Selecting internal and external supply chain functionality

The case of ERP systems versus EMPs

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Abstract

Purpose – Anecdotal evidence suggests that the use of the external supply chain (SC) functionality offered by business-to-business electronic marketplaces (EMPs) results in improved efficiencies and reduced costs in supply chains. Anecdotal evidence also suggests, however, that most of the benefits offered by EMPs could also be achieved by an increase in the firm’s internal SC capabilities. The firm’s decision is thus one of seeking SC efficiencies through internal capabilities (e.g. enterprise resource planning (ERP) systems), through participation in EMPs, or through a combination of both. Seeks to examine this issue.

Design/methodology/approach – This paper conceptually examines the choice of using ERP systems versus EMPs within the context of value creation and competitiveness in an SC partnership. Then a dynamic, non-linear model is proposed to support this decision.

Findings – Three findings stand out. First, while small firms are often well served with just using EMPs, large firms are better off using a well-balanced portfolio of internal and external capabilities along with their SC processes. Second, unless a sufficient level of internal information technology capabilities is present, firms with a large scope of stock-keeping units will not be able to significantly improve their SC effectiveness by just using EMPs. Finally, the successful acquisition of SC capabilities depends on the level of uncertainty of the associated technology and market.

Originality/value – This paper considers a range of organizational and environmental factors that impact the choice between EMPs and ERP systems that have not previously been considered. The findings have a major impact on the choice of internal versus external functionality to increase the firm’s SC capabilities.

Keywords Supply chain management, Electronic commerce, Business-to-business marketing

Paper type Research paper

1. Value creation in supply chain management

Traditionally, supply chain processes have been characterized by great inefficiencies. In a typical firm, once demand has been recognized and until the actual placement of an order, a number of steps need to be performed involving staff from up to three functional areas (Turban et al., 1999). Moreover, a supplier’s order entry clerk often replicates its customer’s requisition paper work, making cross-company supply chain processes inefficient (Hammer, 2001). Those inefficiencies may be alleviated by using one of two basic information technologies designed to manage complex information flows within or between firms. A firm may implement an enterprise resource planning (ERP) system to automate inventory management as well as sales and order

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generation, including the associated approval processes. Alternatively, it may choose to use electronic business-to-business marketplaces (EMPs) to streamline the purchasing and sales process by connecting to its supply chain partners and automating the generation and transmission of order and sales information (Kalakota, 2000; Kalakota and Robinson, 2000).

It is not clear if the use of EMP or ERP systems do in fact offer significant payoffs. Many of the about 1,700 EMPs currently online (Young, 2002) still have to prove that they are viable. Moreover, while 70 percent of all US high tech firms have subscribed to at least one exchange, only 20 percent of them have actually performed transactions online (AT Kearney, 2000). Similarly, implementing a potentially costly ERP system might not pay off. Anecdotal evidence suggests that many firms achieve a negative return on their investment and that ERP implementations have been difficult and come with uncertain benefits (Mabert et al., 2000). Because of the sobering reality, the old concept of value creation has regained importance and is now being applied to ERP systems and EMPs (Kerrigan et al., 2001).

The measurement of value creation is based on the customer’s opinion of what adds value to the product or service received (Porter and Millar, 1985). In the context of supply chain management the definition of customers extends to the firm’s inbound and outbound supply chain partners. In this case, value can be defined as the ratio between the service level and the associated transition cost. Hence, value in a supply chain is generated by lowering the firm’s or partner’s cost of sourcing or sales or increasing the service level. This can be achieved, for example, by linking a partner’s supply chain processes and, ideally, automating transactions (e.g. Kalakota and Robinson, 2001).

To date, the literature has shown that the use of EMPs may result in improved efficiencies and reduced costs through the access to markets (e.g. see Kalakota and Robinson, 2001). EMPs, however, also offer supply chain functionality such as sourcing automation or supplier performance measurement, which substantially overlap with functions available in ERP systems. The effect of selecting an ERP versus EMP functionality on the firm’s value creation potential along its supply chain processes has not been investigated. In this paper this choice is investigated with a focus on value creation in the supply chain. A decision model is developed that aids decision makers in optimizing the appropriate mix of internal and external supply chain functionality over a given planning horizon.

When attempting to create value through more efficient supply chain processes, both the benefits and the costs of ERP systems and EMPs must be investigated. The benefits come from the functionality offered by each solution and the possibility of creating supply chain capabilities along the selected process. The first benefit impacts the firm’s operational efficiency at any given time while the second has a long-term (strategic) value. The costs include not only the cost of running and using a system but also that of implementing, maintaining and upgrading it.

In the following section, the benefits and costs associated with the use of EMPs and ERP systems are discussed. In the third section of this paper, a decision model is introduced that allows firms to optimize the current mix of internal and external supply chain functionality while taking into account the short and long-term benefits and costs of either solution. Finally, in the last section, we draw our conclusions and summarize the most important points from this research.
2. Value creation through EMPs and ERP systems
This section discusses how value is created through internal functionality and the use of external functionality. The following sub-section describes how ERP systems and EMPs may create value to the firm and its supply chain partners. The second sub-section examines the conditions under which value creation through external systems is effective. In the last sub-section we discuss the types of costs that can affect the value of ERP systems and EMPs for supply chain processes.

2.1. Value creation mechanisms for EMPs and ERP systems
Value in EMPs is created through market mechanisms and functionality that facilitates the automation of transactions. Two main EMP market-making mechanisms are explained by Kaplan and Swahney (2000): aggregation and matching. Exchanges aggregate demand by bringing together a large number of buyers and sellers. For example, purchasers in buying consortia can be expected to reduce costs through volume pricing, real-time information for supplier negotiations, the consolidation of suppliers, and the control and management of suppliers (Gotschall, 2000). In contrast, matching creates value by providing a platform for buyers and sellers that enables them to negotiate purchasing contracts quickly (Kaplan and Swahney, 2000). It also allows buyers and sellers to access an existing market quickly.

Apart from providing market mechanisms, EMPs also offer a variety of supply chain functionalities and services that may add considerable value to the firm. These functionalities include a wide range of tools, such as sourcing, billing and payment automation; catalog management; contract creation and management; collaboration and negotiation mechanisms; logistics management through the integration of third party logistics providers; supplier performance control; and interfaces that facilitate integration with ERP and legacy systems (see Table I). Some EMPs also offer functionalities such as quotation management, supplier management, auctions, and operational performance measurement (Biehl and Kim, 2003). Distribution management, i.e. the scheduling and optimization of a firm’s own logistics resources, is usually not offered.

In contrast to EMPs, ERP systems are designed to add value by managing the complexity of business processes. ERP systems trace their origins to material requirements planning and manufacturing resource planning (MRP) systems. MRP systems link a firm’s demand side with its supply side by breaking down demand into requirements for parts and components. They then schedule the ordering or manufacture of parts and components while adjusting for inventory on hand. ERP systems are a further extension of MRP systems. They integrate data flows across all business functions and include a large set of optimization and reporting routines.

A review of the functionalities of ERP systems (Biehl and Kim, 2003) reveals that most packages offer a full set of supply chain capabilities, including the planning and execution of marketing activities (the demand side), shop floor and inventory management, ordering, billing, and invoicing, with the potential of delegating ordering and receiving to the end-user (see Table I). In addition, most packages schedule and optimize distribution through functionality such as management of logistics suppliers or transportation planning. Lastly, ERP systems are now capable of internet integration and, in extension, enterprise application integration through XML and customized interfaces. The internet integration facilitates online ordering and sales; the
linking of suppliers’ and customers’ ERP systems to the firm’s; online analytical processing to create (near-) real time processing and promising of orders and increase inventory visibility; access to financial clearinghouses for online financial transactions; collaborative sourcing and contract negotiation, and a variety of pricing procedures such as auctions and dynamic pricing. These functions only work, however, when ERP systems are connected to those of the firm’s suppliers and customers through value added networks (VANs) or EMPs.

This review of EMP and ERP supply chain functionality highlights the functional overlap between EMPs and ERP systems. Most selling and purchasing functionality, for example, would be usable by a firm through either its ERP system or an EMP it has subscribed to. A few notable differences exist, however. First, in addition to providing supply chain functionality, EMPs give a firm immediate access to a base of potential suppliers and customers (matching) and provide the potential for lower-cost purchasing through aggregation. The larger the EMP’s customer base, the greater the benefits from these market mechanisms. Second, a firm without an ERP system would be able to use EMP functionality efficiently only if it was dealing with a very small range of stock-keeping units (SKUs). Such a firm might use a web interface to submit requests for quotations or bids and interact with its supply chain partners. Many small or medium-sized firms, especially those with simple product structures, would fall into this category. For firms with a large number of SKUs, however, the use of a web-interface would be very inefficient as it would take considerable time to retrieve and type product information into the web interface. Clearly, the efficiency of using supply chain functionality provided by EMPs would be greatly increased if the

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**Notes:** + Usually supported; ✓ Supported when connected to supplier network or EMP; O Supported by some EMPs; × Usually not supported

**Source:** Biehl and Kim (2003)
EMP was connected to a materials management (e.g. ERP) system internal to the firm. This system could automatically generate and transmit to the EMP smaller orders and larger orders after revision by purchasing staff.

This finding signifies that, as the scope of SKUs and the complexity of the firm’s operations increase, the successful use of EMP functionality becomes more dependent on the existence of internal systems capabilities (see Figure 1). In other words, a firm with many products or a complex product structure will not be able to fix its operations by just subscribing to an EMP. Instead, as a first step, it has to build up internal supply chain capabilities that enable it to use EMP functionality in an efficient manner. These internal supply chain capabilities may be based on good process design as well as IS functionality that manages the back-end operations, i.e. an ERP system (Kalakota and Robinson, 2001). That is, as the degree of internal functionality increases, the efficiency with which external functionality can be used increases.

While this insight is valuable and indicates a clear delineation of benefits for (small) firms with a narrow scope of SKUs, the benefits realized by medium-sized and larger firms depend also on a more strategic factor: the development of supply chain capabilities that enable it to operate more efficiently than its competitors. The latter is heavily influenced by the choice of internal versus external functionalities and discussed in the next sub-section.

2.2. Internal versus external supply chain capabilities
The management of technology literature indicates that a set of core capabilities is necessary to gain a competitive edge (Duysters and Hagedorn, 2000[1]. In business management, possessing a capability implies the potential to or having the functionality necessary for carrying out a task. An extension of the term capability leads to the definition of core competencies. According to Prahalad and Hamel (1990, p. 81) core competencies are “corporate wide technologies and production skills [...] that empower individual businesses to adapt quickly to changing opportunities”. As compared to the definition of capabilities, core capabilities are those available within the firm that can be used to extract market power vis-à-vis competitors. They enable the firm to differentiate itself based on cost, flexibility and other competitive factors and are the basis for competitive, long-term advantage in the marketplace (Porter, 1979).

In order to remain competitive, the firm needs to possess certain levels of capabilities (complementary assets) at each stage of its supply chain processes. According to social capital theory, the firm’s external networks, including suppliers, complement its internal capabilities (ICs) in the pursuit of offering products and services at competitive prices and quality (Lee et al., 2001). The capabilities available

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**Figure 1.**
Examples of criteria for the selection of EMPs versus ERP systems
within (e.g. ERP system) or to the firm (e.g. EMP) should ensure processes that add more value to its customers and are more efficient than those of competitors. As a result, a performance differential is generated which supports the firm’s strategy.

The literature points out that external appropriation of capabilities, however, is not a frequently chosen solution to a firm’s problems, especially when technological uncertainty is high. Two literature streams support this assertion. First, transaction cost theory (Williamson, 1975) suggests that overall transaction costs are reduced if the most efficient governance mechanism is chosen: bureaucracy, markets and clans (Ouchi, 1980). At one extreme, the use of EMPs would be a good choice if the EMP market was very competitive. The firm could use the services of its members with a high degree of certainty, and the customization (specificity) of interfaces was not a major undertaking, thus ensuring that the firm is exposed to only a small level of opportunism by its suppliers. At the other extreme, if the market was prone to much uncertainty or dominated by a few powerful EMP providers, the firm might prefer to use internal governance mechanisms (i.e. an ERP system).

Second, the management of technology literature found that technological uncertainty prevents firms from internalizing external capabilities (Steensma and Fairbank, 1999) and, in such a case firms tend to opt for internal solutions (White, 2000) instead. In other words, when the rate of change in the EMP environment is high, the firm’s gain in terms of learning and effective acquisition of supply chain capabilities through access to EMP functionality is uncertain.

Clearly, the ongoing consolidation in the EMP arena and frequent updates of EMPs’ offerings signify such a technological uncertainty (e.g. Kalakota and Robinson, 2001), and the EMP market is presently consolidating. Hence, the use of EMPs for the sake of transaction efficiency or acquiring long-term supply chain capabilities may be of little benefit for either small or large firms. Once the EMP market is consolidated, however, and updates will tend to be additions to rather than changes in existing functionalities, the use of EMP-provided supply chain functionality may become more attractive from the viewpoint of organizational capabilities.

Successful participation in EMPs also depends on a firm’s motivation and commitment. To use EMPs effectively, firms need to have successfully reengineered their business processes (the same goes for ERP systems), have extensive knowledge about their EMPs and transactional procedures, and understand the cause-and-effect relationships of their EMP activities. As well, successful firms keep abreast of changing technology and the markets (Grewal, 2001).

In an environment prone to changes and uncertainty it is difficult and time-consuming to constantly keep abreast of changes in technology and functionality. Moreover, the long-term viability of external solutions is not guaranteed. Under these conditions it might be safer to think of external functionality as a short-term fix rather than a long-term solution. Hence, due to the very limited capacity to build organizational capabilities in such an environment, the strategic benefits from using EMPs are unclear. In contrast, in a stable environment, a firm would be able to more freely decide between the use of ERP versus EMP functionality.

Having discussed the choice between EMP and ERPs in terms of the potential for appropriating supply chain capabilities, the next sub-section investigates the last component of the value equation: the types of costs that need to be considered when making this decision.
2.3. Value creation as a function of costs

The costs that must be considered when investing in and using internal and external solutions include not only the cost of running and maintaining the systems or subscribing the EMPs (herein referred to as maintenance cost), but also the cost of purchasing and implementing the functionalities (transition cost). In addition to these costs, which can be measured relatively easily, the firm must also consider the opportunity cost of not running efficient supply chain processes. This cost is termed competitive cost. Lastly, the firm realizes a long-term benefit from the acquisition of capabilities (salvage value). The four types of costs are explained in the following paragraphs. Note that these costs also capture the costs set out in transaction theory, including the transaction cost, the cost of setting up and controlling the chosen governance mechanism, and the potential cost due to opportunistic behavior (transaction risk).

The competitive cost can be thought of as the opportunity cost of using inefficient (relative to the firm’s competitors) supply chain processes for serving customers and suppliers. For example, a supplier capable of completing transactions with the firm efficiently will incur a lower cost of sales and be willing to pass part of those savings on to the firm. Clearly, the higher the firm’s sourcing capabilities, the lower its competitive cost. Moreover, the more important an inefficient process, the more the firm loses financially through higher supply chain costs relative to its competitors. Hence, the more important a process to the competitive position, the more the firm’s competitiveness will improve as a result of an increase in the firm’s supply chain capabilities. As a consequence, important processes should first be thoroughly examined.

The competitive cost takes into account both the level of internal capabilities (ICs) and the effectively used level of external capabilities (ECs) for all supply chain processes investigated. The effectively used level of ECs reflects the actual level of EMP functionality subscribed to and the effectiveness with which this functionality can be used given the firm’s internal processes and systems. While the competitive cost decreases with increasing levels of ICs, ECs or the effectiveness with which ECs can be used, it does so at a non-increasing rate. This is due to diminishing returns: if the firm’s supply chain capabilities are high already, increasing them further will be more difficult and costly than if they were low. Finally, the competitive costs depend on the firm’s transaction volume. Clearly, the benefit from having high supply chain capabilities is greater with a high transaction volume for which standardized and automated processing can be used than a small volume.

The transition cost represents the cost of changing the levels of ICs and the degree to which ECs are used. The transition cost includes the cost of purchasing IT hardware and software, implementing it, simplifying processes with or without the help of consultants, linking internal processes or systems to an EMP or supplier, etc. The transition cost occurs only when the level of internal or use of ECs is changed.

The cost of implementing ERP systems ranges from almost 6 percent to 14 percent of firms’ annual revenues, with over 40 percent of firms spending less than $5 million (Mabert et al., 2000). An EMP, on the other hand, requires only a small fixed cost to link it to the firm’s internal information systems via an interface. Typically, this cost ranges from a few thousand to a few million dollars, depending on the complexity of the interface required. Private value-added networks, which may be an option for very large firms, are more costly to set up than EMPs (Biehl and Kim, 2003).

The transition cost is also impacted by the speed of implementation. The management of technology literature indicates that technological change is subject to
diseconomies of scale (e.g. Hayes and Clark, 1986; Carrillo and Gaimon, 2000). The greater the change at a particular point of time, the greater the cost which is due to the increased need for coordination and the higher level of simultaneous interdependencies. Therefore, the transition cost increases at an increasing rate with the level of change in ERP systems or EMPs. Clearly, changing ERP systems also tends to be more costly than changing access to EMPs.

The maintenance cost is the periodically recurring cost of maintaining ICs and using ECs. It includes such costs as the maintenance of the firm’s IT equipment and software, ongoing user training, as well as periodic subscription fees to EMPs. Clearly, the higher the levels of ICs or use of ECs, the higher the maintenance cost.

Information regarding the maintenance cost of ERP systems is difficult to estimate due to the wide range of possible scenarios. It depends primarily on the number of people employed to maintain the ERP system. A variety of costing structures exists for EMPs, some charging a combination of monthly and transaction-based fees. ChemConnect, for example, charges between 0.2 percent and 2 percent of the transaction volume (Chemical Week, 1999). This cost may be significant for firms operating in a competitive industry. Private networks may offer a lower variable cost, which, as with an ERP system, mostly depends on the number of people employed to maintain them (Biehl and Kim, 2003).

The salvage value reflects the benefit the firm realizes from building long-term capabilities. Capabilities are built through an organizational learning process that typically includes the selection, implementation and use of internal or external supply chain functionality (i.e. ERP systems or EMPs). Note that process re-design, a step often necessary for the implementation of ERP systems, is part of the implementation phase.

Recall that in the currently uncertain environment that characterizes EMPs, the appropriation of capabilities is inhibited. As a result, the long-term benefits derivable through the use of EMPs are currently significantly smaller than those obtainable through the implementation and use of ERP systems.

Note that the four cost components discussed above completely capture the value of investing or disinvesting in internal and external supply chain functionality. The benefits derived from the functionalities are reflected in a decrease in the competitive and potentially the maintenance costs. Each change is subject to some transition costs. Overall, the firm would optimally minimize the total cost across all its major supply chain processes over a certain period of time. This is done with the help of a decision model that trades off the use if internal supply chain functionalities (e.g. as provided by ERP systems) and external functionalities (i.e. as provided by EMPs) over a given planning horizon.

3. A decision model for selecting ERP and EMP functionality

3.1. Model formulation
We are now ready to formulate a decision model based on the discussion of how value is generated in a supply chain partnership. The decision model can be used to optimize the levels of internal and access to external supply chain functionality over a pre-defined planning horizon. This section explains the decision model in more detail.

The objective function contains the three cost terms and salvage value discussed in section 2.3. The objective (equation (1)) is to be maximized subject to the constraints
The first cost term in equation (1) represents the competitive cost. The competitive cost is a function of the internal supply chain functionalities at time \( t \) for supply chain process \( i \) (e.g. ordering or catalogue management), \( L_i(t) \), the level of external supply chain functionality \( i \) (designed for process type \( i \)) provided by EMP \( j \), \( M_{ij} \) as well as the subscription level to EMP \( j \), \( V_j \), see also Appendix 1 for definitions of variables. Recall that the subscribed-to functionalities can be used with an effectiveness \( \varepsilon \) that depends on the firm’s level of internal supply chain capabilities, \( \varepsilon(L_i) \). Finally, the benefit derived from the reduction in the competitive cost is proportional to the firm’s transaction volume, \( p(t) \), and may change over time, \( t \).

Common sense dictates that the competitive cost can easily be reduced when the firm starts out with low capabilities, but is more difficult to reduce further when the level of capabilities is high. Hence, the law of diminishing returns applies. Mathematically, as the level of internal or externally accessed capabilities increases, the competitive cost decreases at a non-increasing rate (please see Appendix 1 and equation (2) for the partial derivatives describing first and second order conditions).

The second cost term in the objective function reflects the transition cost. Clearly, the introduction of an information system or the coding of an interface to connect to an EMP consumes time and resources. The transition cost reflects this by increasing with the rate of change in the levels of internal functionalities (\( L_i \)) and subscription to external functionalities (\( V_j \)). Since the transition cost is incurred when functionalities are either increased or decreased, the cost is convex in the rate of change (see Appendix 1). It may also change over time as the cost structure of ERP systems may change. Recall that the transition cost is subject to diseconomies of scale. Hence, as a rate of change increases linearly, the corresponding transition cost increases at an increasing rate.

The third cost term represents the maintenance cost. Typically, the higher the levels of internal functionality and subscribed-to external functionality, the higher the maintenance cost. Moreover, the maintenance cost may change over time as EMPs adjust their pricing structures or ERP systems become more user-friendly. Depending on the IT structure prevalent in the firm, the maintenance costs may be subject to economies or diseconomies of scale. Hence, no second-order conditions are specified in the model. They can be added later to suit the decision maker’s circumstances.

The last term in the objective function shows the salvage value. The salvage value reflects the value of internal and externally appropriated capabilities at the end of the planning horizon, \( t = T \), respectively. Since diminishing returns of increasing capabilities are already modeled in the competitive cost function, no further assumptions regarding the second order conditions of the salvage value are made.

Note that all cost and revenue terms are discounted with the discount rate \( \rho \).

Following the discussion in the previous section, the objective function is subject to some constraints. The constraints reflect relationships between variables, especially the decision (control) variables and state variables (equation (2)). Biehl (2002) provides...
a more detailed discussion of these relationships. The constraints also ensure that the values of certain variables do not exceed given quantities. For example, due to financial limitations the firm may be able to expend only a certain amount of transition costs at any time. These types of constraints are shown in Appendix 1 but have to be explicitly taken into account when solving the decision model:

\[ L' = l, \quad L \geq 0, \quad \text{with} \quad L(t = 0) = L_0 \quad \text{(2a)} \]

\[ V' = v, \quad V \geq 0, \quad \text{with} \quad V(t = 0) = V_0. \quad \text{(2b)} \]

The above non-linear and dynamic model can be solved using optimal control theory (e.g. Sethi and Thompson, 2000). Instead of mathematically solving the model (for a solution approach to a similar model, see Biehl (2002)), in this paper we show that it is easily implemented in Excel and solved using the Excel Solver. Before doing so, however, another important point must be addressed, which is how to assess the firm’s current level of capabilities. This is done in the following sub-section.

3.2. Appraising the status quo: setting up the model

Before being able to use the decision model, the functions and starting values have to be calibrated. As the costs of setting up and maintaining information systems are known and have been reported in the literature (e.g. Meta Group, 1999; Mabert et al., 2000), the discussion focuses on the assessment of the competitive costs. The factors that influence the competitive cost include the following:

- The firm’s current ICs and ECs in each of the supply chain processes to be considered, relative to the best-practice competitor (the benchmark). For example, one competitor may define the benchmark in the inventory tracking category, another one in product design, and yet another one in purchasing transactions. The benchmark may also be found outside the firm’s own industry. The benchmark is then defined as a level of 1 (or 100 percent), which allows easily to express the firm’s capabilities in relation to this benchmark.

- The degree to which the firm’s internal supply chain capabilities can efficiently support external functionality (i.e. EMPs). If the firm’s internal information system was capable of supporting only a fraction of the EMP functionalities, the use of EMPs might be inefficient and not add much value. The level of EMP functionalities subscribed to, adjusted by the effectiveness with which the firm can use them, is termed the effectively used level of ECs.

- The degree of technical and market uncertainty must be estimated. For example, if uncertainty exists regarding the supply chain functionality of EMPs or their integration capabilities, the effective value of EMP functionality must be adjusted since it will be difficult for the firm to use it to create capabilities.

- The importance of the capabilities to the firm’s competitive position. The importance depends on the firm’s core capabilities and differentiation strategy. Much like the level of capabilities, the importance of capabilities may change over time as order winners become order qualifiers or customer preferences change. For example, the opportunity cost arising from an inefficient process that is important to the firm or its supply chain partners would be much higher than that from a similarly inefficient process that was not as important.
Assessing the importance of the capabilities helps in establishing the relative magnitude of the costs associated with the various supply chain processes to be modeled. It also helps in estimating the relative magnitude of the competitive costs to the other cost and benefit terms in the model.

Tools often used to determine a firm’s competitive position include Porter’s (1979) five forces model; an analysis of the firm’s strengths, weaknesses, opportunities and threats (SWOT analysis); and an analysis of a firm’s comparative (i.e. short-term) and competitive (i.e. long-term) competencies vis-à-vis those of its competitors. As these tools are widely used, they are not explained any further in this paper.

3.3. Running the model: an example

A decision model to help in deriving a firm’s IS transition strategy can easily be implemented in Excel, as shown in Figure 2. In Excel, the cells are connected to each other through the functions represented in the above formulation of the decision model (please see Appendix 2 for the specific functions and values used in this example). The Excel Solver can then be used to derive an optimal solution by adjusting the amount of change in ICs and use of ECs over time (the firm’s decision variables) with the goal of minimizing the total profit. Note that, for the purpose of keeping the tables in Table I

![Optimization model for supply chain capabilities](https://example.com/optimization.png)
readable, a resolution of only two supply chain processes, Proc 1 and Proc 2, was used. However, the tables can be extended with little difficulty.

To illustrate, the example firm used in the model starts out with a relatively low level of ICs for process 1 (0.30) and a low subscription rate to one or more EMPs for the same process (0.20, see Figure 3). Taking into account the capabilities of the EMPs (0.70) and the effectiveness with which EMPs can be used, this amounts to a total capabilities level of 0.38 for supply chain process 1. This lack of capabilities relative to the benchmark results in a competitive opportunity cost of 1.4 million. Over time, the firm invests in a mix of internal and external functionality to increase the capabilities to the benchmark in less than two years. Thereafter, in a continuous improvement process, the capabilities are further improved by another almost 50 percent over three years. Such a continuous improvement process must be planned since competitors may also increase their capabilities during the planning horizon.

The competitive cost, which represents the major cost component for our example firm at the beginning of the planning horizon, decreases steadily over time (see Figure 4). Similarly, most costs for improving the firm’s total supply chain capabilities are incurred at the beginning of the planning horizon. This allows the firm to take advantage of the resulting improvement for a longer period of time. Due to the diseconomies associated with a quick transition, however, the investments are distributed over a number of years. Such results are typical of the management of technology literature (e.g. Biehl and Gaimon, 1999) and hold for many scenarios in the choice between ERP and EMP functionality as well.

Note that the amount of transition can be used as a proxy for the learning that takes place and, hence, the salvage values associated with the accumulation of capabilities. Accordingly, most benefits from these capabilities are realized at the beginning of the planning horizon. In this particular example, instead of leveling off near zero, however, they keep at a higher positive level due to the increase in internal capabilities for process 2 after the closing down of the second EMP.

Figure 3.
Supply chain capabilities over the planning horizon
As the levels of capabilities increase, the maintenance costs increase as well. The maintenance costs keep the firm from further investing in internal or external functionality. Lastly, it is instructive to compare the total cost of the optimal solution to that of the scenario where the firm does not engage in a development of internal or external supply chain capabilities. Figure 2 indicates that the base cost equals $30.3 million, whereas the optimized solution $16.1 million. That is, the firm, besides satisfying its supply chain partners, is able to save $14.2 million over the span of five years. While these figures are clearly based on a hypothetical scenario, they show that a potentially substantial amount of value can be generated to the firm and its supply chain partners through the use of such a strategic planning model.

4. Conclusions
This paper has investigated the tradeoffs between using internal and external supply chain capabilities, such as ERP systems and EMPs, respectively. We use value analysis to derive the factors important to the optimization of supply chain processes. Based on the discussion of these benefits and costs, a decision model is derived that allows firms to optimize strategic investments in internal and external supply chain functionalities (i.e. ERP systems and EMPs) to improve its supply chain capabilities over a given planning horizon.

Several valuable insights have been derived in this paper. First, ERP systems, which lead to internal supply chain capabilities (ICs), are designed to integrate a firm’s information flows across almost all functions. They are designed to manage complexity and are ready to be connected to either VANs or EMPs. VANs or EMPs are necessary to take advantage of transaction automation functionality. EMPs, besides providing market-making mechanisms, give almost instant access to a supply and customer base. Moreover, they allow automating certain supply chain processes without the costly investment of an internal IT system. However, as a firm’s scope of
SKUs increases, using EMP functionality as a disconnected solution becomes inefficient. As a result, firms with a wide range of SKUs cannot significantly improve their value generation and competitiveness by using EMPs if their internal supply chain capabilities are low. Lacking the infrastructure necessary to efficiently use EMPs, the firm is unable to generate real value and, consequently, a real competitive advantage from the subscription.

Based on this insight, investing in an ERP system (i.e. ICs) comes with a double benefit if the firm uses or intends to use EMPs. Since an increase in ICs also improves the effectiveness with which external capabilities (i.e. EMPs) can be used, adding ICs benefits the firm in two ways:

1. the direct increase in ICs; and
2. the increase in the effectiveness with which the firm is able to use external supply chain functionality.

Another important point relates external supply chain functionality (i.e. EMPs) to the potential for acquiring supply chain capabilities. The acquisition of capabilities from external sources is difficult in an environment characterized by technical or market uncertainty. Since this is the case in the market of public EMPs, their use often makes it difficult for a firm to acquire the necessary supply chain capabilities. Once the consolidation of EMPs has subsided and EMPs have become technically mature, the reliance on EMPs becomes a more viable alternative to the use of internal supply chain functionality for the purpose of developing capabilities.

A last insight derives from the fact that the supply chain consists of a number of processes (e.g. supplier search, order management, order execution, inventory management, etc.). As illustrated in the optimization model, firms usually have an uneven mix of ICs and ECs across those processes. This scenario is supported by the fact that firms often join a number of different EMPs to access a mix of different markets and supply chain functionalities along the processes. That is, the firm should use a well-defined portfolio of EMPs based on access and functionality to complement its set of internal capabilities. The above tools can help firms in deciding which mix to use over time.

In conclusion, many important considerations in the decision of whether to implement an ERP system or use EMPs for supply chain purposes have not been previously discussed in the literature. Despite the insights derived from this analysis, further research is required. In particular, although the model introduced in this paper reflects the interactions between the ICs and ECs, a firm wishing to use such a model should empirically investigate the typical functional relationships between ICs and ECs under various conditions, including the firm’s initial level of ICs and the development of ERP system and EMP capabilities over time. Moreover, the model proposed above does not yet explicitly take into account interactions between supply chain processes, such as cross-over benefits. The model should be further developed to take such interactions into account. Finally, it would be beneficial to investigate mathematically the model using optimal control theory. The use of optimal control theory would yield strategic investment policies and the explanation of how exactly exogenous factors, such as technological uncertainty or certain cost types, would affect the firm’s investment strategy.
Note
1. A capability can generally be defined as an ability for performing a task (Merriam-Webster, 2004).

References


**Appendix 1. Notation**

$L_i(t)$ = Level of internal supply chain capabilities the firm possesses to execute the $ith$ supply chain process at time $t$ (state variable); $L_i(t) \in [0, 1]V_i$; $L_i(0) = L_{i0}$.

$M_{ij}(t)$ = Level of inbound supply chain capabilities a type $j$ EMP possesses to execute the $ith$ supply chain process at time $t$ (exogenous, changes with EMP capabilities); $M_i(t) \in [0, 1]V_i$.

$e_i(L_i(t))$ = Effectiveness with which external capabilities of process type $i$ can be used at time $t$; $M_i(t) \in [0, 1]V_i$, $e_{iLL} > 0$, $e_{iLL} \leq 0$.

$V_j(t)$ = Firm’s level of use of type $j$ EMPs at time $t$ (state variable); $V_j(t) \in [0, 1]V_j$; $V_j(0) = V_{j0}$.

$l(t)$ = Change in the level of internal capabilities (control variable); $l_i(t) = L_i(t)$ and $l_i(t) \in [l_i^-, l_i^+]V_i$.

$v_j(t)$ = Change in the level of involvement in EMPs (control variable); $v_j(t) = V_j^-(t)$ and $v_j(t) \in [V^-_j(t), V^+_j(t)]V_j$.

$c_1[l_i(t), e_i(t)M_{ij}(t)V_j(t)]$ = Competitive cost due to operational inefficiencies at time $t$; $c_{1L} \leq 0$, $c_{1LL} > 0$, $c_{1V} \leq 0$, $c_{1M} \leq 0$, $c_{1MM} > 0$, $c_{1V} > 0$.

$c_2[v_i(t), l_i(t)]$ = Cost of changing the levels of internal capabilities and use of EMPs at time $t$; $c_{2v} \geq 0$ if $l_i \geq 0$, $c_{2v} < 0$ if $l_i < 0$, $c_{2v} \leq 0$; $c_{2v} \geq 0$ if $l_i \geq 0$, $c_{2v} < 0$ if $l_i < 0$, $c_{2vW} \leq 0$. 
\[ c_3[L_i(t), V_j(t)] = \text{Cost of maintaining the levels of internal capabilities and use of EMPS at time } t; \ c_{3L} > 0, \ c_{3V} > 0. \]

\[ S_iL_i(T), Z_iM_iV_j(T) = \text{Salvage values through the use of internal capabilities and EMPS, respectively, at the terminal time, } T; \ S_{Li} > 0, \ Z_V > 0. \]

**Appendix 2. Specific functions and values used in example**

**Decision variables**

\[ l_1(t), l_2(t), v_1(t), v_2(t). \]

**Starting values**

\[ L_1(0) = 0.3, \ L_2(0) = 0, \ V_1(0) = 0.2, \ V_2(0) = 0.4. \]

EC functionality as shown in Figure 2.

\[ t = 0 \ldots 20 \text{ quarters (= 5 years).} \]

**Capabilities**

\[ L_i(t) = L_i(t-1) + l_i(t-1). \]

\[ V_j(t) = V_j(t-1) + v_j(t-1). \]

**Effectively used ECs**

\[ E_i(t) = V_j(t)M_i(t)^*\text{SQRT}(0.3 + L_i(t)). \]

**Costs**

\[ C_{11}(t) = \left[ 2,500 - 4,000\exp(-L_1(t)E_1(t)/2) \right] / 1.07^t. \]

\[ C_{12}(t) = \left[ 1,500 - 2,500\exp(-L_2(t)E_2(t)/2) \right] / 1.07^t. \]

\[ C_2(t) = -120,000v_i^2 / 1.07^t. \]

\[ C_{31,2}(t) = \left[ -300L_{1,2}(t) \right] / 1.07^t \quad \text{(ICs).} \]

\[ C_{33,4}(t) = \left[ -100V_{3,4}(t)M_{3,4}(t) \right] / 1.07^t \quad \text{(ECs).} \]

**Salvage value**

\[ \left[ 6,000^* \left\{ \max(0, l_1(t)) + \max(0, l_2(t)) \right\} + 1,200^* \left\{ \max(0, v_1(t)M_1(t)) + \max(0, v_2(t)M_2(t)) \right\} \right] / 1.07^5. \]

The case of ERP systems versus EMPS.