



Invited Review

Enterprise resource planning: Developments and directions for operations management research

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Abstract

Enterprise resource planning (ERP) has come to mean many things over the last several decades. Divergent applications by practitioners and academics, as well as by researchers in alternative fields of study, has allowed for considerable proliferation of information on the topic and for a considerable amount of confusion regarding the meaning of the term. In reviewing ERP research two distinct research streams emerge. The first focuses on the fundamental corporate capabilities driving ERP as a strategic concept. A second stream focuses on the details associated with implementing information systems and their relative success and cost. This paper briefly discusses these research streams and suggests some ideas for related future research.

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Keywords: ERP; Enterprise resource planning; Operations management; Frameworks; Alignment

1. Introduction—The many views of ERP

Speculation on the future development and success of enterprise resource planning (ERP) is the topic of many popular press articles. These articles, typically written by individuals associated with the ERP companies, are often focused on the merits of the featured software. Unfortunately, in order to distinguish the merits of alternate packages, these same authors find it useful to introduce new terms designed to emphasize potential appeal.

In reality many of these “new” terms do not actually represent new concepts, but simply the re-packaging of existing ideas. The end result of accepting and disseminating these new terms into general discussions on the topic only leads to increased confusion over time.

A case in point is the variability with which the term “ERP” itself has been used over the last decade. The fundamental benefits of ERP systems do not in fact come from their inherent “planning” capabilities but rather from their abilities to process transactions efficiently and to provide organized record keeping structures for such transactions. Planning and decision support applications represent optional additions to the basic transaction processing, query and report capabilities included with a typical system.

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Such a realization often comes as a surprise to academics and practitioners alike, having anticipated greater decision support intelligence to be built into ERP packages. This is particularly salient when they discover that simple time series based techniques are used for forecasting or basic trial-and-error techniques are used for master scheduling. Even slightly more advanced techniques (i.e. auto-regression forecasting and linear programming approaches) are typically not part of standard package installations.

Ambiguity about the term ERP has also led to a relatively limited line of research in the area. Most ERP research to date has involved exploratory surveys, targeting common and ubiquitous issues like “cost”, “time” and “success”. They have also tended to focus on only the initial issues confronting ERP practitioners, such as vendor selection and package implementation (Davenport, 1998). Studies on usage and extendibility for operational and strategic benefit have been much less common, regardless of the fact that such issues most likely represent the motivating long-term rationale behind adoption in the first place.

Although the exploratory focus may be interpreted as problematic, perhaps one of the most crippling constraints on the growth of ERP research has been the mere fact that “getting the system to run” often dominates discussions with companies. Consider the operational challenges associated with supporting literally thousands of users, potentially located in many different sites, all accessing a single integrated database. The computer hardware and network technology is complex and the tasks required to keep these operating often becomes the focus of information system practitioners. This complexity may be one of the reasons why attempts to link benefits to ERP investments have proven so difficult.

Because of this difficulty, business academics that associate ERP systems with “software”, rather than “concepts”, may be inclined to simply disregard the role of ERP systems in research and educational settings. Along these lines, some faculty see the teaching of ERP topics as more the role of corporate “trainers” than academic educators. Likewise, many researchers have viewed the ability to provide contributions in the area of

ERP research as relegated to programmers and human–computer interaction specialists.

Still others believe the ERP age has passed. Buzzwords like “B2B”, “B2C”, and “CRM” and just about anything else preceded by an “e-” seem to have taken center stage. Yet ironically, each of these new terms at their most basic levels represent extensions of ERP systems to the customer, as far as physical distribution capabilities are concerned, and to the supplier with regards to purchasing applications. So are researchers in danger of missing the big picture on these new ideas? Possibly. Is it too late to make up for lost time? A realistic understanding of the role that ERP systems now play in major international corporations, and their continued diffusion among small and medium firms over the last few years, suggests that the answer is clearly “No”.

However, in attempting to study the appropriateness of such extensions researchers must come to terms with the capabilities of the larger systems that support them. Otherwise we risk encountering inconsistencies of the type that lead to perpetuation of the infamous “productivity paradox” (Brynjolfsson and Hitt, 1996; Brynjolfsson, 1993). This “paradox” was originally cited to describe the difficulty of linking investments in IT to productivity levels. By focusing on traditional interpretations and metrics of productivity, which by their nature provide only limited views on firm success, many early searches for such linkages were not only theoretically unfounded but also not surprisingly fruitless. A later focus on alternative views on productivity growth and more logically structured measures of IT usage ultimately provided much more in-depth understandings of the strategic concepts supported by the IT and the mechanisms through which benefits could be observed (Brynjolfsson, 1998; Caruso, 1999).

Ultimately researchers should keep in mind that ERP systems and these new extensions do not simply represent add-on tools that assist businesses with fleeting tasks. On the contrary, ERP systems represent corporate infrastructures, much in the same way that physical highway systems do. As corporations and academics gain increased experience with how this infrastructure impacts business decisions in their disciplines, research into

the idiosyncrasies of ERP system design and use should emerge as a recognizable forum for knowledge exchange and research.

2. Enterprise resource planning defined

The concept of ERP, and the systems designed to supply the functionality required to make this concept a reality, represent a significant step in the long history of technology assisted business-process integration. Earlier concepts such as MRP and MRPII, were designed to assist planners by logically linking various forms of process information in specific business contexts such as manufacturing. The ERP concept was subsequently designed to integrate these smaller otherwise isolated systems so that real-time resource accountability across all business units and facilities of a corporation could be maintained. As a result peripheral issues such as the elimination of conflicting information, the reduction in data redundancy, standardization of business unit interfaces, global access and security all fell under the objectives of ERP system design. Today more than ever, the capability of such systems to allow additional decision support and information analysis packages to be “bolted on” has become another critical feature.

Because of the importance of these developments, as a first step towards organizing future ERP research it is critical to make a clear distinction between references to the ERP concept and references to ERP “systems”. The interpretations of a number of authors clarify this distinction. For example, Mabert et al. (2000) describe a concept-based definition of ERP as involving the “seamless integration of processes across functional areas with improved workflow, standardization of various business practices, improved order management, accurate accounting of inventory and better supply chain management”. ERP systems on the other hand are merely the vehicles through which this is accomplished.

Bendoly (2001) takes a parallel approach to separating the ERP concept from definition of ERP systems. This approach emphasizes that ERP systems should not be looked at simply as tools

that have a fixed and measurable output, but rather as a technological infrastructure designed to support the capability of all other tools and processes used by a firm. Using arguments based on the theory of swift-even flow (Schmenner and Swink, 1998) and its ties to the law of bottlenecks (Goldratt, 1989), the proposal is that the benefits made possible from both the presence of such architecture and the process of establishing it are analogous to those provided by continuous improvement mechanisms. Subsequently, the presence of ERP architectures in-house is predicted to provide gains to future non-ERP concept and system implementations (Soliman and Youssef, 1998).

A similar view is taken by Palaniswamy and Tyler (2000). The design of this architecture (the system itself) should therefore be based on an understanding of the actual processes used by the firm and should allow for the eased introduction of future processes that the firm believes may offer competitive value. Object-oriented approaches to ERP system designs have become the standard for excellence towards implementing these objectives (Battacharjee and Ramesh, 2000; Fayyad and Schmidt, 1997).

Along the same lines, any reengineering of a business process that the system is intended to support should not be handled with the intent of accommodating the system. Rather, reengineering should involve the implementation of best practices, specifically supported by the system, that improves the performance of the enterprise as a whole. All in all, researchers generally agree that the task requires a mix of cross-functional strategic planning and enterprise-wide corporate diplomacy (Bingi et al., 1999). The concept of ERP is fundamentally tied to the integration, standardization, extension and assurance of future flexibility for corporate processes, whereas the system represents the technical manifestation of these goals and the changes required to attain and maintain them (Ng et al., 1999).

Yet another concept based definition comes from the work of Stratman and Roth (1999), which considers the competence of firms regarding not only the use of ERP strategies but also the maintenance of these strategies. This competence

extends to the ability to recognize opportunities for system development and innovation. Such opportunities do not simply refer to the availability of new system technologies to be purchased, but new ways of strategically operating based on the conveniences provided by the ERP system and strategies in place.

3. Research into enterprise resource planning

Based on these distinctions between ERP as a management concept and the ERP systems (both informational and operational) two broad streams of ERP research presents themselves. Concept research would tend to focus more on the potential impact of ERP on the performance of various business functions. In contrast, systems research would tend to focus on the intricacies of package and process design to meet such conceptual objectives. Implementation and maintenance research genres fits predominantly in this second category, as do issues dealing with upgrading, modification and extension. Furthermore within both concentrations a number of traditional OM/OR research paradigms can comfortably be applied. Fig. 1 provides an illustration of how several tried and proven research streams may find clear application in the two categories identified.

Because of the rich heritage of these paradigms, a range of research methodologies ranging from case studies to math programming can easily be applied within either stream. Subsequently as these areas develop, it would not be surprising to see researchers categorize their works by a “method-

ological” dimension as well (i.e. normative modeling vs. empirical testing). As an example, of such methodological distinctions in the realm of large systems, Benton and Shin (1998) provide a review of research into the comparison of MRP and JIT concepts and their supporting systems. In this review they distinguish between studies that use math modeling and simulation approaches, commonly referred to as operations research (OR) approaches, from those that provide survey results or general discussions on the topics. In their view, “OR” models provide unique opportunities in their ability to evaluate existing concepts as well as their ability to assess yet to be developed hybrid systems based on the merger of complex concepts. The results of these studies are valuable in that they provide insights that could not be fully understood otherwise, and that often cannot be tested empirically in real companies.

Gardiner and Blackstone’s (1993) study of the effect of MRP lot sizing and dispatching rules on customer service, and Buzacott and Shanthikumar (1994) consideration of safety stock and safety time issues, provide recent examples of the mathematical evaluation of the MRP concept, building on earlier comparative works of MRP and Kanban concepts (Krajewski et al., 1987; Buzacott, 1989; Rees et al., 1989; Grunwald et al., 1989). Recent hybrid models include those of Chaudhury and Whinston (1990) and Ding and Yuen (1991), both of which provide simulation analyses of the benefits possible from the merger of MRP and Kanban concepts. Huq and Huq (1994) also provide simulation-based evidence of the potential benefits of MRP/JIT hybridization. Extending

Concept Oriented <i>(Operational and Strategic Usage)</i>	Systems Oriented <i>(Implementation and Maintenance)</i>
<ul style="list-style-type: none"> ◆ Scheduling and Project Management of Resources & Processes ◆ Inventory and Supply Chain Mgmt ◆ Quality Control / Management ◆ Demand Forecasting and Yield Mgmt 	<ul style="list-style-type: none"> ◆ Scheduling and Project Management of Design & Change ◆ Business Process Re-engineering ◆ New Product/Service Development ◆ Concurrent Engineering

Fig. 1. Traditional OM/OR paradigms associated with concept and systems based ERP research.

these types of studies to enterprise contexts may be possible, thus developing an OR modeling stream of ERP research. For example, extending OR study measures to consider enterprise measures of return on investment and asset turnover may lead to a better understanding of the potential of ERP decision support.

Since OR modeling has yet to make significant headway in the realm of ERP however, for the moment we are restricted to considering how the existing works in ERP research represent the more general “concept vs. system” classification scheme. As stated earlier, one common systems focused approach to ERP research has emphasized implementation success, hence following a long tradition of IT research already established. In fact Lee (2000) points out that future research into ERP should ideally make use of foundations that have already been established for identifying corporate benefits and the mechanisms that bring them about. Studies in the implementation area range from anecdotally motivated theoretical frameworks (Cliffe, 1999; Prasad et al., 1999; Markus et al., 2000) to empirically supported investigations (Holland and Light, 1999; Mabert et al., 2000, 2003; Zhou et al., 2001). The impact of both internal and external corporate relationships on ERP system implementation and maintenance are repeatedly cited as critical (Hirt and Swanson, 1999, 2001; Robey et al., 2002). Other works have focused on knowledge management issues relating to access and proliferation of the information maintained by an enterprise system (Van den Hoven, 2001). Ultimately, the assumption of course is that the effectiveness of associated knowledge management practices can allow for better applicability of such information in the greater realm of the ERP concept.

Another example of systems oriented research coupled with the use of an empirical methodology is the consideration of the validity of a proposed framework based on anecdotal evidence taken from practitioner experience with ERP installations, such as that presented by the Flexibility-Centralization matrix of Jacobs and Whybark (2000) shown in Fig. 2.

Based on their experience, most firms prior to implementing ERP, tend to appear in the upper

Flexibility	High	Common Client Multiple Processes	Multiple Clients Multiple Processes
	Low	Common Client “Best Practices”	Multiple Clients “Best Practices”
		High	Low
		Centralization	

Fig. 2. Alignment in ERP solution strategies.

right corner of the framework. ERP implementation tends to push for lower-right quadrant strategies.

In contrast, to this system focused framework, the work of Upton and McAfee (2000), represents a predominantly concept-oriented consideration of ERP issues. These authors look to the accepted principle of continuous improvement in manufacturing settings and the impact that presence of ERP systems has on the long-term improvement path of such operations. Another concept-focused work is that of Frederix (2001) in which a methodology for resource planning in certain extended enterprises, specifically within the semi-conductor industry, is proposed and compared to less efficient techniques. With analogy to the work of Van den Hoven (2001), supposedly the use of such a methodology could benefit greatly from knowledge reaped through appropriate system-focused strategies. Most recently, Mundal and Gunasekaran (2002) have also provided an assessment of the global features of the ERP concept in an inventory control application through a case study examination.

With this said, the opportunity for research that bridge the gap between concept and system considerations is perhaps most intriguing. Such efforts include that of Bendoly and Jacobs (2002) in which system and concept strategies are considered simultaneously and the relative importance of alignment within and between the two contexts compared. Benefit evaluation frameworks have also been recently proposed to encapsulate both system and concept considerations (Sarkis and Sundarraj, 2000), as have empirical studies of

vendor selection (Van Everdingen et al., 2000) and usage (Poston and Grabski, 2000, 2001). Studies of fit and alignment have also focussed on international cultural distinctions and the global robustness of so-called ‘best-practices’ (Soh et al., 2000).

Finally, it is critical to emphasize that although there may be a wide range of methodologies and contextual emphasis under which ERP research can be conducted, academic researchers need have a clear understanding of the intended audience. When research surrounds an emerging technology, it can be all too easy to pursue surveys that ultimately neither contribute to or test academic theory, but rather simply provide descriptive statistics that capture the current state of a popular idea. These types of statistics might best be captured by common trade journals and consulting companies as part of their marketing activities.

4. Future research directions

Beyond the research issues raised by these special issue articles, it is worth emphasizing that the realm of ERP research and development is constantly changing. During the years in which ERP was an emerging concept, and only a handful of vendors could be recognized, study tended to focus on the offerings of these few firms. Because of the novelty of these systems and unavailability of alternatives, costs were prohibitive for all but very large firms. Today however, a much larger pool of ERP vendors exists, many catering to small and medium sized enterprise niches. It will be interesting to see how these more focused applications develop. They may become quite sophisticated in their decision support role.

ERP systems, like other new technologies that have emerged over the years, will soon become well understood. Issues of implementation will cease to be a problem as individuals with real experience emerge to guide companies. Further, the hype associated with promised capabilities should dissolve into well understood strengths and weaknesses of the systems offered by major vendors. This is not to say that these system will not continue to develop, it is just that true knowledge about the systems will be available. Many of to-

day’s “experts” have little more than a few years of experience. Further, this experience is, for the most part, highly focused on particular segments of a particular vendor’s software. True experts that understand the complete scope of an ERP offering are still not readily available.

One very interesting avenue of research that relates to implementation experience is the comparison of the recent ERP experience with that of other new technologies of the past. Consider the stir that numerical control machine tools, programmable robots, and automated guided vehicles created in the mid-1980s. The promise of “lightless” factories that were referred to as flexible manufacturing systems, 24-hour operation and unlimited factory flexibility enticed many companies to invest large sums of money. Unfortunately, most of these projects fell far short of initial expectations. Today, these technologies are well understood and they are now intelligently used when appropriate. There are many parallels between ERPs integration and the integration promised through flexible manufacturing system technology of the past. Much could be learned by comparisons of the adoption cycle of past new technologies with the ERP cycle.

Certainly, a major shift will be away from basic implementation research itself, and into the much richer area of ERP extendibility (both in concept and system-wide). Some work in system extension has already begun to appear (Fingar, 2000). With the growing popularity of B2B and B2C e-commerce systems, as well as other technologies such as data mining and customer resource management systems, there should be a strong interest in assessing how to best integrate the functionality of these systems to provide competitive advantage for the firm. New business models implied by these developments may emerge.

Ironically, the development of next generation hybrid systems aided so much by the efforts of OR modelers in merging MRP and alternative concepts has yet to see any similar substantial support in the context of ERP. Yet ERP as a concept combining global and inter-departmental information sharing and opportunities for collaboration should represent much more fertile ground for such models, particularly since the concept also

generally encompasses that of MRP. Researchers should be encouraged to consider how the availability of real time accounting, sales and HR data for example impact real time MRP and purchasing decisions, and vice-versa. The global nature of ERP should also encourage research into the hybridization of supply chain, MRP and other functional models critical to the enterprise.

ERP systems now offer businesses an information platform where many of the techniques, concepts and strategies that we have studied over the years can actually be applied. The reality is that much academic research is terribly restrictive in its applicability. In comparison, ERP vendors are forced to tailor their software to market niches such as high volume repetitive manufacturing, the process industry, automotive suppliers, hospitals/health care providers, restaurants, etc. since these consumers will simply not buy software that is will not work in their particular niche. We can learn much about the assumptions that ERP vendors make about these market niches. Furthermore, many of our own academic research efforts in the area should require a test of applicability before additional speculation is made. Studies of the environments, data availability, and common logic that emerge from these commercial market niches could be invaluable towards better understanding the applicability of academic research.

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