabilities, which currently exist as well as which are desirable, along the supply chain.
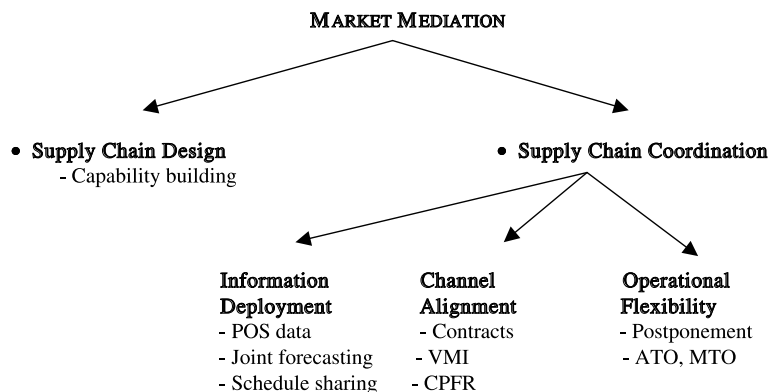

Fig. 2. Matching demand and supply in a supply chain.

Note that such mappings are also consistent with our thinking on the three pillars supporting the supply chain (Fig. 1).

Supply chain coordination, is concerned with the coordination of the three types of flows once the supply chain design is finalized. Effective supply chain strategies (Fig. 2) combine a range of approaches from operational flexibility such as the make-to-order (MTO) or postponement capability, channel alignment (e.g., vendor-managed inventories, VMI), and joint decision making through information deployment (e.g., collaborative planning, forecasting and replenishment, CPFR). These approaches, in turn, typically lead to new forms of organizational structures (e.g., process orientation) and new forms of interorganizational collaboration (e.g., outsourcing via third-party service providers or contract manufacturers). This transformation has coincided with the emergence of information and communication technologies facilitating closer collaboration and promoting supply chain transparency. Technological breakthroughs, particularly in information technology, can significantly enhance both the efficiency of the network operations and the effectiveness of customer service on a global basis.

Fine (1998) argues that all competitive advantage is temporary. From this perspective, supply chain solutions can, at best, be temporary as well. In other words, SCM is a *dynamic* challenge that requires a series of solutions in the face of changing industry requirements. The validity of a particular supply chain solution is therefore determined by the clockspeed of the industry, which reflects the rate of change in products, processes, technologies, and organizational structures in that industry.

3. Enterprise resource planning systems

Our research focuses on understanding the impact of ERP systems on supply chain performance. Our objective is to establish conditions under which ERP can be a critical enabler or a severe handicap for superior supply chain performance. There are different ways of defining ERP: a business perspective, a technical perspective or a functional perspective. We discuss each of these in some detail below.

One way of looking at ERP is as a combination of business processes and information technology. For instance, J.D. Edwards, an American ERP system vendor, defines ERP as an umbrella term for integrated business software systems that power a corporate information structure, controlling a broad range of activities, from the procurement of supplies to shop floor control and financial accounting. It provides the glue that binds management functions across geographic sites and complex heterogeneous networks. From a more strategic perspective, JBA, a British consulting firm, views ERP as a business approach that starts in the boardroom and permeates the entire organization.

From a technical perspective, ERP can be seen as the logical extension of MRP systems of 1970s and of MRP II systems of 1980s. ERP's impact, however, has been much more significant. Following the American Production and Inventory Control Society's (APICS) "MRP Crusade," sales of MRP software and implementation support exceeded one billion dollars in the United States by 1989. Worldwide sales of ERP packages together with implementation support, on the other hand, have exceeded fifteen billion dollars at the turn of the century with annual growth rates of over 30%. In spite of the significant slowdown in IT spending, ERP is expected to become a 10-billion dollar industry by 2004. A recent survey by *Fortune* magazine revealed that seven out of the top ten global pharmaceutical and petroleum companies, nine out of top ten global computer companies, and all of the top ten global chemical companies are using *SAP*'s *R/3*.

Functionally, an ERP system primarily supports the management and administration of the *deployment* of resources within a single (though possibly multi-site) organization. These resources can be materials, production capacity, human labor, or capital. Roughly speaking, current ERP systems contribute to this aim by providing three different types of functionality:

- A *transaction processing* engine, allowing for the integrated management of data throughout the enterprise;

- *Work flow management* functions controlling the numerous process flows that exist in the enterprise, such as the order-to-cash process or the purchasing processes;
- *Decision support* functions, assisting in the creation of plans (e.g., by doing an MRP run), or in deciding on the acceptance of a specific customer order (e.g., by performing an available-to-promise (ATP) check).

As a result, ERP provides the following business functionality:

- ERP systems have replaced a myriad of old, undocumented, non-integrated legacy systems by state-of-the-art, integrated and maintainable software. It is hard to overestimate the crucial importance of this obvious point. As an illustration, during the preparation of our workshop, one interviewee described a real-life situation where a relatively simple change in the logistic process (direct, and therefore cross-border, delivery form factory to customer) was found to be very sensible. However, implementation of this process had to be canceled because it would involve the modification of six separate IT systems. Just the effort needed to convince their owners to agree to the change was already expected to be higher then the potential savings. The number of local IT systems to be replaced by an integrated ERP system usually runs into the dozens up to a hundred or more in multinational companies.
- ERP systems provide an enterprise transaction backbone that constitutes the glue between all kinds of best-of-breed solutions for specific processes or business areas. It allows these best-of-breed solutions to leverage the investments made in the ERP systems, and partly explains the impressive ROI's achieved by these solutions.
- ERP systems can be instrumental in transforming functionally oriented organizations into process oriented ones. The very nature of the ERP system forces one to think process-wise, rather than department-wise. Indeed, some of the unexpected benefits of ERP implementations may well stem from improved communi-

cation between different departments across business processes (McAfee, 1998).

Implementing an ERP system in a company is normally a formidable task. A typical ERP implementation initiative takes anywhere between one and three years and typical budgets are in tens to hundreds of millions of dollars. Clearly, there is an urgent need for understanding the costs and benefits of ERP, the implementation challenges, and the management of the system once it goes live. Yet, in spite of the explosive growth of the ERP ecosystem, very little academic research has been done on the business impacts of ERP systems once they are implemented. Recently, several surveys by management consultancies and research institutes have shown that, in general, ERP implementations so far have yielded very little business benefits (Buckhout et al., 1999). Popular press and trade journals have documented both stellar successes and miserable failures (AVNET, 1999), but with very little explanation on the underlying causes. The current paper is a first attempt at understanding the causal relation between ERP and SCM.

4. Research method

4.1. A Delphi study research design

Since academic literature is relatively thin compared to the vast experience accumulated by practitioners in implementing ERP systems, we felt that it would be sensible to develop our initial theories by listening to experts from business. For this type of exploratory, theory-building research, a Delphi study is an appropriate research design. In general terms, the Delphi study is a method for structuring a group communication process so that the process is effective in allowing individuals to deal with complex problems (Linstone and Turoff, 1975; Delbecq et al., 1975). The Delphi technique lends itself especially well to exploratory theory building (Meredith et al., 1989; Neely, 1993) on complex, interdisciplinary issues, often involving a number of new or future trends

Table 1
Industry backgrounds of participants in the Delphi study

Sector	# Participants
Automotive	2
Chemicals	5
Consumer electronics	2
Food & beverages	2
Logistics service providers	7
Petrochemicals	1
Semiconductors	2
Telecommunications	2
Total	23

(e.g., Klassen and Whybark, 1994; Akkermans et al., 1999).

One essential characteristic of the Delphi study is the group size of at least 20 respondents to overcome risks of individual biases contaminating the aggregate responses. A group size of 23 supply chain executives from a variety of industries (Table 1), where ERP and SCM are both very important facts of contemporary business life, satisfies this condition. Moreover, all participants were selected on the basis of their personal experience in these two intersecting areas of interest.

Another defining characteristic of Delphi studies is the opportunity of receiving feedback on earlier comments as well as the opportunity of further elaboration on the basis of that feedback. In this particular research design, this feedback was almost instantaneous and continuous, thanks to the use of an electronic group decision support system (GDSS) (Nunamaker, 1989; Eden and Radford, 1990; Jessup and Valacich, 1993). This GDSS (the package used was *group system* of *ventana* systems) projected respondent comments on a central screen and on each participant's individual screen immediately after these were typed in on the laptop computers that were available to everyone. Participants could read everybody else's entries, they could comment on them or add further explanatory texts to their own original entries. All such entries were done anonymously. Meanwhile, participants could also conduct oral discussions with their neighbors or with the facilitators. Insights from these conversations usually quickly found their way into entries submitted for reading by the entire group.

4.2. The Delphi workshop script

On June 30, 1999, all participants convened for the day in a room that enabled GDSS-supported conferencing in both plenary and subgroup mode. The analytical goals of the day were clearly explained at the start of the workshop:

1. identify key SCM trends;
2. assess the expected business impact of these SCM trends;
3. assess the expected ERP support for these SCM trends;
4. identify key limitations (if any) in current ERP systems for effective SCM support.

In order to obtain these results, an eight-step workshop script was employed (visualized in Fig. 3). Horizontal bars indicate the number of different items that resulted from each step.

Step 1: Position and define SCM and ERP.

In order to avoid confusions regarding terminology, a brief explanation was given by one of the authors. Broadly speaking, this explanation was not too different from the contents of Sections 2 and 3 of this article. It summarized what was known from the literature prior to the Delphi study.

Step 2: Generate SCM trends (22 items).

Next, participants were asked to key in 2–3 key SCM trends. Like in nominal group technique (NGT), this was on an individual and anonymous
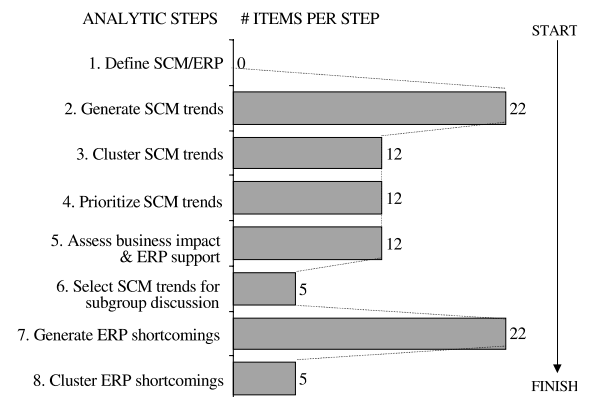

Fig. 3. Analytic steps in the Delphi study.

manner, ensuring a broad range of topics submitted and preventing group think biases (McGrath, 1984). Unlike NGT, participants could see what items had already been submitted, which provided the advantage of eliminating duplicate entries. This resulted in a total of 22 SCM trends.

Step 3: Group SCM trends (12 items).

Further clustering was attempted in the next step. The group evaluated the submitted SCM trends one by one to see if they could be combined with one or more others. Whenever possible, items were grouped, but all original information was retained. This process led to a remaining set of 12 key SCM trends.

Step 4: Prioritize SCM trends (12 items).

Voting took place over these 12 trends. Each participant could choose 3 trends he/she felt to be most important. This resulted in a ranked list of still 12 items, reproduced in Table 2 to be discussed in Section 5.1. Strictly speaking, this analytical step was not required to proceed to steps 5–8, but was felt to yield useful insights in its own right.

Step 5: Assess SCM trends on business impact and ERP support.

Participants were then asked to rank the top-12 SCM trends on two dimensions: the expected business impact of each trend and the degree in which ERP could be expected to support or hinder this trend. These assessments were aggregated and the overall scores were displayed visually on a scatter plot similar to the one shown in Fig. 4. These results are discussed in detail in Section 5.2.
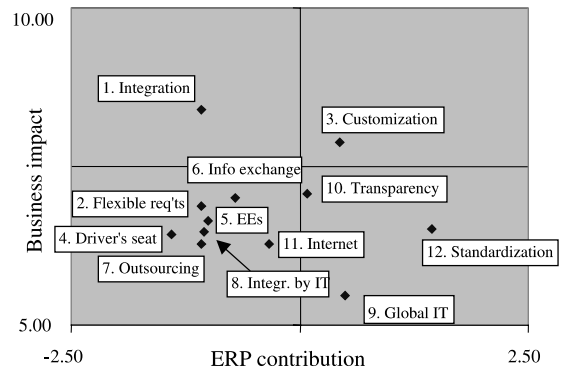

Fig. 4. Business impact of SCM initiatives and ERP's contribution.

Step 6: Select five SCM trends for subgroup discussion.

Five trends from the top-12 list were selected for a more in-depth discussion. Five subgroups of participants volunteered for each of the five specific topics. Trends 1 (Integration), 3 (Customization), 4 (Driver seat), 6 (Info exchange), and 10 (Transparency) from Table 2 were selected in this manner.

Step 7: Identify ERP limitations (22 ITEMS).

The five subgroups of four to five experts were given a number of questions regarding their selected topic. A key question for our present investigation was "What shortcomings do current ERP systems exhibit in supporting this particular SCM trend?" Participants conducted their discussions once again both orally and via the GDSS.

Table 2
Voting results on key trends in SCM (Top-12 of 22)

Key issues in SCM	Votes (%)
1. Further integration of activities between suppliers and customers across the entire chain	87
2. How to maintain flexibility in ERP systems to deal with changing supply chain needs?	57
3. Mass customization: complex assortments, shorter cycle times, less inventory	39
4. Who will be in the driver's seat in supply chain co-ordination?	35
5. Supply chains consisting of several enterprises	35
6. Full exchange of information with all the players in the chain	35
7. Further outsourcing of activities such as physical distribution, finance & administration	30
8. Enhancements of IT-tools required to integrate the different parties in the supply chain	30
9. Globalization: how to build worldwide ERP systems?	26
10. Greater transparency of the global market place	26
11. Internet technology will be the backbone to connect systems of partners in the chain	26
12. Standardization of processes and information definitions, the rest is IT infrastructure	22

Table 3
Shortcomings of current ERP systems for SCM from group discussions of selected themes

Shortcomings of current ERP systems mentioned, grouped by common threads	From discussion group on theme:
1. Lack of EE functionality: the ability to support operations across multiple organizations	
• EE functionality	1. (Integration)
• EE functionality	4. (Driver seat)
• ERP systems miss linking across the boundaries of enterprises	7. (Transparency)
• ERP systems do not interconnect easily with other than partner systems	7. (Transparency)
• Information exchange between parties is underdeveloped	1. (Integration)
• Ability to support multiple coding system to enable cross-company implementations	1. (Integration)
2. Lack of flexibility in adapting to ever-changing supply chain needs	
• Flexibility to adapt to changing business models	3. (Customization)
• Flexibility to adapt to changes in business processes	7. (Transparency)
3. Lack of more advanced supporting functionality beyond transaction management	
• Flow-based information exchange instead of ordering-based	1. (Integration)
• MRP-based instead of finite capacity; ERP + required	1. (Integration)
• Advanced planning systems with proven functionality	3. (Customization)
• Connections with tactical decisions	4. (Driver seat)
• From transactions to information for decision support	4. (Driver seat)
4. Lack of open, modular, internet-like system architectures	
• Modular set of systems	4. (Driver seat)
• Module manager for the supply chain	4. (Driver seat)
• Connectivity	3. (Customization)
• Web-enabled ERP	6. (Info exchange)
• "Let Microsoft buy Baan"	6. (Info exchange)
5. Various	
• IT (network technology, big, shared databases, XML,...)	6. (Info exchange)
• Customization will remain necessary	1. (Integration)
• Identification of barriers and developing business cases to overcome these	6. (Info exchange)

The Delphi session was concluded by a plenary discussion of the subgroup results as noted down in the GDSS, which led to some additional refinements to the analysis.

Step 8: Cluster ERP limitations (five remaining ITEMS).

A wrap-up and a dinner concluded the day. Afterwards, the authors removed redundancies from the five lists of ERP shortcomings. This resulted in 22 different items. These have been clustered into five main groups (Table 3). The implications from this list are discussed in Section 5.3.

5. Delphi study findings

This section describes the main empirical results from the Delphi workshop. Section 5.1 describes

the results of the first four steps of the workshop script as described in the previous section. It shows the top-12 SCM trends for the coming years as seen by our panel of experts. Section 5.2 focuses on the perceived contributions of ERP systems to these key SCM trends, again based upon a group assessment from our panel. Section 5.3 concentrates further on those ERP characteristics that were deemed as negative.

5.1. Key trends in supply chain management for the coming years

The first phase of our Delphi workshop consisted of constructing a ranked list of key SCM trends, or issues, depending on how much one welcomes these developments, for the coming years. In our workshop script described in Section

4, this corresponds to steps 1–4. Table 2 shows the results from those steps. Perhaps the most striking finding is that the results are not that striking at all. That is, the top priority items generated by these European SCM professionals, based on their practical experiences in their daily work, seems to correspond very well with our description of SCM priorities from an academic perspective in Section 2. We illustrate this by briefly discussing each of the key trends from our clockspeed perspective.

Just about every panel expert sees further integration of activities between suppliers and customers across the entire chain as one of the three biggest trends in SCM (Trend #1, 87% of votes). This coincides with a strong trend towards mass customization (Trend #3, 39% of votes). Both trends may have a similar root cause, i.e., increased competition driven by growing consumer power helped by an increasing transparency of the global market place (Trend #10). Ever-increasing customer requirements such as mass customization translate into operational challenges such as complex assortments and short cycle times. Furthermore, rapidly changing customer requirements not only tolerate very little inventory in the supply chain, but also require drastic modifications in supply chain topologies. This poses a difficult challenge to ERP systems: how to maintain sufficient flexibility when supply chain needs keep changing (Trend #2, 57% of votes). As if to ensure seamless integration between suppliers and customers, our #1 trend, would not be enough of a challenge to ERP systems in its own right!

Our panel of experts recognizes the difficulty of a single organization to satisfy the changing requirements of consumers. They expect that supply chains will consist of several enterprises (Trend #5) and that non-core activities such as physical distribution and F&A will be increasingly outsourced (Trend #7). An important issue for our panel then becomes who will be sitting in the "driver's seat" in this chain (Trend #4), since conventional power mechanisms no longer apply in a network of independent firms. What may be an unsettling perspective for our panel of experts is that Fine (1998) clockspeed perspective asserts that supply chain managers may simply have no say in the decision of who will be in this driver's

seat; power will be wielded by the entity with the next breakthrough technology.

What does seem to be a difference—at least of emphasis—between this practitioner forum and the Fine (1998) framework is the focus on information exchange and IT that emerges from especially the lower half of the Top 12 in Table 2. This may quite possibly be at least partly due to the overall theme of the workshop, which was after all the impact of IT on SCM. Nevertheless, it cannot be denied that the remaining trends focus more on information exchange and technology required to make all the above-mentioned "clockspeed phenomena" happen.

Greater and faster-changing demands from customers will need to lead to faster and more comprehensive information exchanges between all the players in the chain (Trend #6). In terms of technology, this will not just mean better ERP systems but, in general, enhanced IT-tools to integrate the different parties in the supply chain (Trend #8). Internet technology is most likely to provide the technological means for doing so (Trend #11). This will make distributed architectures possible, in which standardization takes place mainly at the level of information definitions and processes (Trend #12), so that local flexibility in information usage can be maintained up to a point. Needless to say, all these developments are taking place on a global scale. Hence, IT for SCM in general, and ERP systems in particular, will have to be developed on a worldwide basis (Trend #9).

5.2. Expected impacts of ERP on SCM trends

Fig. 4 reflects the output of Step 5 of our workshop script, which was a simple form of multi-criteria analysis. It shows the aggregate scores of each of the top-12 SCM trends from Table 2 on two dimensions: the expected business impact of each trend and the degree to which ERP could be expected to support or hinder this trend.

The first observation to be made from this scatter plot is that our experts were, in general, not overly optimistic about the contribution of ERP to future SCM developments. Only three, or perhaps four of the twelve key SCM trends are perceived as

being supported by ERP, the rest is perceived to be hindered by ERP systems. In subsequent sections, we will go deeper into the reasons for this hindrance. Broadly speaking, ERP seems to be hindering the more strategic business trends (integration, driver's seat, outsourcing, extended enterprises (EEs)). At the same time, ERP is seen to provide support for the more technical issues such as standardization and global IT systems.

There are two clear exceptions to this conclusion that the strategic SCM-ERP link is negative, while the technical SCM-ERP is positive. The first is that the technical issue of the need to have IT tools that will integrate the supply chains of multiple partners (Trend #8), is seen to be hindered by current ERP systems. We will return to this issue in the next section. The second is that the strategic issue of mass customization (Trend #3) is perceived as being supported by ERP systems. While our Delphi panel was referring to the interface with the final customer, the ability to configure a customer-specific order into production may well be a strategic asset afforded by ERP systems.

5.3. SCM Limitations of current ERP systems

The final part of the Delphi workshop (steps 6–8) were intended to explore why current ERP systems are not perceived to be helpful for many of the key SCM trends for the coming years. Our analysis focused on the shortcomings of ERP systems, rather than their current advantages for SCM, because shortcomings provide opportunities for improved IT support for SCM. The ERP industry has become a tightly knit ecosystem of software vendors, middleware vendors, supply chain experts, specialty-software houses, and hardware vendors. This ecosystem is also evolving fairly rapidly in an effort to provide effective supply chain solutions. It is therefore important to understand the capabilities afforded by the current technology and to identify the desirable features of future versions.

Desirable features of future ERP systems, or, negatively formulated, shortcomings of current ERP systems, were indeed identified by our panel of experts. Table 3 lists the main shortcomings in current ERP systems as they were generated in subgroup discussions on five themes selected from the twelve top SCM trends identified earlier on. Frequently, multiple subgroup discussions mentioned similar ERP shortcomings for different SCM trends. This explains why, for instance, "extended enterprise functionality" is mentioned twice in this table. This is because both the group discussing the SCM issue of "Integration of activities between suppliers and customers across the entire chain" (Trend #1) and the group on "Who will be in the driver's seat in supply chain coordination?" (Trend #4) arrived at the conclusion that current ERP systems are not helpful in these areas because they do not support operations across multiple organizations. We now discuss the four clear clusters that emerged out of these subgroup discussions.

(1) *EE functionality:* The lack of extended enterprise functionality is indeed the first and most prominent common thread that emerges from the subgroup discussions. Current ERP systems are developed to manage the goods flow within a single enterprise under central control, but the market is moving towards interorganizational supply chains. Our panel of practitioners sees ERP systems as difficult to interconnect with other systems, leading to underdevelopment of information exchange between parties.

(2) *Flexibility in adapting to changing supply chain needs:* A second shortcoming of current ERP systems is their inflexible nature. As one logistics manager remarked: "All our efforts in continuous improvement on the production floor have first been frozen for a year and a half by our ERP package implementation. Now we are still struggling to get it operating properly. And from then on, any change that is to be supported by our IT system will have long delays and high costs because of the difficulties in making changes to the system." This same point has been made by Upon and McAfee (2000), who also note the difference between continuous improvement approaches and the "big bang" approach inherent to current ERP systems. As customer demands continue to change ever more rapidly, and business processes and supply chain structures have to adapt ever more quickly in response, ERP systems should not be stifling process innovation but accommodating it.

(3) *Beyond transactions—more advanced supporting functionality:* For most of the experts on our panel, as for the vast majority of firms having implemented ERP systems, ERP implementation means that they have implemented a transaction management system. In itself, this was a necessary investment in infrastructure to end IT fragmentation. Hence, it is no longer necessary for a salesperson to write down a customer request taken over the telephone and spend the following two days figuring out whether the customer request can be satisfied. The new system makes the supply chain fully transparent, enabling the salesperson to answer the customer inquiry right away. The ERP system is usually also capable of figuring out the best way to deliver the product to the customer, invoice the customer, and credit the salesperson. However, available to promise (ATP) is an emerging concept within ERP circles. The challenge is not to figure out whether the customer order can be satisfied with the goods available *somewhere* along the supply chain, but to decide whether it is economically meaningful to allocate supply chain capacity to this potential order. The ATP concept is one of the examples of system functionality moving beyond transaction management towards more tactical decision support functionality. The lack of this kind of functionality was also mentioned in different subgroup discussions as a shortcoming of current ERP systems.

Open, modular, internet-like system architectures: Current ERP packages have integrated system architecture. This enables them to cover most of the transactions in the various functional departments of purchasing, production, sales, distribution, HRM and F&A. Typically, they integrate transactions across different geographical or business units. In this sense, they are a great improvement over the fragmented patchwork of local legacy systems that they tend to replace (Davenport, 1998). However, integration also has its drawbacks. According to our panel, the challenge for current ERP systems is to move to a more modular, internet-like system architecture. This would improve information exchange with all the players in the chain (Trend #6) and make the power structures in extended supply chains less dependent on the ERP system of the dominant player in that chain (Trend #4). Also, it would improve communication with the final customer, directly of via customer systems, less cumbersome than it is today, (Trend #3, "mass customization").

6. Discussion

In this section we reflect on the exploratory findings from the Delphi workshop as described in the previous section. In this section, we identified three sets of findings: (1) a prioritized list of SCM trends; (2) contributions of ERP to selected SCM trends, (3) shortcomings of ERP in supporting other SCM trends. We have seen that our panel identified similar SCM trends as are identified in the recent literature. Regarding the latter two sets of findings, we reiterate that there is little or no literature to be found, i.e. literature that links ERP with SCM. Therefore, our discussion focuses on these.

6.1. SCM opportunities for ERP

Our panel of experts identified a number of key SCM trends for which ERP provides clear support. These were, in order of decreasing business impact, (1) mass customization, (2) standardization and (3) global IT/ERP systems.

6.1.1. Mass customization

Mass customization, tailoring a product to meet the specific needs of an individual customer (Pine, 1993), involves the delivery of a wide variety of customer-specific goods or services quickly, efficiently, and at low cost. Mass customization therefore combines the advantages of mass production (such as Ford Model T) and craft production (such as tailor-made suits). ERP supports mass customization only if customers can configure their products as a combination of a number of predefined options. The emergence of "configurators" in the ERP ecosystem supports this aspect of mass customization. A configurator in this context is a computer program that translates individual customer demands into feasible product

specifications. Using such a configurator, it becomes possible to start an assemble-to-order process. The integration provided by the ERP system would ensure that the unique product ordered by the customer is properly translated into the appropriate production orders. Moreover, the sophistication of current ERP systems makes it possible to construct catalogues containing a large number of standard end products.

We have observed this type of functionality generally in the low-volume high-tech environments. It is still to be seen whether ERP will be able or even required to support the massive volumes of unique customer orders (and thus: production orders) in a high-volume environment. For commodity products, the customization dimension is not achieved in the product itself, but rather in the services associated with it, i.e., the personal customer profile that is maintained and the personal delivery of goods ordered.

As with almost any type of functionality, a rich industry of best-of-breed solutions running on top of ERP does exist. The level of sophistication provided by these solutions varies from "modest" (just click on the options you want) to "very high" (where rule-based expert system functionality supports the user in defining the best product configuration meeting a set of functional requirements, while checking on completeness and consistency). These types of systems are typically found in the high tech electronics industries.

6.1.2. Standardization

We consider standardization from two different points of view: the enterprise-internal perspective and the supply chain-wide perspective. Starting with the former, an enterprise wide ERP system does have a huge impact on standardization of both processes and data. ERP allows for efficient processing of, for example, engineering changes in bills of material or updates in customer data.

Regarding standardization of processes, ERP almost enforces processes through its use of best-practice templates. Increasingly, suppliers and customers, who operate at a pan-European or global scale, expect consistency in all contacts with the enterprise, regardless of geographic location.

ERP is helping here. It facilitates consistent behavior among all supply chain partners by having harmonized processes and by providing access to a single source of data. In addition, by standardizing data and processes, ERP technically enables consistent performance measurement for their own enterprise as well as for monitoring their partners' performance.

Seen from the supply chain perspective, some ERP vendors have set a de facto standard in certain industries (e.g. SAP in Oil and Gas; Baan in Aerospace). This helps in the standardization of business processes and data models across entire sectors, even more so because ERP implementations are often based on best-practice process templates. Such a convergence around process templates may create uniform information flows and process structures within an industry. This convergence may make dynamic reconfigurations of supply chains within that industry easier.

6.1.3. Global IT

Globalization of businesses requires worldwide ERP implementations. The main issue with global ERP implementations is not as much technology: state-of-the-art in IT allows for accessing an ERP system from any location in the world. Moreover, as ERP systems are increasingly web-enabled, the technical limitations diminish even further. Compared to the old legacy systems, ERP does provide significant benefits: some of them lie in their technical architecture (client/server computing), others stem from their functional (multi-lingual, multi-currency and time-zone capabilities). The *real* issues in 'global IT' are mostly of an organizational nature. In other words, some organizational choices have to be made prior to technology deployment. These choices include:

- To what extent does a global company really *need*- or *want*-harmonized processes? Where does one draw the line between local and global processes?
- Should the company standardize systems or interfaces? The former option enforces similar processes on a global scale; the latter option allows local-for-local processes, but ensures standardized communication channels between any

parts of the organization. If one truly believes in the networked economy, the latter option is the preferred one, as it supports dynamic supply chain design. In particular, the configuration of the enterprise as a "network of cooperating business units" will evolve continually: with a high frequency business units will enter and leave the network. Having a monolithic, global ERP system will put severe constraints on this agility.

- The time needed to do a global roll out of ERP (where it might take up to 10 years) will prohibit a truly global, harmonized system.

6.2. SCM shortcomings of current ERP systems

Our industry experts highlighted four shortcomings in ERP: (1) EE functionality, (2) flexibility in adapting to changes in the environment, (3) more advanced decision support functionality and (4) lack of (web-enabled) modularity. In our view, the fourth shortcoming is the root cause for the former three. When it would be possible to have 'plug and play' modularity, preferably even 'hot swappable' components (as is the case with modern disk storage devices), the flexibility needed to follow dynamic business processes could be achieved. Web enabling these modules would even make it possible to 'borrow' specific functions from one's trading partners. The current highly integrated nature of ERP prevents this flexibility.

In our discussion of these shortcomings, we will also emphasize alternatives to current ERP systems. Therefore, we will take into account not just the products available from the leading ERP vendors but also the offerings from the flourishing industry of supply-chain-oriented complementary software. These companies are developing tools specifically for such functions as advanced planning and scheduling (APS) and specific business processes, such as "demand planning," "customer order management," "warehouse management," among others. This ecosystem of applications can be glued together by dedicated connectivity tools, allowing applications to communicate with each other, occasionally via the Internet Protocol, but also via e-mail based connections, classic EDI, or XML.

6.2.1. Lack of extended enterprise functionality

In our opinion, EE functionality entails the ability to share internal data efficiently with supply chain partners and to accommodate the data made available by your partners. This data sharing can be deployed either for operational decision making or for calculating supply chain-wide performance measures. Moreover, EE functionality enables business processes that are distributed over multiple organizational entities. For instance, in a classical order capturing process, this would mean doing a distributed ATP check, delegating the credit check to a financial service provider, and relying on a logistic service provider to be able to promise a specific delivery time window.

ERP systems lack EE functionality. However, one could not realistically expect EE functionality to be available in the current ERP systems because, *by their design*, ERP systems focus on managing only *internal* resources in an integrated manner. It is possible to overcome these shortcomings by implementing a range of add-ons, such as connectivity software, processware (a specific type of connectivity software that offers not only pure data exchange facilities, but also some elementary logic reflecting specific business process flows), data warehousing tools, or supply chain execution systems.

6.2.2. Lack of flexibility in adapting to changing supply chain needs

When discussing flexibility, one should distinguish this concept at different levels ranging from purely operational to more strategic. In Section 2, we discussed supply chain design versus supply chain coordination. An IT system should be sufficiently flexible to change as customers are asking for different kinds or different quantities of products. This is supply chain *coordination*. ERP is capable of supporting such coordination.

Our panel, however, was emphasizing that flexibility with ERP systems appears to be more problematic in supply chain *design*. For instance, a single organization might have different types of relationships with its supplier and customer base. Its ERP system should be sufficiently flexible to accommodate a multitude of relationships. Some suppliers may have adopted VMI, some may have

adopted CPFR, and others may still be engaged in a classical vendor/buyer relation. The ERP system should be able to accommodate all these different modes of collaboration simultaneously and be able to change efficiently from one mode to another. Gartner Institute emphasizes that the ability to engage into—and disengage from—collaborative relationships is of critical importance. Even more problematic will be situations in which the composition of the actors in the supply chain frequently changes from one customer order to another, i.e., when the supply chain becomes increasingly market responsive (Fisher, 1997).

Another type of flexibility that is less specific for SCM but may be at least as important is the possibility to redesign business processes. As stated in Section 2, supply chain design is facilitated not only by a set of enabling information technologies, but also by a set of new and/or redesigned processes. On the one hand, IT cannot enhance supply chain performance unless processes and organizational structures are redesigned. On the other hand, process reengineering relies heavily on the use of IT to create innovative processes for enhancing supply chain performance. Here ERP offers indeed a considerable opportunity: when considering implementing an ERP system, which will change the way people work, it seems logical to combine this effort with business process reengineering along the supply chain.

Unfortunately, in an understandable effort to contain the costs, complexity, and duration of ERP implementations, many companies have adopted a process reengineering approach that is governed by the functionality inherent in the selected ERP system. Such an approach typically entails the use of business process templates that reflect best practices in a particular industry. This is adequate if these best practices actually mean an improvement over the current business practices. But, if processes that are being standardized represent a unique source of competitive advantage, then the ERP implementation will increase the strategic risk of losing such a competitive advantage.

Another long-term disadvantage might stem from the very nature of reengineering initiatives. Such initiatives, typically aimed at strategic leaps,

require a major expenditure of funds and considerable outside expertise. Lower-level employees are affected by the decisions made, since they are the end users of any new process, technology or equipment. However, they are not typically involved in the decision making process and the implementation, since these are considered the domain of experts. In other words, lower-level employees are trained on the use of the new technology, but they are not consulted during the selection and implementation phases.

This is in stark contrast with the experience in the manufacturing sector that spent the last two decades adopting a continuous improvement approach within the just-in-time and total quality management philosophies. Continuous improvement demands considerable involvement at the lower and middle levels of an organization, relying upon their intimate, on-going knowledge of the operation. Clearly, a better balance between the two approaches is needed for effective ERP implementations. For instance, in the preparation to our workshop, a European maker of high-tech manufacturing equipment complained that continuous improvement initiatives such as just-in-time manufacturing, kanban control, and set up time reduction severely stagnated during and after the ERP implementation.

6.2.3. Lack of advanced decision support capabilities

A recent trend in the ERP world is the emergence of APS. In itself, planning with longer time horizons and across different units is nothing new for ERP, even for MRP systems. However, as it becomes increasingly apparent that supply chains, rather than individual organizations, compete, there is an increasing demand for collaborative architectures in decision support software. Advanced decision support capabilities used to be the exclusive focus of dedicated APS vendors such as Manugistics, *i*2 Technologies, Numetrix and SynQuest. Increasingly, however, ERP vendors themselves are entering this arena. The common view is that, for the moment, they are significantly lagging behind in functionality, but fare much better when it comes to integration. The dedicated APS vendors exploit their head start by entering

the area of collaborative distributed planning, where the focus of the ERP vendors is still very much on the internal supply chains.

The developments in the ATP area are still very much focused on the internal supply chain. Currently, the following functionality is usually discussed:

1. Existing ERP systems can perform an ATP check by checking against inventory levels (or the MPS) and provide answers like "Yes, I can accept your order because I have inventory available, or it fits within my MPS."
2. APS systems that have real-time access to enterprise data can do "*capable* to promise" (CTP) checks: "Yes, I can accept your order, because I have spare capacity that I can use to produce your order." Additional functionality would check not only on the technical feasibility of the order, but also on its profitability: "Yes, I will accept your order because I have capacity available, and it is profitable (enough) for me to allocate this capacity to meet your requirements."
3. A next level of sophistication will be reached when such CTP checks are performed in an engineer-to-order environment: This would provide answers like "Yes, I can design a new product for you, and yes, it is profitable for me to do so."

By including the capabilities of other supply chain partners, yet another level of sophistication can be obtained. Rephrasing the three levels, the possible answers would then become:

4. "Yes, I can accept your order, because throughout the supply chain products and materials are available."
5. "Yes, I can accept your order because I have spare capacity, my suppliers have capacity to produce subassemblies, my logistic service provider is able to deliver the product at the moment you need it, and the overall landed cost does make this order commercially attractive."
6. "Yes, I can accept your order because I as well as my supply chain partners have development capacity available."

The ultimate level of sophistication might be reached when one is able to react to a customer order as follows:

7. "Yes, I can accept your customer order; I will design a new supply chain specifically for you."

The state-of-the-art in joint ERP/APS solutions is able to provide real-time support in doing internal ATP/CTP checks as mentioned under (1) and (2). For cross-enterprise collaboration, technologies are just entering the market. Examples might be found in Microsoft's Value Chain Initiative or *i*2 Technologies' Intelligent E-Business Initiative. Both initiatives define an architecture, heavily relying on Internet technology, that allows *real-time* communication between ERP systems, transport and warehouse management systems, and APS systems.

6.2.4. Lack of open, modular system architecture

A fourth group of shortcomings mentioned by our panel of experts was that current ERP systems lack a modular, open, and internet-like system architecture, or "web-enabled ERP" as one subgroup called it. Basically, this shortcoming is the reverse side of some of the generic advantages of ERP listed in Section 3, where we noted that ERP was intended originally to replace a multitude of local legacy systems; a great deal of emphasis was therefore placed on its integrated architecture. In the new networked economy, this former strength is rapidly becoming a weakness. Upon and McAfee (2000) further discuss the handicaps of the lack of an open modular ERP system architecture.

7. Conclusion

Several management and academic writers have recently asserted that the advent of the network economy is fundamentally changing prevailing business models in general and SCM in particular. The relevant entity for analyzing potential business success is no longer the individual firm, but the chain of delivering and supplying organizations; the individual firm is only a single part of this network. This greatly increases the importance

of supply chain management for corporate survival. This study has confirmed this assertion by asking a panel of 23 European SCM executives their assessments of key SCM trends.

Of a much more exploratory nature are this study's findings regarding the impact of current ERP systems on these SCM trends. The general conclusion to be taken from our Delphi study is that one should not expect too much from ERP for SCM in extended enterprises. Perhaps this is not surprising. ERP systems have become a de facto standard in business because they replace a patchwork of local legacy systems. Once ERP is installed, there exists a process-oriented enterprise transaction backbone that can support—within a single firm—developments in many business areas, including SCM. But ERP systems were never designed just to support SCM, and certainly not across multiple enterprises. Their architectural advantage of being fully integrated for one firm becomes a strategic disadvantage in this new business environment, where modular, open and flexible IT solutions are required. Time will tell if these solutions will be generated on top of, complementary to, or instead of ERP systems, and if these solutions will be owned by the current ERP software vendors or other parties. But time alone will not be sufficient. More in-depth research is also required, which may fill the current gap in timely academic research on the business impact of ERP systems.

Since the organization of the workshop, the rapid development of more open, modular, and flexible IT solutions has been encouraging. The emergence of the internet and its communication protocol along with voluntary industry-specific standards (e.g. XML, Rosettanet) will certainly facilitate interfacing the individual ERP implementations. Moreover, these technologies and concepts aid significantly in creating 'plug and play' infrastructures, in which specific solutions for specific problems can 'easily' be added to an exisiting ERP environment. This would enable the creation of a seamless supply chain and the realization of tangible benefits from the significant IT investments of the past decade.

While the advances in information and communication technology infrastructure rendered supply chain transparency easy to achieve, supply chain collaboration is still an ill-understood concept. Research in supply-chain-wide performance assessment and incentive design is necessary to provide a sound theoretical basis to complement these technological advances.

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